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Sensory quality control in food companies: towards improving knowledge, attitudes and practices assessment as well as sensory quality management

by

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Submitted in partial fulfilment of the requirements for the degree

PhD (Food Science)

in the

Department of Food and Consumer Sciences
Faculty of Natural and Agricultural Sciences
University of Pretoria
Pretoria

June 2021

DECLARATION

I, Ogheneyoma Onojakpor, declare that the thesis, which I hereby submit for the degree PhD (Food Science) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Ogheneyoma Onojakpor

June 2021

DEDICATION

This research work is dedicated to the Almighty God for His love, grace, and faithfulness to me in the past, now and always.

ACKNOWLEDGEMENTS

I would like to extend my sincere gratitude to the following:

My supervisor, Prof. H.L. de Kock, for her consistent support and guidance throughout this research work. I am extremely grateful for her understanding and support towards ensuring a good family - work balance and for believing in me.

The teaching and administrative staff and postgraduate students of the Department of Consumer and Food Sciences for their input and encouragement during this study. Especially to my colleagues who assisted during product evaluation sessions.

Prof Hely Tuorila from the University of Helsinki, Finland, for her enthusiasm and insightful discussions during this research work.

The staff of the case study food company for their warmth, support and for mouth-watering chocolate mousse. The survey participants and sensory panellists for their contribution towards the completion of this study.

The University of Pretoria Commonwealth Doctoral Scholarship programme for their financial support.

My late mother, Emily Onojakpor, for her exemplary love and for showing me that a woman can excel on all fronts. To my parents - Pastor and Pastor Mrs Onojakpor, and all my family members and friends for their prayers, moral and financial support.

My loving husband - Dr. Chijioke Olisah for his love, patience, insightful discussions and for proof reading this work multiple times. To my beautiful daughter - Kekachukwu Olisah for her love and for bringing me smiles and sunshine on dark days.

ABSTRACT

Sensory quality control in food companies: towards improving knowledge, attitudes and practices assessment as well as sensory quality management

by

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Supervisor: Prof. H. L. de Kock

Limited knowledge and support for sensory quality control (SQC) in food companies and the associated misapplication of sensory evaluation principles may lead to defective products reaching consumers. Subsequently, customer dissatisfaction may lead to loss of sales and brand equity. It is therefore vital to assess the knowledge, attitudes and practices related to SQC in food companies to identify areas of improvement and deployment of targeted interventions. However, no tool could be found for evaluating SQC related knowledge and attitudes. Furthermore, despite the widely acknowledged link between waste and over-reliance on finished product monitoring for SQC, the practice of evaluating the sensory properties of finished products is still widely prevalent in the food industry. The focus on finished product may be due to the limited availability of research to develop a reliable system that manages sensory quality throughout the manufacturing process. Most studies focus on SQC of unit operations such as baking.

The first part of this study focused developing and validating of a questionnaire to assess SQC knowledge, attitudes and practices in the food industry. The questionnaire was developed based on sensory evaluation literature and was improved and validated through multiple phases and tests. These include content validation by sensory experts (n=6), tests to assess the clarity of questions by food company employees (n=8), item selection by item response analyses, factorial validity by exploratory factor analysis (EFA, n= 56 and 120) and confirmatory factor analysis (CFA, n= 225) and known groups validity. The knowledge questions retained in the final questionnaire had acceptable difficulty (-3 to +3) and discrimination (≥ 0.35) indices, while the attitude and practices questions had acceptable item-total correlation (≥ 0.20). Questions in the knowledge section formed one factor, which had a good model fit and good

internal reliability. The attitudes questions formed two factors that accounted for negative and positive dispositions towards SQC. The model fit was however weak and will require improvement. The practices questions formed one factor with a good model fit and internal consistency.

Overall, the results from the study demonstrate that the knowledge and practices sections of the questionnaire are valid measures for use in the food industry. The attitude section was not validated, hence it needs further refinement. However, the attitude section can still be used, and the results interpreted with caution. Food companies and other stakeholders can use the questionnaire developed in this study to rapidly assess the SQC related knowledge and attitudes of their employees and to audit company SQC practices towards unveiling areas of improvement of sensory quality systems.

The second part of the study illustrates the development of a system (using a chocolate mousse case study) that prevents the occurrence of sensory defects across the manufacturing steps and thus ensures consumer satisfaction. First, the critical sensory quality indicators that drive consumer preferences were identified. These were used to define the product's sensory specification and the severity of potential sensory defects. The severity and likelihood of occurrence of a sensory defect throughout the manufacturing process were used to identify the critical steps that must be controlled to prevent the occurrence of a sensory defect. Finally, a system for monitoring and control of the critical manufacturing steps was defined.

The sensory quality system was developed based on established scientific principles of preference mapping and risk assessment. Thus, implementing the sensory quality system described is expected to prevent the occurrence of sensory defects and reduce the frequency of finished product testing by changing the goal from monitoring to validation. The focus on the sensory attributes that are critical to consumer preference would also ensure their satisfaction. Further research into the proposed system would be useful to validate its effectiveness.

This study is the first to validate a questionnaire for assessing sensory quality control knowledge and practices in the food industry. It is also the first to demonstrate a system-based approach to sensory quality control, from the definition of sensory quality specification to control of the process from ingredient receipt to dispatch of the finished product.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CCP	Critical control point
CFA	Confirmatory factor analysis
CFI	Comparative fit index
DC	Discrimination index
DI	Difficulty index
DWLS	Diagonally weighted least square
EFA	Exploratory factor analysis
ICC	Intra-class correlation coefficient
IFT	Institute of Food Technologists
IRT	Item response theory
ITC	Item to total correlation
ISO	International organisation for standardisation
KAP	Knowledge, attitudes and practices
NPD	Non-positive definite
OPRP	Operational prerequisite program
PCA	Principal component analysis
PLS	Partial least square
QA	Quality assurance
QC	Quality control
RMSEA	Root mean square error of approximation
SED	Sensory Evaluation Division
SQC	Sensory quality control
SRMR	Standardized root-mean-square residual
TFI	Tucker-Lewis fit index
ULS	Unweighted least square
WTO	World Trade Organisation

1 INTRODUCTION

1.1 PROBLEM STATEMENT

Trends such as globalisation, increasing disposable income of consumers, and an overall increase in the standard of food available to consumers have made it imperative for food companies to maintain a quality advantage over their competitors (Kilcast, 2010, Grunert, 2005). Sensory quality is an important aspect of product differentiation that food companies can use to maintain market relevance (Raz et al., 2008). Sensory quality is one of the most obvious characteristics of a food product and a significant driver of product selection. Thus, most consumer complaints are directly related to the presence of sensory defects (Dzung et al., 2003). Customer dissatisfaction resulting from sensory defects in a food product often leads to financial losses (Zabaleta et al., 2016) and probably loss of brand equity for the manufacturer. Sensory defects are usually a result of small drifts in product quality that accumulates over time and thus require regular control and monitoring for early detection (Schiano et al., 2017). Many food companies apply some form of sensory quality management and control to ensure the consistent products and consumer satisfaction (Munoz, 2002, Hansen et al., 2005). Sensory quality management, like other quality management systems, involves identifying customer requirements and establishing system and product controls to ensure that the product meets the established requirements (Curt et al., 2004, Vasconcellos, 2003).

Several studies on sensory quality management have focused on aspects such as the development of sensory evaluation methods (Kraggerud et al., 2012, Etaio et al., 2012, Costell, 2002), the standardisation of the testing environment (Trautmann et al., 2017), and selection and training of panellists (González-Casado et al., 2019, Etaio et al., 2010). Some studies have evaluated the effect of raw materials or processing factors on the sensory quality of the finished product (Yue et al., 2017, González-Álvarez et al., 2013). Also, studies have captured the over-reliance on finished product testing which may lead to waste and financial loss, because defective products are often detected late in the production process (Endrizzi et al., 2013, Stefanova and Zlateva, 2018, Munoz, 2002). Some studies have focused on sensory quality control (SQC) of unit operations (Davidson et al., 1999, Perrot et al., 2000).

Despite, the widely available information on the application of sensory evaluation in quality control, food companies may struggle to develop and implement practical SQC systems (Kilcast, 2010). This may be due to the difficulty in justifying the inadequacy of relying on instrumental and chemical analyses to monitor sensory quality and thus the financial and human resource investments needed for SQC (Endrizzi et al., 2013, Kilcast, 2010). Food companies may also find it more difficult to outsource SQC functions, unlike the application of sensory evaluation activities for product development (Kilcast, 2010). Thus, inhouse expertise in sensory evaluation is essential to justify investments in SQC and for the development and implementation of a sensory quality management system. Furthermore, SQC, like other aspects of manufacturing process control, usually rests on the shoulders of company staff (Curt et al., 2004).

While subject specific knowledge and attitude are drivers of behaviour (Nyarugwe et al., 2018, Ko, 2013), the relationship is reciprocal as behaviour and attitude may influence knowledge gains (Schrader and Lawless, 2004). Therefore, a multi-construct (knowledge, attitudes, and practices) approach is widely used in other fields such as food safety to understand behaviour (Ko, 2013, da Cunha et al., 2019, Nyarugwe et al., 2018). Very few studies have attempted to capture sensory quality practices in the food industry. One study by the Sensory Evaluation Division (SED) of the Institute of Food Technologists (IFT) evaluated the role of sensory quality control in food companies (Stone and Sidel, 2004). Another study by Brand and Arnold (1977) explored the use of sensory evaluation by product development groups. Both questionnaires were not validated and did not evaluate the knowledge and attitude of respondents.

Several researchers have recommended a holistic approach to sensory quality management that is based on the identification and satisfaction of customer requirement through process design, risk management, and monitoring (An and Wang, 2016, Tzia et al., 2015). Furthermore, a system approach to sensory quality management will enable the prioritization, control and monitoring of the significant materials, and processing steps that influence the sensory properties critical to consumer acceptance of the product (Aumatell, 2011, Kilcast, 2010). This strategic monitoring of critical steps and materials will prevent over-reliance on finished product testing and its associated waste (Stefanova and Zlateva, 2018). Very few studies have taken a system approach to the management of sensory quality (Curt et al., 2004). No study has illustrated a sensory defect prevention system based on the definition of consumer preferences and identification and control of the critical processing steps.

1.2 AIMS AND OBJECTIVES

The aim of this research was to understand and establish two strategies for improving sensory quality control in food companies (Figure 1.1). Findings of this study will have economic and sustainability benefits by reducing the waste associated with finished product testing and promoting improvements in the sensory quality system.

Therefore, the objectives of this study were:

1. To develop and validate a sensory quality knowledge, attitudes, and practices evaluation tool. This tool can be used to rapidly assess food company employees and the SQC systems of food companies in order to identify potential gaps and areas of improvement for the management of the sensory quality of products.
2. To develop and implement a preventive, product life cycle based SQC system for maintaining food product sensory quality through the identification and management of critical steps with the aim of ensuring consumer satisfaction.

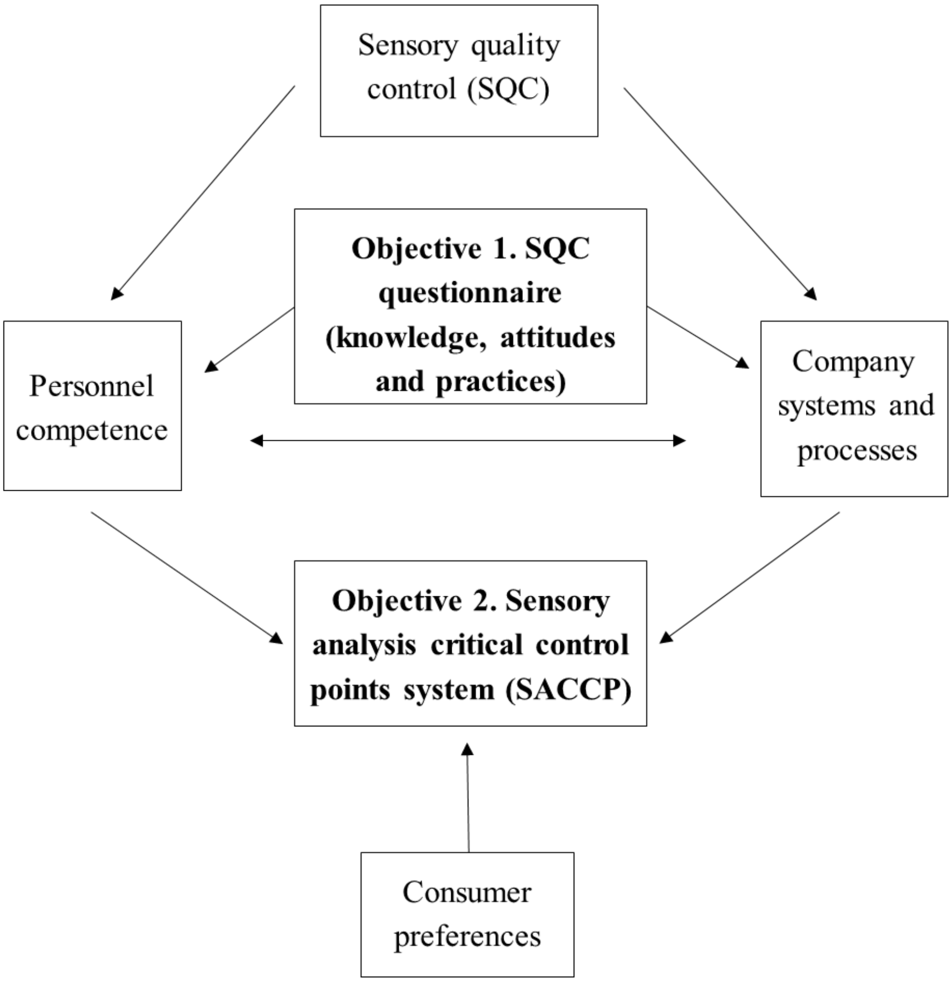

Figure 1.1 Schematic representation of the how the study relates to sensory quality control

1.3 OVERVIEW OF THE THESIS STRUCTURE

This thesis is presented in seven chapters:

This introduction is the first chapter, presenting the identification of the problem that is addressed and the project objectives.

Chapter two is a review of literature on sensory quality control. Published sensory quality control research from 2000- 2019 were reviewed to identify the main research themes as well as the gaps.

Chapter three presents the experimental work on the objectives of the study, a brief introduction of the structure of this chapter is provided. The section is divided into four subchapters, 3.1 and 3.2 relate to the objective one while 3.3 and 3.4 are for objective two. Subchapter one (3.1) details the development of the questionnaire based on psychometric principles on scale development, while subchapter two (3.2) presents the validation of the questionnaire. Subchapter three (3.3) describes the implementation of a system approach to sensory quality control for a case study product (chocolate mousse). Subchapter four (3.4) covers the development of the sensory specification for the case study product (chocolate mousse). The sub-chapters were written as individual studies following the guidelines of the journal Food Quality and Preference.

Chapter four is introduced briefly; it presents a critical review of the methods and findings of this study, which causes some repetition or overlap with chapter three.

Chapter five presents the conclusions drawn from the study.

Chapter six presents the references cited in the preceding chapters.

Chapter seven outlines the publications, presentations, and posters from this research. This chapter is followed by the appendices.

2 LITERATURE REVIEW

This chapter presents a review of literature related to sensory quality control (SQC) in the food industry. First, it provides a brief introduction to the topic, then it describes the components of an SQC programme. Some benefits and limitations of the implementation of SQC in the food industry are highlighted. There is a short discussion on the use of instruments for sensory quality monitoring. A textual analysis of studies carried out on sensory quality control from 2000 – 2019 is presented and the importance of a systems approach to SQC is discussed. The literature on the assessment of food company employee knowledge, attitudes and practices is also reviewed. Finally, the production and sensory characteristics of chocolate mousse are described, as a case study focusing on the production of this product type is used in the research for illustration of the proposed sensory quality system.

2.1 SENSORY QUALITY CONTROL IN FOOD PRODUCTION

Food quality is an important subject for food producers, legislators and consumers alike as it determines consumer acceptance of products, brand image and the market value of the product (Grunert, 2005). Quality is characterized by the features of a product that are relevant for consumer preference and acceptance. Although consumers' acceptance of a food product is also affected by other factors such as safety, nutritional value, brand, price and/or context of use, sensory quality is a major determinant, and it is usually one of the first properties of the product to be appraised by consumers (Lahne, 2016). Furthermore, sensory defects are the most common sources of consumer complaints, which may lead to loss of sales and may negatively affect customer loyalty (Dzung et al., 2003). The sensory quality of a food product refers to its sensory properties such as appearance, odour, taste, texture/ mouthfeel, and flavour that are perceived by the senses of the consumer (Varzakas and Tzia, 2015). It is the sum of the interactions and contributions from its raw materials, processing conditions, packaging, storage conditions and the final preparation by the consumer (Curt et al., 2004). Regular monitoring of sensory quality through sensory based quality assurance/ quality control (QA/QC) programmes is critical to ensure the delivery of consistent products and thus consumer satisfaction. This is because the human senses are sometimes more sensitive and always more complex than instrumental sensors and may give a more exhaustive and relevant response compared to other measurements (Kilcast, 2010).

Sensory quality control (SQC) is the application of sensory evaluation techniques and methods to the development of sensory quality specifications, the control and monitoring of product sensory quality for conformance with the agreed standard (Costell, 2002). "Sensory evaluation is a scientific discipline used to evoke, measure, analyse and interpret reactions to characteristics of food and materials as they are perceived through the senses of sight, smell, taste, touch and hearing" (Sensory Evaluation Division, IFT, 1975). Despite its importance, the integration of sensory evaluation into QA/QC in the food and beverage industry has achieved only moderate success compared to other aspects such as product traceability, pest control and food safety (McGrew and Chambers, 2011). While most food companies are aware of sensory evaluation, it has not been widely used by small food companies (Endrizzi et al., 2013). Smaller food companies often lack the expertise to control quality in general and by extension sensory quality (Allais et al., 2007) resulting in the prevalence of marginal SQC programmes. Marginal SQC programmes do not meet the requirements for good sensory practices, these programmes are ridden with short cuts such as the use of too few or untrained panellists, use of ambiguous specifications, and no clear protocols for sample preparation and evaluation. A few companies, typically the larger ones, have an established sensory department/group responsible for all sensory activities and thus have a robust SQC system in place (McGrew and Chambers, 2011).

Assessment of the sensory quality of food is a common practice in food processing and service, however the progress towards more formal sensory evaluation has been driven by the rise of industrial food manufacturing and trading (Carbonell-Barrachina, 2007). Sensory quality assessments in the food industry may include regular tasting sessions by the management team, on-line monitoring or finished product monitoring by untrained production operatives or expert 'tasters' (product evaluators). However, these practices differ from modern SQC where established good sensory practices such as the screening and training of panellists, use of established specifications, standardisation of sample preparation and evaluation, and regulation of the test environment provide scientific controls that ensure the collection of reliable data (Bittante et al., 2011). Most companies' SQC efforts rely on end-product testing, which may be too late in the food chain as it leads to wastage of resources when defective products need to be discarded, reworked, or sold at a lower price (Stefanova and Zlateva, 2018). To prevent such waste and improve the efficiency of the SQC system, several authors have recommended a more holistic approach that involves monitoring of the sensory properties of raw materials and in-process goods (Aumatell, 2011, Stefanova and Zlateva, 2018). This can only be achieved within a system with a well understood objective, based on which the components of the SQC system are designed (Stone and Sidel, 2004a)

2.2 COMPONENTS OF AN SQC SYSTEM

2.2.1 People

This should include all human resources involved in developing and implementing the SQC programme. This includes the SQC programme coordinator / manager, the technicians or support staff and the panellists; statisticians and sensory consultants may also be involved on an ad hoc or fulltime basis as required. The number and roles of the people involved in SQC at each company largely depends on the company's size and strategy. Larger companies have dedicated sensory teams with multiple panels, while smaller companies may delegate sensory-related responsibilities to quality staff with sensory training and have one panel (Kilcast, 2010). The increasing automation of food production and consequent reduction of employee numbers may negatively affect the availability of staff to take up SQC responsibilities and impact the implementation of a valid SQC system.

The programme coordinator (panel leader) oversees the development and continuous improvement of the sensory quality programme, the recruitment and training of sensory technicians and panellists, ensures provision of facilities and supplies and provides reports and periodic performance reviews of the system to the relevant stakeholders (ISO, 2006a). The panel leader should possess good food science and sensory science knowledge, basic statistical knowledge as well as good organisation, motivation and communication skills (Kilcast, 2010). The support staff, such as the panel technician are responsible for sample preparation and service, cleaning of the product evaluation area and management of supplies inventory (ISO, 2006a). Support staff should be trained on good sensory practices and the sensory methods used by the company. Sensory quality awareness programmes may also be carried out for all production and quality personnel to foster ownership of product sensory quality. This will improve the consideration of product sensory quality at every step of the production process right to the final product.

Panellists are responsible for routine product and material evaluations. Panel creation usually follows these stages: recruitment, selection, training, and qualification. Candidates may be recruited externally from the surrounding community or internally from company staff based on their availability, health status, aptitude for food and their interest in sensory evaluation. Candidates are screened and selected based on their ability to sense, recognize, discriminate, order, memorize and describe different sensations perceived from the food (González-Casado et al., 2019). Successful candidates undergo both general and product-specific sensory evaluation training to acquaint them with the product/s, the specifications, sensory methods and develop their ability to identify and describe deviations from the specification (Kraggerud et al., 2012). After training, panellists are selected based on their ability to provide valid sensory data that is repeatable and reproducible (Rossi, 2001). Regular product assessment, periodic panellist re-screening and regular training should improve panellist performance (Etaio et al., 2010b). Panellist re-screening and training should be carried out at least annually or more frequently where the panellists or panel do not meet the performance requirements to ensure the reliability of the data obtained from panellists and encourage panellists' commitment and performance.

2.2.2 Sensory quality specification/ standard

This is a clear, concise description of the "ideal" product, highlighting important sensory properties and their acceptable limits of variation (Stefanova and Zlateva, 2018). Costell (2002) described three different sensory quality standards that are in use in the food industry- a written standard, a product standard or a mental standard. A written standard is a written description of the target sensory quality. A product standard is a control product that possesses the desired sensory quality usually for one or a few of the sensory attributes, thus more than one control is usually needed for one product (King et al., 2002). Product standards are usually products with long shelf life as their sensory qualities remains stable for a long period and they are mostly used for evaluation of raw materials rather than finished products (Costell, 2002). The mental standard consists of a mental picture of the target product, the standard is agreed to without a physical or written description. This is used mostly by product experts and may be problematic as different experts may use different criteria.

The sensory specification should be defined by management based on the assessment of representative production samples to identify the normal variation in sensory properties that do not result in detectable quality defects. The specification should also consider information from consumer studies highlighting the sensory properties that drive product preference (Costell, 2002). A specification determined in this way prevents wastage of time and resources evaluating unimportant attributes and facilitates objective product assessment so that the product meets consumers expectations (Kraggerud et al., 2012). Once the specification is developed, the criteria for product acceptance/rejection must be documented and agreed to by plant management.

The ideal specification should clearly define the acceptable range of the sensory properties that are important for product acceptance. If a scale is used, physical reference samples could be identified that are representative of scale anchors. Physical samples representative of the target intensities of different attributes should be provided where possible. The use of references provides fast access to reliable, relevant information for control and improvement of product sensory quality (Hansen et al., 2005) and also promotes staff awareness of product sensory quality (Metheringham and Rodway, 2001). The sensory specification needs to be updated periodically to account for evolving consumer preferences and market trends. Some common shortfalls in the description of the sensory specification include the use of vague or very technical terms, inadequate input from consumer preferences and focus on visual attributes (Kilcast, 2010).

2.2.3 Samples

These are the materials or products used for panellists training and routine product evaluation. Samples of common sensory defects associated with the product should be included during training to familiarize panellists with them. Due consideration needs to be given to the sampling plan for regular product evaluations as part of quality control- the number of samples per batch/ shift and the points of sampling should be determined and documented. Other aspects to be considered include sample characteristics such as the quantity served, the serving temperature, dilution, coding with randomly selected three digits, and randomised order of serving to minimize the introduction of bias (Varzakas and Tzia, 2015).

2.2.4 Product evaluation facilities

The need for a standardized environment that will facilitate the collection of reproducible data and minimize any bias from the environment support the choice of a dedicated sensory evaluation testing location (Varzakas and Tzia, 2015). Early recommendations described the ideal location for routine product evaluation as one that is free from strong odours, free from distracting sounds, well-lit and preferably equipped with individual booths to minimize distractions and influence among panellists and from the environment. In practice, this can be achieved by using a well-designed sensory laboratory. In modern sensory evaluation, the choice of environment depends on the objective of the task. While traditional recommendations are still relevant for SQC, home use tests and other locations tailored to match the consumers 'regular' product usage context are increasingly adopted for consumer studies (Stelick and Dando, 2018).

Where the product requires some preparation before evaluation (for example. raw sausages), it is necessary to also have available appropriate equipment such as hand washing facilities, a cooker, a refrigerator, a freezer, a microwave oven and a food processor (Carpenter et al., 2012). Panellists should not have any interaction with the food preparation process to prevent any bias due to prior interaction with the product. Utensils dedicated to the preparation and serving of samples for sensory evaluation should be provided. All serving utensils used for product assessment should be identical to prevent the introduction of bias.

2.2.5 Sensory methods

This includes the objective and subjective sensory evaluation methods used for panel screening and training, specification setting, product assessment and control of panel performance (Kraggerud et al., 2012). The choice of sensory evaluation method depends on several factors such as the objective of the study, the nature of the product, time available, budget for evaluation, and panellist expertise (Kraggerud et al., 2012).

In general, hedonic tests and quantitative descriptive analysis are used to identify the drivers of consumer liking for the development of the sensory specifications. Literature has shown the use of descriptive or discrimination tests in panel screening and assessment and for routine product evaluation in SQC (Ojeda et al., 2015a, Trautmann et al., 2014). Several research studies have focused on the development and validation of sensory methods for SQC, these include the quality index method ((Hyldig and Green-Petersen, 2005), deterioration index method (Vaz-Pires and Seixas, 2006, Sabbag et al., 2005), sensory quality index (Imm et al., 2011) and quality scoring (Kraggerud et al., 2012).

The deterioration index method (DIM) was developed to evaluate the changes in product quality that take place during storage. A trained panel uses a five-point structured scale to rate the samples on a list of quality attributes (Sabbag et al., 2005). The deterioration index was determined as a sum of the scores given for each quality attribute; higher scores indicate higher deterioration. This method was illustrated using frankfurter production and validated by comparison with the microbial count and physicochemical parameters. A limitation of this method was that the score given for each quality attribute was selected by consensus amongst panellists. The Quality index method determines the sensory quality and freshness of fish by evaluating several visual quality parameters using three or four- point scales (Hyldig and Green-Petersen, 2005). Similar to the DIM method, the scores on all quality attributes are added to determine the quality index (QI). This total score increases with an increase in deterioration. A description of the testing conditions was provided by the authors, as well as a description of the scoring criteria along with visual examples. The QIM provided a non-destructive, rapid method for the assessment of the freshness of fish as well as the estimation of the shelf life of the fish. The method was specifically designed for fish and needs to be modified for different species and has not been widely adopted for other products.

Etaio et al. (2010a) described a method for the assessment of the sensory quality of protected designation of origin (PDO) red wine from Rioja Alavesa. The wines are evaluated on eight weighted sensory parameters by assessors with product-specific training using a structured seven-point scale. The overall quality is determined by adding the score on each sensory attribute after due consideration of its weighting, the higher the overall quality, the better the wine. A limitation of the method is the use of several decision diagrams to guide the assessment and scoring of the wines. The method was validated by assessing the repeatability and reproducibility of the scores and attribute identification as well as the reproducibility in discriminative ability in scores and attribute identification (Etaio et al., 2010c).

A scoring system for evaluating the sensory quality of date palm based on 11 sensory attributes weighted based on their importance by consumers was developed by Ismail et al. (2001). The total quality score was determined as the sum of the attributes' scores, with higher scores denoting higher quality. The method considered both positive sensory attributes and defects. The scoring system was trialled using a trained panel; there was good agreement between the scoring system data and consumer preference data. In another method described by Imm et al. (2011), the sensory quality index (SQI) was calculated as a ratio of consumers' overall acceptability of the product at the end of its shelf life to their overall acceptability at the beginning of shelf life using a nine-point hedonic scale. The SQI method was designed to assess the sensory quality changes that occur over the shelf life of some refrigerated food products.

The SQI can also be set as a target quality level for the distribution of the product. The SQI method allows for the comparison of the sensory quality of products with different acceptability levels. A limitation of this method is that the sensory quality of the finished product at the end of manufacturing is considered ideal, this may not be the case depending on variations across batches and manufacturing errors. The products were assessed only at the beginning and end of their shelf life. Furthermore, consumers assessed their preference of the product, which is a subjective measure of quality.

Kraggerud et al. (2012) implemented the quality scoring method defined by the International Organisation for Standardisation (ISO), 2009 and the International Dairy Federation (IDF), 1997. The method consisted of the assessment of cheese by a trained panel using a textual description of the standard on four sensory quality attributes and a scale of 1 to 5, in order of increasing quality. The authors attempted to validate the method by correlating the findings to quantitative descriptive data and consumer preference data. While there was a significant correlation between the quality scoring data and descriptive data, this was not so for the preference data; the authors explained that this might indicate differences between consumer expectations and the standard used for quality scoring. A limitation of the quality scoring method is the focus on the identification of defects and deviations from the standard.

2.2.6 Evaluation protocol

All sample preparation, serving, and evaluation protocols need to be standardized and documented to reduce the introduction of variation and bias. All foods should be prepared following good hygienic practices to ensure food safety. Clear, concise, and adequate information should be provided to sensory evaluation technicians or assistants on the sampling point(s), sample preparation instructions, serving temperature. sample size, the type of serving container, the use of a carrier, the number of samples to be evaluated per session, the use of palate cleansers, etc. to enable the collection of accurate, repeatable measurements (Kilcast, 2010). Previous studies have shown that the product scores on different attributes were affected by the sample size (De Wijk et al 2003). Samples should be served at the normal consumption temperature.

Sample evaluation instructions should be provided to panellists, this includes information on the evaluation method, protocols for palate cleansing and swallowing or expectoration of samples after evaluation. Samples should be labelled with random three-digit codes and the sample serving order randomized during sensory evaluation to avoid bias due to order of presentation. Data collection should be standardized to improve efficiency and traceability, identifying information such as session number, panellist code, product code, serving order, etc., should be documented.

2.2.7 Data analysis/ management

Technological advances have led to the increasing adoption of computerized data capturing, analysis, and storage instead of the use of paper ballots and scorecards (Findlay, 2002). This improves the speed, ease and accuracy of data collection and analysis. Ideally, data validation should be carried out to assess panel performance prior to further data analysis for every sensory evaluation project to improve the confidence in the data (Carpenter et al., 2012). Analysis of sensory evaluation data rely more heavily on statistical methods due to technological advancements and the improved ease of data analysis (Lawless and Heymann, 2010). The choice of statistical technique depends on the complexity of the data and the objective of the evaluation.

Univariate techniques, such as measures of central tendency, t-test and analysis of variance (ANOVA) are traditionally used to summarize sensory data and identify differences between samples (Munoz, 2002, González-Álvarez et al., 2013). The use of multivariate statistical methods is also gaining traction as they provide more complex and detailed outputs compared to univariate methods, detecting and visualizing patterns and relationships between products and sensory attributes (Lawless and Heymann, 2010). Techniques such as principal component analysis (PCA) and correspondence analysis (Ojeda et al., 2015b, González-Álvarez et al., 2013) have been used to describe and visualize the relationship between products. These may be useful in highlighting redundant descriptors. Univariate and multivariate control charts such as the X bar chart and T^2 Hotelling chart used in quality and process control are also useful for SQC (Munoz, 2002, Imm et al., 2009).

2.3 SENSORY QUALITY CONTROL BY INSTRUMENTS

SQC using a human panel has some inherent challenges and bias related to the assessment of food by humans, these affects the efficiency of data collection and reliability of the data collected (Zhang et al., 2008). These challenges include panellist fatigue, health constraints, variations in panellist's mood and difficulty in performing online assessments (Loutfi et al., 2015, Zhang et al., 2008). Furthermore, sensory evaluation using a human panel may sometimes be considered as labour intensive, expensive and time consuming (Caine et al., 2003). These have led to the use of physical instruments such as rheometers, texture analysers and colorimeters and more recently the development of electronic noses and tongues (E-nose and E-tongue) for measuring sensory attributes. E-noses and tongues are sensor systems that differ from other instrumental methods in that they mimic the function of the relevant human senses (Peris and Escuder-Gilabert, 2016).

These instruments measure the physical and chemical composition of the food products that are important contributors to the sensory quality perceived by consumers. The use of instruments may be faster, more cost-effective in the long term, and more suitable for on-line or at-line in monitoring of ~~some~~ sensory attributes than the use of human panels (Zhang et al., 2008). However, instrumental methods may not replace human assessments of the sensory perception in some foods (Schlossareck and Ross, 2019). A decision needs to be made on the suitability and practicality of using a human panel, instruments, or a combination of both. A combination can be beneficial to have a comprehensive understanding of product quality. Where instrumental methods are used, it is important to establish a relationship between the results obtained and the sensory perception of the attribute/s using a human panel (Hansen et al., 2005).

Instrumental measurements often focus on discrete physicochemical properties of food products, such as colour and viscosity. Colorimeters (Rocha and Bolini, 2015, ZIMBRU et al., 2020), rheometers and texture analysers (Caine et al., 2003, Cardarelli et al., 2008, Taghizadeh et al., 2018) are widely used in literature to measure these properties. Some authors have also explored the relationship between the instrumental and sensory data of specific food products (Caine et al., 2003, Chumngoen and Tan, 2015, O'Sullivan et al., 2003). The relationship usually varies from one product and/or property to another. For instance, the study by Chumngoen and Tan (2015) revealed a high positive correlation between the colour data of cooked chicken obtained from a trained panel and that of a colorimeter. A similar relationship was also observed between sensory hardness and instrumental collagen content data. Kilcast and Clegg (2002) reported a positive correlation between sensory overall creaminess and instrumental viscosity for chocolate mousse. While Caine et al. (2003) reported a negative correlation between the hardness, cohesiveness and chewiness of cooked beef steaks determined by instrumental texture analysis and the data for initial tenderness and overall tenderness from a trained panel. These findings emphasise the need to establish a significant positive relationship between the data trained panel and instruments to ensure that the data from the instrument is relevant.

E-noses and tongues usually consist of multiple sensors equipped with chemosensitive materials with different selectivity that detect tastants and odorants, and a pattern recognition unit such as a neural network (Winquist et al., 2000, Son and Park, 2018). The instrument is calibrated by training it to recognize a wide array of product samples or reference compounds selected by human panels and sensory personnel, the models developed are validated with unknown samples (Bleibaum et al., 2002). Since chemical sensors are usually used for e -noses and tongues, they are sometimes unable to distinguish between chemicals with similar structures (Son and Park, 2018). More recently bioelectronic noses and tongues have been developed with biosensors to improve the sensitivity and specificity of existing instruments (Garcia-Hernandez et al., 2019).

E-noses and tongues have been successfully used in the prediction of the final quality of finished products from the raw materials (Hansen et al., 2005, Garcia-Hernandez et al., 2019). This may have applications in the on-line or at-line measurements of the sensory quality of food products. E-noses and tongues have been used for profiling and classification of protected designation of origin (PDO) food products such as Chinese vinegar (Zhang et al., 2008) and fermented milk (Winquist et al., 2000), this will be useful for SQC in determining the authenticity of such products. The e-tongue has also been successfully used to discriminate between varying levels of capsaicin in paneer cheese samples. The results showed a high degree of discrimination (93%) and that the device may perform better than humans in discriminating low concentrations (below 3.75 ppm) and high concentrations (above 15 ppm) of capsaicin (Schlossareck and Ross, 2019).

Despite the increasing adoption of instruments (particularly e noses and tongues), their application in industry is still limited, this may be due to challenges in reproducibility and selectivity of sensors (Loutfi et al., 2015). For instance, the multiple sensors in the e-tongue described by Schlossareck and Ross (2019) were shown to be cross selective, thus samples with the highest concentration of the spicy compound did not correspond to the spicy sensor as all the sensors are used to discriminate between samples. In general, an important challenge with the use of instruments in the analysis of sensory quality of products is the need to establish a significant correlation between the relevant sensory and instrumental data (Zhang et al., 2008; Bleibaum et al., 2002).

2.4 BENEFITS AND LIMITATIONS OF SQC

The benefits and relevance of SQC in the food industry are manifold. At the centre of these is the importance of maintaining standardised product sensory quality to ensure initial selection and repeat purchase of food products by consumers (Hansen et al., 2005). An important aim of the SQC system is to promote customer acceptance and loyalty by monitoring and ensuring the consistency of the product's sensory characteristics across and within batches (Endrizzi et al., 2013). The data collected from SQC can also be used as input for trouble shooting and process and quality improvements (Kraggerud et al., 2012). The implementation of SQC will also promote awareness of the sensory quality of products by staff (Kilcast, 2010) and provide evidence of the organisation's commitment to product quality. The sensory specification developed for SQC may also be useful for communications within an industry and with other partners such as, suppliers, retailers and marketing staff (Stone and Sidel, 2004b, Hashmi, 2007). SQC also provides important evidence for the authenticity of PDO products as reported for wine (Etaio et al., 2010a), cheese (Endrizzi et al., 2013, Ojeda et al., 2015) and pepper (Torre et al., 2012) amongst others. Information from SQC may also be used in the determination of the economic value of food products (Feria-Morales, 2002).

While there has been considerable growth in the adoption of SQC, especially in the food industry; this has not matched its potential (Munoz, 2002). This could be due to certain limitations in the adoption and implementation of SQC, these limitations are often inter-related. These include inadequate management commitment and support, limited understanding of how to integrate sensory quality information with other product quality measures (Stone and Sidel, 2004a). Other contributing factors are the limited success of previous SQC programmes, difficulty in justifying the cost and time investments, especially for companies that have not had mass product rejection due to sensory defects (Munoz, 2002). Other limitations include the use of inappropriate sensory methods, too few panellists, use of ambiguous specifications, introduction of bias due to inappropriate practices (Costell, 2002); McGrew, 2011). All of these may be linked to an underlying challenge- limited sensory evaluation expertise of company staff.

2.5 THEMATIC CLASSIFICATION OF SQC STUDIES 2000- 2019

A systematic review of the literature on SQC was carried out to highlight the areas of focus and trends. Research articles indexed in Web of Science (WOS) and Scopus databases between 1 January 2000 and December 2019 were retrieved. The ‘Article Title, Abstract, and Keywords’ of all articles were searched using the keyword “sensory quality control”. A total of 69 and 39 articles were retrieved from WOS and Scopus, respectively. Duplicate entries (34), books (16), patents (3), meeting (3) and others (6) were removed. Articles’ abstracts and full texts (where necessary) were reviewed to select and justify their inclusion in the review; a further 12 entries were removed as they were not related to the topic of interest. Twenty-eight (28) articles were included in the review, a summary of the retained articles is shown in Table 2.1.

The articles retained from the literature search revealed three main themes. The highest number of articles focused on sensory evaluation methods (12), sensory panel management (6), factorial experiments (5), sensory data management (2) and miscellaneous aspects - those that did not fall into any of the other groups (3).

Table 2.1 The scope of study and case study product of SQC studies published from 2000 - 2019 and retrieved from Web of Science and Scopus using 'sensory quality control' as search keyword

Scope	Reference	Product
Sensory methods		
Method development	Etaio et al., 2012	Wine
	Etaio et al., 2010	Wine
	Imm et al., 2009	Jajang sauce
	Johansson, 2007	Beer
	Ojeda et al., 2015	Dairy (cheese)
Comparison of sensory methods	Kraggerud et al., 2012	Dairy (cheese)
	Paz et al., 2001	Margarine and Mozarella cheese
Sensory methods vs other methods	Liu et al., 2017	Pork
	Zabaleta et al., 2017	Dairy (milk and cheese)
	Meier-Dinkel et al., 2015	Pork (boar)
	Hansen et al., 2005	Meat loaf
	Mauris et al., 2000	Sausage
Sensory panel management		
	Gonzalez Casado et al., 2019	Dry-cured ham
	Morlein et al., 2015	Pork (boar)
	Trautmann et al., 2017	Pork
	Trautman et al., 2014	Pork (boar)
	Etaio et al., 2010	Wine
	Torre et al., 2012	Pepper
Formulation and processing studies		
	Zhao et al., 2017	Soy-pork dish
	Sheng-Kun et al., 2017	Apricot
	Meier-Dinkel et al., 2016	Pork
	Tian et al., 2015	Chinese water chestnut
	Gonzalez-Alvarez et al., 2013	Wine
Sensory data management		
	Arana et al., 2015	Canned white asparagus
	Findlay, 2002	NA
Miscellaneous		
Defect identification	Zabaleta et al., 2016	Dairy (cheese)
Sensory lexicon development	Pereira et al., 2015	Sausage
Manufacturing system management	Curt et al., 2002	Sausage

NA- Not applicable

Sensory evaluation methods

The development of new sensory evaluation methods, comparison of existing methods and comparison of sensory methods and other instrumental or chemical methods used in SQC has received considerable attention in literature. Despite this, the misuse of sensory methods is also well documented (Stone and Sidel, 2004b, Costell, 2002). Sometimes the sensory method may need to be tailored for a specific product, this is usually the case for PDO products whose sensory properties are usually an important differentiator between these products and other products. Etaio et al. (2010a) described the development of an accredited method for SQC of

PDO wine from Rioja Alavesa (red wine). The development of suitable references for the sensory descriptors was also presented. Two other studies, Ojeda et al. (2015a) and Etaio et al. (2012) described methods that enabled a more detailed description and differentiation of PDO Idiazabal cheese and PDO Bizkaiko txakoli wine, respectively. The methods modified earlier methods that focused on the rejection of products based on the presence of sensory defects. In the new methods, positive sensory characteristics were also described and classified in detail.

Some studies compared different sensory evaluation methods. A positive significant correlation between the data from a novel and an established method indicates that the novel method may provide relevant data. A significant correlation was found between sensory quality data of cheese obtained by descriptive sensory evaluation and a quality scoring method (Kraggerud et al., 2012). There was also a good agreement (>85%) between the sensory quality data for Margarine and Mozzarella cheese from two sensory evaluation methods, the global impression (GI) method and the analytical method for sensory evaluation (APSE) (Paz et al., 2001). The global impression (GI) method is a rapid method based on a five-category qualitative scale while the analytical method for sensory evaluation (APSE) is a defect assessment method.

Several studies have been carried out to establish the relationship between sensory quality evaluation using a human panel and assessment by chemical methods. For example, moderate agreement was found between the detection of two marker compounds of boar taint (androstenone and skatole) by a trained sensory panel and chemical analysis (Meier-Dinkel et al., 2015). Boar taint is a sensory defect that may influence consumers' satisfaction of pork products. Liu et al. (2017) investigated the causes of variation between analysis of androstenone and skatole, the compounds responsible for the undesirable boar taint, by chemical and sensory evaluation methods. The study revealed that the fatty acids composition of the product could not explain the disagreement found between the two methods. A study by (Zabaleta et al., 2017) identified the chemical compounds related to the human perception of balanced flavour or off flavour in ewe's raw milk commercial cheeses.

As previously discussed, instrumental methods have been identified as an alternative to using a human panel in monitoring sensory quality, particularly for on-line/ at-line measurements. The suitability of instrumental measurements may depend on the food material being assessed as revealed in a study by Hansen et al. (2005). In this study, an electronic nose could detect the presence of volatile compounds in the raw materials that resulted in defective products but was unable to detect the volatile compounds in all defective finished products (meatloaf). The authors attributed this variance to the change in volatile profile due to cooking. Another study revealed a good correlation between data from instrumental assessment of sausage crust quality using specialized image software and the data from human panellists (Mauris et al., 2000).

Sensory panel management

The use of objective methods in the selection, training and validation of sensory quality panels cannot be overemphasised because the validity of the data obtained depends on the sensitivity and accuracy of the instrument, in this case, the sensory quality panel. Panellist selection must be based on their sensory acuity and descriptive ability for the specific attributes of concern. For instance, in the case of detecting boar taint in pork products, Mörlein et al. (2015) tested the ability of panellists to detect androstenone and skatole at relevant concentrations and measured the discrimination ability of panellists to differentiate varying levels of the odorants. The authors emphasised that an appropriate number of defective and total number of samples must be included in selection and qualification tests as the smaller the sample number, the larger the uncertainty (confidence interval). A guide for estimating the number of boar tainted samples that should be evaluated by potential panellists at various combinations of true sensitivity, power, and significance levels (for example, Figure 2.1).

A similar study was carried out by Trautmann et al. (2014). Results revealed that the androstenone detection threshold for panellists significantly affected the sensory rating of samples but the skatole detection threshold did not. Thus, it may be beneficial for panellist screening tests to include multiple sensory defects to capture such variations in detection thresholds. Another study by Etaio et al. (2010b) also assessed panellists' ability to identify reference samples as part of screening tests. The study revealed that the reference identification test was more difficult than basic screening tests, with more panellists requiring a retest to pass. Thus, providing evidence of the importance of product-specific tests during panellists screening.

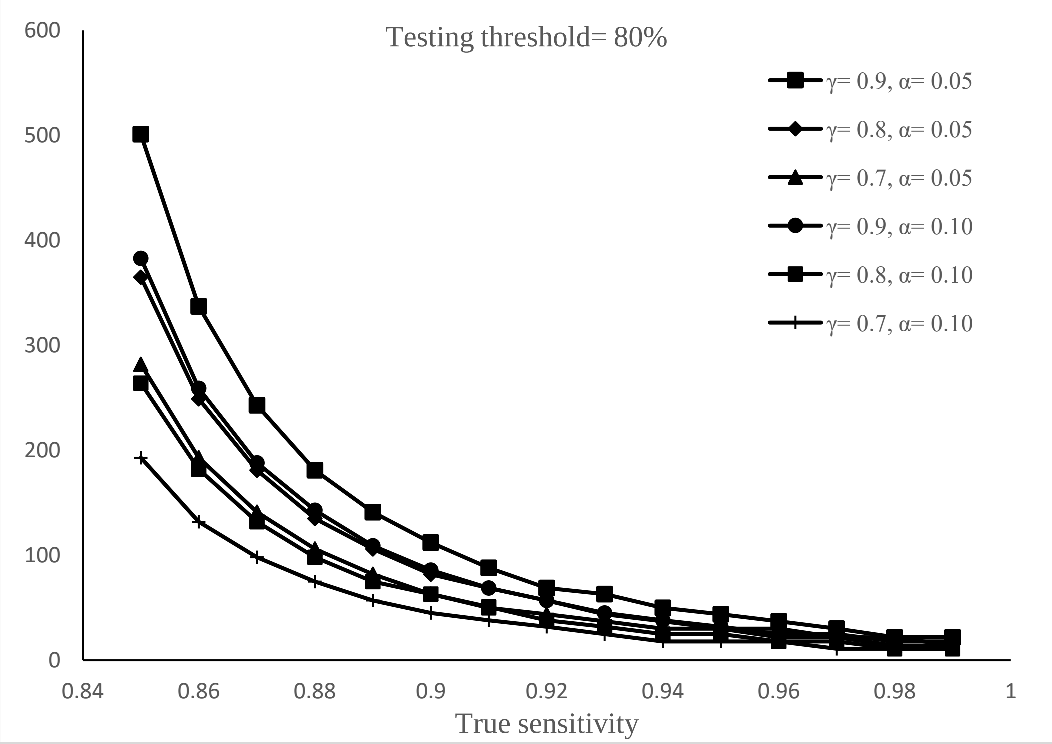

Figure 2.1 The number of boar tainted samples required at different levels of true sensitivity for various combinations of power (γ) and significance level (α) at a testing threshold (πo) = 0.8 (Mörlein et al., 2015)

Training of selected panellists, in the articles captured, usually included both general and specific sensory evaluation training. Etaio et al. (2010b) described a method for the selection, training and qualification of panellists used for SQC of Rioja Alavesa red wines. The authors emphasised the importance of extensive product-specific and method-specific training. Panellists were also trained and assessed on the identification of reference standards. In another study by Torre et al. (2012), three independent sensory panels were used to identify and validate acidity references for PDO peppers (Piquillo de Lodosa). The use of suitable references play an important role in establishing intensity ranges and may improve the reliability of the results; references are also particularly beneficial where sensory data will be compared over time or across panels (Torre et al., 2012). Torre et al. (2012) also emphasised the importance of the choice of measurement scale for training and product evaluation as it determines the nature and quality of the information collected and affects the ease of data collection and training required for panellists.

Contrary to the widely accepted notion that a noise-free environment is necessary for sensory evaluation, Trautmann et al. (2017) showed that constant noise did not affect panellists' performance on boar taint olfactory tests. Thus, standardisation of the testing environment should be the focus for choosing a location for product evaluation as part of SQC.

Panellists and panel performance have been assessed using statistical parameters such as their standard deviation of repeatability (SDR), standard deviation of reproducibility (SDRr) (Etaio et al., 2010b), repeatability index (RI), deviation index (DI), intermediate precision index (IP) (González-Casado et al., 2019).

Formulation and process modelling

Studies to evaluate the effect of ingredient and process control on the sensory quality of products are important during product design and optimization. One such study was carried out to assess the effect of sugar concentration of grapes on the sensory properties of young and aged wine (González-Álvarez et al., 2013). The study revealed that sweet wines obtained by natural grape dehydration were preferred to those obtained by alcohol fortification. The impact of packaging type on sensory quality of soy sauce-stewed pork dishes was studied by Yue et al. (2017), they revealed that modified atmosphere packaging retarded the deterioration of sensory quality better than vacuum packaging.

Sheng-kun et al. (2017) studied the effect of different conditions of hot air drying on the colour of dried white apricots. The authors reported that drying temperature affected the colour and drying time while the wind speed had no effect. Tian et al. (2015) studied the effect of a mild heat pre-treatment on the sensory quality of sliced Chinese water chestnuts using quantitative descriptive analysis. Mild heat pre-treatment preserved the colour, flavour and texture of the product. These studies may indicate the importance of processing conditions on the sensory quality of the final product and thus the need for process controls to be part of the sensory quality control strategy.

A study carried out by Meier-Dinkel et al. (2016) revealed that consumer acceptance of pork chops could be predicted by the fat score from sensory evaluation of pork back fat by trained panellists. Furthermore, an increase in the level of off flavour resulted in a rapid increase in the rejection of the meat regardless of whether it was consumed alone or as part of a meal. This implied that human assessment of the quality of products could be a valuable tool to ensure customer satisfaction. Calibration of an instrument based on product evaluation scores from the human panel may provide for an efficient and reliable quality screening tool on the production or processing line as humans cannot screen every pork chop.

Data collection and analysis

Development and improved accessibility to computers and the internet has several advantages for SQC (Findlay, 2002). The use of computers and the internet has facilitated the automation of data collection from multiple remote sites, eased data collation and storage, improved the speed and accuracy of statistical analysis and presentation of results in graphs and control charts. Findlay (2002) described the use of a purpose-built SQC software (Compusense® QC) that analyses data collected from panellists and assigned a quality grade for each attribute of a product using a pre-determined target range. The use of some existing statistical techniques in new sensory quality applications may also be beneficial to the advancement of sensory quality control. Statistical techniques such as capability analysis and X over bar ($\bar{x}$) charts (Figure 2.2) have been used to estimate and monitor out of specification products (Imm et al., 2009). Agglomerative cluster analysis (AHC) has been used to group different manufacturers of protected geographical indication (PGI) canned white asparagus based on the sensory descriptors with the highest quality scores (Arana et al., 2016). They suggested that AHC allowed the visual representation of sensory quality data in a detailed and, easy to interpret manner.

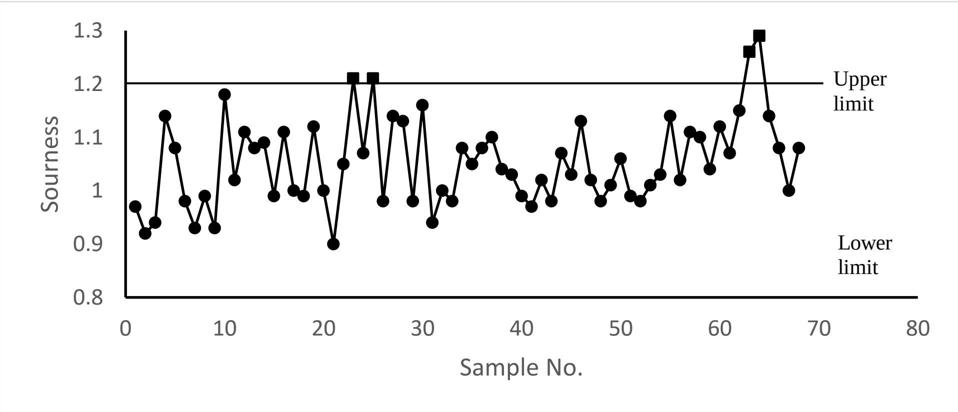

Figure 2.2 $\bar{x}$ chart of sourness rating of samples over multiple sessions (Sample No.). Square markers are out-of-specification samples and round markers are in-specification samples (Imm et al., 2009)

Miscellaneous aspects

Zabaleta et al. (2016) studied the main sensory defects associated with semi-hard raw cheeses made from ewe's milk. Their study revealed that sensory defects related to the internal structure of the cheese (examples cracks and caverns) were the most common. Different types of sensory defects were prevalent in certain types of cheese, for example, prevalence of animal flavour in medium and long ripened cheese. This study pointed out the importance of identifying the prevalent sensory defects associated with each product as this may differ even within very similar products.

The development of a lexicon for the descriptive sensory evaluation of Morcela de Arroz (a ready to eat rice and blood sausage produced in Monchique, Portugal) was documented by Pereira et al. (2015). The authors argued that a well-defined lexicon facilitates the objective description of products and is thus necessary for obtaining valid QC data. Curt et al. (2004) described an SQC system based on the identification and management of points of deviations from the desired sensory quality along the manufacturing operation. The authors also focused on operator-led management of sensory quality based on formalization and transfer of process knowledge.

Trends in SQC literature

The high number of papers found on sensory evaluation methods compared to other aspects is evidence of its relevance for SQC. It may also support previous findings regarding the need to tailor sensory evaluation methods to meet the SQC needs of specific products and their respective manufacturing operations, thus resulting in studies to address this. Three studies assessed the correlation between the use of chemical methods and a human panel to assess sensory quality. This is important to ensure that the data collected using chemical methods is relevant to consumers' perception of the sensory quality of the product (Stone and Sidel, 2004a). Five studies on SQC of PDO or PGI food products were carried out between 2010 and 2015; this may indicate a period of industrial interest in the certification and authentication of these products.

Studies on panel selection and management have highlighted the need to assess the sensory acuity of potential panellists for critical sensory attributes of the product; these may include both defective and desirable attributes. This is necessary particularly in cases such as boar taint detected in pork products, where existing evidence reveal insensitivity to the odorant among some individuals with otherwise normal olfactory performance (Trautmann et al., 2014). Only two of the research articles on panel management included the validation of the sensory panel, this may be an indication of the slow adoption of the validation step despite its importance to demonstrate the panel performance. Of the six articles on panel management, four were related to boar taint, these may be due to industry interest related to EU regulations regarding boar taint (Mörlein et al., 2015).

Several studies in literature and reported here have illustrated that the sensory quality of the final product is determined by the quality of the ingredients, all steps of processing and preparation prior to the consumption of the product. However, only one of the studies (Curt et al., 2004) retrieved from the literature search focused on managing sensory quality across all stages of the manufacturing process (system approach). Most SQC studies have focused on unit operations, panellists' management, or sensory evaluation methods. More studies focusing on a system approach to SQC are necessary.

2.6 SYSTEM BASED SENSORY QUALITY MANAGEMENT

System based sensory quality management considers the sensory quality at all steps of the product processing, ideally from farm to fork. For reasons of practicality, and due to the considerable influence of the manufacturing process on the sensory quality of the final product, companies may focus on the manufacturing process as seen in Curt et al. (2004). A system approach to sensory quality will allow identification of potential causes of deviations from the target sensory quality at each point in the manufacturing process. This allows for the deployment of strategies to prevent the occurrence of these causes of deviation resulting in a preventive and proactive, rather than a reactive approach of focusing on finished product testing for sensory quality management. This strategy was also supported by Aumatell (2011) who recommended that SQC monitoring should be carried out on the food ingredients and during processing.

The importance of a system approach to SQC has been advocated in other reports. Varzakas and Tzia (2015) explored the effect of system factors such as raw materials, processing conditions, packaging, etc. on the sensory quality of food. They provided examples of some food processing steps/practices that are critical for specific sensory attributes (for example, Maillard reaction to colour of baked foods) and recommended a system approach to SQC (Figure 2.3). One author, Stefanova and Zlateva (2018), suggested that monitoring of sensory quality indicators in a responsive and timely manner at earlier stages of production would be more cost efficient and more effective at ensuring consumer satisfaction.

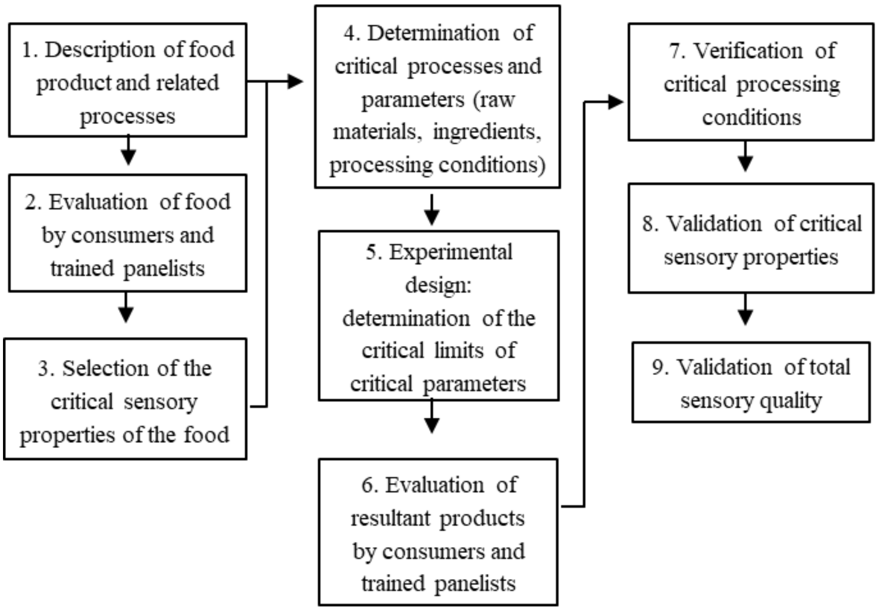

Figure 2.3 Steps for designing and validating the sensory quality system (Tzia et al., 2015)

A similar systems approach, hazard analysis and critical control points (HACCP), has been widely accepted and successful in the management of food safety. HACCP is a preventive, risk-based system used for identifying, assessing, and controlling hazards in food processing steps that are critical to food safety (Kafetzopoulos et al., 2013). The risk-based, semiquantitative means of assessing hazards using the HACCP system has been successfully applied in the Vulnerability Assessment and Critical Control Points (VACCP) and Threat Assessment and Critical Control Points (TACCP) systems for management of food defence and food fraud, respectively (Manning and Soon, 2016).

2.6.1 Tools / methods for system based sensory quality management

An and Wang (2016) proposed a sensory quality system based on the satisfaction of customer requirements using a systems approach. They described a system that was divided into four layers: target quality, function configuration, question and method/tools layers. The target layer described customers' quality requirements and breaks it down to executable components linked with the sensory attributes. The configuration layer identifies quality related processes and activities and how they contribute to achieving the target. The question layer assesses the possible points in the process where sensory quality failure can be introduced. While the method layer includes all the tools employed to manage sensory quality throughout the product life cycle. No case study example of the system was presented and some of the tools described (such as QFD – quality function deployment and FMEA- failure mode and effects analysis) may require specialized expertise for their implementation.

Curt et al. (2004) described a system-based sensory quality management process that is accomplished in three steps. This was illustrated with two sausage manufacturing operations. First, the causes of sensory defects were identified, an example would be the effect of mincing on the sticky defect in sausages. This was achieved by the establishment of cause-and-effect relations of the raw material and processing on the finished product, these relationships were identified based on the existing knowledge of the product and its processing using cause and effect diagrams. The second step involved the identification of control measures for preventing or eliminating deviations from the desired sensory quality, for example, the use of temperature control prior to the mincing stage. A plan for the improvement of sensory quality control was proposed in the third step, this was based on an assessment of the suitability of the control measures for the effective management of the sensory properties.

Two of the three steps described by Curt et al. (2004) are similar to the three main aims of HACCP- hazard identification, assessment and control (Kafetzopoulos et al., 2013), thus highlighting the similarities between both strategies for quality management. Like in HACCP, it is expected that when the sensory quality management is correctly applied, the products will possess the desired (target) sensory quality (Kafetzopoulos et al., 2013). However, Curt et al. (2004) did not describe the assessment of the causes of the sensory defects or prioritize them to identity the critical ones.

2.6.2 Control of critical steps

Identification and control of the processing steps that significantly impact the control and management of the important sensory attributes should be an important sensory quality management strategy (Varzakas and Tzia, 2015). Aumatell (2011) suggested strategic SQC monitoring of only the critical steps, while other steps can be monitored by chemical or physical methods. This prioritization may be applied to determine the sensory properties that are critical to consumer preference of the product. This is important as while all sensory properties of the product may affect consumer acceptance, they vary in their level of importance for product selection by consumers (Chong et al., 2020). The critical sensory properties are those that have the most influence on consumer liking and reflect their expectations and requirements regarding the product (Varzakas and Tzia, 2015). Reduction of the sensory quality monitoring to only a few critical ones may reduce the cost and time spent on monitoring and enable adequate alignment of the quality system to meet customer requirements. These savings may also increase the adoption of sensory quality management, particularly by small and medium food companies.

External preference mapping is a class of data modelling techniques usually used for understanding the sensory properties that drive consumer preference (Cariou et al., 2014). Several studies have used external preference mapping to visualise and understand consumer preferences for specific products (Chong et al., 2020, Ares et al., 2011, Kraggerud et al., 2012), an example of a preference map is shown in Figure 2.4. These studies usually state the application of findings in developing the sensory specification and product optimization, however, its relevance in reducing the number of sensory attributes monitored during quality control to only a critical few is not usually acknowledged. Another potential technique for selection of critical sensory attributes and processing steps for SQC monitoring may be the hazard assessment principles of HACCP. In HACCP, the critical hazards for controlling food safety are identified by considering the severity of the hazard and the likelihood of its occurrence (Kafetzopoulos et al., 2013). Then the critical steps are identified as the steps in the manufacturing process where it is critical to control a significant hazard.

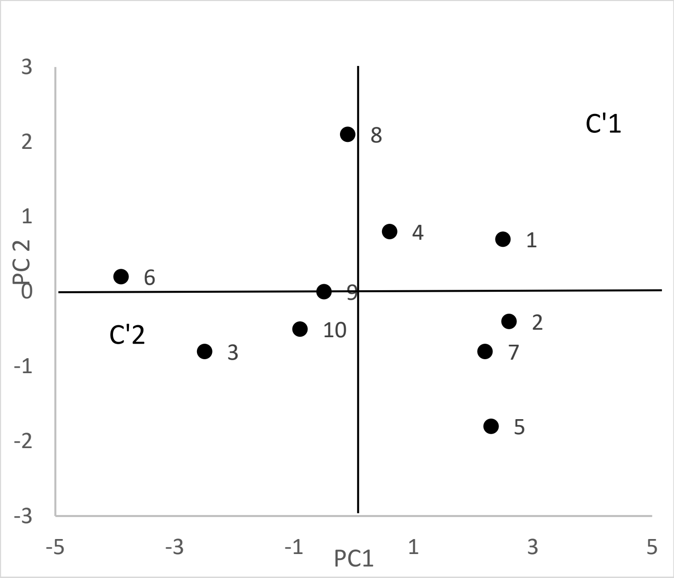

Figure 2.4 External preference map of consumer clusters (C'1 and C'2) using the spatial representation of the instrumental texture properties of a group of products (1-10). Consumer clusters are located close to their most preferred products (Ares et al., 2006)

2.7 COMPETENCE OF SENSORY QUALITY PERSONNEL

SQC, like other aspects of quality control in food companies, usually rests on the shoulders of company employees (Curt et al., 2004). This may be sensory technologists in larger companies or quality staff with sensory evaluation responsibilities in smaller companies with few staff numbers. Maintaining consistent product sensory quality is not the sole responsibility of the sensory technologist and/or production operators. Other operation staff also have a role to play. The monitoring and control of raw materials and processing conditions are usually carried out by production staff (Curt et al., 2002), who may not understand the role of these steps on the sensory quality of the final product. Hence, a company-wide awareness of the importance of sensory quality to product success and an understanding of the contribution of different job functions to the sensory quality of the final product will encourage ownership of responsibility and thus the success of the SQC system. This dependence on employees has been widely investigated and established for a related quality concept- food safety (Nyarugwe et al., 2018). Several factors that influence food company employees' food safety practices have been identified; these include their knowledge, attitudes, level of motivation as well as organisational factors such as policies, training approach and provision of an enabling environment (da Cunha et al., 2019). These factors will also be important for SQC and should be assessed towards the identification of areas of improvement.

2.7.1 Assessment of sensory evaluation related knowledge and behaviour of food company employees

Food company employees are assessed for their knowledge and practices by themselves, peers, supervisors and/or third-party organisations, the most common being self-assessment (Zanin et al., 2017). Several methods have been used to assess the knowledge and behaviour of food company employees on food safety and hygiene. The methods include face to face interviews, observation of workplace practices, document analysis and self-administered questionnaires (Karaman, 2012, Nyarugwe et al., 2018, da Cunha et al., 2019). Other assessments measures and tools include rubrics, randomized trials, and performance-based measures (Schrader and Lawless, 2004, Peeters et al., 2013). The different assessment methods have their inherent advantages and disadvantages, the most popular being self-assessment surveys using questionnaires.

Self-administered questionnaires are popularly used for measuring knowledge and compliance to good practice (Launiala, 2009). Some advantages and disadvantages of the use of questionnaires are shown in Table 2.2.

Table 2.2 Advantages and disadvantages of the use of questionnaires in behavioural research (da Cunha et al., 2019, Rust and Golombok, 2014, Seale, 2012, Launiala, 2009)

Advantages	Disadvantages
Easily administered in multiple locations	Inappropriate for respondents with a low literacy level
Cost-effective data collection	Difficult to verify the identity of respondents
Allow collection of quantitative data	Not easy to probe responses further
Collection of generalizable data	Self- reported practices may differ from actual practices
Allow anonymity of the respondent	
The scoring is objective	

Questionnaires used for the assessment of sensory evaluation practices

Despite the many research reports available on the development of validated questionnaires and assessment of food company employees' knowledge, attitudes and practices (KAPs) with regards to food safety (Zanin et al., 2017), none was found for sensory evaluation and SQC. The use of very few sensory evaluation questionnaires is documented in the literature. The results of a survey on sensory evaluation in food product development groups by Brand and

Arnold (1977) was reported in Stone and Sidel (2004a). The responses revealed that sensory evaluation was carried out in 56 of the 62 companies contacted. The companies reported that they used several sensory evaluation methods such as triangle tests, hedonic scaling, and paired comparison tests. Responses also revealed some confusion in the understanding of the questions or knowledge of sensory methods as 25 companies and seven companies reported the use of single sample presentation and scoring as sensory methods, respectively (Stone and Sidel, 2004a).

The Sensory Evaluation Division (SED) of the Institute of Food Technologists (IFT) also carried out a survey in 2001 and 2002 on the role of sensory evaluation within companies. There were 27 responses in year 2001 and 122 in year 2002. In the year 2002, 39% of respondents were manufacturers of food and beverages, 14% were academics, 11% were ingredient manufacturers, and smaller numbers were from consulting, manufacturers of consumer care goods and other groups. Only 41% of respondents reported that their company carried out SQC functions internally, this was lower than 79% who reported that consumer/ preference testing was carried out internally. Data analysis was carried out internally for 78% of respondents. Furthermore, 71% of respondents reported that their companies outsourced some sensory evaluation services; 14% reported that their companies outsourced less than 25% of SQC functions and 2% reported less than 50% outsourcing of SQC related services. This revealed that most of the SQC related activities and data analysis were carried out internally, thus, emphasizing the need for sensory evaluation expertise to be in place or developed by food companies. Both surveys did not assess employee knowledge or attitudes related to SQC and the development and validation of the questionnaires were not documented.

Knowledge, attitudes and practices (KAP) studies

The widespread use of KAP studies in the assessment of food quality related practices rests on the understanding of the importance of knowledge and attitudes in the modulation of behaviour (da Cunha et al., 2019). While subject specific behaviour is facilitated by the possession of requisite knowledge and attitude (Ko, 2013, Nyarugwe et al., 2018), behaviours can also influence knowledge gains (Schrader and Lawless, 2004). Hence a multi-construct (knowledge, attitude attitudes and practices) approach rather than the sole focus on knowledge or practices is necessary to adequately study and understand behaviour regarding SQC. KAP studies rely on the dynamic interaction between knowledge, attitudes and practices that have been described by the social cognitive theory (SCT) and the knowledge attitude behaviour (KAB) model. The KAB Model proposes that the acquisition of new knowledge leads to changes in attitudes and eventually practices (Kwol et al., 2020). SCT proposes that learning relies on the triadic, reciprocal relationship between personal disposition, environmental influences and behaviour (Richards et al., 2017).

Knowledge

Knowledge refers to the sum of all information or understanding a person possesses on a subject (Schrader and Lawless (2004); in this case the subject of interest is sensory evaluation. Knowledge is acquired by education, experiences and reasoning; existing knowledge facilitates learning (Bakken and Dobbs, 2016, Schrader and Lawless, 2004). Limited sensory evaluation expertise has been highlighted as a limitation to the implementation of successful sensory evaluation programmes (Endrizzi et al., 2013). Thus, it is important to assess the sensory evaluation knowledge of relevant food company employees and to train them to adequately perform their sensory quality related responsibilities. Knowledge assessment will be beneficial to identify employee training needs and other potential strategies for the improvement of the SQC system.

Attitude

Attitude, in particular “intention to act”, has been suggested to be the best indicator of behaviour (Ko, 2013), this is because a person with the requisite food quality knowledge may not be willing to put it into practice (da Cunha et al., 2019). Attitude refers to an individual’s thoughts, mental state, and feelings about a subject or issue (Launiala, 2009). Positive attitudes are a vital link between knowledge gains and positive change in behaviour (Ko, 2013). Food company employees with the right attitude usually try to adopt the right practices (Nyarugwe et al., 2018), this should also apply to sensory evaluation. Thus, the assessment of SQC related attitudes of food company employees will aid in understanding the link between their knowledge and practices.

Practice

Practice refers to the observable actions in the execution of job responsibilities (Nyarugwe et al., 2018). To a large extent, the SQC practices of a food company depend on their organisational culture and quality control strategy. SQC practices may also depend more on the company than the employee due to requirements for good sensory practices (such as experimental control of samples, panellists and the testing environment). Employee sensory quality monitoring efforts without the adherence to these good sensory practices is at best food tasting. Furthermore, an enabling environment is necessary for the application of employee knowledge (Nyarugwe et al., 2018). Thus, it is important to assess the level of compliance of the company to good sensory practices to unveil possible areas of improvement assessment (Zanin et al., 2017).

2.7.2 Questionnaire development

The establishment of the validity and reliability of questionnaires is necessary to ensure the collection of relevant, accurate and reproducible data, reducing measurement errors and improving confidence in the findings (Singh, 2017). One strategy for doing this is to pilot test the questionnaire prior to the collection of data. A pilot study may also be useful to test the feasibility of questionnaire administration and identify potential problem areas such as participant recruitment and coding errors (Rubio et al., 2003). The sequence of the questionnaire development activities varies from one study to another, but the steps commonly followed are summarized in Figure 2.5.

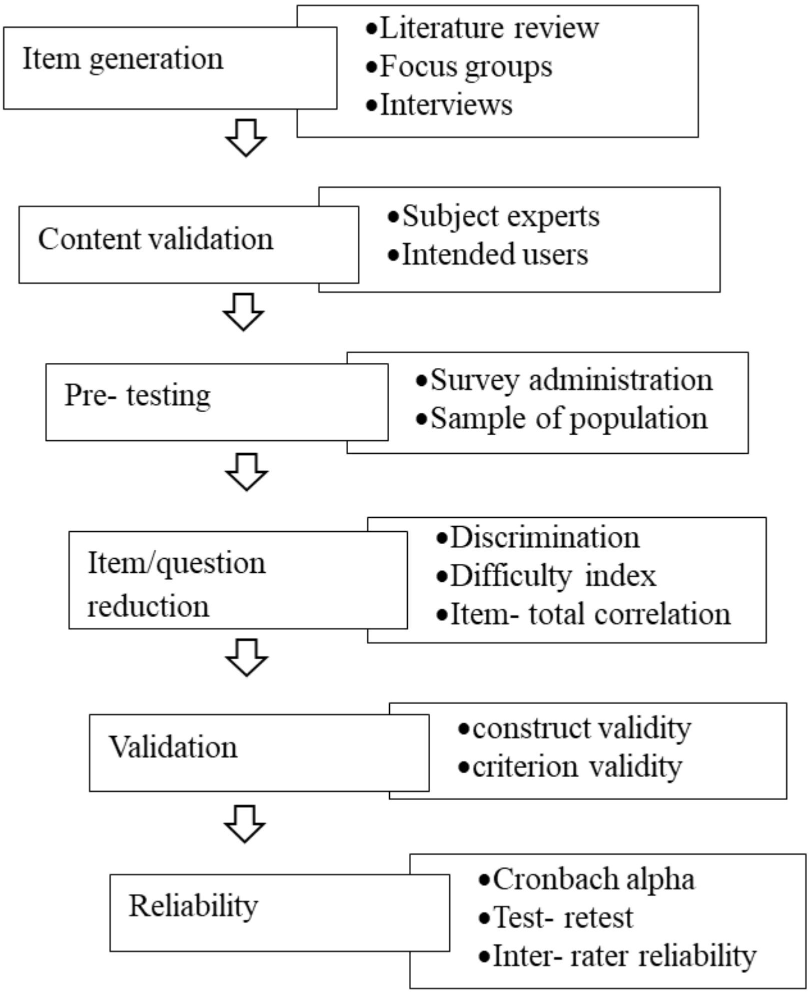

Figure 2.5 Steps for questionnaire development and validation (Boateng et al., 2018)

Item / question analysis

Item analysis is useful to reduce the pool of questions to a manageable number by enabling the selection of questions that will allow the most total variance/ coverage of the principles (for example, *of SQC*) and the removal of redundant questions (Rust and Golombok, 2014). These tests are particularly useful where there is a right or wrong answer based on the context, such as for selecting the best questions to test the knowledge of SQC. The difficulty index for each sensory quality knowledge question may also be refers to the proportion of respondents that answer the question correctly; the acceptable range is 0.1 – 0.9 (Whati et al., 2005, Rust and Golombok, 2014). The discrimination index, a measure of the ability of each question to differentiate between respondents with differing levels of, for example, *SQC* related knowledge, may be calculated by ‘subtracting the proportion of respondents answering correctly in the lowest quartile from the proportion answering correctly in the highest quartile' (Pande et al., 2000). The acceptable range is 0.2 and above (Chen et al., 2013).

Validity

Validity refers to the accuracy and relevance of the data collected; it is related to the reduction of systematic errors and generalizability of the findings (Peeters et al., 2013, Boateng et al., 2018). Three types of interconnected validity evidence are described in literature: content, construct, and criterion validity (Singh, 2017, Rubio et al., 2003, Peeters et al., 2013).

Content validation reflects the relevance of the questions to the subject of interest- e.g., *SQC* by considering its definition by existing literature and subject experts (Peeters et al., 2013, Rubio et al., 2003). Two forms of content validity are face validity and logical validity. Face validity involves the use of the target respondents (*such as food company employees*) to assess if the questionnaire appears to measure the subject of interest. While evidence of logical validity can be established by using *sensory* experts to assess the extent to which the questionnaire is representative of the subject (Rubio et al., 2003).

Construct validity refers to the extent to which the questions cover aspects or sub-topics of *e.g., SQC*, it is further divided into three types- convergent/ discriminant validity, known groups validity and factorial validity – which is the most reported types (Rubio et al., 2003, Boateng et al., 2018). Convergent/ divergent validity is established by using techniques such as product-moment coefficient and latent variable modelling to examine the degree of similarity or difference between the results obtained when a subject is measured in different ways (such as interview and self-report) or when different subjects (*for example, SQC and food safety practitioners*) are estimated with the same method (Boateng et al., 2018). Factorial validity is determined by carrying out factor analysis such as exploratory factor analysis (EFA), principal components analysis (PCA), confirmatory analysis (CFA) and/or structural equation modelling (SEM) (Rubio et al., 2003). Factor analysis methods can be used to evaluate the underlying structure of a questionnaire (e.g., *a SQC questionnaire*) and the correlation between the questions (Carpenter, 2018). Where the results reveal that SQC is made up of multiple subscales (factors), the questionnaire should be divided, and the factors characterized. The number of factors retained are determined by several criteria: the Kaiser eigenvalue greater than 1 rule, the Scree test, Velicer's minimum average partial (MAP) test, parallel analysis and the total percentage variance explained (Watson 2017, Carpenter, 2018). Known groups validity is assessed by comparing the data obtained from two sample populations where a theoretical basis of their expected performance has been established (Rust and Golombok, 2009).

Criterion validity compares the accuracy of the data collected using the questionnaire with another established related criterion (the gold standard) (Singh, 2017; Boateng et al., 2018). Criterion validity is determined by using bivariate and multivariate regression methods to estimate the strength and significance of association between the current test and the established criterion (Boateng et al., 2018). Criterion validity is classified into three types based on when the established criterion was measured- predictive, concurrent or postdictive validity if the criterion was measured before, during or after administration of the questionnaire, respectively (Rubio et al., 2003).

Reliability

Reliability refers to the consistency or reproducibility of the data obtained from the same population (Peeters et al., 2013; Boateng et al., 2018). Reliability estimates can be absolute or relative in nature; the former refers to the reproducibility or equality of scores in a sample, while the latter refers to the consistency or similarity between the scores in a sample (Peeters et al., 2013; Koo and Li, 2016). Standard error of measurement is an example of an absolute measure of reliability, while internal consistency is an example of a relative measure of reliability (Peeters et al., 2013). The reliability of questionnaires is usually considered in three ways as described in Singh (2017) and Boateng et al. (2018).

Test-retest reliability assesses the consistency of respondents' performance on repeat administration of the test where the condition under evaluation has not changed (Jones et al., 2015), such as evaluating the performance on the SQC related knowledge test of a group of food company employees at two administrations of the test two weeks apart. Parallel-forms reliability is a form of test-retest reliability that involves the administration of two systematically linked versions of a test to respondents instead of repeat administration of the same test (Rust and Golombok, 2009).

Internal consistency assesses the consistency of responses to questions 'on a single test occasion/ within an assessment' and is commonly assessed as the Cronbach's α coefficient or Kuder-Richardson formula 20 for bivariate questions (e.g., yes/no type questions). The benchmark for acceptance is a value ≥ 0.70 (Leech et al., 2005, Taber, 2018). Internal consistency can also be assessed by calculating the item-total correlation for each question.

Inter-rater reliability assesses the consistency of ratings for the same group of questions by a group of judges, where the rating involves an element of subjectivity (Koo and Li, 2016, Peeters et al., 2013). It will be useful for determining the consistency of experts' or intended users' ratings on the content validity of a SQC questionnaire. It is usually estimated as the intraclass correlation coefficient, analysis of variance (ANOVA) and the Pearson product-moment correlation coefficient (Rust and Golombok, 2009; Trevethan, 2016).

2.8 CASE STUDY: SQC OF CHOCOLATE MOUSSE

In this research, a case study focusing on SQC of chocolate mousse is included. For that reason, the next section of the literature review will briefly review the ingredients, production and product characteristics of chocolate mousse.

Mousse is a dairy-based (*usually*) gelled foam that is available in sweet and savoury options, with a sweet chocolate flavour option being the most popular (Clegg et al., 2003). The sensory and nutritional characteristics of mousse are part of its appeal for consumers (Cardarelli et al., 2008). This may be due to the reduction in the caloric density by the incorporation of air and its richness in protein and fat. Mousse have even been successfully used as a medium for the incorporation of prebiotics and probiotics into consumers' diets (Cardarelli et al., 2008, Aragon-Alegro et al., 2007). They are traditionally homemade; however, they are also commercially available as ready to eat desserts or as pre-mix powders that can be reconstituted. Traditionally, mousse is an aqueous emulsion that consists of air, a water phase, and an oil phase (Mor et al., 2010). The water phase consists of water, a mixture of sugars (these act as sweeteners and bulking agents), and a foaming agent/s (such as egg white, skimmed milk powder, cream and esters of monoglycerides). The oil phase consists of a mixture of solids such as milk powder, oil-rich nut flours and appropriate fat or fat blends. Emulsifiers and stabilizers such as gelatin and gelatin peptides, may also be added to achieve and maintain the desired foam texture (Duquenne et al., 2016, Cardarelli et al., 2008).

Industrial chocolate mousse production follows the steps described in Clegg et al. (2003) (Figure 2.6). The ingredients (except the emulsifier) are weighed according to the formulation and cooked under agitation to 84 ^{o}C. This achieves pasteurization and also melting of the fat to aid mixing of the water and oil phases (Mor et al., 2010). The mixture is cooled to 17 ^{o}C then the emulsifier is added and mixed. Subsequently, the mixture is cooled and aerated using aeration equipment *such as a Mondomix machine* to incorporate air until the desired bubble size and volume are achieved. The mousse is blast chilled to 5 ^{o}C and stored at 4 ± 1 ^{o}C until consumption.

Like other food products, the appearance and flavour properties contribute to the acceptability of mousse, however as a dairy-based foam, mousse texture properties such as creaminess are very important to its quality and acceptability (Kilcast and Clegg, 2002). Several studies have been carried out to evaluate the effect of product formulation and processing conditions on the instrumental texture and sensory properties of mousse. A study by Kilcast and Clegg (2002) revealed that the perceived creaminess of chocolate mousse was influenced by its flavour and texture properties, this is like reports by Cardarelli et al. (2008). The sensory lexicon used for the descriptive profiling of chocolate mousse by Kilcast and Clegg (2002) is shown in Table 2.3. The study revealed that the size of the air bubbles is the main determinant of perceived creaminess. This result was similar to previous reports on other food foams where products with evenly distributed smaller bubbles were perceived as creamier, more stable and more appealing to consumers (Duquenne et al., 2016). The study by Duquenne et al. (2016), revealed that the addition of gelatin peptides to mousse formulation resulted in a more stable microstructure that may also prevent foam shrinkage that is characteristic of the freezing of mousses. Addition of inulin to chocolate mousse may also increase its firmness and affect its colour but did not affect the overall preference of the product (Cardarelli et al., 2008). Conversely, the addition of soy milk to chocolate mousse formulations negatively influenced its aroma, flavour and acceptance (Taghizadeh et al., 2018).

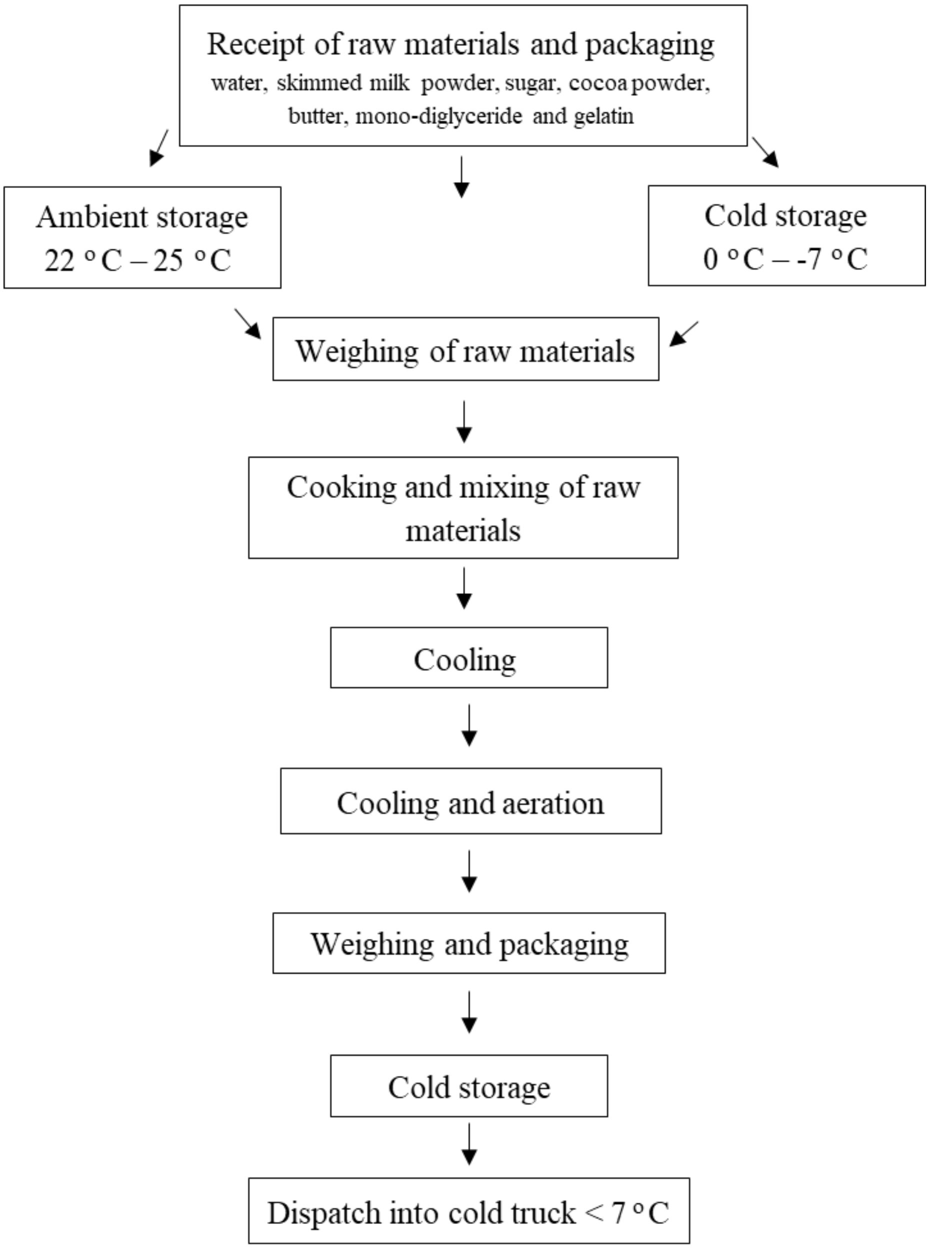

Figure 2.6 Production flow for chocolate mousse (adapted from Clegg et al. (2003) and Kilcast and Clegg (2002))

Table 2.3 Sensory attribute definitions and anchor point for chocolate mousse descriptive profiling (Kilcast and Clegg, 2002)

Sensory attributes	Definitions	Anchor points
Sweet	Degree of perceived sweetness associated with sucrose	Not–Very
Cocoa flavour	Degree of perceived cocoa powder flavour	Low–High
Creamy flavour	Degree of perceived flavour associated with dairy milk or dairy cream	Not–Very
Overall creaminess	A personal assessment of the overall creaminess of the sample	Low–High
Jelly	Degree of perceived jelly texture associated with gelatine	Not–Very
Heaviness	Degree of density/firmness perceived in the mouth,	Light–Heavy
Smoothness/creamy texture	Degree of smoothness/creaminess perceived in the mouth associated with the absence (smooth) or presence (not smooth) of big air bubbles	Not–Very
Bubble size	Perceived size of air bubbles in the mouth	Small–Big
Airy	Amount of air perceived in the mouth	Not–Very
Powdery	Degree of powderiness/ flouriness perceived in the mouth associated with cocoa powder	Not–Very
Fatty	Amount of fat perceived in the mouth	Low–High
Meltdown rate	The speed at which the sample melts down in the mouth	Fast–Slow

2.9 CONCLUDING REMARKS

The review of literature identified the reliance on finished product testing for SQC in food companies. This leads to the detection of defective products late in the production cycle, thus could result in unwanted wastage. The development of a preventive risk-based system that is focused on a lifecycle approach to sensory quality management might reduce over-reliance on finished product testing. There is need for the identification, assessment and management of the critical steps that affect product sensory quality control to reduce wastage of resources and effort monitoring other less important steps.

The literature revealed that a good understanding of the principles of sensory evaluation is necessary for the successful development, and implementation of SQC in food companies. In this regard, a validated questionnaire for assessing the knowledge, attitudes and practices of food company employees will be useful for identifying gaps in employee knowledge and compliance to good sensory practices.

3 RESEARCH CHAPTER

This chapter is divided into four sections. Section one (3.1) elaborates on the development of the sensory quality control knowledge, attitudes, and practices questionnaire (SQC KAP). Section two (3.2) focuses on the refinement and validation of the SQC KAP. Section three (3.3) deals with the development of the sensory analysis critical control points system of SQC and illustration of the system with a case study production (chocolate mousse). The final section (3.4) is about the identification of the critical sensory attributes that drive consumer preference of the case study product.

3.1 DEVELOPMENT AND PILOT TESTING OF A QUESTIONNAIRE TO ASSESS SENSORY QUALITY CONTROL (SQC) KNOWLEDGE, ATTITUDES AND PRACTICES (KAP) OF FOOD COMPANY EMPLOYEES

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Abstract

Sound sensory evaluation knowledge and attitude are central to the successful development and implementation of a sensory quality programme. This study focused on the development and pilot testing of a questionnaire to assess the sensory quality control (SQC) knowledge, attitudes and practices (KAP) of food company employees. The initial questionnaire consisted of 43 questions divided into four sections: respondent and company characteristics, knowledge, attitudes and practices. Six subject matter experts and eight food company employees reviewed the questions for content validity and clarity. The questionnaire was modified, and a pilot test (n = 56) was carried out to determine the psychometric properties of the questionnaire. The final revised questionnaire with 37 questions had acceptable content validity and clarity. The knowledge questions showed acceptable difficulty and discrimination indices; item-total correlation ranged from 0.3 to 0.9 for both the attitudes and practices sections. Exploratory factor analysis led to the retention of three factors for attitudes and one factor for the practices sections, respectively. Cronbach's α ranged from 0.6 to 0.9. The questionnaire is a tool that can be used to rapidly identify gaps in SQC knowledge and attitudes of food employees, as well as to identify areas of improvement of a company's SQC system.

This phase of the study has been published:

Onojakpor, O. and de Kock, H.L., 2020. Development and pilot testing of a questionnaire to assess sensory quality control (SQC) knowledge, attitudes and practices (KAP) of food company employees. *Food Quality and Preference*, *86*, p.103996.

3.1.1 Introduction

The sensory quality of a food product is one of the most important considerations that drive product selection, purchase and consumption (Costell, 2002, Hansen, Petersen & Byrne, 2005). It may also be an indicator of food safety, quality of raw materials and processing conditions thus contributing to the perceived value of a food product (Varzakas and Tzia, 2015). Sensory defects are the leading cause of customer complaints and have also been linked to food losses and waste (Dzung et al., 2003). Some customers may not complain but will choose a different product in the future, resulting in loss of sales and brand equity.

Quality control (QC) encompasses the set of procedures that ensure the compliance of products and processes to set standards through monitoring and the implementation of remedial actions where necessary (Mitra, 2016). Although QC is widely practised in the food industry, several authors have reported low or marginal uptake of sensory quality control (SQC) (Munoz, 2002; Kilcast, 2010; Endrizzi, Aprea, Biasioli, Corollaro, Demattè, Penasa, Bittante & Gasperi, 2013). Reasons for this include cost constraints, time constraints, inadequate expertise and limited management support. Furthermore, there is a paucity of published studies on SQC. This may be because SQC studies require collaboration with food companies with limited time and funds for such research (Saguy, 2011; Jackson, 2015) or that many prefer to keep such research confidential and proprietary to the company. Literature has highlighted the use of unsuitable sensory methods, untrained assessors and inappropriate standards as limitations to the success of sensory evaluation programmes (Costell, 2002; Kilcast, 2010). Adequate sensory evaluation knowledge is key to addressing these limitations (Stone and Sidel, 2004).

Knowledge potentially influences individual attitudes and beliefs, and eventually behaviour (Schrader & Lawless, 2004; De Pretto, Acreman, Ashfold, Mohankumar & Campos-Arceiz, 2015). It facilitates deductive reasoning and thus helps to acquire further information (Schrader & Lawless, 2004). Quantitative knowledge, attitude and practices (KAP) data can be cost-effectively collected at multiple locations simultaneously using questionnaires. The findings could unveil weaknesses and strengths of processes and can facilitate optimisation strategies (Schrader & Lawless, 2004; Launiala, 2009). Pilot testing of questionnaires is necessary to ensure that the data to be collected will be relevant, accurate and reproducible (Hair, Anderson, Babin & Black, 2010; Jones, Lamp, Neelon, Nicholson, Schneider, Swanson & Zidenberg-Cherr, 2015). Both the validity (accuracy of the questionnaire) and the reliability (consistency of the measurements obtained) need to be ascertained (Singh, 2017). Three types of validity tests are typically considered: content, construct and criterion validity (Rubio, Berg-Weger, Tebb, Lee, & Rauch, 2003; Sarmugam, Worsley & Flood, 2014; Singh, 2017). Content validation reflects the extent to which the questions are representative of the construct/subject of interest, and construct validity relates to the degree to which the test measures the theoretical construct of interest. Criterion validity evaluates the relationship between performance on the test and another related established criterion (the gold standard) (Rubio et al., 2003; Boateng, Neilands, Frongillo, Melgar-Quiñonez and Young, 2018). Reliability is commonly assessed as the Cronbach's α coefficient, which is a measure of the relatedness of the questions (Tavakol and Dennick, 2011; Cho and Kim, 2015).

Most KAP studies collect self-reported employee data, as employees are the possessors of organisational knowledge (Birasnav, 2014). Employees should also report on organisational culture and practices, as these influence employee attitude and the application of knowledge (Doorewaard and Benschop, 2003; Ansari-Lari, Soodbakhsh & Lakzadeh, 2009). Furthermore, some practices (e.g., SQC) are implemented at the organisational level and thus do not depend solely on the knowledge of the employee.

While several valid and reliable food safety and nutrition KAP instruments exist, none could be found for SQC. The only study found was a survey carried out by the Sensory Evaluation Division (SED) of the Institute of Food Technologists in 2001 and 2002 reported by Stone and Sidel (2004). The SED online survey focused on the 'function of sensory within a company', evaluating the sensory methods used but did not cover the minimal requirements for sensory evaluation programmes. The questionnaire was neither validated nor its development documented. The aim of this study was to develop and pilot test a tool to assess SQC related KAP in food companies. The questionnaire could be used to evaluate the sensory evaluation KAP of food company employees, highlighting gaps and providing baseline information for interventions around improvement in SQC. External organisations may also use the level of compliance of the company to good sensory evaluation practices to evaluate its commitment to product sensory quality.

3.1.2 Methods

3.1.2.1 Ethical Approval

The ethics committee of the University of Pretoria approved the study (EC 180000041). All respondents provided consent. No remuneration was provided for respondents other than an entry to a draw to win a sensory evaluation textbook. The questionnaire was pilot-tested in three studies (Figure 3.1.1). Data were collected in English.

3.1.2.2 Initial questionnaire

The self-administered questionnaire was developed from published scientific literature, other questionnaires and books on sensory evaluation and psychometrics. The initial questionnaire (Appendix 1) consisted of 43 questions which are divided into four sections: respondents and company characteristics, knowledge, attitudes and practices.

Respondents and company characteristics section

Selected characteristics of the respondents and their employers such as their main job function, sensory evaluation related job functions, the size of the company, the number of products manufactured, company location etc., were collected using 12 multiple-choice questions. These questions (C1- C12) are shown in Appendix 1. The options for company size were based on the number of employees as per the World Trade Organisation definitions (WTO, 2016).

Knowledge section

This consisted of 15 questions with three response options: ‘yes’, ‘no’ and ‘I don’t know’ (Table 3.1.1). The ‘I don’t know’ option was added to differentiate incorrect knowledge from lack of knowledge and to decrease the probability of a respondent opting for the right answer by chance (Agüeria, Terni, Baldovino & Civit, 2018). The knowledge section covered sensory science topics such as senses/sensory physiology, sensory methods, good sensory practices, statistics and SQC (Table 3.1.1).

Attitudes Section

The attitude of respondents and their perceptions of their company’s disposition towards SQC were measured with eight questions (Table 3.1.2). Respondents rated their level of agreement to six attitude statements (A1 to A6) using a five-point Likert scale (1 = strongly disagree to 5

= strongly agree) and for two questions (A7 and A8) ranked the level of importance of various statements from least to most important.

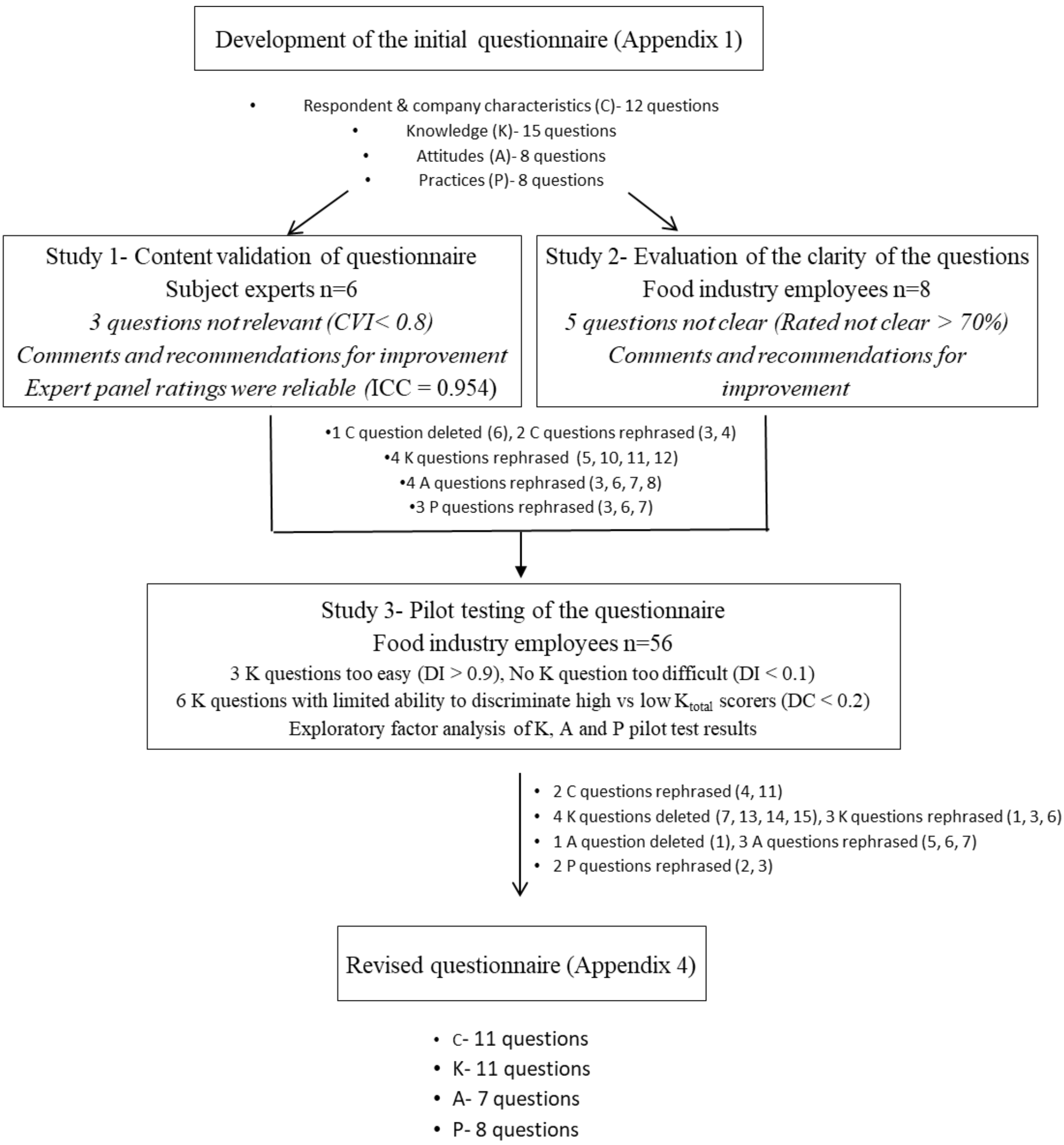


Figure 3.1.1 Development and pilot testing of a questionnaire to assess sensory quality control (SQC) knowledge, attitudes and practices (KAP) of food company employees. CVI = content validation index; ICC = Intra-class correlation coefficient DI = difficulty index

Practices Section

The respondents' perceptions of the compliance of their company with good SQC practices were assessed using eight multiple-choice questions (Table 3.1.4). The three answer options covered a range of practices with varying compliance to good practice regarding sensory evaluation and SQC (Stone and Sidel, 2004 and Lawless and Heymann, 2010). Practices assessed included the standards used, nature of panellists, test location and the frequency of product evaluations.

3.1.3 Study 1- Content validation

As shown in Figure 3.1.1, the initial questionnaire (43 questions) was content validated by six sensory evaluation experts, three academics, two industry scientists and one consultant. Three of the experts had over ten years, and the other three had between five and ten years of experience. The experts individually rated whether or not each of the questions was relevant to the research issue under investigation using a five-point Likert scale (1 = strongly disagree to 5 = for strongly agree). The content validity index (CVI) of each question was calculated as the ratio of the number of experts that gave a relevance rating >3 (k) to the total number of experts, therefore $\frac{k}{6}$. A question was considered relevant if CVI > 0.8 (Rubio et al., 2003; Dos Santos, Riner & Henriques, 2019). The experts were also asked to make recommendations for improving the questionnaire.

The reliability of the expert ratings was computed as the Intra-class correlation coefficient (ICC) consistency measure derived from a two-way mixed effects ANOVA model (IBM SPSS version 25). Reliability (ICC values) was categorised as poor (<0.50), moderate (0.50 to 0.75), good (0.76 to 0.90) or excellent (>0.90) (Rubio et al., 2003: Koo & Li, 2016).

3.1.3.1 Study 2- Clarity test

The clarity of the initial questionnaire was pre-tested by a convenience sample of eight food industry employees from Nigeria and South Africa (Figure 3.1.1). Respondents were given a brief description of the study and the URL link to the online survey. Respondents individually answered yes or no to the question- 'Is this question clear?' for each of the 43 questions. Eight respondents were used to account for varying perceptions regarding question clarity. Each question was considered clear if at least six of the eight respondents (>70 %) answered yes. The respondents could also make comments and recommendations.

3.1.3.2 Study 3 - Pilot test

The initial questionnaire was modified (13 questions were rephrased, 1 was removed) based on studies 1 and 2. The revised questionnaire was then pilot tested by another convenience sample of food company employees from Ethiopia, Nigeria and South Africa. Recruitment was carried out using snowball sampling, respondents were recruited face-to-face or via email or LinkedIn, and interested persons were asked to forward the invitation to complete the questionnaire to their food industry contacts. Data were exported from the survey platform (Qualtrics, Provo, United States of America) as an SPSS data file.

Responses to the respondent and company characteristics section were used for profiling the respondents. Responses to the knowledge questions were scored as described in Sarmugam et al., (2014). Correct answers to the knowledge questions were scored '1' (shown in Table 3.1.1), while 'I don't know' and wrong answers were scored '0'. Answers to the attitude questions (A1 to A6) were scored 1-5 (strongly disagree - strongly agree). The scores were reversed for A1 and A3 as they were negatively phrased. Answers to the practices questions were scored 1-3, except for question P6 (what materials/ products are assessed as part of sensory quality control in your food company?), where a score of '1' was awarded for each of the options selecting raw materials, in-process materials or finished goods and '0' for samples from product development. The sum of scores for knowledge and practices sections were used to determine the total scores (K_{total} and P_{total}). For the attitude section, A_{total} is the sum of scores for questions A1 to A6. The performance of respondents on the different sections was categorised as poor <50%, good (50% – 74%) and very good ≥75%. All statistical analyses were performed using IBM SPSS version 25 unless stated otherwise.

The difficulty indexes (DI) of the knowledge questions were determined as the proportion of respondents who answered correctly, the criterion for acceptance was a DI value from 0.1 to 0.9 (Whati, Senekal, Steyn, Nel, Lombard and Norris, 2005; Underhill-Blazey, Stopfer, Chittenden, Nayak, Lansang Lederman, Garber & Gundersen,.2019). The discrimination indexes (DC) of the knowledge questions were determined by subtracting the proportion of respondents who answered correctly in the low K_{total} scorers' group (the lower 25th percentile) from that of the high K_{total} scorers' group (upper 25th percentile) (Boateng et al., 2018), a value ≥ 0.2 was considered acceptable (Chen, Soo, Ab Rahman, Rostenberghe & Harith, 2013).

Construct validity was assessed by comparing the K_{total} scores of respondents with sensory evaluation related functions and those without and also respondents with prior awareness of sensory evaluation and those without using the Mann-Whitney U test (Sarmugam et al., 2014). It was expected that the former groups in both pairs would score higher on the knowledge section. Respondents were segmented based on their responses to the questions 'Have you heard about sensory evaluation prior to this study?' (C10 in Appendix 1 and 'Which of the following sensory related functions are you involved in?' (C12 in Appendix 1), respectively. Spearman's rho coefficient was used to evaluate the relationship between K_{total} and A_{total} scores of respondents (Sarmugam et al., 2014).

Construct validity of all sections were evaluated by exploratory factor analysis (EFA) using the principal axis factoring (PAF) method (Leech, Barrett and Morgan, 2015). The Kaiser Meyer Olkin measure of sampling adequacy (KMO MSA) and Bartlett's test of sphericity were assessed as outputs of the EFA prior to factor retention to test the degree of correlation between the questions and the sufficiency of the data collected. The benchmarks for acceptability were >0.5 and < 0.05, respectively (Watson, 2017). The number of factors retained was determined by multiple criteria: Kaiser's eigenvalue, scree test, parallel analysis and Velicer's minimum average partial (MAP) test (Boateng et al., 2018). The reliability of the retained factors was computed as Cronbach α and their relatedness as corrected item to total correlations (ITC), values ≥ 0.70 and ≥ 0.2, respectively, were considered satisfactory (Ducak and Keller, 2016; Boateng et al., 2018; Taber, 2018).

3.1.4 Results and Discussion

3.1.4.1 Content validation by experts (Study 1)

The experts considered three questions (C3, C4 and K13) irrelevant to the assessment of the SQC KAP, as highlighted in Figure 3.1.1. K13 was removed while C3 and C4 were retained as these were deemed important to form a complete profile of respondents' companies. All other questions were considered relevant (CVI > 0.80).

The ICC value was 0.954 (excellent), indicating that the ratings for the different questions by the different experts were very similar. The experts also gave some recommendations such as rephrasing questions C4, K5, K11, A1 and P3 and changing the response options for questions A7 and A8 from ranking to a rating scale, these were effected (Appendix 2).

3.1.4.2 Clarity test (Study 2)

Five knowledge questions (K2, K3, K5, K10 and K11) were deemed 'unclear' as less than 70% of respondents rated them as clear (Figure 3.1.1). It is possible that different respondents applied different criteria to determine whether a question was phrased clearly or not. Three questions (K2, K5 and K11) may have been unclear due to unfamiliar terms, e.g., one respondent stated for K2, 'I answered no as I am unfamiliar with the term used'. Comments for K11 were 'Maybe include what is meant by a t-test' and 'Not everyone in industry working with sensory evaluation understands statistical terms'. The terms were retained as they were considered necessary to test advanced level sensory evaluation knowledge. Questions C4, K3, K5, K10, K11, K12, A6, P6 and P7 were rephrased to improve clarity based on respondents' ratings and recommendations. A comment by one respondent- 'Not everyone is privileged to know this', led to the deletion of question C6 (Estimate the annual projected/ real gross income of your company?). Respondents gave recommendations for improving the questionnaire (Appendix 3).

3.1.4.3 Pilot test (Study 3)

A total of 71 responses were collected, and 56 responses were analysed. Responses were included if the respondent completed the respondent and company characteristics section and at least one of the KAP sections. Fifty-one respondents had completed all sections, and an additional five respondents completed the respondent and company characteristics section and at least one of the KAP sections. Analyses were carried out separately for the different sections. Most of the responses (n = 61) were collected online via the survey platform Qualtrics, while 10 respondents completed printed copies of the questionnaire. The median online survey completion time was 13 minutes 27 seconds. Most of the respondents (70%) completed the online survey within 18 minutes; this is longer than the 15 minutes completion time estimated by the researchers. Two respondents contacted the researchers and complained of difficulty with moving from one section to the next online. This may have been due to poor internet connection, possibly contributing to the attrition rate, thus, emphasising the importance of paper-based surveys (Couper, 2000).

3.1.4.4 Characteristics of pilot test respondents and their companies

Of the 56 respondents, four (7%) worked for microenterprises (less than 10 employees), 33 (59%) for large food companies (over 250 employees) and 19 (34%) for small and medium companies. Eight of the 56 respondents (12%) had neither heard of sensory evaluation nor reported that their companies practised SQC. This number is of importance as three of these respondents worked in large companies with assumingly access to funds and expertise to carry out SQC. The respondents also had job roles (two working in quality assurance and two in production) where SQC are generally considered important (Lawless and Heymann, 2010). Customer complaints due to unacceptable sensory quality of products in the last 12 months were reported by 38% (21) of the respondents. The question related to customer complaints (C11) is important as it might highlight the potential consequences of an inadequate SQC programme and may indicate the need for improvement in the management of product sensory quality in companies. Due to the relatively small number of respondents and convenience sampling procedure, it is not possible nor the intention here to draw inferences about the larger population. Survey results were interpreted with caution.

3.1.4.5 Assessment of SQC knowledge

Eleven of the respondents (20 %) had poor knowledge (K_{total} <50%), 40 (71%) had good knowledge (K_{total} between 50% and 75%) and five respondents (9%) had excellent knowledge (K_{total} >75%). The DI of three questions (K7, K14 and K15) were > 0.9 (Table 3.1.1), reflecting that the questions were too easy and therefore not appropriate for testing the knowledge level of the respondents. The DI of each question is equivalent to its mean. Two questions (K14 and K15) were related to SQC: 'Does ingredient quality contribute to the sensory quality of the finished food product?' and 'Does preparation conditions contribute to the sensory quality of the finished food product?'. This indicates that most respondents understand the contribution of raw materials and preparation conditions to the sensory quality of the finished product. The third question (K7) was related to good sensory evaluation practices: 'Is the order of presenting samples important during sensory tests?'. No question had a DI < 0.1, so none was too difficult. However, the DI of five questions (K2, K9. K10, K11 and K13) (Table 3.1.1) were below 0.3, indicating substantial difficulty. Both K10 and K11 relate to the use of statistics to analyse sensory data, and K9 and K13 relate to sensory methods in quality control, indicating potential knowledge gaps in these areas as previously reported by Costell (2002) and Stone and Sidel (2004).

Table 3.1.1 Knowledge (K) questions difficulty level and ability to discriminate between low and high Ktotal scorers in the pilot test (study 3, n = 56 respondents)

No.	**Question** ***Response options: Yes, No, I don't know***	**Correct answer**	**Difficulty index (DI) (0.1-0.9)**	**Discrimination index (DC) (≥0.2)**
K1	Can you smell food while it is in your mouth?	Yes	0.70	0.64
K2	Is umami one of the basic tastes?	Yes	0.25	0.64
K3	Can product feel be judged with the eyes?	Yes	0.64	0.36
K4	Should you judge product flavour if you have a cold/flu?	No	0.89	0.14
K5	Is palate cleansing (e.g., rinsing mouth with water) a good sensory practice?	Yes	0.89	0.21
K6	Should food tasters know the allergens in the food they will be tasting?	Yes	0.88	0.14
K7	Is the order of presenting samples important during sensory tests?	Yes	0.93	0.07
K8	Is a triangle test a sensory discrimination method?	Yes	0.43	0.57
K9	Should preference questions be asked during descriptive sensory tests?	No	0.20	0.36
K10	Is a one tailed alternative hypothesis suitable for analysing the results of a triangle test?	Yes	0.16	0.29
K11	Is a t-test used for analysing sensory differences between more than two products?	No	0.11	0.29
K12	Should people without sensory evaluation training be used for sensory quality control tests?	No	0.68	0.43
K13	Are consumer preference tests suitable for sensory quality control?	No	0.13	0.07
K14	Does ingredient quality contribute to the sensory quality of the finished food product?	Yes	1.00	0.00
K15	Does preparation conditions contribute to the sensory quality of the finished food product?	Yes	0.98	0.07

DI = difficulty index

DC = discrimination index

Six questions (K4, K6, K7, K13, K14, K15) (Table 3.1.1) had DC < 0.2 indicating a limited ability to discriminate between high and low K_{total} scorers (Dickson-Spillmann, Siegrist & Keller, 2011; Jones et al., 2015). The determination of the DC is useful in question selection during questionnaire development. Questions with both DC and DI values that do not fall within the acceptable ranges were removed from the questionnaire. Thus, K7, K14 and K15 were deleted.

As expected, respondents who had heard of sensory evaluation prior to this study had higher K_{total} scores (*p = 0.04*) than those that were unaware of the discipline (Table 3.1.2). Those familiar with sensory evaluation may have had relevant training and/or experience. Contrary to expectation, respondents with sensory evaluation related functions did not score higher (*p = 0.24*) than those without involvement in such functions. The respondents who were not involved in sensory evaluation related functions at the time may have also received sensory evaluation training or served such functions at some other stage.

Table 3.1.2 Comparison of total knowledge questions scores (Ktotal) of respondent groups (study 3 pilot testing n=56 respondents) with different awareness of and involvement with sensory evaluation

Question	Group	n	Median	U-value
Prior awareness of sensory evaluation (C10)	Yes	48	9	0.04
	No	8	6	
Involvement in sensory evaluation related functions (C12)	Yes	48	9	0.24
	No	8	6	

Preliminary assessment of the knowledge section to test its suitability for EFA revealed unacceptable KMO MSA of 0.444 and Bartlett's test of sphericity of 0.236. Therefore factor analysis was not pursued further. These measures indicate a limited degree of correlation between the questions and limitations regarding the sufficiency of the data collected. This outcome is comparable to previous questionnaire development studies on nutrition knowledge where factor analysis was not carried out (Dickson-Spillmann et al., 2011; Sarmugam et al., 2014 and Jones et al., 2015). However, the authors did not give reasons for their decisions. The low KMO MSA indicates the need to include more subject related questions and/or a larger sample of respondents (Hair et al., 2010) to improve the correlation between questions and their suitability for factor analysis. An insignificant Bartlett's test may indicate the need to improve the correlation between questions by dividing the section into subsections to account for the distinct knowledge aspects (Taber, 2018) such as statistics, good sensory practices and physiology of the senses.

3.1.4.6 Assessment of food employees' attitudes towards SQC

Respondents displayed a positive attitude towards SQC, with 48 out of 53 (91%) scoring above 74% of the maximum A_{total} (sum of A1 to A6) and the remaining five (9%) scoring above 49%. EFA was carried out for the attitudes section to evaluate the relationship between the questions in this section. KMO MSA for the attitudes section was initially 0.67, and Bartlett's test of sphericity was significant ($p<0.0001$), indicating an acceptable level of common variance among the questions (Watson, 2017). Factor analysis revealed a five-factor solution (Eigenvalues > 1), a three-factor solution (scree plot and parallel analysis) or two-factor solution (Velicer's MAP test) for the attitudes section. Forced extractions of two and three factors using the varimax rotation, which allows for correlation between factors, were carried out. This led to the retention of the three-factor solution (Table 3.1.3) based on the best logical interpretation (Watson, 2017). Barriers to the implementation of SQC take up the first factor, benefits of SQC the second, and the employee and company attitude statements the third. The three factors 1, 2 and 3 accounted for 24%, 19% and 10% of the total variance (Table 3.1.3), respectively, i.e., a total of 53%, which is within the expected range of 50- 60% that is commonly reported for similar studies (Williams, Onsman & Brown 2010). The factors retained were representative of the sub-sections: employee or company attitudes, benefits and barriers to the implementation of SQC (Table 3.1.3). Examination of the factor loadings and reliability analysis led to the removal of question A1, as it did not load significantly on any factor and it had a negative ITC value (-0.04). Respondents may have misinterpreted the question as it was the first for this section and it was reverse worded. After the deletion of question A1, the KMO MSA increased to 0.69, indicating a better correlation between the questions (Watson, 2017).

Table 3.1.3 Exploratory factor analysis (EFA) and internal consistency (Cronbach's alpha) of the attitudes (A) questions in the pilot test (study 3)

No	Question Response options: Strongly disagree to Strongly agree (1-5)	Median	Factors Loadings (*>0.3)			Item-total correlation (#>0.2)
			1	2	3	
A1	Taste and appearance are not important to consumer acceptance of food product	5			-0.15	-0.04
A2	I know the sensory attributes important for consumer acceptance of my company's products	4			0.37	0.32
A3	Maintaining product sensory quality is not part of my job responsibility	5		0.31	0.38	0.40
A4	I have a clear role in maintaining consistent product sensory quality	4			0.63	0.57
A5	My company believes that consumer satisfaction depends on consistent sensory quality	4			0.47	0.34
A6	My company provides the tools (equipment, procedures etc.) needed to make products of consistent sensory quality	4			0.34	0.27
A7	These are common benefits of the implementation of a sensory quality control programme. Please select their level of importance to your company from 1=not important to 5=extremely important					
A7_1	Reduce customer complaints	5		0.73		0.68
A7_2	Increase sales	5		0.58		0.38
A7_3	Improve product sensory quality	5		0.57	0.43	0.60
A7_4	Reduce waste	4		0.72		0.66
A7_5	Encourage employees to take responsibility for product quality	5		0.78		0.70
A8	These are common barriers to the implementation of a sensory quality control programme. Please select their level of importance in your company from 1=not important to 5=extremely important					
A8_1	Low sensory expertise	4	0.63			0.59
A8_2	Consumes too much time	3	0.70		0.39	0.51
A8_3	Too expensive	3	0.57			0.50
A8_4	Not enough facilities	4	0.66		-0.33	0.64
A8_5	Low company management interest	4	0.72			0.63
A8_6	Low employee interest	3	0.67			0.61
	% Variance accounted for		24	19	10	
	Cronbach α		0.81	0.82	0.62	

*- Criteria for acceptance of factor loading is a value >0.3

#- Criteria for acceptance of Item-total correlation is a value >0.2

Cronbach's α for the sub-categories barriers and benefits of the implementation of SQC were 0.81 and 0.82, respectively (Table 3.1.3). These indicate good inter-relatedness between the questions in each sub-category. The values also suggest a substantial contribution of each question to the total section performance and the absence of or a low degree of measurement errors (Tavakol and Dennick, 2011; Taber, 2018). The values are similar to the internal consistencies observed in the development of the nutrition KAP questionnaire by Chen et al. (2013). The Cronbach's α coefficient for the employee/company attitudes sub-scale was 0.62. This indicates a lesser common variance among the questions compared to the other two sub-categories. It may also be an indication of the complexity of the questions due to their focus on both personal and corporate attitudes (Table 3.1.3). Further improvement of these questions is desirable to better assess employee/ company attitudes.

There was a statistically insignificant correlation ($r = 0.08$, $p = 0.28$) between the K_{total} and A_{total} scores. The lack of a significant correlation may be because the attitudes section assessed both the respondent and their company while the knowledge questions focused on the respondent. Several authors (Munoz 2002; Findlay, 2002; Kilcast, 2010) have discussed the importance of management support in the successful implementation of SQC, howbeit not frequently discussed is the role of employee support and motivation. There may be some resistance to change from employees during the introduction of a new system or optimisation of an existing one; some employees may consider SQC as additional work. Thus, it was important to consider attitude on both fronts: the company and the employees.

3.1.4.7 Assessment of SQC practices

Of the 47 respondents who reported that their company implemented SQC, four respondents (9%) reported marginal practices (P_{total} < 50%), 12 (26%) reported good practices (P_{total} between 50 and 75%), and 31 (66%) reported very good practices (P_{total} > 75%). Seventy-nine percent of respondents reported that finished products were evaluated, while 38% reported evaluating raw materials and 30% evaluating in-process materials as part of SQC (P6). Thirty-eight percent of respondents indicated that product samples from product development were assessed as part of SQC in the company. For this group of respondents, it is clear that more emphasis is placed on finished product testing than raw material and in-process testing. Munoz (2002), more than a decade ago, recommended reducing over-reliance on end-product testing by implementing SQC at the ingredient and in-process level. For some products, sensory quality defects in finished goods may be reduced or prevented by adopting raw materials and/or in-process SQC testing. This strategy may also reduce consumer dissatisfaction and wastage associated with finished product sensory quality defects.

The relationships between knowledge or attitudes and practices were not explored further as the questionnaire assessed the practices of the food company, and this is not necessarily dependent on the knowledge or attitude of the employees. The positive attitude and practices reported in this study may have been exaggerated by the mostly unidirectional nature of the questions in both sections; future efforts to balance the direction of the questions will be useful to address this bias.

EFA of the practices section revealed one factor (Eigenvalue of 5.59), which accounted for a total variance of 73% (Table 3.1.4). All questions loaded unto the one factor with good to excellent factor loadings ranging from 0.61 to 0.95 (Table 3.1.4). The KMO MSA was 0.91, indicating good question sufficiency for the factor. Bartlett's test of sphericity was significant, $p < 0.0001$, indicating that questions were related (Watson, 2017). The internal reliability of the practices section was excellent, with a Cronbach's α value of 0.95, indicating that the questions were measuring a similar construct. The reliability demonstrated is in line with Cronbach's α coefficients for the practice sections of nutrition related KAP questionnaires by Chen et al. (2013) and Schaefer and Zullo (2016).

Table 3.1.4 Exploratory factor analysis (EFA) and internal consistency (Cronbach's alpha) of the practices (P) questions in the pilot test (study 3)

No.	**Question** ***Response options (1 to 3)***	**Median**	**Factor loading (>0.3)**	**Item-total correlation (>0.2)**
P1	How often is **sensory evaluation training** carried out for company staff? *1. Never 2. Once a year 3. More than once a year*	2	0.79	0.76
P2	How often is **sensory quality testing** carried out for each of your company's products? *1. Anytime 2. Based on requests 3. Based on planned schedule*	3	0.79	0.75
P3	How does your company define the target sensory quality of products for quality control purposes? *1. No standard 2. Memorized standard 3. Standard is documented and readily available*	3	0.95	0.91
P4	Who coordinates sensory quality control at your company? *1. Staff with no sensory training 2. An external organisation 3. Staff with sensory training*	3	0.91	0.88
P5	Who carries out sensory quality tests? *1. An external organisation 2. Staff with no sensory training 3. Staff sensory training*	3	0.87	0.85
P6	What materials/products are assessed as part of sensory quality control in the company? *1. Samples from product development 2. Raw materials 3. In-process materials 4. Finished products*	1	0.61	0.59
P7	Where are the products assessed for sensory quality control? *1. No specific area (Anywhere that is comfortable) 2. Specified test area 3. Company's sensory laboratory*	2	0.84	0.79
P8	How are products of unsatisfactory sensory quality managed at your company? *1. No specific procedure 2. Documented procedure 3. Documented procedure with trend analysis*	3	0.94	0.91
	% Variance accounted for		73	
	Cronbach α		0.95	

*- Criteria for acceptance of factor loading is a value >0.3

#- Criteria for acceptance of Item-total correlation is a value >0.2

3.1.5 Implications of the use of the questionnaire

In general, the completion of the SQC KAP questionnaire could promote awareness of sensory evaluation among company employees, thus fostering learning by making respondents conscious of what SQC entails. Respondents' scores for the different sections of the questionnaire could be used to assess performance levels and to identify areas of non-conformance, training needs or attention to facilities and systems. For example, an anonymous respondent (R36) in the pilot survey scored K_{total} = 46%, A_{total} =77% and P_{total} =42%, respectively. The low score areas indicate the need for training of the employee and improvement of the SQC system of the company. The questionnaire could also be used to assess knowledge gains from training programmes by comparing performance before and after training.

Technological advances in instruments and sensors (e.g., electronic nose and tongue, optical scanners), robotics and artificial intelligence are changing the way SQC is carried out in companies by addressing some inherent challenges of using human subjects (Hansen et al., 2005; Zhang, Zhang, Xie, Fan & Bai, 2008). Humans are limited in how many samples they can evaluate before fatigue sets in. Continuous and regular evaluation of some products increases the potential for health concerns. The availability of human assessors for on-line measurements is a challenge. Fast and efficient analysis of SQC data from human subjects requires expertise. Modern technologies may have an impact on the speed, accuracy and cost of SQC. Expertise is needed now more than ever to develop these methods and validate their performance against human assessments in the food industry (Findlay, 2002). The use of online survey collection platforms (Compusense Cloud, Qualtrics, SurveyMonkey® etc.), cheaper and faster internet access and dedicated statistical software applications may enhance the ease, accuracy and speed in questionnaire administration, data collection and analysis.

3.1.6 Limitations of the study and recommendations for further work

A major limitation of this study is the relatively small sample size of the pilot study in comparison to other questionnaire development studies where 120 (Uggioni and Salay, 2013) and 153 respondents (Álvarez-García, Álvarez-Nieto, Pancorbo-Hidalgo, Sanz-Martos, and López-Medina, 2018) were used. However, the number of respondents in this study is similar to pilot studies by Dos Santos et al. (2019) and John, Treharne, Hale, Panoulas, Carroll, and Kitas, (2009) where 65 and 61 respondents were used, respectively. Continued refinement of the questionnaire, and in particular, the knowledge section to include more questions is desirable. Further testing of the questionnaire with more respondents is needed for higher reliability of the factor extraction (Osborne, Costello & Kellow, 2008). Furthermore, a test-retest reliability study could not be carried out as the questionnaire was completed anonymously. In future, the comparison of measures of SQC KAP with other external measures (e.g., product quality specifications compliance, consistency of product quality or consumer perception of the product quality) should be explored. Improvement in SQC KAP as a result of training and other interventions can also be assessed. Confirmatory factor analysis with an independent, larger sample should also be carried out to statistically verify the factor structure derived from this study.

3.1.7 Conclusions

The study details the development and validation of a self-administered questionnaire for assessing the KAP of food company employees with regard to SQC. Thirty-seven questions were retained in the final questionnaire (shown in Appendix 4). The attitude and practices questions demonstrated acceptable content validity, construct validity and internal reliability. However, the pilot study revealed that the knowledge section needs further development. Food companies and relevant stakeholders will be able to use the questionnaire to rapidly evaluate the sensory quality knowledge and attitudes of their employees. It may be useful to identify knowledge gaps and evaluate the effectiveness of SQC training. It may also be developed further and applied in future studies by other researchers.

Conflicts of interest

The authors have no conflict of interest with this work.

Funding

Author Onojakpor was financially supported by the University of Pretoria Commonwealth Doctoral Scholarship programme, South Africa.

3.2 REFINEMENT AND VALIDATION OF THE SENSORY QUALITY CONTROL (SQC) KNOWLEDGE, ATTITUDES AND PRACTICES (KAP) QUESTIONNAIRE

Abstract

In a previous study, an SQC knowledge, attitudes, and practices (KAP) questionnaire was developed and pilot tested on a limited number of food company employees (n=56). This follow-up study was carried out to address the limitations and to refine and validate the new version of the questionnaire with a larger group of respondents.

Twenty-six new questions (k=26) were added, and some questions were modified (k=13). The modified questionnaire consists of 24 knowledge, 13 attitudes and 9 practices questions. Of the 345 responses complete received, 35% (n=120 responses) was used for item analyses and exploratory factor analysis to examine the dimensionality of the sections and for question selection. The internal consistency of the subscales was determined. The remaining 65% (n=225 responses) was used for confirmatory factor analysis and known groups comparison. The impact of respondents' and companies' characteristics on their knowledge and practices was also evaluated.

The final questions had acceptable item indices: difficulty index (-3 to +3), discrimination power ($\geq$ 0.35) and item-total correlation ($\geq$ 0.20). The subscale also had acceptable construct and criterion validity and internal reliability (Cronbach's $\alpha \geq 0.6$). The final SQC-KAP questionnaire consists of 23 knowledge questions (1 scale), 11 attitude questions (2 subscales) and 9 practices questions (1 scale). The knowledge and practices sections had a good model fit, while the attitude section will need to be refined further. The validated SQC-KAP questionnaire can be used to rapidly assess SQC knowledge and attitudes of food employees, as well as the perceived SQC practices in companies in order to identify areas for improvement of SQC programmes.

3.2.1 Introduction

A sensory quality control knowledge, attitudes and practices (SQC KAP) questionnaire was developed and pilot tested in a previous study (Section 3.1). The questionnaire underwent face and content validity. The construct validity of the questionnaire was also tested by exploratory factor analysis and comparing the performance of known groups (such as respondents who had received training and those who had not) using a small group of respondents (n=51). The questionnaire had to be validated using a larger group of respondents. Furthermore, the pilot test revealed several recommendations for the improvement of the questionnaire. For example, the dimensionality of the knowledge section could not be evaluated as the Kaiser Meyer Olkin measure of sampling adequacy (KMO MSA), and Bartlett's test of sphericity were below the benchmark. These indicate that there was a limited correlation between the questions and the sample was not adequate for factor analysis (Watson, 2017). The reviewers of the journal paper published based on the former study also made valuable suggestions for the improvement of the questionnaire. For example, one reviewer noted that the uni-directional nature of the attitude questions may introduce bias to the responses. Therefore, the objective of this follow-up study was to refine and validate the questionnaire for the collection of relevant and accurate data. A larger pool of responses was collected using the refined questionnaire. These were split into two datasets. Dataset 1 was analysed to examine the factor structure of the different sections of the questionnaire using exploratory factor analysis (EFA) and item response theory (IRT). Confirmatory factor analysis (CFA) and comparison of known groups were carried out on dataset2 to confirm the factor structure.

3.2.2 Methods

3.2.2.1 Ethics approval

The study was approved by an ethics committee of the University of Pretoria (180000041). Informed consent was obtained from all respondents before participation. No remuneration was provided for respondents other than an entry to a draw to win a R500 online shopping voucher. The questionnaire was written in English language.

3.2.2.2 Questionnaire refinement

The earlier version of the SQC KAP questionnaire (Appendix 4) was modified in line with recommendations from reviewers and the limitations identified (Section 3.1). The modified questionnaire (Tables 3.2.3, 3.2.4 and 3.2.5) retained the three constructs of the earlier version – knowledge, attitudes, and practices. New questions were added to the different sections of the questionnaire to cover the important sub-topics of sensory quality control based on literature and the expertise of the authors.

The initial respondent/ company characteristics section (C) consisted of 11 questions that were used to profile the respondent. Most of the questions in this section may not be relevant for assessment of employees by their company. This section was modified by adding four questions that assess the nature of the sensory evaluation training received by the respondent, their years of sensory related experience and an assessment of the frequency and causes of customer complaints at their food company.

The initial knowledge section (K) consisted of 11 questions divided into four sub-sections. The sub-sections were retained. However, two of the questions were removed, seven were rephrased (denoted R) and 15 questions were added (denoted N) (Table 3.2.3). The initial questions had yes/ no/ ‘I don’t know’ response options, 13 of the new questions are multiple-choice with three alternatives and an ‘I don’t know’ option to reduce the probability of guessing the right answer. One (1) point was awarded for correct responses and zero (0) points for ‘I don’t know’ or wrong responses (Sarmugam et al., 2014).

The initial attitude section (A) consisted of seven questions, including the Likert scales on the importance of benefits and barriers to SQC (Appendix 1). This section was modified by rephrasing one question (R), adding ten new questions (N) and removing four questions. The modified section with a total of 13 questions was segmented into two subsections- employee attitude (k=6) and company culture (k=7) (Table 3.2.4). Respondents rated their level of agreement to each question using a five-point Likert scale (strongly disagree = 1 to strongly agree = 5). Some questions (k=7, A2, A4, A6, A9, A10, A11, A12) were reverse worded. Thus, the scores were reversed prior to analysis.

The initial practice section (P) consisted of eight questions. This section was modified by rephrasing five questions (P2, P4, P5, P7, P8) and adding one question (P9) (Table 3.2.5). The answer options for five questions (P2, P4, P5, P6 and P8) were rephrased to improve clarity. Respondents selected from three practices, which were scored in order of increasing compliance to good sensory practices (Stone and Sidel, 2004). One (1) point was awarded for the marginal/ poor option and three (3) points for the best option. The revised practices section consists of nine multiple-choice questions.

The revised questionnaire consists of 24 knowledge questions (Table 3.2.3), 13 attitude questions (Table 3.2.4) and 9 practices questions (Table 3.2.5). The respondent and their company characteristics section consist of 15 questions.

3.2.2.3 Respondent recruitment process

Email invites were sent to food industry employees through the major national associations for food science professionals in South Africa and Nigeria [South African Association for Food Science and Technology (*SAAFoST*), and Nigerian Institute of Food Science and Technology *(NIFST*)]. The survey invitation was also shared via a digital food science newsletter (www.foodfocus.co.za), and via some food science related LinkedIn, Facebook and WhatsApp groups. The invites stated that the target respondents were food company employees in production, quality and research and development roles. Respondents were asked to forward the invite to their food industry contacts.

A total of 503 responses were received, 345 responses were complete. Of this number, 35 respondents (10%) could not answer question A13 as it was added after these respondents had started completing the questionnaire. The missing data were imputed using the multiple imputation method (IBM SPSS, version 27) (Lovik et al., 2017). The 345 responses were randomly split into two data sets as suggested by Zahiruddin et al. (2018) using IBM SPSS (version 27) select cases function, dataset 1 (n= 120) was used for EFA and item response analysis while dataset 2 (n=225) was used for CFA and known groups validity tests. The respondents in the two datasets were comparable on most characteristics (Table 3.2.1). For example, 45% of respondents in dataset 1 and 44% in dataset 2 reported the occurrence of customer complaints / reprocessing of products due to product sensory quality issues in their company in the last 12 months. This indicates that splitting the data did not introduce any bias. Respondents indicated that the most likely cause of customer complaints or product reprocessing was storage or distribution issues (22%). This may just be a conscious/ unconscious strategy by company employees to shift the blame from their company and themselves to the storage and distribution companies. Storage and distribution issues may be addressed by knowledge sharing and collaboration with the storage and/or distribution companies.

Table 3.2.1 Selected respondents and company characteristics for dataset 1 (n= 120) and dataset 2 (n=225)

Characteristics	Options	Set 1 (35%) n= 120	Set 2 (65%) n= 225
Main job function	Sales/ Marketing	4	6
	Production/ Manufacturing	20	12
	Quality Assurance	36	50
	Research & Development	30	25
	Others	10	7
Size of company	Micro	12	11
	Small	13	16
	Medium	27	28
	Large	48	45
Prior awareness of sensory evaluation	No	5	8
	Yes	95	92
Frequency of complaint/s or reprocessing of product/s due to unacceptable sensory quality in the last 12 months?	I don't know	9	15
	Never	46	41
	Rarely	20	17
	Occasionally	16	21
	Often	7	5
	All the time	1	1
What are the likely causes of unacceptable sensory quality? (only respondents who reported complaint/s or product reprocessing answered this question. Respondents could select all or none of the options)	Ingredient issues	13	11
	Processing issues	19	17
	Quality control issues	14	15
	Storage and distribution issues	22	23
	Others		3.6
Which of the following sensory related functions are you involved in? (Respondents could select all or none of the options)	None	10	16
	I request sensory tests	26	17
	I plan sensory tests	32	26
	I participate in sensory tests	61	56
	I analyse sensory test data and/or write reports	42	39
	I make decisions based on sensory tests	43	40
How much sensory related experience do you have?	None	3	8
	Less than 1 year	16	18
	1 to 5 years	48	45
	6 to 10 years	14	12
	More than 10 years	20	16
Have you received any sensory evaluation training? (Respondents could select all or none of the options)	No	11	15
	Yes, in house training	43	45
	Yes, training at an academic institution	55	46
	Yes, Other training	6	4

3.2.2.4 Item response theory and exploratory factor analyses

Item response theory (IRT) analysis was used to examine the underlying structure of the knowledge section using R version 4.2, ltm package version 1.1-1 (Awopeju and Afolabi, 2016). IRT analysis is used to demonstrate the validity of tests by evaluating the difficulty and discrimination indices of the question (Arifin and Yusoff, 2017). However, unlike its counterpart- classical test theory, item and model fit can be estimated as well as the degree of guessing. In this study, the data from the knowledge section was fitted to two-parameters logistic (2PL) and three-parameters logistic (3PL) IRT models to determine the best one for analysis. The 2PL model estimates the difficulty and discrimination indices while the 3PL model also estimates the guessing parameter (Nguyen et al., 2014). The models were compared based on their Akaike information criterion (AIC) and the Bayesian information criterion (BIC), the lowest values indicate the best fit (Ward et al., 2016). The unidimensionality of the model was determined by a modified parallel analysis, and the fit of each question to the model was determined by Chi-square goodness of fit index. A non-significant p-value was desirable for both tests ($p > 0.05$) (Zahiruddin et al., 2018). Questions with difficulty levels from -3 to +3 are acceptable, where more negative values indicate easier questions and more positive values indicate more difficult questions (Zahiruddin et al., 2018, Ward et al., 2016). The discrimination parameter (similar to the CTT discrimination index) indicates the extent to which the question discriminates between respondents with different ability levels. Values from 0.35 to 2.50 are acceptable (Zahiruddin et al., 2018). Knowledge questions with unacceptable difficulty and discrimination levels were considered for removal from the questionnaire.

Construct validity was examined by using exploratory factor analysis (EFA) to determine if the structural relationship between the questions support the underlying theoretical concept. EFA of the polychoric correlations matrix of the knowledge, attitudes and practices sections was carried out using the unweighted least square (ULS) estimation method in IBM SPSS 26 (Aletras et al., 2010). The ULS estimation method was used because it is reliable for ordinal data with a small sample size and many variables (Aletras et al., 2010, Holgado-Tello et al., 2009). Polychoric correlations provide a more reliable estimate when the data is ordinal in nature. The normal factor analysis assumes that the data are interval scaled; hence it uses Pearson’s correlation which results in an underestimation of the degree of association between questions as well as their standard errors and consequently a reduction in the factor loadings obtained from the factor analysis (Holgado–Tello et al., 2010).

Prior to the EFA, the suitability of the data for factor analysis was assessed using the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO MSA), a value ≥ 0.6 was acceptable (Tabachnick and Fidell, 2013). Bartlett's test of sphericity was also applied to ensure that the questions are sufficiently correlated to carry out factor analysis. The threshold for acceptance was a value <0.05 (Watson, 2017). The number of factors retained was determined by assessing the eigenvalue, inflection point of the scree plot, the total variance accounted for and parallel analysis (Boateng et al., 2018). The internal consistency of the retained factors was estimated as Cronbach's alpha, values > 0.7 were acceptable (Taber, 2018). The factor loading and item-total correlation (ITC) of the questions in the attitude and practices sections were used to select questions to be retained. A loading ≥ 0.3 and a positive ITC value were acceptable.

3.2.2.5 Confirmatory factor analysis

CFA was carried out to further validate the models revealed for each construct by EFA in study 1 using R Lavaan package (version 0.6-8). CFA was applied to the polychoric correlation matrix using the diagonally weighted least square (DWLS) estimation method, which is the default method for ordinal data (Holgado-Tello et al., 2009). The model fit was estimated using the comparative fit index (CFI), Tucker-Lewis fit index (TLI), root mean square error of approximation (RMSEA) and standardised root-mean-square residual (SRMR). The model was considered excellent and good based on the following cutoff values CFI and TLI Tucker-Lewis fit index (TLI) ≥ 0.95 and ≥ 0.90, respectively; RMSEA and SRMR ≤ 0.06 and ≤ 0.08, respectively (Ward et al., 2016, La Barbera et al., 2020), Chi-square indices were reported but were not used for model selection as the measure has been shown to be biased for sample sizes above 200 (Román and Sánchez-Siles, 2018). The robust fit indices for ordinal data, calculated after correction of interval indices, were reported unless stated otherwise.

Construct validity was also determined by comparing the sum of scores for the knowledge (K_{total}), attitude (A_{total}) and practices (P_{total}) for different groups of respondents using Student's T-test and analysis of variance (ANOVA) (Stanifer et al., 2015). Fisher's least significant difference (LSD) test was used for the separation of means. Respondents were segmented into groups based on the hypotheses presented in Table 3.2.2. Total practices scores (P_{total}) of different groups of respondents were also compared based on the expected impact of company characteristics on SQC practices (Table 3.2.2). Pearson's correlation coefficient was computed for the K_{total} and total attitude (A_{total}) scores of respondents to determine the existence and nature of any underlying relationship. Pearson's coefficient was used as summated scales are usually analysed as interval data (Carifio and Perla, 2008).

Table 3.2.2 Hypotheses on the effect of respondents' and companies' characteristics on their knowledge and practices

No.	Hypothesis
1	Respondents with good sensory evaluation knowledge will have good sensory quality related attitudes as knowledge is a determinant of attitude (Nyarugwe et al., 2018).
2	Respondents with prior awareness of sensory evaluation knowledge will have knowledge scores than those without.
3	Respondents who have received sensory evaluation training will have better sensory evaluation knowledge scores as training improves knowledge (Zanin et al., 2017).
4	Respondents with more sensory evaluation experience will have better sensory evaluation knowledge scores as knowledge improves with relevant experience.
5	Large and medium sized companies will have better SQC practices compared to small food companies as they have better access to expertise and funds compared to smaller companies.
6	Food companies with good sensory practices will have less customer complaints and product reprocessing due to sensory quality issues.

3.2.3 Results and discussion

3.2.3.1 Validation of the knowledge section

Pairwise comparison (using ANOVA) of the IRT models for the knowledge questions revealed that the 2 PL model had a significantly better fit (p= 0.002) than the 3PL model. The 2PL model had lower AIC and BIC indices compared to the 3PL model. The better 2PL model indicates that the questions differ in their ability to discriminate between different levels of knowledge and that guessing did not significantly affect respondents' performance (Ward et al., 2016). Thus, the questions were characterised by their difficulty level, discrimination level and the probability of the average respondent getting the correct answer.

All knowledge questions, except K6, had difficulty and discrimination indices within the threshold of acceptance (Table 3.2.3). The difficulty level ranged from -2.89 (K12) to 2.13 (K22), indicating a good coverage of knowledge abilities, while the discrimination power ranged from 0.35 (K18) to 1.87 (K16), indicating a good ability to distinguish between individuals of different abilities. K6 had an extremely high difficulty level of 45.37 and low discrimination of 0.02. Therefore, it should be removed from the questionnaire. The unidimensionality of the knowledge section was supported by the modified parallel analysis ($p = 0.594$), indicating that the data was suitable for IRT analysis (Zahiruddin et al., 2018). The item goodness of fit index revealed that four questions (K1, K4, K8 and K13) did not fit the model (Table 3.2.3). There was no clear pattern among these questions nor any logical reasoning for the misfit. Thus, the questions were retained as they had acceptable difficulty and discrimination levels (Zahiruddin et al., 2018).

EFA using the unweighted least square (ULS) estimation method of polychoric correlation of the knowledge questions resulted in a non-positive definite (NPD) matrix, with 3 negative eigenvalues that required smoothing prior to factor analysis. NPD matrixes occur more frequently with polychoric correlation matrices than Pearson correlation matrices (Jaworski and Carey, 2007). Possible causes of NPD matrices include the presence of outliers or items with low variance, the use of a small sample, the use of few response categories and the occurrence of multicollinearity (high correlation between variables) (Jaworski and Carey, 2007, Lorenzo-Seva and Ferrando, 2021).

Examination of the correlation matrix did not reveal any evidence of multicollinearity. However, the dataset was implicated on several other possible causes of NPD matrices, such as the sample size, the dichotomous scale and low variance for three questions (K7, K8 and K12). EFA was repeated with sweet smoothing of the correlation matrix to make the matrix positive definite using FACTOR (version 10.10.3) as described by Lorenzo-Seva and Ferrando (2021). Seven factors with eigenvalues greater than one were extracted. Parallel estimation factor, however suggested the retention of one, supporting the unidimensionality of the data.

Table 3.2.3 The descriptive characteristics, IRT parameters and factor loadings of the knowledge (K) questions obtained by item response theory (IRT, n=120) analysis and confirmatory factor analysis (CFA, n=225). R- rephrased, N- new, p- probability of item fit to model

No.	Question Correct =1, Incorrect/ I Don't know = 0	Correct Answer	% Correct	% I Don't know	IRT				CFA Standardized loading
					Difficulty	Discrimi-nation	p	loading	
K1[R]	Can a person smell a food while chewing it in the mouth? a) Yes b) No c) I don't know	a	76	6	-2.252	0.539	0.019	0.475	0.274
K2	Is vanilla one of the basic tastes? a) Yes b) No c) I don't know	b	50	8	-0.004	0.996	0.146	0.706	0.609
K3[N]	Does the sense of hearing contribute to the evaluation of texture when eating an apple? a) Yes b) No c) I don't know	a	78	5	-1.941	0.701	0.756	0.574	0.404
K4[N]	Which one of these relates to the perception of sight? a) Rods b) Triangles c) Squares d) I don't know	a	53	24	-0.206	0.731	0.022	0.590	0.215
K5[N]	Which one of these does trigeminal sensation relate to? a) Visual perception b) Auditory perception c) Flavour perception d) I don't know	c	33	34	1.201	0.666	0.704	0.555	0.304
K6[N]	Which one of these is perceived on the tongue? a) Volatile food compounds b) Water soluble compounds c) Bud binding compounds d) I don't know	b	28	11	43.37	0.02	0.656	0.021	-
K7	Is palate cleansing (e.g., rinsing mouth with water) between tasting different samples a good sensory practice? a) Yes b) No c) I don't know	a	94	3	-2.700	1.267	0.230	0.811	0.156
K8[R]	Should sensory quality panellists be informed of allergens in the food they will be tasting? a) Yes b) No c) I don't know	a	95	1	-2.48	1.59	0.005	0.847	0.377
K9[R]	Should product liking questions be asked during sensory quality control? a) Yes b) No c) I don't know	b	38	3	1.101	0.489	0.635	0.439	0.516

K10[N]	How do you reduce carry over effects from one sample to the next when evaluating many samples? a) By evaluating samples under red light b) By taking rest periods between samples c) By switching sides (left then right) in the mouth during chewing d) I don't know	b	70	13	-1.325	0.708	0.684	0.578	0.455
K11[N]	Which one of these can be ignored when recruiting panellists for sensory quality control of dairy products? a) Their availability for product evaluation b) Their interest in sensory quality control c) Their level of liking of dairy products d) I don't know	c	46	8	0.257	0.718	0.216	0.583	0.309
K12[R]	Should a panellist be asked to judge the flavour of products if he/she has a cold or the flu? a) Yes b) No c) I don't know	b	89	3	-3.077	0.753	0.238	0.601	0.720
K13[R]	Should employees with **no** sensory evaluation training be used for sensory quality control of products? a) Yes b) No c) I don't know	b	75	3	-2.489	0.462	0.015	0.419	0.404
K14	A trained sensory panel has been carrying out sensory quality testing of bread for the past seven months. Which of the following is a way to check the panel performance? a) Monitoring the scores for samples from different batches b) Monitoring the scores for control samples c) Monitoring the time used for product evaluation d) I don't know	b	34	7	0.560	1.710	0.401	0.863	0.547
K15[N]	Which one of these tasks must be completed individually by members of a sensory quality panel? a) Identification of reference standards for sensory descriptors b) Selection of sensory descriptors for quality control purposes c) Evaluation of product samples for quality control purposes d) I don't know	c	59	7	-0.342	1.582	0.246	0.845	0.443
K16[N]	A product sensory specification is…? a) A list of ingredients that affect the sensory quality of the product b) The description of the target sensory properties of the product	b	60	1	-0.347	1.841	0.150	0.879	0.476

	c) The description of the method used to evaluate the product d) I don't know								
K17[N]	The decision to reject/accept a product for release to the market based on its sensory quality depends on …? a) The results of the most senior panellist b) The results of the most experienced panellist c) The results of all the panellists d) I don't know	c	77	1	-2.554	0.490	0.441	0.440	0.521
K18[N]	In which order should product sensory attributes be evaluated during sensory quality control? a) The order of sensory attributes should be varied from one sample to another b) The order of sensory attributes should be the same from one sample to another c) The order in which sensory attributes are evaluated does not matter d) I don't know	b	57	3	-0.840	0.328	0.798	0.312	0.331
K19[R]	Is a paired comparison test a descriptive sensory method? a) Yes b) No c) I don't know	b	34	11	0.967	0.761	0.087	0.605	0.486
K20[N]	Which one of the following is suitable for testing whether two samples are different? a) Triangle test b) Quad test c) Square test d) I don't know	a	67	16	-0.886	0.919	0.575	0.677	0.678
K21[R]	Can a t-test be used to compare the sweetness ratings of two products? a) Yes b) No c) I don't know	a	61	26	-1.025	0.450	0.078	0.411	0.164
K22[N]	Company Z's policy states that white bread that differs from the product specification ($p<0.01$) should be rejected. The sensory quality of Sample X differs from the product specification ($p=0.05$), should it be rejected? a) Yes b) No c) I don't know	b	32	8	2.327	0.339	0.422	0.321	0.248
K23[N]	Which of the following is the most suitable number of panellists for descriptive sensory evaluation? a) 3 b) 5 c) 10 d) I don't know	c	49	9	0.038	0.946	0.373	0.687	0.432
K24[N]	Which of the following tests would be suitable to determine the nature of differences between two brands of apple juice? a) Duo-trio test b) Paired preference test c) Descriptive analysis d) I don't know	c	29	13	0.985	1.108	0.242	0.742	0.372

The one-factor, 23 questions model had a good fit. Model fit indices were χ^2 = 246.32 (df = 230, p < 0.219), CFI= 0.955, TFI= 0.950, RMSEA= 0.02 and SRMR= 0.110. The chi-square statistics indicate that there is no significant difference between the hypothesised model and the observed model (Román and Sánchez-Siles, 2018). This provides supporting evidence of the unidimensional structure indicated by IRT analysis (Zahiruddin et al., 2018). The standard loading for the CFA model is shown in Table 3.2.3. However, the SRMR index was higher than the benchmark (0.106). Examination of the correlation residuals revealed several values greater than the benchmark (0.10). This indicates a misspecification of the relationship between the questions and consequently a high SRMR (Knekta et al., 2019). The SRMR may be decreased by specifying additional associations between questions; modification indices could not identify any recommendations for improving the model. RMSEA has a high accuracy for categorical variables (as in this study), while SRMR is a poorer estimate of model fit, especially for binary data (Garrido et al., 2016, Shi et al., 2020). Hence, the one-factor model is acceptable.

3.2.3.2 Validation of the attitudes section

Based on the theoretical construct of the attitude section, a two-factor solution was expected with the questions loading based on their positive and negative disposition towards SQC or based on whether they relate to employee or company attitudes. EFA of the attitude section resulted in an acceptable KMO MSA of 0.734 and Bartlett's test < 0.0001. Four factors with eigenvalues greater than one were extracted, and these accounted for 67% of the total variance in the data. Parallel analysis suggested the retention of two factors (49% of total variance), while the scree plot indicated a three-factor solution (60% of total variance). All questions had factor loadings > 0.3 for both factor solutions, so they were retained.

Cronbach's α for the three-factor solution was 0.716, 0.277 and 0.693 for factors 1, 2 and 3, respectively. Cronbach's α for the two-factor solution was 0.764 and 0.444, respectively. The low Cronbach's α (<0.60) indicates that the questions for that factor may not be sufficiently related (Knekta et al., 2019). Examination of the reliability statistics for both solutions revealed that A12 had a negative item-total correlation. Hence the question was removed. Factor analysis of the remaining questions resulted in a two-factor solution (based on the scree plot) and a one-factor solution (based on parallel analysis). These accounted for 50% and 61% of the total variance, respectively. The two-factor model was retained. Promax rotation was applied to the two-factor solution, representing negative or positive attitudes (Table 3.2.4). The two factors were moderately correlated (0.555); the correlation was positive as the scores on negative attitude had been reversed. Cronbach's α for the revised two-factor solution were 0.764 and 0.622.

Table 3.2.4 The median, factor loadings, standardized loadings and Cronbach's α of the attitudes (A) questions obtained by exploratory factory analysis (EFA)

No.	**Question** **Response options: strongly disagree to strongly agree**	**Median**	**Initial communality**	**EFA (Loadings > 0.3)**	
				Factor 1	**Factor 2**
A1	Sensory quality of products is important to consumers	5	.429	-	0.508
A2[N]	Sensory quality control is not reliable	4	.448	0.398	-
A3	Employees are responsible for maintaining consistent sensory quality of products	4	.217	-	0.500
A4[N]	Sensory quality control is a waste of time	5	.589	0.404	0.374
A5[N]	Sensory quality control is important	5	.656	-	0.846
A6[N]	Employees do not need training on the sensory quality of products	4	.625	0.524	-
A7[N]	My company maintains that consumer satisfaction depends on the sensory quality of products	4	.486	-	0.510
A8[R]	My company provides the resources needed to make products of good sensory quality	4	.559	-	0.671
A9[N]	My company maintains that sensory quality control hinders production	4	.560	0.829	-
A10[N]	My company regards sensory evaluation training as unnecessary	5	.558	0.666	-
A11[N]	My company is reluctant to change operations to improve product sensory quality	4	.595	0.791	-
A12[N]	My company regards safe products to be of good sensory quality	2	-	-	-
A13[N]	My company produces products of consistent sensory quality	4	.429	-	0.328
	% Variance accounted for			36.5	13.4
	Cronbach α			0.729	0.622

[R]- rephrased, [N]- new

CFA of the two-factor model (with correlation between factors cross-loading of A4) revealed a poor fit with the observed data, χ^2 = 136.238 (df = 53, p < 0.001), CFI = 0.872, TL1 = 0.840, RMSEA = 0.115 and SRMR = 0.104. Examination of the factor loadings revealed marginal loading for some of the questions, with the lowest loadings for A1 (0.429) and A3 (0.396). This indicates that the questions are not strongly related to that factor (Knekta et al., 2019). There were several correlation residuals greater than 0.1, indicating a discrepancy between the correlation matrix of the model and the data and resulting in the high SRMR (Prudon, 2015). However, this was not the only possible source of misspecification as the other goodness of fit indices were poor. Modification indices suggested the cross-loading of several questions. The attitude section needs to be respecified and considerably improved.

3.2.3.3 Validation of the practices section

EFA was carried out on eight of the nine practices questions due to the low variance (zero) in the responses for question P6 (*What materials/products are evaluated as part of sensory quality control in your company*). All respondents whose companies carried out SQC reported that they only evaluated finished products. This indicates the reliance on finished product testing by the companies of these respondents despite the waste associated with over-reliance on finished product testing for SQC (Stefanova and Zlateva, 2018). Question P6 however retained due to its importance to the content validity of the questionnaire (Zahiruddin et al., 2018), but not included in the summated scale. EFA revealed that the correlation matrix of the eight questions was suitable for factor analysis as it had a KMO MSA value of 0.602 and Bartlett's test of sphericity < 0.0001, this is within the acceptable limits (Tabachnick and Fidell, 2013). Factor analysis resulted in two factors with eigenvalues above one. These accounted for a total variance of 69%. Parallel analysis suggested the retention of one factor, which accounted for a suboptimal 47% of the total variance, a variance of 50% and above is recommended (Williams et al., 2010). All questions had an initial communality greater than 0.4. Hence, they were considered for inclusion in the scale.

Prior to the analysis, the questions were expected to load on one factor as there was no indication of subdomains in the practices section. Examination of the one-factor solution revealed that P1 and P2 had marginal factor loadings of 0.287 and 0.383, respectively (Table 3.2.5). They were retained to maintain the content validity of the practices section. On the other hand, all questions loaded well on at least one factor for the two-factor solution. Questions in factor one of the two-factor solution relate to the personnel responsible for SQC activities and the test location, while factor two relates to how SQC activities are carried out. Cronbach's alpha for the one-factor model was 0.683, while that of the two-factor model was 0.695 and 0.633 for factor one and factor two, respectively. This indicates good internal reliability as the values are comparable to the recommended 0.7 (Taber, 2018)

Table 3.2.5 The median, factor loadings, standardized loadings, and Cronbach's α of the practices (P) questions obtained by exploratory factory analysis (EFA) and confirmatory factor analysis (CFA)

No.	Question	Median	Initial Communality	EFA one-factor loading	EFA two-Factors		Factor loading CFA
					Factor1	Factor2	
P1	How often is sensory evaluation training carried out for company staff? a) Never b) Once a year c) More than once a year	2	0.621	0.287	-0.391	0.794	0.706
P2	When is sensory quality testing carried out for company products? a) Anytime (based on convenience of the quality team) b) When there is a problem or complaint c) Based on a planned schedule	3	0.484	0.383	0.556	-	0.476
P3	How does your company define the target sensory quality of products for quality control purposes? a) There is no defined standard/ specification b) It is based on a memorized standard/specification c) The standard/specification is documented and readily available	3	0.650	0.615	0.869	-	0.412
P4	Who manages sensory quality control at your company? a) Company staff with no sensory training b) Company staff with some sensory training c) Company staff with good sensory training and experience	3	0.834	0.734	-	0.934	0.953
P5	Who evaluates the products for sensory quality control? a) Panellist with no sensory training b) Panellist with some sensory training c) Panellist with good product-specific sensory training	3	0.757	0.724	-	0.712	0.830
P6	What materials/products are evaluated as part of sensory quality control in your company? a) Raw materials b) In-process materials c) Finished products	1	0.595	-	-	-	-

No.	Question	Median	Initial Communality	EFA one-factor loading	EFA two-Factors		Factor loading CFA
					Factor1	Factor2	
P7	Where is product sensory quality testing carried out? a) No specific area (Anywhere that is comfortable/available) b) A specified test area c) Company's sensory laboratory	2	0.753	0.661	-	0.486	0.695
P8	How are products of unsatisfactory sensory quality handled at your company? a) No specific procedure b) Based on a documented procedure c) Based on a documented procedure with corrective actions	3	0.648	0.705	0.878	-	0.588
P9[N]	Does your company check product sensory quality before releasing products to the market? a) No b) Yes, sometimes c) Yes, always		0.621	0.769	0.587	-	0.734
	KMO MSA		0.603				
	% Variance accounted for		69	46.6	46.6	22.6	
	Cronbach α			0.683	0.633	0.695	

[R]- rephrased, [N]- new

The one-factor and two-factor models had a good fit after the addition of a correlated error for P3 ↔ P8, r= 0.287. Model fit indices for the one-factor solution was χ^2 = 34.19 (df = 19, p < 0.017), CFI= 0.978, TFI= 0.968, RMSEA= 0.066 and SRMR= 0.068. While that of the two-factor solution was χ^2 = 31.43 (df = 18, p < 0.026), CFI= 0.981, TFI= 0.970, RMSEA= 0.064 and SRMR= 0.065. The two-factor solution was not significantly better (p= 0.24) than the one-factor solution; additionally, the one factor model was supported by the theoretical understanding of the construct. Hence the simpler, one-factor model was retained. The correlation of the residuals was supported by a high (0.973) interitem correlation, which may be linked to similar phrasing of the questions (Bandalos, 2021). The question (P2 and P3) had a low factor loading (<0.50). These questions were retained as they are important for content validity.

3.2.3.4 Known groups validity

There was a statistically significant correlation (r = 0.240, p < 0.001) between the K_{total} and A_{total} scores of respondents (Table 3.2.6). This may be an indication that knowledge is a driver of attitude. The link between knowledge and attitude is controversial. While a positive link was reported in some studies (Ansari-Lari et al., 2010, Al-Shabib et al., 2016), some studies reported that knowledge did not translate into attitude (Zanin et al., 2017). Respondents who have heard of sensory evaluation prior to this study (C9- *Have you heard about sensory evaluation before this study*?) had significantly higher ($p = 0.001$). K_{total} scores than those who had not. The K_{total} scores of respondents with sensory evaluation training was significantly higher than those with no training ($p < 0.001$). The K_{total} scores of respondents with sensory related work experience was significantly higher than those who were not involved in sensory evaluation ($p < 0.004$). This supports previous reports of a positive effect of *sensory evaluation* training and experience on knowledge (Agueria et al., 2018, Ansari-Lari et al., 2010, Al-Shabib et al., 2016).

Table 3.2.6 Comparison of total knowledge scores (Ktotal) of respondent groups (n = 225 respondents) with different characteristics and comparison of total practices scores (Ptotal) and occurrence of customer complaints for companies of different sizes

Question	**Group**	**n**	**Mean ± SD**	**p (2 tailed)**
Have you heard about sensory evaluation before this study?	No	18	10.39 ± 3.93	0.001
	Yes	207	13.95 ± 3.62	
Have you received any sensory evaluation training?	No	34	10.68 ± 3.5	<0.000
	Yes	191	14.20 ± 3.6	
How much sensory related experience do you have?	None	34	12.00 ± 3.42	0.004
	>1 year	190	13.95 ± 3.76	
Was there any customer complaint/s or reprocessing of your company’s product/s due to unacceptable sensory quality in the last 12 months?	No	92	17.7 ± 8.6	0.459
	Yes	100	16.83 ± 7.8	
What is the total number of employees in the company where you work (company size)?	Micro and small	60	13.9 ± 10.2	0.006
	Medium and large	165	18.03 ± 7.5	

(SD, standard deviation ($P < 0.05$)

Comparison of the P_{total} scores of companies in different size classifications indicated that there was a significant difference between their SQC practices ($p = 0.006$) (Table 3.2.6), the size of the company was based on the total number of employees as determined by the World Trade Organisation (WTO, 2016). The P_{total} scores of micro and small companies were significantly lower than that of medium and large companies. As shown in Table 3.2.6, there was no significant difference ($p = 0.742$) between the P_{total} score of respondents who reported different frequencies of occurrence of customer complaints and product reprocessing due to sensory quality issues. Lack of or low frequency of complaints may not be a true reflection of good product sensory quality as consumers differ in their responses to product dissatisfaction. Only a small group (5%) of consumers will complain, others will migrate to an alternative product (Filip, 2013). Furthermore, the volume of consumer complaints received by a company will be affected by the availability of complaint communication channels and the level of effort required to lodge a complaint.

3.2.3.5 Knowledge, attitude and practices performance of respondents

Categorization of respondents based on their K_{total} scores into poor (<50%), good (50- 74%) and excellent (≥75%) categories revealed an almost symmetric distribution of respondents into the three groups. Of the 225 respondents in study 2, 26% had poor knowledge, 53% had good knowledge and 21% had excellent knowledge. Thus, the knowledge section of the questionnaire adequately captured the ability of the respondent. Of the 225 respondents in study 2, 41 (18%) did not report the SQC practices as they were not aware of their company's practices or the company did not carry out SQC. Of the 184 (82%) respondents who reported that their company carried out SQC, the P_{total} scores of 19% revealed poor practices (scored <50%), 11% revealed good practices (scored 50- 74%), and 70% revealed excellent practices (scored ≥75%). This is expected as a large proportion of the respondents (73%) worked in medium to large food companies that ought to have these practices in place.

3.2.3.6 Limitations of the study

A limitation of this study is the exclusion of food company employees with limited access to the internet as the invitation was sent electronically and the survey was administered online. Future studies should endeavour to use paper surveys to ensure adequate representation of this group of employees. This challenge may not be relevant for the assessment of company employees as most companies provide internet access at their facilities.

3.2.4 Conclusions

This study refined and validated the SQC KAP questionnaire. The knowledge section was improved in this revised version by providing better coverage of the main themes of SQC knowledge, the inclusion of multiple-choice questions and its validation using CFA. The test information revealed a good coverage over the range of ability levels. The range of the difficulty of the knowledge questions suggests that the questionnaire will be an effective tool for assessing SQC knowledge. The good level of compliance of the companies in this study to good sensory practices reveals that the questionnaire is suitable for assessing baseline compliance.

Results from IRT analysis, exploratory and confirmatory factor analyses and known groups comparison provide evidence of the validity of the knowledge and practices sections of the questionnaire. CFA was especially useful in detecting the poor fit of the data from the attitudes section to the proposed model, thus, revealing the need for modification. The attitudes section, like other unvalidated scales can be used. However, the results should be interpreted with caution. The revised SQC KAP questionnaire consists of 23 knowledge questions, 12 attitudes questions and 9 practices questions. Although continued improvement and validation will be beneficial, the revised SQC KAP questionnaire can be used to rapidly assess SQC knowledge, attitudes and practices as part of recruitment, training and ongoing employee and sensory quality system assessment.

3.3 THE SENSORY ANALYSIS CRITICAL CONTROL POINT (SACCP) SYSTEM ILLUSTRATED USING A CHOCOLATE MOUSSE PRODUCTION CASE STUDY

Abstract

A preventive system-wide approach to sensory quality control, the sensory analysis critical control point system, is described. This system focuses on the identifying, evaluating, and controlling the causes of sensory defects in the final product. This system is illustrated using a chocolate mousse production case study. The potential sensory defects, their causes, and the critical control points for sensory quality were identified, and a plan for the control and monitoring of the critical control points is described. This method might reduce over-reliance on finished product testing and allows for a preventive rather than reactive approach to sensory quality management. The assessment of the chocolate mousse by the quality team was also evaluated.

3.3.1 Introduction

Consistent sensory quality of food products is an important aspect of product quality as consumer expectations, and thus satisfaction is driven by their experiences and enjoyment of the food (Lawless and Heymann, 2010). The sensory quality of a food product is determined by its raw materials, processing steps, packaging, storage, distribution and retail conditions and the final preparation by the consumer (Curt et al., 2004). Food companies deploy several strategies to ensure that the sensory quality of their products is within pre-defined limits. These strategies usually include recipe formulation, process control and sensory quality testing. Sensory quality control refers to the application of sensory evaluation procedures to evaluate the compliance of a product's sensory quality to a pre-defined standard (Tzia et al., 2015).

While some companies have established robust sensory quality control systems that include the evaluation of raw materials and/or in-process materials, most have marginal systems (McGrew, 2011). Although sensory evaluation has advanced over the last decade, this statement is still relevant, as evidenced in more recent studies where the focus was still on finished product testing (Stefanova and Zlateva, 2018). The evaluation of finished products for sensory quality control, after which, defective products may be reworked, sold at a lower value or discarded leads to significant economic loss (Stefanova and Zlateva, 2018). The evaluation of finished products may be necessary in some cases, such as where there are limitations in the testing of raw materials (e.g., raw meat) and in-process materials (bread dough used for baking bread) by a panel due to issues of food safety or palatability. To prevent the associated waste and improve the efficiency of the quality control system, several authors have recommended less finished product testing and employing a more holistic approach that involves monitoring of the sensory properties of raw materials and in-process goods (Munoz, 2002, Aumatell, 2011, Stefanova and Zlateva, 2018).

A preventive product lifecycle-based approach to sensory defect and quality management may be more effective than finished product testing, which is reactive in nature (Semos and Kontogeorgos, 2007). It will also reduce the waste associated with the latter. Aumatell (2011) also proposed that companies provide specifications for the raw materials to avoid the entrance of a defective ingredient into the production process, and in-process materials should also be evaluated at critical steps to facilitate early detection of sensory defects. Furthermore, chemical and physical methods may be used to monitor sensory quality at non-critical steps, and a human panel used only at critical steps.

Several studies have been carried out to control the sensory properties of food products in unit operations (Perrot et al., 2000, Allais et al., 2007). Allais et al. (2007) focused on the formalisation of expert-operator knowledge to model and control the sensory quality of products during two-unit operations, namely sausage drying and biscuit aeration processes. Perrot et al. (2000) proposed a method for control of biscuit sensory quality during baking using a feedback control system made up of three modules- evaluation, diagnosis and decision. A major limitation of these studies is that they focussed on only one step in the production process. A study by Curt et al. (2004), which focused on all steps of the production, involved the identification of the causes of sensory defects and the formalisation of operator knowledge in the control of the sensory defects. Their study relied on operator knowledge which may be limited in some food companies. A preventive, system-based approach, hazard analysis and critical control points system has been widely implemented and considered successful for the control of food safety. This system has also been successfully modelled and applied to the management of food defence (Vulnerability Assessment and Critical Control Points- VACCP) and food fraud (Threat Assessment and Critical Control Points- TACCP) (Manning and Soon, 2016).

This study introduces a similar method for the management of sensory quality through the identification and control of causes of sensory defects in the production system. Subsequently, the implementation of the sensory analysis critical control points system (SACCP) in a case study chocolate mousse production is described.

3.3.2 Materials and methods

3.3.2.1 Sensory analysis critical control points (SACCP) method of sensory quality assurance

This is a preventive risk-based approach to sensory defect management that is based on the identification, evaluation and control of the causes of sensory defects in the final product. It is based on a principle similar to the hazard analysis critical control point system. Thus, the product is considered to meet the (*sensory*) specification if the (*SACCP*) programme is correctly designed and implemented (Kafetzopoulos et al., 2013).

Some preliminary activities were carried out prior to the development and implementation of the SACCP plan. These were followed by the seven steps of SACCP described in Table 3.3.1.

Table 3.3.1 Description of the steps of SACCP

No.	Steps in SACCP Development	Description
1	Sensory quality defect analysis	This is carried out to identify the significant sensory quality defects that is/ are likely to occur that needs to be controlled or else the final product will not be acceptable to the customer/consumer
2	Determine the critical control points (CCPs)	Critical points at which control can be applied to prevent/ eliminate or reduce a sensory defect to tolerable levels are identified
3	Establish critical limits	This determines the maximum and/or minimum values within which the control measure must be kept at the CCP
4	Establish monitoring procedure	This determines the observations and measurements that can be used to establish whether the CCP is under control
5	Establish corrective action	These are actions or steps that can be taken to prevent undesirable products from reaching the customer/ consumer once a deviation from the CCP is detected
6	Establish verification procedures	These procedures determine the validity/ effectiveness of the SACCP plan ad system operation
7	Establish record keeping and documentation procedures	These are record and documentation procedures for the SACCP plan

3.3.2.2 Development of a SACCP system for chocolate mousse manufacture

Preliminary activities carried out prior to the seven steps of SACCP were:

i. Formation of the SACCP team: A multidisciplinary team of four members (one each from production, research and development, quality and the sensory researcher) was assembled for the developing and implementing the SACCP plan. The team members were individuals with a strong technical background and experience on the production of chocolate mousse. The team also decided on the scope of the SACCP plan.

ii. Detailed product description: A detailed description of the production of chocolate mousse, its ingredients, process steps and intended use was carried out by the SACCP team. The team achieved this through factory observation, employee interviews and document reviews. All production steps from the receipt of raw materials to the packaging of the final product and dispatch were observed and documented. Staff members were informed of the purpose of the project to foster their cooperation. The staff responsible for each step of the production process were interviewed to confirm observed practices. Ingredient specifications, product formulation and monitoring records were reviewed.

iii. The production flow diagram covering all activities in the scope of the SACCP plan from ingredient receipt to dispatch of finished products was constructed and later verified by visual observation of factory operations.

iv. Definition of the target sensory quality: The sensory properties that drive consumer liking/ disliking of chocolate mousse were identified by relating descriptive sensory data to consumer preference using external preference mapping as described in Liggett (2010). Then the target intensity and tolerance range for the important sensory quality properties were described. This was achieved through a consumer preference study and descriptive sensory analysis using a trained sensory panel. The data collected were analysed by external preference mapping (reported in Chapter 4), and the sensory specification was described and approved by management. The drivers of sensory quality may also be identified by internal preference mapping (Liggett, 2010) or by focus group studies which may minimise cost (Oltman et al., 2014).

The seven steps of the SACCP system were carried out as described below.

Sensory defect analysis

This is an important step as its output serves as input in subsequent steps, so the effectiveness of the SACCP plan depends on the correctness of the sensory defect/s analysis. This step focuses on the identification and evaluation of the potential sensory defects at each step of the production process that must be kept within acceptable limits to ensure the final product is acceptable to the target customer/ consumer. A sensory defect is a deviation from the typical/expected sensory quality of the product that may cause a negative sensory experience for the consumer and further impact future consumption of the product.

This step was accomplished through the following:

- Sensory defect identification: Each step of the process was reviewed to identify the potential sensory defect(s) that could occur. The technical knowledge and understanding of the chocolate mousse production by the SACCP team and data from the consumer study were used as a guide.

- Sensory defect evaluation: Here, all the sensory defects identified above were evaluated to identify the critical sensory defects that must be addressed in the SACCP plan. This decision was made based on the severity of the quality loss and the likelihood of its occurrence. The severity refers to the seriousness of the negative experience caused to the consumer by the presence of the sensory defect. The likelihood is the projected frequency of occurrence of the sensory defect. The severity and likelihood of occurrence were qualitatively categorised as low, medium, or high. The justification for the category selected was documented for future reference.

- Description of control measures for sensory defects: The control measures for all the sensory defects were identified and documented. It should be noted that more than one control measure may be needed for a specific sensory defect, and one control measure may be used to control more than one sensory defect.

3.3.2.3 Determine the critical control points (CCPs)

Critical control points are steps in the process where one or more controls must be effected to prevent, eliminate or reduce a sensory defect and achieve the target sensory quality. The CCPs were selected based on the results of the sensory defect analysis. Only sensory defects that could not be controlled by good manufacturing practices and that must be controlled at that point in production to achieve the desired sensory quality were considered in the CCP decision tree (Figure 3.3.1) were identified at CCPs. This decision was based on technical knowledge and experience, as well as literature on the production of chocolate mousse. The CCP decision tree is similar to the one widely used in the HACCP system as a guideline to identify CCPs.

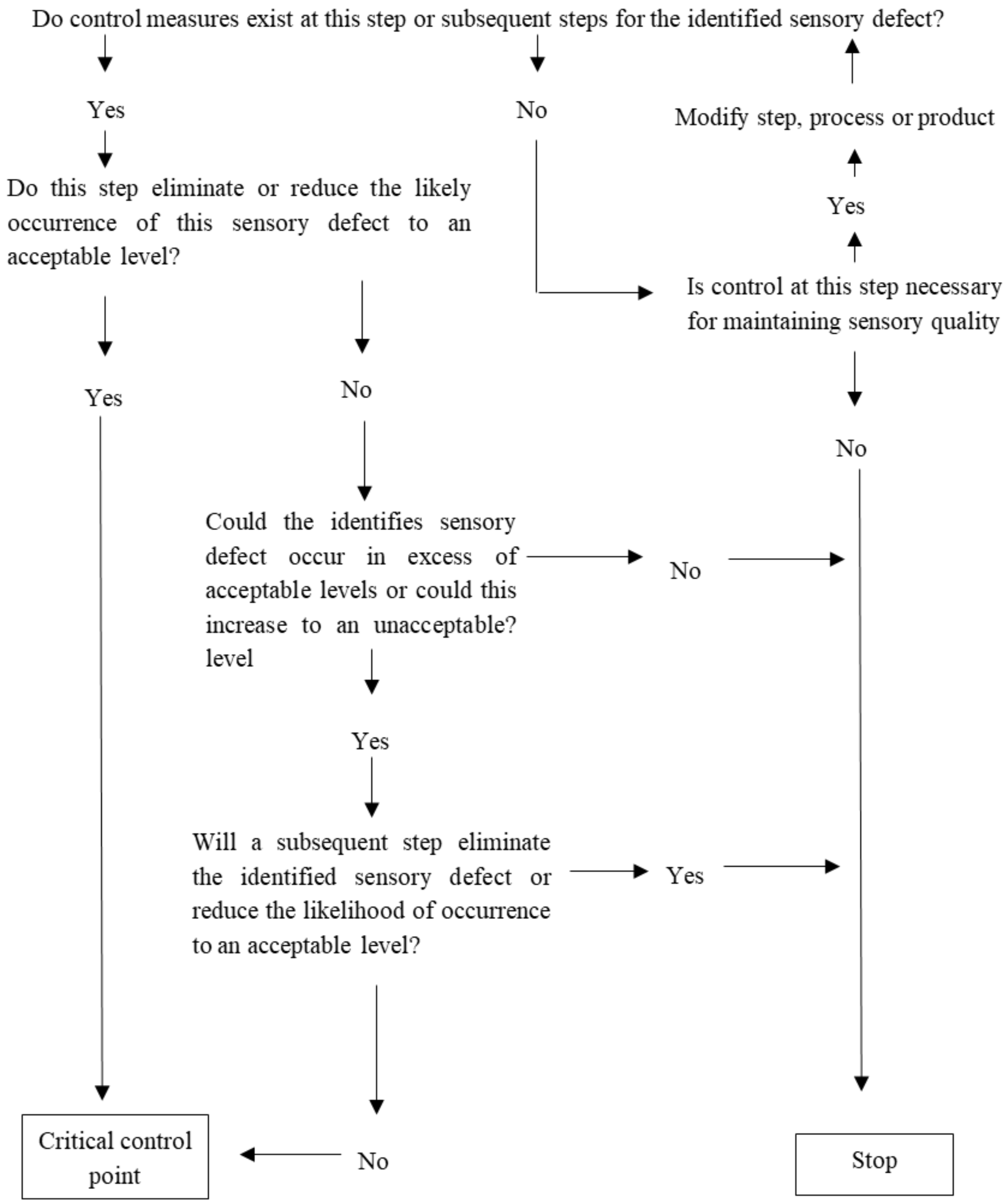


Figure 3.3.1 Critical control point (CCP) decision tree to identify CCPs in the process (Adapted from NACMCF, 1998)

Establish critical limits

The critical limits for the control measures at the CCPs were identified based on technical knowledge and a review of literature on chocolate mousse production (Cardarelli et al., 2008, Mor et al., 2010). The critical limit refers to the maximum and/ or minimum values within which the control measures at the CCP must be maintained to achieve a finished product with the target sensory quality. The critical limit is used to distinguish between acceptable and unacceptable conditions at the CCP.

Establish monitoring procedures

Monitoring procedures that can detect whether the CCP is under control were identified and described. This includes, what is measured, how it is measured, when the measurement is done and who carries out the measurement. Ideally, monitoring procedures that provided continuous real-time data are preferred, however where this is not possible, monitoring procedures that provided rapid, actionable feedback were selected.

Establish corrective action

A clear description of the corrective action(s) to be taken when a deviation is observed at a CCP was documented as part of the SACCP plan. The personnel responsible for carrying out the corrective action and the records to be maintained were also clearly identified. Corrective actions are procedures and steps that are taken to return the process to the pre-defined limit after a deviation is detected.

Establish verification procedures

Procedures to determine the effectiveness of the SACCP plan were identified and documented. The SACCP verification schedule, which shows the frequency of the verification procedures and the personnel responsible, was documented. These verification procedures usually include in-plant audits and evaluations, and random sampling.

Establish record keeping and documentation procedures

All records to be maintained as part of the SACCP plan and the personnel responsible for maintaining the records were identified. Records of the development and implementation SACCP plan were documented and filed for future reference. It is essential that all records are signed, dated and properly filed.

3.3.2.4 Assessment of the effectiveness of sensory quality testing of finished product by the quality team (the verification activity)

The purpose of the verification activity was to confirm that the SACCP plan was adequately controlling the sensory defects and that the company quality team, who are responsible for sensory quality control, will be able to detect a failure in the SACCP system.

Materials

Six ready-to-eat chocolate mousse samples were used in this study. Two samples met the company sensory specification (target samples), one from the company shelf-life retention store (M1), and the other was purchased from the retail market (M2) and the other. The other four samples, M3 to M6, were defective samples that did not meet the company sensory specification (non-target samples).

The case study factory produced refrigerated, ready to eat desserts with a short shelf life. It was a small food company with less than 50 staff, the highest qualification of most of the production operators and supervisors was a high school certificate. The production process was mostly manually done by the operators. This includes the weighing of raw materials, monitoring of the cooking process, release of product into the cooling unit and packaging of the finished product. Production was carried out over two shifts (day and night) in batches.

Assessment procedure

The company quality team (hereafter referred to as panel), made up of the quality personnel (n= 3) and the product development officer, evaluated all six the chocolate mousses in two sessions. The panel displayed a limited ability to screen out defective products. Hence, they received a refresher sensory evaluation training over two 1-hour sessions. The panel re-evaluated the samples over two sessions after the training. The tight operation schedule and high employee turnover rate at the company caused the participants to vary from one session to the next. Only employees that participated in at least three of the four sessions were included in the final analysis.

Fifteen grams (15g) of each sample was served in a 50 mL transparent plastic container labelled with a random three-digit code. The six samples for each session were presented simultaneously. Panellists evaluated the samples from left to right following a balanced order design. Samples were presented at 4 ^{o}C ± 2, while evaluations were carried out at room temperature (25 ^{o}C ± 2) in a conference room at the company. Panellists evaluated each sample on three sensory attributes (visual, taste/ flavour, texture) using a three-point scale (1- unsatisfactory, 2- satisfactory and 3- acceptable). Samples that meet the sensory specification (i.e., the target samples) were rated 2 and/or 3 on all attributes. The count of correctly identified samples (both in-spec and out-of-spec) for each participant before and after the sensory evaluation training was compared using the chi-square test of independence (Ammann et al., 2020).

3.3.3 Results and Discussion (Application to chocolate mousse manufacture)

3.3.3.1 Preliminary Activities

The SACCP team consisted of the product development manager, quality assurance manager, document controller, production supervisor and an independent sensory evaluation technician (the PhD student). The SACCP plan covered the manufacturing operation, i.e., from ingredient receipt, through processing, storage and dispatch for distribution.

The production process and the ingredients are shown in Figure 3.3.2 (Note that for reasons of confidentiality, typical ingredients and production flow diagram for chocolate mousse are presented). Ingredients were received at the company warehouse and stored at the storage temperature recommended by the supplier. Water was supplied from the municipal potable water system, and other ingredients were supplied from accredited suppliers. Skimmed milk, sugar, stabiliser and emulsifier were stored at ambient temperature (25 ± 2 ^{o}C), butter was refrigerated at 4 ± 2 ^{o}C. All the ingredients were weighed according to the formulation. They were cooked to 85 ^{o}C under agitation. The mixture was cooled to ~ 14 ^{o}C and moved to an industrial Mondomix (Haas-Mondomix, Almere, Netherlands), where the mixture was cooled and aerated until the desired density and/or overrun is achieved. The foam was packed in plastic tubs using piping bags and blast chilled to <5 ^{o}C. The mousse was stored at ~ 4 ^{o}C for 24 h prior to dispatching to retail stores/retail distribution centres in cold trucks (< 7 ^{o}C).

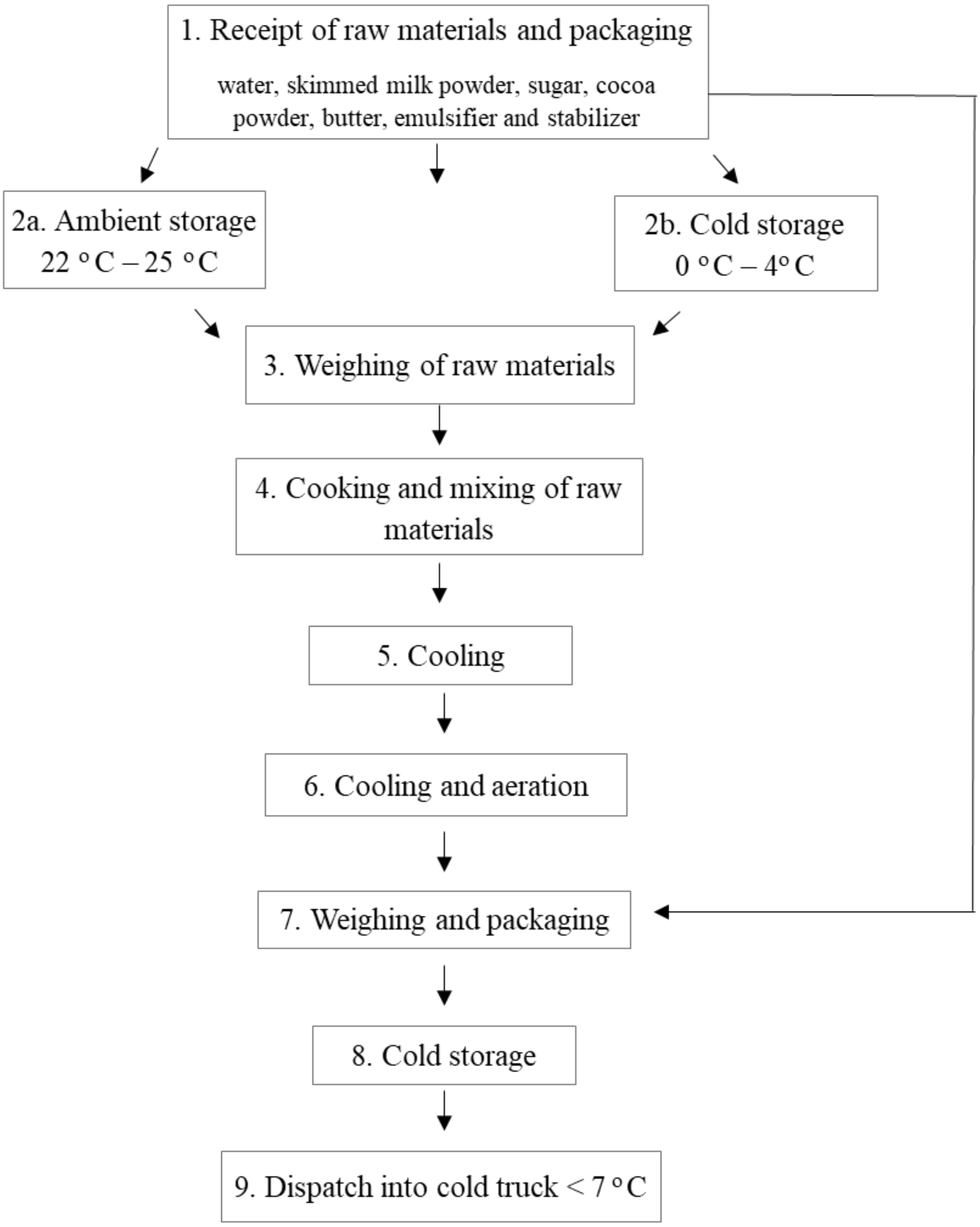


Figure 3.3.2 Production process for chocolate mousse

The drivers of liking and disliking of chocolate mousse for different groups of consumers were identified and a sensory specification was developed as described in section 3.4 and shown in Table 3.3.2. This was done through external preference mapping of chocolate mousse liking data collected from 78 consumers and descriptive sensory data from a trained panel of eight members. Smoothness, sweetness and milk flavour were identified as drivers of liking, while mouth coating, cocoa aroma and cocoa flavour and bitterness were drivers of disliking. The drivers of preference revealed in this study are similar to those reported in studies on other dairy products. For example, consumer preference for strawberry flavoured yoghurt was driven by the intensity of the brightness, flavour, viscosity, and smoothness (Janiaski et al., 2016). In comparison, preference for French yoghurt was driven by the intensity of the colour, thickness, smoothness, and viscosity (Masson et al., 2016).

Table 3.3.2 Sensory specification for chocolate mousse

Sensory attribute	Description	Target (IN)
Brown colour	The sensory characteristics perceived on visual inspection of a scooped spoonful of product under artificial daylight.	Light brown chocolate colour (picture showing the target colour intensity should be provided)
Aeration	Honeycomb structure. Evaluated by looking at the product surface after scooping a spoonful under artificial daylight	Even, honeycomb structure (Picture should be provided with the desired honeycomb structure)
Smoothness	Absence of lumps, particles and grits. Evaluated by eating a teaspoon full of product	No grits or lumps
Thickness	Resistance of the food to compression between the tongue and palate. Evaluated by eating a teaspoon full of product	Firm, spoonable, holds form briefly before melting in the mouth.
Milk flavour, chocolate flavour	The flavour perceived in the mouth when eating a teaspoon full of product.	Moderate milk chocolate flavour with no off flavour (references should be identified with by the panel)
Sweetness	The sweet taste perceived in the mouth when eating a teaspoon full of product.	Low sweetness typical of unsweetened full cream milk
Bitterness	The bitter taste perceived in the mouth when eating a teaspoon full of product.	Low bitterness, typical of milk chocolate (references should be identified with by the panel)

3.3.3.2 Sensory defect analysis

The potential sensory defects were identified, and their significance determined (Table 3.3.3). The sensory defects were classified under four categories, off appearance, off aroma, off flavour and off texture. The classification was based on the drivers of consumer preference, the production process and existing literature (Zabaleta et al., 2016). Off aroma and off flavour were considered as medium severity, while off texture was regarded as high severity as the foam structure is the most important identifying characteristic of mousses (Mor et al., 2010). Furthermore, the foam structure is susceptible to deformation (ZIMBRU et al., 2020) and is more likely to be impacted by processing and post-production handling compared to the other sensory properties. Visual texture may also contribute to the visual appeal of aerated food products (Duquenne et al., 2016). The significance of each sensory defect was determined and justified by using technical data as documented in the defect analysis table (Table 3.3.4).

Sensory defect analysis revealed two CCPs:

CCP 1: Weighing of raw materials/ ingredients

CCP2: Cooling and aeration

CCP 1 was related to off aroma, off taste and texture due to human error in weighing the raw materials for the chocolate mousse. This step is not automated, so the likelihood of an error is medium to high. This step was considered critical as a deviation from the recipe formulation may severely impact the sensory quality of the finished product (Cardarelli et al., 2008). The severity of a defect introduced at this depends on the nature and degree of variation from the recipe formulation as well as the sensory acuity of the consumer. For instance, while the addition of *Lactobacillus paracasei* and inulin did not significantly affect consumer preference(Aragon-Alegro et al., 2007), significant differences were perceived in its colour, flavour and texture by a trained panel (Cardarelli et al., 2008).

CCP 2 was related to a defect in the chocolate mousse foam structure introduced during the aeration of the product. The unique texture and appearance of aerated products such as chocolate mousse are important drivers of consumer preference (Campbell and Mougeot, 1999). The aeration step is critical as the level of aeration, bubble size and distribution of aerated products (such as chocolate mousse) determine textural appearance and mouthfeel (Duquenne et al., 2016, Campbell and Mougeot, 1999). The beater speed and amount of air incorporated into chocolate mousse have been found to significantly affect its texture properties (Kilcast and Clegg, 2002). Overall, creaminess increased with a decrease in bubble size that was attributed to an increase in beater speed. The aeration process also impacted the intensity of the cocoa flavour. Furthermore, the potential for variability is high (high likelihood of occurrence) as the aerating equipment was manually regulated, and the setting changed from batch to batch. The CCPs, their critical limits, monitoring procedures and corrective actions for deviations are shown in Table 3.3.4.

Table 3.3.3 Defect analysis for the production of chocolate mousse

Process Step No.	Ingredient or process step	Potential sensory defects introduced or controlled at the step (appearance, odour, flavour, texture)	Is the potential defect significant	Justification for decision (likelihood, severity)	What control measures can be applied to prevent the significant defect	Is this step a critical control point (CCP)
1	Receipt of packaging and raw materials	Off aroma & taste	No	Low likelihood as all ingredients are supplied with a certificate of analysis or conformance and any defect will be detected at a later stage. Medium severity as aroma and taste are not the dominant sensory properties of chocolate mousse.	Only approved suppliers are used, and a certificate of analysis is provided with each batch of ingredients.	No
2a	Ambient storage	Off aroma & taste	No	Low likelihood due to regular inspection and cleaning of storage areas. Medium severity as aroma and taste are not the dominant sensory properties of chocolate mousse.	Regular inspection of storage area to ensure proper ventilation and regular cleaning of storage area.	No
2b	Cold storage- butter	Off aroma & taste	No	Temperature is monitored by warehouse staff. Low likelihood as the raw materials are sealed and good warehouse practices are adhered to. Medium severity as aroma and taste are not the dominant sensory properties of chocolate mousse.	Regular inspection of the cold room by the warehouse staff. Temperature is monitored by warehouse staff	No. OPRP 1
3	Weighing of ingredients	Off aroma, appearance, taste & texture	Yes	High likelihood as the ingredient are manually weighed and any mistake at this point may not be rectified at a later stage. Medium severity for off aroma and taste as they are not the dominant sensory property and high severity for flavour and texture as these are the dominant sensory property.	Ingredients are measured according to the product formulation. Weighing scale verification is carried out daily. The scale is calibrated annually.	Yes- CCP 1

Process Step No.	Ingredient or process step	Potential sensory defects introduced or controlled at the step (appearance, odour, flavour, texture)	Is the potential defect significant	Justification for decision (likelihood, severity)	What control measures can be applied to prevent the significant defect	Is this step a critical control point (CCP)
4	Cooking and mixing of raw materials	Off texture	No	Low likelihood due to the mixing operation during the cooking. High severity as texture is the dominant sensory property.	Equipment is inspected daily by operator to ensure good working condition.	No
5	Cooling	Off aroma, taste & texture	No	Low likelihood as the heat exchanger is flushed with warm water prior to use and the system is enclosed.	Heat exchanger is cleaned daily to ensure the removal of any residues.	No
6	Cooling and aeration	Off texture	Yes	High likelihood as the volume of product and thus setting of the equipment varies from one batch to another and the severity of a texture defect is high.	The density of the foam is monitored prior to packing every batch.	Yes- CCP2
7	Weighing and packaging	None	No	-	-	No
8	Cold storage	Off aroma, taste & texture	Yes	Low likelihood as cold storage is maintained. High severity as temperature fluctuations may affect the foam structure.	The product is rapidly cooled to below 5 ^{o}C. The temperature of the cold room monitored.	No- OPRP 1
9	Dispatch into cold truck < 7 ^{o}C	Off texture	Yes	Low likelihood as cold storage is maintained. High severity as temperature fluctuations may affect the foam structure.	The temperature is monitored continuously an hour.	No- OPRP 1

OPRP- operational prerequisite programme

Table 3.3.4 SACCP plan for the production of chocolate mousse showing the critical control points (CCPs) and operational prerequisite programmes (OPRPs), their critical limits, monitoring activities and corrective actions.

Process Step No.	Control No./ CCP No.	Control description/ CCP description	Critical limit	Monitoring procedure			Corrective action
				What	How & Who	Frequency	
3	CCP 1	Weighing of ingredients	Formulation	Ingredients	Weighing of ingredients must be according to the formulation, every batch, low risk person.	Every batch	Hold, report to QA Manager.
6	CCP 2	Density and temperature control	Density *(0.8-0.9)* g/cm^3	Density	The equipment operator determined the density of the foam by weighing 1 L of the product prior to packaging.	Every batch	The equipment setting is adjusted, aeration and cooling continues until the critical limit is achieved.
8	OPRP 1	Temperature control	Temperature ≤ $5\,^{o}C$	Temperature	The cold room temperature is monitored with a thermometer by warehouse operator.	Every 4 hours	Keep temperature below 5 ^{o}C or report to QA Manager.
9	OPRP 2	Temperature control	Temperature ≤ 5 ^{o}C	Temperature	The temperature of the truck is assessed using a thermometer an hour before product is loaded unto the truck.	Every truck	Do not load product into Truck.

CCP- Critical control point, OPRP- operational prerequisite programme

3.3.3.3 Monitoring procedure and corrective action

The monitoring procedures for the CCPs were identified. These are physical measurements that are carried out for each batch of production (or as necessary) by the production operator responsible for that step. The determination of the monitoring procedure is important as its reliability and accuracy largely determine the effectiveness of the CCP (Kafetzopoulos et al., 2013). For CCP1, the weight of each ingredient was monitored for conformance with the formulation and signed off by the production operator. Where an error is detected, the process is stopped, and the error is reported to the QA Manager for a decision to be taken. For CCP 2, the density of the foam is measured by weighing 1 L of the finished product. Where the density is not within the critical limit, the setting of the machine is adjusted until the density meets the critical limit. The critical limit was determined from experience and literature (Mor et al., 2010).

The SACCP system allowed the process to be tailored to prevent the occurrence of a sensory defect/s as well as promote the achievement of the desirable sensory quality. The implementation of SACCP enabled the identification of potential sensory defects, their assessment and the identification of the CCPs. This system also facilitated the determination of adequate controls not only for a CCP but also for other points in the process.

3.3.3.4 Verification and documentation procedures

A schedule was agreed upon for the verification of the implementation of the SACCP system (Table 3.3.5). The monitoring of the CCPs was verified daily by the quality controllers. The calibration of the weighing scale used for the raw materials and the foam is also carried out daily before the start of production and verified by the quality controllers. Records of the monitoring and calibration are reviewed daily by the document controller.

The implementation of the SACCP plan does not eliminate finished product testing. However, it reduces over-reliance on finished product testing, allowing its evolution from a monitoring activity to a verification activity. Finished product testing may be done on a regular basis during the initial implementation phase to validate the method; then testing may become less frequent and for verification purposes. This will be beneficial in time and cost savings as the physical monitoring activities are more practical, cheaper and easier to carry out compared to the sensory evaluation of finished products.

Furthermore, the finished product is assessed by the company's trained quality panel once weekly to verify the effectiveness of the SACCP system. Good sensory practices (such as the use of a suitable method, use of a trained panel, standardised sample preparation and serving protocols and controlled test environment) must be followed for all sensory evaluation sessions to ensure the collection of objective and reliable data.

The records maintained include the following:

i. Supporting documentation used for the development of the SACCP plan
ii. The SACCP plan and all related documents.
iii. Records of monitoring activities
iv. Incident reporting and corrective actions
v. Records of periodic reviews of the SACCP plan
vi. Staff details and training records

Table 3.3.5 The SACCP verification schedule for chocolate mousse manufacturing showing what will be carried out, when and the personnel responsible

Activity	Frequency	Responsibility	Reviewer
Verification activities scheduling	Annually or upon a modification of the SACCP System	SACCP Coordinator	SACCP Team
Initial validation of SACCP plan	Prior to and during Initial Implementation of the SACCP plan	SACCP Coordinator	Plant manager
Validation after modification of production operation	Change in product, critical limit, process or equipment. After system failure, etc.	SACCP Coordinator	SACCP Team
Verification of CCP Monitoring as described in the SACCP plan (e.g., monitoring of density)	According to SACCP Plan (e.g., once per shift)	Quality controller	Document controller
Finished product testing	Once weekly	Sensory panel	SACCP Coordinator
Review of Monitoring, Corrective Action Records to Show Compliance with the Plan	Quarterly	Document controller	SACCP coordinator
Comprehensive SACCP System Verification	Annually	SACCP Coordinator	Plant Manager

SACCP- Sensory analysis critical control points system

3.3.3.5 Sensory quality testing of chocolate mousse

The initial verification activity revealed that the members of the company's sensory panel were unable to identify the target samples, this was indicated by the high rate of correct identification of the samples. The panellists showed limited ability to discriminate and screen out defective products, as evidenced by the low number of correctly identified samples for most panellists (Table 3.3.6). A good ability to identify both target and defective samples are desirable, as a panellists can display a good ability to identify target samples by ignoring minor differences from the specification and thus lead to the acceptance of a defective product (Meier-Dinkel et al., 2015). A discussion with the team after the evaluation revealed that they were able to identify the sensory defects that were present in the defective samples contrary to the evidence from the product ratings. Some panellists may have considered their personal preferences in the rating of the product samples.

The quality team was trained on their sensory quality specification and good sensory practices such as disregarding personal preference, concentrating on the task and palate-cleansing at the beginning and between samples. The use of the rating scale categories was explained again. After the training, the quality team re-evaluated the samples. They were able to identify and screen out all the defective samples (Table 3.3.6). The panel's ability to correctly identify the target and defective samples is expected to improve further with regular product evaluation and subsequent refresher training (Etaio et al., 2010).

Table 3.3.6 Percentage of correctly identified samples to the total number of chocolate mousse samples (n = 16) evaluated by members of the company quality panel (P1- P4) before and after sensory evaluation training

Quality panel	Target samples		Non-target samples	
	Before training (%)	**After training (%)**	**Before training (%)**	**After training (%)**
P1	60^a	100^a	38^a	100^b
P2	100^a	100^a	50^a	100^b
P3	100^a	100^a	38^a	100^b
P4	100^a	50^a	100^a	100^a

[ab] Target samples or non-target samples with different superscripts in a row indicate significant differences for before and after training performance for specific panellists ($p < 0.05$)

The results obtained from the evaluation of the finished products by the sensory panel revealed the need for regular refresher sensory evaluation training and validation of the panel in line with the literature. Training is also important as panellists may not regularly participate in sensory evaluations due to other job responsibilities. The employees responsible for all monitoring activities should also be trained on the importance of sensory quality and their role in maintaining the consistent sensory quality of the product. Furthermore, high employee turnover in some food companies (and observed at this plant), which may also impact on the integrity of the sensory panel and monitoring activities, makes regular sensory evaluation training very important for the success of the sensory quality system.

3.3.4 Conclusions

The SACCP system of sensory quality control allows for risk-based management of sensory defects. Sensory defect analysis led to the identification of the weighing of ingredients and aeration of the in-process slurry as the two critical control points in the production of chocolate mousse at the case study factory. The implementation of the SACCP system also led to the identification of the appropriate monitoring activities- confirmation and documentation of the weight of the ingredients and monitoring of the density of the aerated foam. Corrective actions and a verification schedule were also defined. The monitoring of the CCPs should reduce over-reliance on finished product testing as a monitoring activity and progress to a verification activity. The sensory quality assessment of the chocolate mousse by the panel revealed their limited ability to screen out defective products. The panel thus received sensory evaluation training, which improved their ability to screen out defective samples.

3.4 UNDERSTANDING CONSUMER LIKING OF CHOCOLATE MOUSSE USING EXTERNAL PREFERENCE MAPPING APPLICATION

Abstract

An understanding of the drivers of consumer preference and selection of a product is necessary to develop a consumer-oriented sensory specification for quality control to ensure that the product meets consumers expectations. The study's objective was to identify the sensory properties that drive consumer liking/disliking of chocolate mousse and subsequently develop a sensory specification for the case study product (target product). Six chocolate mousse samples (M1 – M6) were profiled by eight trained sensory panellists using 21 attributes over three replicate sessions. The overall liking of five of the chocolate mousses was rated by 79 consumers who also commented on what they liked/disliked about the products. The consumers were clustered into groups based on their preferences, partial least square (PLS) regression and comment analysis were applied to determine the critical sensory attributes that contribute to the overall acceptability of the chocolate mousses. The sensory specification for the target product was subsequently developed.

The chocolate mousses differed in the intensity of the brown colour, cocoa and milk flavours and their aeration, among other sensory attributes. Consumers were clustered into three main groups, cluster 1 (n=32) and 2 (n=22) preferred chocolate mousse samples with higher intensities of smoothness, milk aroma and vanilla flavour, while they disliked products with higher intensities of cocoa flavour and bitterness. There was no clear driver of liking for cluster 3 (n=24). However, the drivers of disliking were slower melt rate and higher thickness. There was a significant difference in consumers descriptions of their preference for the chocolate mousses. The five most often mentioned sensory descriptors used by consumers to describe the products were chocolate flavour, non-chocolate flavour, sweetness, texture, and aeration in decreasing order of frequency.

3.4.1 Introduction

Chocolate mousse is a stabilised dairy foam that is popularly consumed as a dessert or snack. As with other food products, sensory quality is a major determinant of the selection of chocolate mousse by consumers (Lahne et al., 2014). Several studies have been carried out to evaluate the effect of ingredients and processing factors on the sensory properties of mousse (Duquenne et al., 2016, Kilcast and Clegg, 2002, ZIMBRU et al., 2020). Studies have also been carried out to ascertain the acceptability of functional chocolate mousses (Aragon-Alegro et al., 2007, Taghizadeh et al., 2018, Cardarelli et al., 2008). Previous studies have evaluated the drivers of consumer preference and acceptance of dairy products such as chocolate milk (Thompson et al., 2004); yoghurt and whey beverages (Janiaski et al., 2016, Masson et al., 2016, Bogue and Ritson, 2004); sweetened condensed milk (Ares et al., 2006). However, there is limited research on the sensory properties that drive consumer liking/disliking of mousse.

The sensory quality of a food product is a major determinant of consumer preference and purchasing pattern (Hung and Verbeke, 2018). Food companies usually deploy a sensory quality programme to keep product sensory quality within agreed limits to promote consumer satisfaction (Lawless and Heymann, 2010). This is in line with the ISO 9001 guideline that ‘‘top management shall ensure that customer requirements are determined and are met with the aim of enhancing customer satisfaction’’ (Kraggerud et al., 2012). In view of this requirement, a sensory quality specification based on the sensory attributes that are critical to consumer acceptance is very important for the success of any sensory quality programme.

The sensory properties that drive consumer preference are usually identified by relating consumer preference to sensory data and/or instrumental data using multivariate preference mapping techniques such as internal preference mapping (IPM), external preference mapping (EPM) and partial least squares (PLS) regression (Ares et al 2006; Masson et al 2018). Such applications are useful in product development and reformulation of existing products that are tailored to better meet consumer needs (Thompson et al., 2004, Ares et al., 2006). The application of these techniques in sensory quality control has been scarcely studied. Hence, the focus of this study was to apply a PLS approach to define a sensory specification for chocolate mousse for quality control purposes, taking cognisance of consumer preferences for chocolate mousse. The sensory map was generated from multiple product samples to provide some insight on the sensory attributes that differentiate the target product from that of competitors and to inform options for product optimisation based on consumer preferences.

3.4.2 Materials and Methods

3.4.2.1 Materials

Six commercial chocolate mousses were evaluated. Two were from the case study factory. One (M1) was collected from the factory, while the second (M2) was purchased from retail stores. Two ready-to-eat competing products (M3 and M6) were purchased from retail stores and transported in chilled cooler boxes at 4 ± 2 ^{o}C. Two competing powder pre-mixes (M4 and M5) were purchased from retail stores and reconstituted according to the manufacturers' instructions a day before evaluation. The products were selected based on their availability and to capture widely differing sensory profiles that are available to consumers. All products were refrigerated at 4 ± 2 ^{o}C and consumed within their use by / best before dates.

3.4.2.2 Ethical Approval

The use of human subjects was approved by an ethics committee of the University of Pretoria (180000041). Each participant signed a consent form prior to taking part in the study. Participants were duly informed of the potential allergens in the product.

3.4.2.3 Pre-mix preparation

The pre-mix chocolate mousse powders were prepared in 1 L batches. 250 mL of chilled full cream milk was poured into a clear, odourless 1 L plastic beaker, the powder pre-mix (25 g of M4 and 30 g of M5) was added to the milk. The ingredients were mixed and aerated by whipping with an electric mixer (Robot Coupe Mini MP 240 VV, Paris) for 30 s at low speed (speed 1). The sides and bottom of the bowl were scraped to prevent lumps, and then the mixture was whipped for three min (2 min 30 s for M5) at high speed (speed 7). The beaker was sealed with cling film, and the product was refrigerated at 4 ± 2 ^{o}C until evaluation.

3.4.2.4 Sensory Profiling

The sensory evaluation of the chocolate mousses was conducted at the University of Pretoria Sensory Evaluation Laboratory, which was designed in accordance with guidelines of the International Organisation for Standardization (ISO-8589, 2007). Quantitative descriptive analysis (QDA) of six commercial chocolate mousses was carried out by a trained panel of eight members (six females and two males, aged 18 to 55 years). The panel was selected based on their availability from a pool of trained panellists of the Department of Consumer and Food Sciences, University of Pretoria. The panellists had been screened for their ability to perceive, identify and describe product sensory attributes. Selected panellists were trained for 9 h over 3 days to familiarise them with the sensory characteristics of the product range, the evaluation protocol and scale and the use of the data acquisition software Compusense Cloud version 7.8.2 (Compusense Inc., Guelph, ON, Canada). Panellists evaluated the chocolate mousses, individually generated and selected by consensus 21 sensory attributes and scale anchors to be used for descriptive profiling of the chocolate mousses (Table 3.4.1).

Quantitative descriptive analysis (QDA) was done by the trained panel using a nine-point unstructured intensity scale (e.g., 1- not sweet to 9- very sweet). Product evaluations were carried out in three 90 mins sessions, one session a week for three consecutive weeks. Three different batches of products were randomly selected, each one week apart, and evaluated over three weeks. Evaluations took place in individual booths, under white light at room temperature (25 ± 2 ^{o}C), and samples were served at 4 ± 2 ^{o}C. About 25 g of chocolate mousse was served to panellists in glass ramekins. Panellists evaluated all six chocolate mousses; the order of sample presentation was randomised over the panel using the Williams Latin square design. Panellists were instructed to cleanse their palate with filtered tap water before evaluating the first sample and between samples.

Table 3.4.1 Sensory attributes, their definitions and scale anchor points used by the trained sensory panel to evaluate chocolate mousse samples

Sensory Attributes	Definitions	Standards	Scale
Aroma			
Chocolate	The aroma that is typical of dark (75%) chocolate	**9=** Illovo smooth chocolate sauce	1= No aroma 9= Intense aroma
Cocoa	The aroma that is typical of roasted cocoa beans and cocoa powder	**9=** 10% Warm cocoa powder in water solution	1= No aroma 9= Intense aroma
Milk	The aroma that is typical of milk and cream	**9=** Cold Clover full cream UHT milk	1= No aroma 9= Intense aroma
Appearance			
Brown colour	Brown colour characteristic of dark chocolate	**9=** 10% cocoa powder in water solution **5=** 10% Warm cocoa powder in UHT milk	1 = Light brown 9 = Dark brown
Aeration	The number of visible air pockets	**9=** Woolworths chocolate whipped cream	1 = Not aerated 9 = Very aerated
Gloss	The shine of the surface that is characteristic of egg white	**9=** Egg white	1 = Not glossy 9 = very glossy
Hold	The ability of the product to retain its shape typical of gelatin products	**9=** prepared jelly	1 = No hold 9 = High hold
In mouth texture			
Smoothness	The absence of lumps and particles	**9=** Parmalat plain medium fat yoghurt	1 = Not smooth 9 = Very smooth
Thickness	Resistance of the food to compression	**9=** Parmalat plain medium fat yoghurt	1 = Not thick 9 = Very thick
Melt rate	Time it takes the product to melt completely when moved between the tongue and palate.	**9=** Parmalat plain medium fat yoghurt	1 = Very fast 9 = Very slow
Taste and Flavour			
Sweet	A taste typical of sugar and honey	**9=** 25% sucrose solution	1 = Not sweet 9 = Very sweet
Bitter	The typical taste of quinine and caffeine	**9=** 5% cocoa powder in water solution	1 = Not bitter 9 = Very bitter
Milk	A flavour characteristic of full cream milk	**9=** Cold Clover full cream UHT milk	1 = No flavour 9 = Intense flavour
Chocolate	A flavour characteristic of dark (75%) chocolate	**9=** Illovo smooth chocolate sauce	1 = No flavour 9 = Intense flavour

Sensory Attributes	Definitions	Standards	Scale
Cocoa	A flavour characteristic of cocoa powder dissolved in water	**9=** 10% cocoa powder in water solution	1 = No flavour 9 = Intense flavour
Vanilla	A flavour characteristic of vanilla	**9=** 33% Robertson vanilla flavour in water	1 = No flavour 9 = Intense flavour
Earthy	A flavour characteristic of cocoa	**9=** Moist earth	1 = No flavour 9 = Intense flavour
Aftertaste			
Sour	An acid like taste typical of fermented products	**9=** Plain Parmalat medium fat yoghurt	0 = Not sour 9 = Very sour
Bitter	The typical taste of quinine and caffeine	**9=** 5% cocoa powder in water solution	0 = Not bitter 9 = Very bitter
Astringent	The feeling of dryness of the mouth and tongue that is typical of green tea	**9=** Plain Clover double cream yoghurt	1 = Not astringent 9 = Very astringent
Mouthcoating	The feeling of a fatty coating on the tongue and surfaces of the mouth after product is expectorated	**9=** cream	0 = No coating 9 = intense coating

3.4.2.5 Instrumental colour measurements

The colour of the chocolate mousse samples was evaluated using a CR 410 Chromameter (Konica Minolta, Japan) using the Commission Internationale de l'Eclairage (CIE) L*a*b* scale as described in (ZIMBRU et al., 2020). The colour measurements were expressed as lightness (L*), red-green (a*) and yellow-blue (b*). About 50g of the chocolate mousse was scooped using a large stainless-steel spatula and placed in a plastic weighing dish. The chromameter was calibrated with a white standard plate prior to taking the colour readings of the chocolate mousse samples. The evaluations were carried out in triplicate using samples from the same batches used for descriptive sensory analysis.

3.4.2.6 Consumer preference

A total of 79 consumers were screened from a pool of 394 based on their availability and regular consumption of chocolate mousse (at least twice a month). Consumers were aged 18 to 60 years, with 59% female and 41% male. All consumers reviewed and completed a consent form before participating in product evaluations. Ideally, the consumers used in this study should be the target consumers of the case study product based on criteria such as socio-economic and preference patterns.

Consumers were presented with the five chocolate mousse samples (M2 - M6) simultaneously and instructed to taste the samples from left to right. Each sample was labelled with a three-digit code and the samples were presented according to a balanced random Williams design. About 25 g of chocolate mousse was served in 50 mL plastic portion cups and covered with lids. Evaluations took place in individual booths, under white light at room temperature (25 ± 2 ^{o} C) in a sensory laboratory. Samples were served at 4 ± 2 ^{o} C. Consumers assessed the same batch of samples used by the trained panel for the first session of sensory profiling. Consumers evaluated at least two batches of the various chocolate mousses. Three or more batches are desirable to account for any batch effect.

Consumers rated the overall liking of each sample using a nine-point structured hedonic scale (1- dislike extremely to 9- like extremely). They were subsequently asked to comment on their liking or disliking of the sample using their own vocabulary. Consumers also reported their age and gender. Responses were recorded electronically using the Compusense cloud data capturing system (Compusense Inc., Guelph, ON, Canada). Consumers were prompted on the computer screen to confirm that the correct sample was being evaluated at the time of providing feedback. Consumers were instructed to cleanse their palate with distilled water served at room temperature prior to evaluating the first sample and before subsequent sample evaluations.

3.4.2.7 Data Analysis

Data analysis was carried out using XLSTAT 2020 (Addinsoft, Paris, France). Panel analysis was carried out to determine the sensory attributes that discriminated significantly between products. These were retained for further analysis. The QDA data were subjected to two-way ANOVA with panellists and product effects. (Masson et al., 2016). Fisher's lowest significant difference (LSD) test was used for mean separation of sensory attributes ($P < 0.05$) (Varela et al., 2014). The sensory map showing the relationship between the mousse samples and the sensory attributes was visualised using PCA (Liggett, 2010). PCA is also useful for identifying outlier products and highly correlated sensory attributes.

The mean values from the instrumental colour parameters (L*a*b*) were determined. The data were subjected to one-way ANOVA and Fisher's LSD test for comparison of means. The total colour difference (ΔE) between chocolate mousse samples were calculated using Equation 1. ΔE values were classified as not noticeable different (<1), noticeable to the experienced observer (1-2), noticeable to the inexperienced observer (2- 3.5) and clearly different in colour (>3.5) (Mokrzycki and Tatol, 2011).

$$\Delta E^* = \sqrt{[(\Delta L^{*2}) + (\Delta a^{*2}) + (\Delta b^{*2})]} \quad \text{(Equation 1)}$$

Consumers liking data were subjected to two-way analysis of variance (ANOVA) and subsequently to Fisher's LSD test for comparison of means (Varela et al., 2014). Consumers were grouped based on their liking data using hierarchical cluster analysis (Euclidean distance and Ward's criteria) with automatic truncation (Masson et al., 2016). Cluster analysis was applied to produce homogenous sub-groups of consumers prior to averaging preference data for PLS, thus, improving the relevance of the resulting PLS model (Liggett, 2010).

Comments from consumers on their liking/disliking of the chocolate mousses were prepared for analysis by correcting spelling errors, removing connectors and auxiliary terms, removing ambiguous words and grouping similar sensory descriptors- see Table 3.4.2 (Symoneaux et al., 2012). Comments were subsequently reviewed, and the valence (liking/disliking) of the sensory attributes for each product was identified based on the context and the overall liking score. Only the sensory descriptors that were mentioned by at least 5% of consumers for at least one product were retained for further analysis (Mahieu et al., 2020). A frequency table of the sensory descriptors (L- for liking, D- for disliking) versus each product was developed. The significance of the difference between the frequency of liking and disliking comments for different products was evaluated using the Chi-square test (Mahieu et al., 2020). Chi-square by cell analysis was also carried out to identify the cells that contributed to the significance of the global Chi-square.

Table 3.4.2 Terms retained for grouping the sensory attributes used by consumers to describe the chocolate mousse samples

Comment group	Terms used by consumers
Look	appearance, visual, gloss
Smell	smell, aroma, odour
Aeration	aerated, airy, bubbly, foamy, soft, frothy, melt in my mouth
Texture	texture, mouthfeel, consistency,
Smooth	smooth, creamy, lumps, grainy, lumpy
Chocolate	chocolate flavour, chocolate taste, cocoa
Flavour (non-chocolate)	milk, off-flavour, bland, taste, artificial, off-taste
Sweet	sweet, sweetness
Bittern	Bitter, bitterness
Hedonic	delicious, awesome, great, good, bad

PLS regression was used to simultaneously relate the average overall liking of each consumer cluster (dependent variables) to the average intensity of the sensory attributes from the trained panel (independent variables). The model fit and predictive model quality were assessed as R^2 and Q^2 cumulative (Tenenhaus et al., 2005). Model selection was based on the values of the goodness of fit (R^2), predictive quality (Q^2), Q^2 cum and degrees of freedom (df). The variable importance of projection output was used to determine the critical sensory attributes.

3.4.3 Results and discussion

3.4.3.1 Sensory Mapping: Description of the sensory space.

Twenty-one sensory attributes were selected by the trained sensory panel to characterise the sensory properties of chocolate mousse (Table 3.4.1). These sensory attributes were similar to those in previous descriptive studies on dairy products (Masson et al., 2016, Thompson et al., 2004, Kilcast and Clegg, 2002). Panel analysis revealed that the chocolate mousses were significantly different ($P < 0.05$) on 17 attributes and not different for hold, sourness, chocolate aroma and chocolate flavour. This shows that the trained panel was able to distinguish between the chocolate mousses (Ares et al., 2006). Of the 17 attributes, 12 displayed a significant panellist-product interaction, however, the highly significant product effects ($P \leq 0.0002$) and panel correlation circle indicate that the disagreement between panellists was due to differences in their use of the intensity scale and that the panel had a good agreement on the intensity of the attributes. This observation is similar to previous studies that showed a significant panellist-product interaction despite a highly significant product effect, and this was attributed to differences in the use of the scale by the panel (Ares et al., 2006, Masson et al., 2016).

Table 3.4.3 The mean intensities and standard deviation for the sensory attributes for the different chocolate mousse samples

Sensory attributes	M1	M2	M3	M4	M5	M6
Cocoa aroma	$5.79^{a} \pm 1.93$	$5.67^{a} \pm 1.74$	$5.25^{a} \pm 1.98$	$6.54^{ab} \pm 2.15$	$6.96^{b} \pm 2.10$	$4.92^{a} \pm 1.89$
Milk aroma	$5.33^{a} \pm 2.04$	$4.88^{a} \pm 2.21$	$6.04^{b} \pm 1.88$	$3.71^{a} \pm 2.27$	$3.50^{a} \pm 2.34$	$5.71^{b} \pm 2.03$
Brown colour	$6.21^{b} \pm 1.25$	$6.00^{b} \pm 1.25$	$5.04^{a} \pm 1.30$	$7.86^{c} \pm 0.99$	$7.71^{c} \pm 1.23$	$4.71^{a} \pm 1.20$
Gloss	$2.92^{a} \pm 2.08$	$2.79^{a} \pm 1.98$	$4.83^{b} \pm 2.12$	$7.79^{c} \pm 1.10$	$7.42^{c} \pm 1.47$	$4.71^{b} \pm 2.03$
Aeration	$7.67^{b} \pm 1.40$	$7.88^{b} \pm 1.08$	$7.88^{b} \pm 1.33$	$3.42^{a} \pm 2.54$	$3.88^{a} \pm 2.31$	$7.71^{b} \pm 1.33$
Thickness	$7.71^{ab} \pm 1.33$	$8.33^{b} \pm 0.82$	$6.33^{a} \pm 1.34$	$7.21^{ab} \pm 1.64$	$7.42^{ab} \pm 1.74$	$6.21^{a} \pm 1.53$
Smoothness	$7.79^{ab} \pm 1.22$	$7.54^{ab} \pm 1.35$	$8.17^{ab} \pm 1.49$	$7.25^{a} \pm 1.62$	$7.04^{a} \pm 1.60$	$8.50^{b} \pm 0.78$
Melt rate	$5.42^{a} \pm 2.38$	$5.75^{a} \pm 2.44$	$4.04^{a} \pm 2.54$	$5.13^{a} \pm 2.19$	$5.54^{a} \pm 2.52$	$4.04^{a} \pm 2.46$
Sweetness	$4.88^{a} \pm 1.83$	$4.83^{a} \pm 1.90$	$7.25^{b} \pm 1.19$	$6.58^{b} \pm 1.84$	$6.63^{b} \pm 1.74$	$7.13^{b} \pm 1.48$
Bitterness	$5.38^{b} \pm 1.86$	$5.33^{b} \pm 1.63$	$2.80^{a} \pm 1.50$	$6.25^{b} \pm 1.59$	$6.54^{b} \pm 1.74$	$3.50^{a} \pm 1.79$
Milk flavour	$5.63^{b} \pm 2.16$	$5.92^{b} \pm 2.10$	$6.42^{b} \pm 1.74$	$3.58^{a} \pm 2.04$	$3.63^{a} \pm 2.32$	$6.58^{b} \pm 1.56$
Earthy	$3.21^{a} \pm 1.84$	$3.38^{b} \pm 2.00$	$1.71^{a} \pm 0.86$	$6.08^{c} \pm 1.98$	$6.13^{c} \pm 2.29$	$2.08^{a} \pm 1.61$
Vanilla flavour	$2.13^{a} \pm 1.62$	$1.58^{a} \pm 1.21$	$4.54^{b} \pm 2.83$	$1.42^{a} \pm 1.14$	$1.21^{a} \pm 0.51$	$3.83^{b} \pm 2.79$
Cocoa flavour	$6.04^{ab} \pm 1.78$	$5.88^{ab} \pm 1.68$	$5.13^{a} \pm 1.39$	$6.88^{b} \pm 1.57$	$7.42^{b} \pm 1.64$	$5.21^{a} \pm 1.61$
Bitterness	$5.00^{b} \pm 2.27$	$5.17^{b} \pm 2.06$	$2.83^{a} \pm 1.90$	$6.25^{b} \pm 1.80$	$6.42^{b} \pm 2.06$	$3.46^{ab} \pm 2.04$
Astringent	$5.25^{ab} \pm 2.13$	$5.63^{ab} \pm 2.12$	$3.96^{a} \pm 2.42$	$5.92^{b} \pm 2.45$	$6.25^{b} \pm 2.03$	$4.75^{ab} \pm 2.51$
Mouthcoating	4.38 ± 2.53	4.17 ± 2.35	4.54 ± 2.47	5.33 ± 2.33	5.79 ± 2.36	4.67 ± 2.14

Mean values on the same row with different superscripts differ significantly ($P<0.05$).

Table 3.4.3 shows the average intensities of the sensory attributes for the mousse samples obtained from the trained panel. The chocolate mousses samples differed only slightly for some attributes (such as smoothness, melt rate) that may be considered typical of mousses and differed more widely on some attributes such as gloss and bitterness which may be aspects of product differentiation. When compared with the other products, the target products (M1 and M2) were thicker, highly aerated with a slower melt rate (Table 3.4.3). M1 and M2 had medium intensities for colour, bitterness, smoothness, cocoa flavour and milk flavour and low intensities for sweetness and gloss.

PCA of mean descriptive data revealed two principal components (PCs) with eigenvalues greater than one. These accounted for 98.6 % of the total variance (PC1- 78.25% and PC2- 20.39%). PC 1 separated samples on the left (M4 and M5) from those on the right (M1, M2, M3 and M6) based on the prevalence of cocoa or milk flavour, respectively. Samples on the left were associated with higher intensities of cocoa flavour and darker brown colour, while those on the right were characterised by higher intensities of milk and vanilla flavour, as well as smoothness. PC2 separated samples at the top of the plot (M3, M6, M4 and M5) from the ones at the bottom (M1 and M2), with samples at the bottom appearing thicker with a slower melting rate, while those at the top were sweeter. As expected, the PCA plot showed the attributes that differed to a lesser degree among products towards the middle (Tenenhaus et al., 2005). The products differed to a greater extent on gloss, aeration and earthy flavour. The products were separated into three distinct clusters representing different sensory profiles.

The target products formed a different cluster indicating a unique product offering among this group of products. In comparison to the other products, the target product is characterised by higher intensities of thickness, lower intensity of sweetness and moderate intensity of cocoa and milk flavours (Figure 3.4.1).

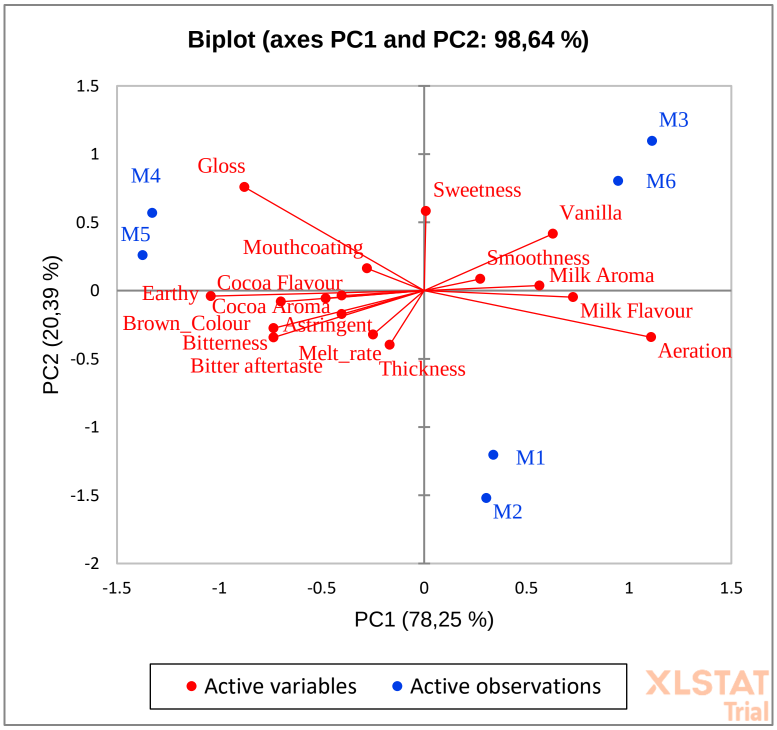


Figure 3.4.1 PCA biplot of the sensory profile of six chocolate mousse products (M1-M6) on the first two principal components (PC)- PC1 and PC2

As expected, there was a positive linear relationship between cocoa aroma and flavour, earthy flavour and brown colour. These indicate that the brown colour and earthy flavour may be due to the cocoa or chocolate concentration in the sample. In some cases, the addition of a colouring agent contributes to the intensity of the colour; colouring agents were added to two of the chocolate mousses evaluated in this study- M4 and M2. A negative correlation was observed between the cocoa aroma and flavour intensity and the milk aroma and flavour intensity. This is expected as the intensity of the cocoa flavour is reduced by the addition of milk resulting in an inverse relationship. There was a positive correlation between milk aroma, milk flavour and aeration. There was a positive correlation between mouth coating and gloss. This is expected as both properties are related to the fat content and/or chocolate content *of the mousse* (Pastor et al., 2007).

3.4.3.2 Instrumental colour evaluation

The chocolate mousses were characterised by a mixture of redness and yellowness as revealed by positive a* and b* values (Table 3.4.4). As expected, their lightness (L*) was more towards the black region than the white region, sample M6 was the lightest (50.86), while sample M4 was the darkest (36.69). The range of L*a*b* values obtained in this study was similar to those obtained for chocolate milk (Thompson et al., 2004) and dark chocolate (Machalkova et al., 2014) in previous studies. The target chocolate mousse had medium lightness compared to the other samples.

There was a significant difference between the chocolate mousses for all the colour parameters measured (Table 3.4.4). The colour difference between the mousses ranged from 1.76 (only noticeable to the experienced observer) to 14.35 (perceived as different colours). Samples M3 and M6 which had the lowest colour difference (ΔE= 1.76). The difference between all other pairs was > 2 and may therefore be noticeable to consumers (Gaze et al., 2015a, Mokrzycki and Tatol, 2011). Consumers may choose to consider colour when judging product quality during selection. The difference in colour between samples M1 and M2 was distinct and noticeable to the inexperienced observer, with the latter being lighter in colour. This may be an indication of inconsistent product quality, or that storage and distribution conditions have made sample M2 lighter with time. The impact of the storage conditions is not clear. However it may be related to changes in the microstructure of the product, as light scattering by protein and fat particles affect the lightness of dairy products (Park et al., 2015). This highlights the importance of storing chocolate mousse under optimal conditions to prevent undesirable changes in the colour and other characteristics of the product.

Table 3.4.4 The mean values for the instrumental colour parameters (L*a*b*) and the colour difference (ΔE) between the chocolate mousse samples

Product		**M1**	**M2**	**M3**	**M4**	**M5**	**M6**
L*		44.91^{b}	47.05^{bc}	49.23^{cd}	36.69^{a}	38.96^{a}	50.86^{d}
a*		12.00^{bc}	11.67^{ab}	11.57^{ab}	12.25^{cd}	11.29^{a}	11.78^{abc}
b*		15.33^{cd}	15.49^{d}	13.43^{b}	11.81^{a}	11.97^{a}	14.05^{bc}
ΔE	M1		2.17	4.74	8.95	6.87	6.09
	M2			3.00	11.01	8.83	4.07
	M3				12.66	10.38	1.76
	M4					2.47	14.35
	M5						12.09

Mean values on the same row for L*a*b* values with different superscripts, differ significantly ($P<0.05$).

Table 3.4.5 Correlation between the intensity of the sensory attributes obtained by the trained panel and L*A*B* values obtained by instrumental colour analysis of the chocolate mousses

Variables	**Cocoa Aroma**	**Milk Aroma**	**Brown Colour**	**Gloss**	**Aeratio-n**	**Smooth-ness**	**Sweet-ness**	**Bitter-ness**	**Milk Flavour**	**Earthy**	**Vanilla**	**Cocoa Flavour**	**Bitter-ness**	**Astring-ent**	**Mouth-coating**	**L***	**A***	**B***
Cocoa aroma	**1**	**-0.947**	**0.975**	0.667	**-0.885**	**-0.960**	-0.102	**0.899**	**-0.968**	**0.962**	**-0.828**	**0.986**	**0.919**	**0.850**	0.787	**-0.951**	-0.065	-0.622
Milk aroma	**-0.947**	**1**	**-0.956**	-0.708	**0.920**	**0.925**	0.063	**-0.916**	**0.962**	**-0.991**	**0.867**	**-0.968**	**-0.948**	**-0.928**	-0.794	**0.931**	-0.012	0.636
Brown colour	**0.975**	**-0.956**	**1**	0.663	**-0.904**	**-0.950**	-0.148	**0.925**	**-0.981**	**0.981**	**-0.861**	**0.968**	**0.947**	**0.868**	0.734	**-0.989**	0.146	-0.604
Gloss	0.667	-0.708	0.663	**1**	**-0.914**	-0.508	0.638	0.405	-0.790	0.730	-0.271	0.656	0.477	0.424	**0.938**	-0.730	-0.012	**-0.991**
Aeration	**-0.885**	**0.920**	**-0.904**	**-0.914**	**1**	0.781	-0.271	-0.737	**0.967**	**-0.942**	0.630	**-0.888**	-0.789	-0.728	**-0.919**	**0.935**	-0.100	**0.868**
Smooth-ness	**-0.960**	**0.925**	**-0.950**	-0.508	0.781	**1**	0.290	**-0.920**	**0.899**	**-0.922**	**0.900**	**-0.937**	**-0.936**	**-0.877**	-0.617	**0.898**	0.057	0.458
Sweetness	-0.102	0.063	-0.148	0.638	-0.271	0.290	**1**	-0.431	-0.039	-0.053	0.549	-0.123	-0.359	-0.364	0.491	0.047	-0.213	-0.698
Bitterness	**0.899**	**-0.916**	**0.925**	0.405	-0.737	**-0.920**	-0.431	**1**	**-0.865**	**0.918**	**-0.982**	**0.935**	**0.995**	**0.972**	0.556	**-0.873**	0.134	-0.314
Milk flavour	**-0.968**	**0.962**	**-0.981**	-0.790	**0.967**	**0.899**	-0.039	**-0.865**	**1**	**-0.986**	0.776	**-0.965**	**-0.899**	**-0.827**	**-0.848**	**0.987**	-0.096	0.738
Earthy	**0.962**	**-0.991**	**0.981**	0.730	**-0.942**	**-0.922**	-0.053	**0.918**	**-0.986**	**1**	**-0.852**	**0.976**	**0.948**	**0.904**	0.806	**-0.969**	0.089	-0.662
Vanilla	**-0.828**	**0.867**	**-0.861**	-0.271	0.630	**0.900**	0.549	**-0.982**	0.776	**-0.852**	**1**	**-0.865**	**-0.972**	**-0.968**	-0.419	0.789	-0.125	0.175
Cocoa flavour	**0.986**	**-0.968**	**0.968**	0.656	**-0.888**	**-0.937**	-0.123	**0.935**	**-0.965**	**0.976**	**-0.865**	**1**	**0.951**	**0.910**	0.799	**-0.939**	-0.043	-0.594
Bitterness	**0.919**	**-0.948**	**0.947**	0.477	-0.789	**-0.936**	-0.359	**0.995**	**-0.899**	**0.948**	**-0.972**	**0.951**	**1**	**0.975**	0.607	**-0.901**	0.128	-0.389
Astringent	**0.850**	**-0.928**	**0.868**	0.424	-0.728	**-0.877**	-0.364	**0.972**	**-0.827**	**0.904**	**-0.968**	**0.910**	**0.975**	**1**	0.580	-0.806	0.042	-0.322
Mouth-coating	0.787	-0.794	0.734	**0.938**	**-0.919**	-0.617	0.491	0.556	**-0.848**	0.806	-0.419	0.799	0.607	0.580	**1**	-0.767	-0.195	**-0.916**
L*	**-0.951**	**0.931**	**-0.989**	-0.730	**0.935**	**0.898**	0.047	**-0.873**	**0.987**	**-0.969**	0.789	**-0.939**	**-0.901**	-0.806	-0.767	**1**	-0.223	0.677
A*	-0.065	-0.012	0.146	-0.012	-0.100	0.057	-0.213	0.134	-0.096	0.089	-0.125	-0.043	0.128	0.042	-0.195	-0.223	**1**	0.066
B*	-0.622	0.636	-0.604	**-0.991**	**0.868**	0.458	-0.698	-0.314	0.738	-0.662	0.175	-0.594	-0.389	-0.322	**-0.916**	0.677	0.066	**1**

Values displayed in bold are significant ($P<0.05$)

As expected, there was a negative correlation between the intensity of the brown colour perceived by the trained panel and the instrumental colour parameters L* (r = -0.989) and b* (-0.636) (Table 3.4.5). The relationship between the colour from the trained panel and L* and b* values is similar to previous results obtained by Thompson et al. (2004). There was also a strong negative correlation between L* and cocoa aroma (r = -0.951) and cocoa flavour (r = -0.939) (Table 3.4.5). While there was a strong positive relationship between L* and milk aroma (r = 0.931) and milk flavour (r = 0.987). A similar, however moderate relationship was observed between b* and cocoa aroma (-0.622), cocoa flavour (-0.594), milk aroma (0.636) and milk flavour (0.738). This strongly suggests a causal link between the cocoa and milk concentrations and the colour of the chocolate mousse. The a* values did not correlate significantly with any of the sensory attributes.

3.4.3.3 Consumer liking

There were significant differences (P< 0.0001) in the overall liking of the chocolate mousses by consumers (Table 3.4.7). The mean liking ratings ranged from 4.64 to 7.33, indicating that the chocolate mousses were generally liked. Data from one consumer was not included as they gave the same rating for all products, so the data may not contribute to understanding the drivers of product preference (Arditti, 1997; Liggett, 2011). Pairwise comparison of the overall liking of the mousses by all consumers resulted in three groups of products- M3 and M6 were the most preferred mousses (group 1), M4 was moderately liked (group 2), and M5 was least preferred (group 3). M2 (the target product) overlapped between groups 2 and 3 and was moderate to least liked (Table 3.4.7).

Table 3.4.6 Mean overall liking of the chocolate mousses by consumer clusters using a 9 pt hedonic rating scale (1- dislike extremely to 9 like extremely)

Consumers	**n**	**M3**	**M4**	**M2**	**M5**	**M6**
All	78	7.08^{a}	6.01^{b}	5.28^{bc}	4.64^{c}	7.33^{a}
Cluster 1	32	8.13^{a}	7.34^{a}	6.03^{b}	5.56^{b}	7.97^{a}
Cluster 2	22	6.86^{a}	3.73^{b}	6.32^{a}	3.73^{b}	7.68^{a}
Cluster 3	24	5.88^{ab}	6.33^{a}	3.33^{c}	4.25^{bc}	6.17^{a}

Mean values on the same row with different superscripts are significantly different (P < 0.05).

Cluster analysis resulted in three consumer clusters (Figure 3.4.2). Cluster 1 (C1) consisted of 32 consumers, cluster 2 (C2) had 22 consumers, while cluster 3 (C3) had 24 consumers. All three clusters had different preference patterns, as revealed by the results of the ANOVA (Table 3.4.5). Consumers in cluster 1 liked all the chocolate mousses. There were however significant differences between the overall liking rating for the different products. These suggest that consumers in C1 did not distinguish well among the different products (Bernstein, 2015). Consumers in C2 liked the products with higher intensities of vanilla and milk flavour. In comparison, consumers in C3 liked M4 and M6, which were characterised by moderate sweetness and thickness (Figure 3.4.1).

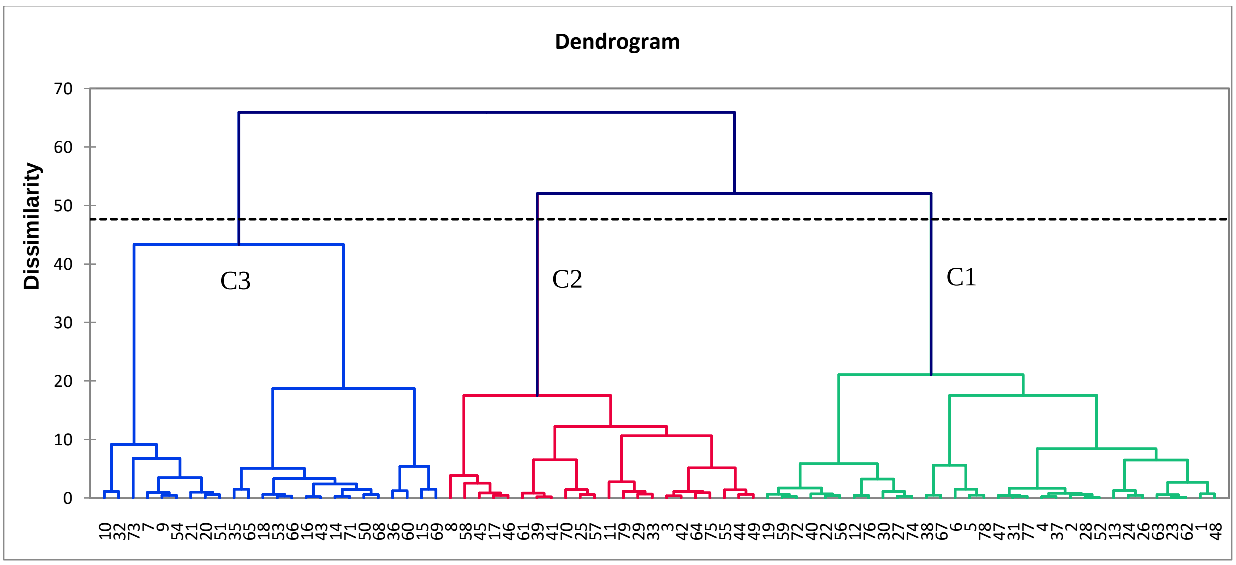


Figure 3.4.2 Dendogram of consumer segmentation by hierarchical clustering based on their overall liking ratings of the chocolate mousse. C1, C2, C3 represents cluster 1, 2 and 3, respectively

Analysis of consumer free comments resulted in twelve groups of sensory attributes (Table 3.4.7). Two categories- mouthcoating and aftertaste were removed as less than 5% of consumers described sensory perceptions related to it. Chi-square (χ^2) test of association was significant for both the like (χ^2 = 56.2, df= 4, p = 0.048) and dislike comments (χ^2 = 70, df= 4, p = 0.019) for the products, revealing that consumers used a different number of comments to describe liking and disliking of the products (Sharma et al., 2019).

Table 3.4.7 Frequency table of count of like (L) and dislike (D) comments for each mousse

Comment group	M2	M3	M4	M5	M6	%[a]
Like comments						
L_look	2	6	5	6	5	4.1
L_smell	1	2	3	1	**0** (-)	1.2
L_aeration	9	**26** (+)	**2** (-)	**4** (-)	**28** (+)	11.9
L_texture	14	12	16	6	1	10.7
L_smooth	14	**10** (-)	14	**17** (+)	18	12.6
L_chocolate	17	22	29	16	26	19.0
L_flavour	14	30	14	12	26	16.6
L_sweet	16	22	18	10	25	15.7
L_bitter	1	1	1	**0** (-)	**0** (-)	0.5
L_aftertaste	1	2	2	2	3	1.7
L_hedonic	4	10	8	5	8	6.0
Dislike comments						
D_look	7	4	2	**3** (-)	5	5.4
D_smell	1	**0** (-)	2	5	2	2.6
D_aeration	**2** (-)	2	9	8	2	6.0
D_texture	12	7	21	24	5	17.9
D_smooth	3	4	5	8	**0** (-)	5.2
D_chocolate	16	13	17	21	9	19.7
D_flavour	**22** (+)	5	9	20	5	15.8
D_sweet	9	**11** (+)	10	**8** (-)	8	11.9
D_bitter	3	**0** (-)	4	7	**0** (-)	3.6
D_aftertaste	13	2	7	14	3	10.1
D_hedonic	3	**0** (-)	**0** (-)	4	**0** (-)	1.8

Values displayed in bold font indicate that the observed frequency is significantly different (higher +, lower -) than the expected theoretical frequency. [a] - Percentage of mentions for the sensory descriptor in comparison to the total number of like and dislike comments.

Chocolate flavour, non-chocolate flavour and sweetness received the highest count for product liking comments, while chocolate flavour, non-chocolate flavour and texture received the highest count for product disliking comments (Table 3.4.7). This indicates the importance of chocolate flavour and flavour in general to consumer preference for chocolate mousse. Despite the variance in the number of comments for like/ dislike of chocolate flavour, there was no significant difference in the expected and observed frequencies for the different products. The insignificant difference may be an indication that consumers varied widely on their preferred intensity of chocolate flavour. The chocolate flavour intensity for three of the products (M3, M4, M6) was generally liked than disliked, as evidenced by the higher frequency of like comments compared to dislike. While similar frequencies of like and dislike comments were observed for M2, M5 had a higher number of dislike comments compared to like comments (Table 3.4.7). Comments on the liking of the aeration of the products followed a similar pattern as the average overall liking. The two most-liked products had a significantly higher observed frequency than expected, while the two least-liked products had significantly lower observed frequency. These trends may be an indication that aeration is a driver of liking. A similar trend was observed in a previous study on consumer preference of apples (Symoneaux et al., 2012).

Overall, look, smell, and bitterness received the lowest counts for both liking and disliking comments. This may be an indication that these attributes were not important drivers of consumer preference. There was no significant difference in the expected and observed frequencies of like/ dislike comments on look, smoothness and hedonic categories.

3.4.3.4 Drivers of liking using PLS regression

The PLS regression of the average liking of the three clusters of consumers on the average intensity of the 17 sensory attributes resulted in a model with four components. The model was automatically selected by using the default method in XLSTAT- Jack-knife (leave-one-out) and the predictive residual sum of squares (PRESS) criterion. The criterion which is commonly used selects the number of components that give the minimum prediction error. This criterion has however been criticised to favour overfitting (selection of too many components) (Deng et al., 2015, Gómez-Carracedo et al., 2007). All model fit indices- Q^2 cumulated index (Q^2 cum), variance of consumer liking explained (R^2Y cum), and the variance of panel sensory data explained (R^2X cum) attained the maximum value (1) for the model with four PLS components (Table 3.4.7). The resulting correlation circle for descriptive sensory data and consumer liking data is shown in Figure 3.4.3.

Table 3.4.8 PLS regression statistics for the four-component model selected by XLSTAT and that of the model selected based on the Q2 index for each consumer cluster (C1, C2, and C3)

	All clusters (C1- C3)				C1	C2	C3		
Statistic	Com1	Com2	Com3	Com4	Com1	Com1	Com1	Com2	Com3
Q^2 cum	0.384	0.676	0.904	1.000	0.439	0.892	-0.045	0.200	0.906
R^2Y cum	0.537	0.835	0.984	1.000	0.649	0.937	0.487	0.759	0.996
R^2X cum	0.780	0.979	0.987	1.000	0.767	0.781	0.615	0.979	0.988

Com- component

The PLS regression was rerun for each consumer cluster separately to improve the precision of the PLS model (Tenenhaus et al., 2005), the optimal number of components indicated by the maximum Q^2 and R^2 indices was used (Liggett, 2010). This resulted in one component for clusters C1 and C2 and three components for C3. It is noteworthy that when the PLS regression was rerun for individual clusters, XLSTAT automatically selected the same number of components indicated by the Q^2 index for C1 and C2 but still retained the four components for C3. A model with three components was forced. The selection of variables after PLS is an important step in reducing a large number of predictor variables (sensory attributes) to a smaller number of relevant variables that best explain the variance in the response variable (consumer liking) (Farrés et al., 2015). For individual clusters of consumers, the important sensory attributes that drive liking were identified as those with variable importance for the projection (VIP) greater than 0.8 and where the standard deviation of its standard coefficient does not cross the y axis (Janiaski et al., 2016). The standard coefficient also depicts the direction (positive or negative) of the influence of the sensory attribute on consumers liking.

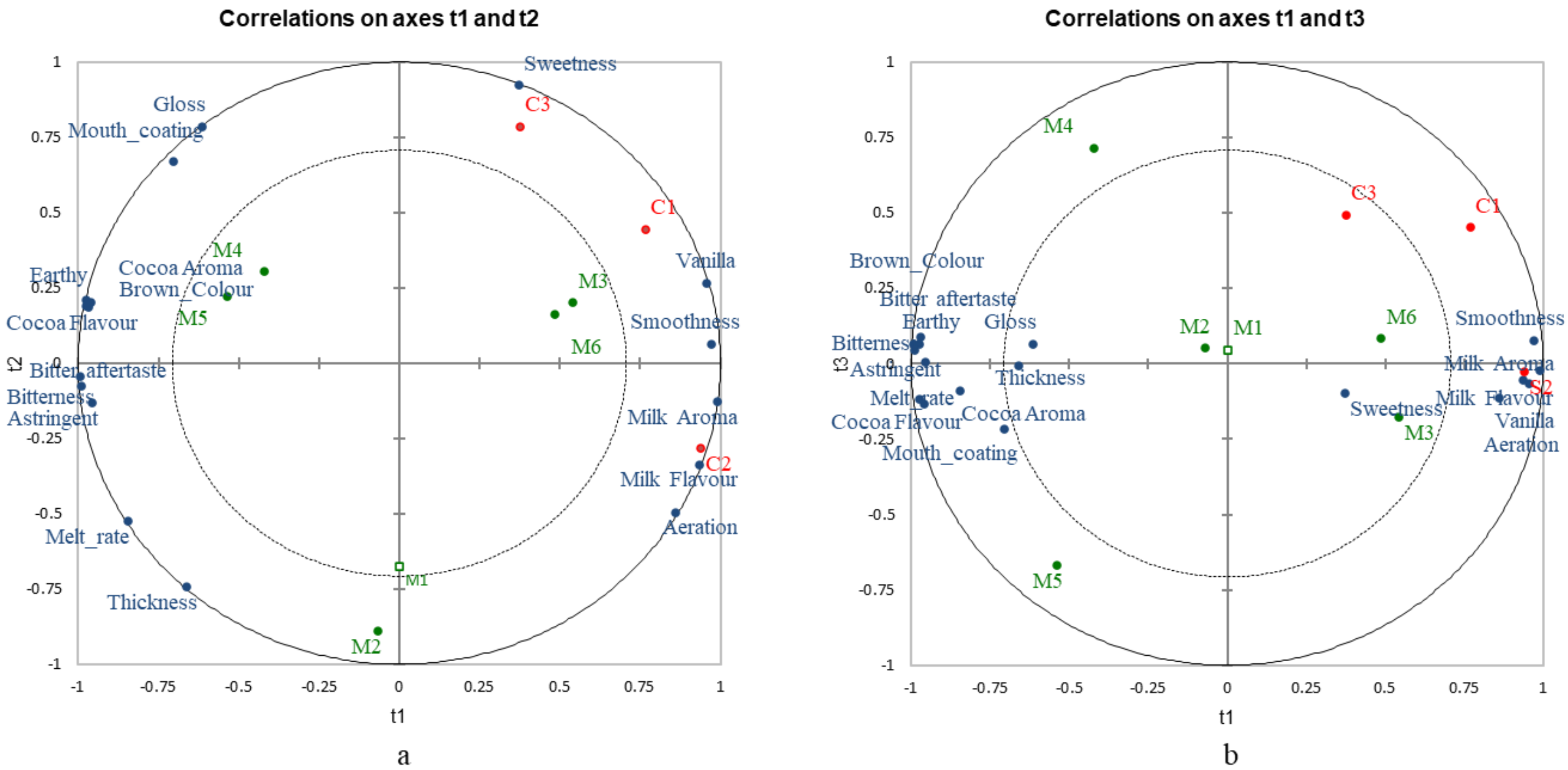
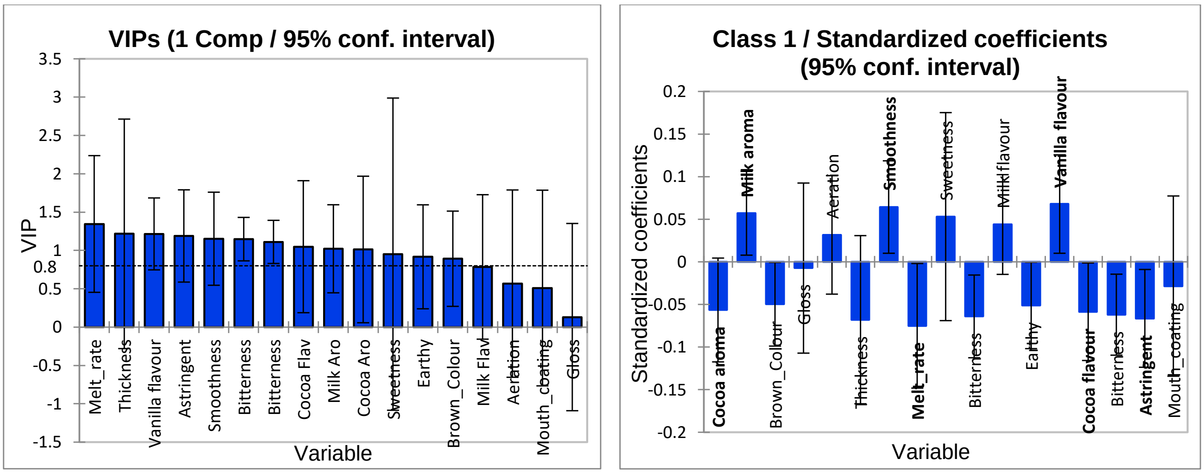


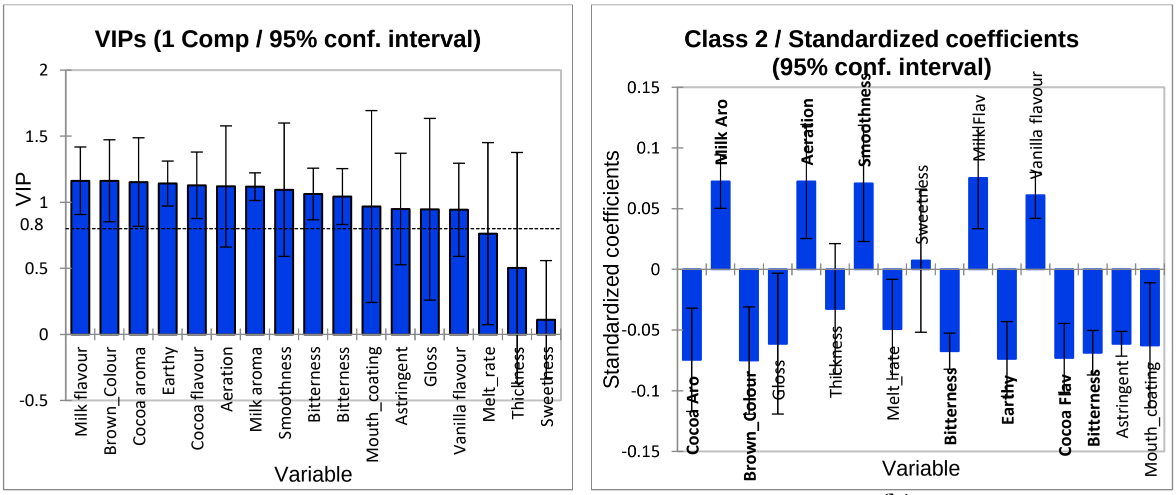
Figure 3.4.3 Correlation circle of the sensory attributes (blue), the overall liking of the consumer clusters (red) and the products (green) on two PLS components t1 and t2 (a) and t1 and t3 (b)



(a) (b)

Figure 3.4.4 (a)Variable importance for the projection (VIP) and (b) regression coefficients of all attributes for cluster 1. Attributes with VIP greater than 0.8 are important drivers of liking/disliking

The quality of the regression for the one-component model for C1 showed a poor fit as indicated by the Q^2 cum index (0.439) (Table 3.4.7). The poor fit of the PLS model for cluster 1 is similar to the model fit obtained in some previous studies (Gaze et al., 2015b, Liggett, 2010). The authors suggested that the poor fit may be an indication of the non-linear nature of the relationship between consumer liking and the sensory data. Consumers in C1 liked all the products despite their different sensory properties; thus, product liking and the sensory attributes may have a non-linear relationship which is not well accounted for by PLS regression (Cariou et al., 2014). The low model fit may also be due to the heterogeneity of the consumers in that cluster (Tenenhaus et al., 2005). For C1, the standard coefficients (Figure 3.4.4b) reveal that drivers of liking were smoothness, vanilla flavour and milk aroma. In comparison, the drivers of disliking were melt rate, cocoa flavour, astringency, bitterness, brown colour and earthy flavour. Four variables- milk flavour, aeration, mouth coating and gloss had a VIP below 0.8 and were not relevant to the preference of chocolate mousse for these consumers.

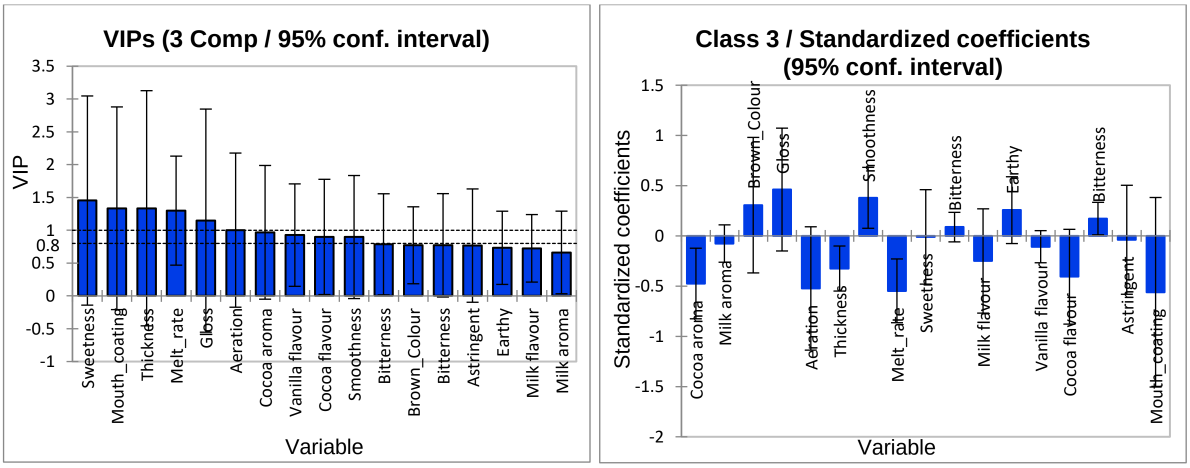


(a) (b)

Figure 3.4.5 (a)Variable importance for the projection (VIP) and (b) regression coefficients of all attributes for cluster 2. Attributes with VIP greater than 0.8 are important drivers of liking/disliking

As shown in Table 3.4.8, a good model fit was obtained for C2 (0.892) and C3 (0.906), thus indicating good global goodness of fit and predictive quality (Tenenhaus et al., 2005, Gaze et al., 2015b). While a good R^2Y cum and R^2X cum (typically above 0.5) indicate that the model adequately summarised the dependent and independent data sets (Gaze et al., 2015b). The drivers of liking for C2 were similar to that of C1, while they differed for the drivers of disliking. Product liking for C2 was driven by higher intensities of smoothness, vanilla flavour, aeration, milk aroma and flavour (Figure 3.4.5b). The drivers of disliking were brown colour, cocoa aroma and flavour, bitterness, gloss, mouthcoating and astringency. The VIP scores revealed that melt rate, thickness and sweetness were not relevant to the preference of chocolate mousse for consumers in cluster 2. The irrelevance of thickness is unexpected as texture properties are usually of utmost importance in consumer preference of semisolid milk products (Janiaski et al., 2016).

The drivers of liking for cluster 3 were smoothness and gloss, while drivers of disliking were melt rate, aeration, mouthcoating, cocoa aroma and flavour and thickness (Figure 3.4.6b). Six variables were irrelevant (VIP < 0.8) to the preference of C3 consumers, these were bitterness, brown colour, astringent, earthy, milk flavour and milk aroma. The drivers of liking identified in this study are similar to previous studies where flavour, smoothness, colour and viscosity influenced consumer liking of yoghurt products (Janiaski et al., 2016, Masson et al., 2016).



(a) (b)

Figure 3.4.6 (a)Variable importance for the projection (VIP) and (b) regression coefficients of all attributes for cluster 3. Attributes with VIP greater than 0.8 are important drivers of liking/disliking

Information from preference mapping and the comment analysis are complementary and allow a better understanding of consumer preference. For example, the high frequencies of comments on chocolate flavour, sweetness and texture indicate their importance to consumer preference and supports similar findings from preference mapping. There was some disparity between the findings from preference mapping and comment analysis. This is similar to reports by Symoneaux et al. (2012). Although astringency and bitterness were indicated as significant drivers of preference for some consumer clusters by preference mapping, the low frequency of comments on both descriptors may indicate that they were not important for most consumers. The disparity in the importance of these sensory attributes may indicate higher sensitivity of the panel to detect differences in the intensities of these attributes in the product compared to consumers.

3.4.3.5 Sensory specification for quality control

Considering the drivers of liking for consumers that liked M2 (C1 and C2), the characteristics that drove liking of M2 were aeration, smoothness, moderate milk aroma and flavour, while the drivers of disliking were high colour intensity, melt rate, cocoa and bitterness. Findings from comment analysis support these observations and provide more information on the drivers of consumer preference for M2. A higher frequency of like comments for M2's aeration, smoothness and sweetness compared to dislike comments was observed, thus supporting the role of these sensory attributes as drivers of liking. The opposite trend was observed for comments relating to the appearance, non-chocolate flavour and aftertaste of M2, so these may be drivers of disliking. A similar number of like and dislike comments were observed for chocolate flavour and texture. This may indicate that almost the same number of consumers liked/disliked these sensory attributes in M2. These attributes along with the descriptive sensory data from the trained panel were used to develop the sensory specification or M2 (Table 3.4.9).

Findings from preference mapping and comment analysis reveal some potential points of improvement of the sensory quality of M2. The aftertaste of the product may be improved as this was a driver of disliking. Further investigations into the intensity of the thickness and melt rate may also be carried out as M2 is characterised by high intensities of these attributes, which were identified as drivers of disliking for C3 consumers.

Table 3.4.9 Sensory specifications for the target chocolate mousse

Sensory attribute	**Description**	**Target (IN)**
Brown colour	The sensory characteristics perceived on visual inspection of a scooped spoonful of product under artificial daylight.	Light brown chocolate colour (picture showing the target colour intensity should be provided)
Aeration	Honeycomb structure. Evaluated by looking at the product surface after scooping a spoonful under artificial daylight	Even, honeycomb structure (Picture should be provided with the desired honeycomb structure)
Smoothness	Absence of lumps, particles and grits. Evaluated by eating a teaspoon full of product	No grits or lumps
Thickness	Resistance of the food to compression between the tongue and palate. Evaluated by eating a teaspoon full of product	Firm, spoonable, holds form briefly before melting in the mouth.
Milk flavour, chocolate flavour	The flavour perceived in the mouth when eating a teaspoon full of product.	Moderate milk chocolate flavour with no off flavour (references should be identified by the panel)
Sweetness	The sweet taste perceived in the mouth when eating a teaspoon full of product.	Low sweetness typical of unsweetened full cream milk
Bitterness	The bitter taste perceived in the mouth when eating a teaspoon full of product.	Low bitterness, typical of milk chocolate (references should be identified by the panel)

3.4.4 Conclusions

This study illustrated the development of a sensory specification for quality control of chocolate mousse based on the critical sensory attributes identified by preference mapping and comment analysis and their average intensity in the target product. The critical sensory attributes identified by preference mapping varied from one consumer cluster to another. In summary, the drivers of liking of chocolate mousse by C1 and C2 was driven by higher intensities of smoothness, aeration, vanilla flavour, milk aroma and flavour. Furthermore, the drivers of disliking were low melt rate and high intensities of cocoa aroma and flavour, astringency, gloss and bitterness. For C2, the drivers of liking were higher intensities of smoothness, aeration, milk aroma and flavour (Figure 3.4.3b). Comment analysis revealed that chocolate flavour, non-chocolate flavour, sweetness and texture were important drivers of preference. Thus, supporting the findings from the PLS regression. The target product was characterised by light brown colour, even honeycomb structure, high smoothness and thickness, milk chocolate flavour and a low sweetness.

These findings enabled the development of the sensory quality specification for the target mousse. The development of a sensory quality specification based on critical sensory indicators could be used to ensure that the screening of products during sensory quality control is based on criteria that are relevant to the consumer. The methods described in this study can be applied to other products.

4 DISCUSSION

This chapter provides a critical discussion of the various steps taken to develop, pilot test and validate a questionnaire to assess sensory quality control knowledge, attitudes and practices in the food industry. The development of a sensory quality system based on the identification and monitoring of critical sensory indicators is critically reviewed. Subsequently, the results of the questionnaire development and validation are discussed. Then, the implementation of the sensory quality system in the chocolate mousse case study is reviewed.

4.1.1 Research design

Sensory quality control (SQC) systems in food companies are usually designed and implemented by employees (Kilcast, 2010), thus sound knowledge and competence are necessary for success in the process. The knowledge, attitude and practices (KAP) model have been widely used to understand and drive improvements in practices based on knowledge and attitude focused interventions (Zanin et al., 2017). The marginal or wrong application of sensory principles has been discussed in literature (Munoz, 2002, Costell, 2002, McGrew and Chambers, 2011), however, a tool for the evaluation of SQC related knowledge has not been documented. Therefore, this study focused on applying the KAP model to develop and validate a questionnaire for the assessment of food company employees' SQC related knowledge, attitudes and practices.

Another widely discouraged and marginal SQC practice is the reliance on finished product testing (Munoz, 2002, An and Wang, 2016, Stefanova and Zlateva, 2018) as defective products are often detected late in the production chain which may lead to waste (Stefanova and Zlateva, 2018). Some authors have suggested the monitoring of raw and in-process materials as well as the reliance on physical and chemical analyses for monitoring most stages and the utilization of a trained panel for monitoring of only the critical steps (Aumatell, 2011, Munoz, 2002). The second objective of this study was to describe the development of a sensory quality system based on defect assessment and targeted monitoring of critical steps in the production process. This system was illustrated using chocolate mousse production. This is one of the first studies that presents a system-wide approach to sensory quality management and the first to use a defect rating system based on drivers of consumer liking/ disliking.

4.1.2 Ethics approval

Ethics approval was obtained from the Ethics committee of the Faculty of Natural and Agricultural sciences, University of Pretoria prior to the commencement of the study (180000041- Appendix 6). Informed consent was obtained from all participants before they took part in the study. The consent form clearly stated the purpose of the study, that participation was voluntary and how the data collected would be used. Participants were also informed of their right to withdrawal from the study with no penalty and their rights to access their data. Participants in the sensory evaluation tests were duly informed of the ingredients and/or likely allergens in the samples. The consent forms used for the pilot and validation studies are presented in Appendices 6 and 7, respectively. The online questionnaire used on Qualtrics platform for the validation study is provided in Appendix 8.

4.2 QUESTIONNAIRE DEVELOPMENT AND VALIDATION

4.2.1 Questionnaire development

A structured, self-administered questionnaire was developed based on existing literature on sensory quality control (Kilcast, 2010, Stone and Sidel, 2004, Munoz, 2002, Lawless and Heymann, 2010). In line with the KAP model, the questionnaire had three sections- knowledge (15 questions), attitudes (seven questions), and practices (eight questions). A fourth section (respondent and company characteristics- 12 questions) was used to collect descriptive information for profiling respondents and their companies. The questionnaire was written in English, which may have impacted the responses as this is not the mother tongue of most respondents. In addition, respondents with low to medium literacy levels may struggle to understand some questions.

The knowledge questions had three possible responses ‘yes’/ ‘no’/ ‘I don’t know’. Correct responses were awarded one (1) point, incorrect and I don’t know responses were awarded zero (0) point (Zahiruddin et al., 2018). The ‘I don’t know’ option was included to reduce the incidence of guessing and to determine the respondent’s awareness of their lack of knowledge (Agüeria et al., 2018). The five-point Likert scale (1- strongly disagree to 5- for strongly agree) commonly used in the assessment of attitudes was adopted, five (5) points were awarded for most positive attitude and one (1) point for most negative attitude, i.e., 1- strongly disagree to 5- for strongly agree, the scoring was reversed for negatively-worded questions (Zahiruddin et al., 2018). The practice questions had three multiple-choice options ranging from marginal/

least good- awarded one (1) point to very good practice- awarded three (3) points, P6 had three (select all that apply) responses awarded one (1) point each and summed to get a total score.

A sum of scores for each section was computed for each respondent and their performance classified. A total score ≥ 50% on the knowledge, attitudes or practices section was considered good and acceptable (Agüeria et al., 2018). While a total score ≥ 75% was excellent.

4.2.1.1 Respondent recruitment and data collection

Respondents were sent the invitation to participate in the pilot phase via LinkedIn and email. While for the validation phase, the survey invite was shared with some food science groups on LinkedIn, Facebook, and WhatsApp. The invitation was also emailed to members of the national associations for food science professionals in Nigeria and South Africa (Nigerian Institute of Food Science and Technology- NIFST and South African Association for Food Science and Technology- SAAFoST) and through the webpage and newsletter of food focus (www.foodfocus.co.za). Individuals interested in sensory evaluation could have been more likely to complete the survey because of the invitation process, causing bias in the responses. Respondents completed the questionnaire online on the Qualtrics^{XM} (Qualtrics LLC, Provo, USA) platform (www.qualtrics.com). The administration of the questionnaire online may have led to the exclusion of food company employees with limited access to the internet. Thus, future studies should consider using paper questionnaires in addition to online administration.

4.2.1.2 Content validation and pilot testing of the questionnaire

Validity tests are carried out to determine the accuracy and relevance of the measurements collected by the questionnaire to its intended purpose (Knekta et al., 2019). There are three types of related validity evidence, content, construct, and criterion validity. Content validity provides information on the relevance of the questions to the subject of interest (construct) (Peeters et al., 2013). Content validity is commonly assessed by a group of experts who rate the relevance of the question to the construct (Rubio et al., 2003). It can also be assessed as face validity, which determines whether the language used reflect the subject of interest. it is usually evaluated by a sample of the intended users of the questionnaire. Construct validity relates to the extent to which the subject of interest is covered. Three types of evidence can be used to support construct validity – factorial validity, convergent/ discriminant validity, and known groups validity. Item reduction analysis. Criterion validity examines the relationship between the score on the test and performance on a related measure (Boateng et al., 2018). This was not assessed in this study as a related existing measure was not found for comparison with the questionnaire. Item reduction analyses are a set of tests used to improve the validity and reliability of a test by ensuring that only the most functional and internally consistent questions that support a parsimonious model are included (Boateng et al., 2018).

Content validity

In this study, the content validity index (CVI) of each question was used to determine its relevance in the assessment of SQC related knowledge, attitudes, and practices. The CVI of a questionnaire is usually determined prior to the collection of data from the target population. The early determination of the content validity will provide information on the clarity and representativeness of the questions (Rubio et al., 2003). Typically, five to seven subject experts or members of the target population judge the content validity of the questions (Boateng et al., 2018). Hence, the relevance of the questions in the study was independently examined by six sensory evaluation experts using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). A question was relevant if five out of the six experts agreed (rated it 4 or 5) (Rubio et al., 2003, Dos Santos et al., 2019). Due consideration was taken to select experts with varied and extensive sensory evaluation knowledge and experience. Three of the experts were academics, and three were sensory scientists in the food industry. Three of the experts had over ten years of experience, and the other three had over five years of sensory evaluation experience. Content validity was not carried out after more questions were added to the questionnaire as new questions were added based on the common sensory evaluation themes of the previously validated questionnaire.

Factorial validity

Factorial validity (a form of construct validity) examines the structural relationship between the questions/ items to determine the nature and extent of correlation and if they measure one underlying topic or several sub-topics (Peeters et al., 2013). This is usually achieved by carrying out exploratory factor analysis (EFA), confirmatory factor analysis (CFA) and item response theory analysis. As the name implies, EFA is exploratory in nature, the goal is to group the questions into unobserved variables (factors) based on the correlation patterns observed in the data. (Knekta et al., 2019). EFA is commonly used in the development of new measurement instruments to determine the dimensionality of the questions (Flora and Flake, 2017). The principal axis factoring (PAF) method was used as it has been shown to produce reliable estimates for non-normal data (such as the study data), and for high or low communalities (Watson, 2017). Multiple criteria such as eigenvalue, parallel analysis (PA), Velicer's minimum average partial (MAP) correlation test, the inflection point on the scree plot, etc. were used to select the factors that provide the simplest model and adequately represents the underlying pattern. Multiple criteria are recommended as there is no single best method for determining the number of factors (Schmitt and Sass, 2011). The PA and Velicer's MAP tests are usually recommended by researchers as eigenvalue and scree test are heuristic (Knekta et al., 2019). The retention of factors based on the eigenvalue criterion usually leads to over-extraction, and the scree test sometimes reveals multiple inflection points (Watson, 2017). CFA is carried out to confirm a factor structure that was postulated either by sound theoretical knowledge or an EFA. The major difference between EFA and CFA is that for the former the relationship between the observed variable and the factor(s) is freely estimated, while for the latter, it is restricted (Flora and Flake, 2017). In the pilot study, the suitability of the data for factor analysis was determined by Kaiser-Meyer Olkin's measure of sampling adequacy (KMO MSA) and a Bartlett's test of sphericity, the threshold for acceptance was values greater than 0.6 and less than 0.05, respectively (Watson, 2017). These indicate that the questions are correlated and that the sample is adequate. The internal consistency of the retained factors was determined as the Cronbach's α.

Known groups validity

Construct validity was assessed by comparing the performance of different groups of respondents who are expected to have different levels of knowledge or practices (for companies) (Stanifer et al., 2015). Respondents were classified based on the information they provided in the respondent/ company characteristics section. Some demographic information such as education level which may have impacted the understanding of the questions and knowledge level of respondents was not collected. Furthermore, the responses were compared using one characteristic (factor) per time, a multivariate analysis may better capture the effect of causal factors on knowledge, attitudes and practices as it will capture the relationship between multiple factors and the observed data better representing real-life context.

Item analysis

This is usually accomplished through the classical test theory (CTT) or item response theory (IRT). Both theories estimate similar item parameters- difficulty and discrimination; however, while the estimates generated by CTT are sample specific, IRT estimates are sample independent (Mead and Meade, 2010). Additionally, IRT estimates itema and model fit. In literature, the IRT model is selected based on the item response format, the assumption that and items' discrimination power is constant etc. (Nguyen et al., 2014). In this study the best model is selected from the three possible IRT models for dichotomous data- the three parameter logistic (3PL) model that relates responses to the respondent's ability three item parameters- difficulty, discrimination and guessing; the 2PL model assumes there is no guessing and the 1PL model sets a single discrimination parameter across all items (Ward et al., 2016). The 1PL model is usually favoured due to its parsimony and smaller sample size requirements, however, the assumption of a constant discrimination power for all questions usually does not hold in the real world (Nguyen et al., 2014), thus it was not considered in this study.

CTT difficulty and discrimination indices were determined for the knowledge questions in the pilot study. The difficulty index was estimated as the proportion of respondents who selected the correct answer to the total respondents, values from 0.1 to 0.9 were considered acceptable (Whati et al., 2005). The higher the difficulty index, the easier the question. This allows the selection of questions of the right (*average)* level of difficulty (Pande et al., 2000). The discrimination index was determined by ranking respondents based on their total score and finding the average of the difference between the number of respondents who select the correct answer in the upper quartile from those in the lower quartile. Values ≥ 0.2 were considered acceptable (Chen et al., 2013).

Reliability

Reliability is a measure of the reproducibility of the test that is considered an evidence of validity by some researchers (Peeters et al., 2013). There are several types of reliability evidence that could be considered: internal consistency, inter-rater reliability, composite reliability, etc. A commonly used measure of reliability is internal consistency which estimates whether questions of the same factor generate similar responses on a specific administration of the test. The Cronbach's α is a test of internal reliability (Singh, 2017). The inter-rater and intra-rater reliability assesses consistency across judges and across multiple ratings from the safe judge, respectively. Both forms of reliability are usually determined as the intraclass correlation coefficient (ICC) (Koo and Li, 2016). Internal consistency of the retained factors in the pilot study was assessed as Cronbach's α. Cronbach's α has been argued to underestimate the internal consistency of ordinal variables due to the underestimation of the correlation between these variables, however this is a misconception as Cronbach's α is computed based on the covariance of the data and makes no assumptions about the nature of the distribution (Chalmers, 2018). Moreover, the popular alternative, ordinal alpha, is not suitable as it leads to an overestimation (more so for dichotomous data) as it estimates the unobserved relationship between the variables using polychoric correlations. Thus, Cronbach's α was used in this study.

4.2.1.3 Questionnaire refinement and validation

The questionnaire was refined based on the limitations revealed in the pilot study and recommendations for improvement of the questionnaire from reviewers of the journal paper published on the pilot test. The revision included the addition of new questions (K- 15, A- 10, P- 1 questions), rephrasing of existing questions (K- 7, A- 1, P- 5 questions), modification of the response options (P- 5 questions) and deletion of some questions (K- 2 and A- 4 questions). The revised questionnaire comprised 24 knowledge, 13 attitudes and, nine practice questions. As in the pilot study, a respondent and company characteristics section was included to collect information for profiling the respondents and their company. The data collected in the refinement study was split into two, 35% for IRT analysis and EFA, and 65% for CFA. This is because the use of the same sample for EFA and CFA is largely condemned by researchers as the results from the latter may not be generalisable and may be due to sample-specific relationships (Flora and Flake, 2017, Knekta et al., 2019).

In the questionnaire refinement study, IRT analysis was carried out on the knowledge questions to select questions of optimal difficulty and discrimination power. The data was fitted to the 1 PL, 2 PL and 3 PL models (Ward et al., 2016). The model fit indices were compared to select the best model. The parameter estimates generated by the selected model was used for question selection.

EFA was carried out on the polychoric correlation matrices of the attitude and practices sections by the unweighted least squares method using IBM SPSS 26 (Aletras et al., 2010). EFA was used to examine the underlying structure of the refine questionnaire. The number of factors retained was determined by the logical interpretation of the proposed by parallel analysis and the scree plot. The internal consistency of the retained factors was determined as the Cronbach's α.

CFA of the polychoric matrices was performed in R Version 4.0.5 with Lavaan package using the diagonally weighted least square (WLS) estimation method (Zahiruddin et al., 2018) to confirm the factor model proposed by the EFA. The polychoric matrices were used instead of Pearson's correlation matrices for factor analysis in the questionnaire refinement study as the data is ordinal in nature. Furthermore, the use of Pearson's correlation matrix has been shown to result in the underestimation of the correlation between the variables and thus decrease the factor loadings based (Holgado-Tello et al., 2009). The goodness of fit of the CFA model was determined by multiple indices- comparative fit index (CFI), Tucker-Lewis fit index (TLI), root mean square error of approximation (RMSEA) and standardized root-mean-square residual (SRMR). The threshold for acceptance for the model were values > 0.9, > 0.9, < 0.8, < 0.8 (Ward et al., 2016, La Barbera et al., 2020), respectively.

4.2.2 Research findings- Validation and pilot testing of the questionnaire

The steps taken to validate the questionnaire are summarized in Figure 4.1.

4.2.2.1 Content validation

The initial questionnaire consisted of four sections- respondent and company characteristics (12 questions), knowledge (15 questions), attitudes (eight questions) and practices (eight questions). Content validation of the initial questionnaire by six sensory evaluation experts revealed that most of the questions were relevant to the assessment of SQC KAP. Three questions were considered irrelevant: C3 *(Is your company a part of another larger company*), C4 (*What is the total number of employees at your location*) and K13 (*Are consumer preference tests suitable for sensory quality control*). C3 and C4 were retained as they provided information that is vital to characterize the company of the respondent. The affiliation of a company to a larger company may provide better access to sensory quality expertise and systems that will in turn impact on their sensory quality practices. The number of employees in the company was used to determine the size of the company as defined in World Trade Organisation (WTO) report 2016. K13 was initially retained as it relates to the knowledge of good sensory practices. However, it was removed later as it did not discriminate well between respondents of different knowledge levels.

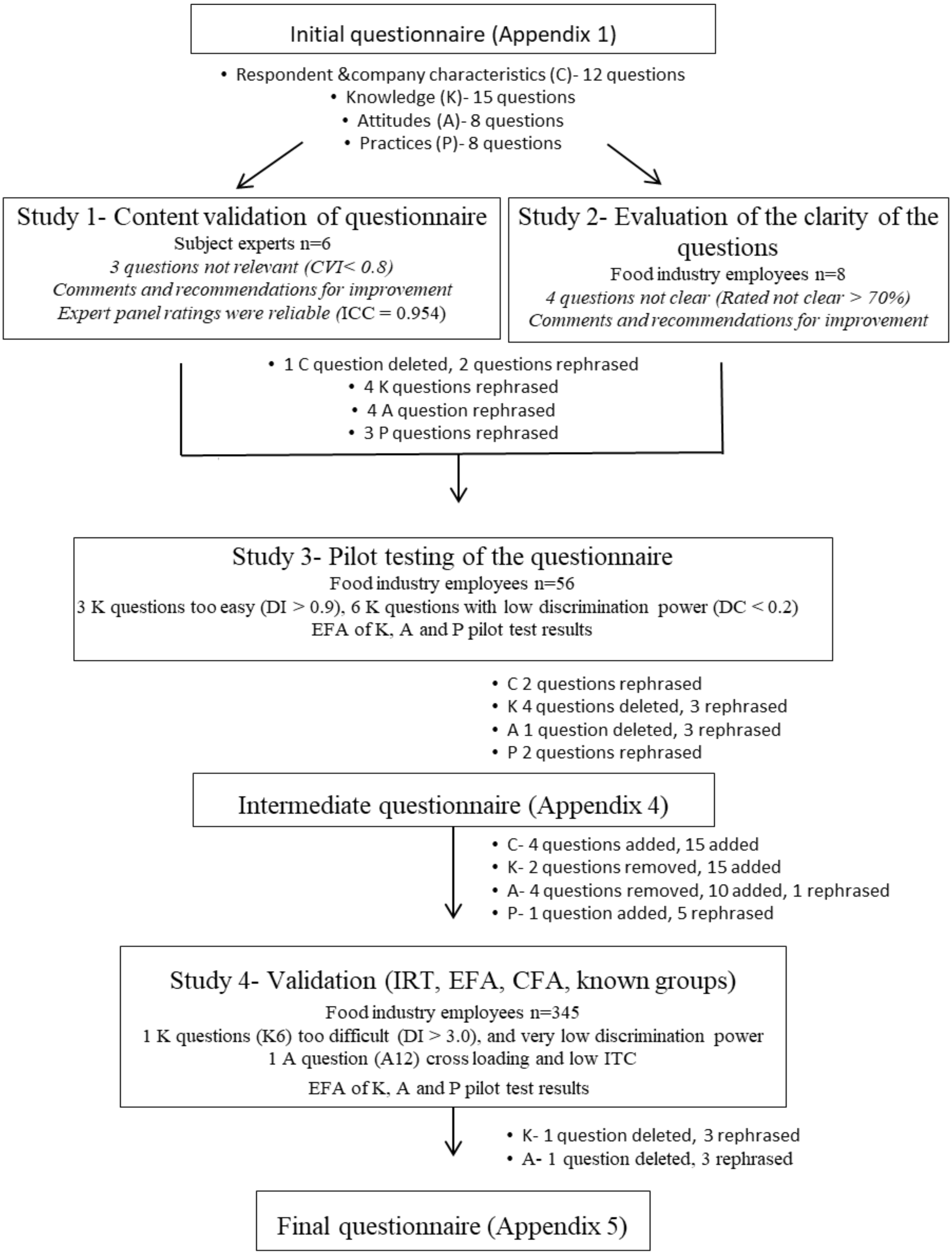


Figure 4.1 Steps of questionnaire validation. CVI- Content validation index, ICC- Intra-class correlation coefficient, DI- difficulty index, DC- discrimination index, IRT- item response theory, EFA- exploratory factor analysis, CFA- confirmatory factor analysis, ITC- item to total correlation

4.2.2.2 Questionnaire clarity

The clarity test carried out by eight food industry professionals revealed that the language of the questions (except for K2, K3, K5, K10 and K11) were clear. Comments from respondents regarding K2 (*Is umami one of the basic tastes?*), K5 (*Is palate cleansing a good sensory practice?*) and K11 (*Is a t-test used for analysing sensory results of more than two products by the same group of people?)* revealed that they were not familiar with the technical terms used and this may have affected the clarity of the questions. The questions (except for K2) were rephrased due to recommendations from the sensory experts and/or the food industry professionals. This is similar to previous studies where questions were rephrased based on the recommendation of experts and intended users (Dickson-Spillmann et al., 2011, Jones et al., 2015).

4.2.2.3 Pilot study and initial validation

A pilot study of the questionnaire was carried out. The purpose of the pilot study was to assess the feasibility and efficiency of the participant recruitment process, survey administration, data coding and analysis strategies (Rubio, 2003). The pilot study revealed that the knowledge section was not suitable for factor analysis due to its dichotomous nature as well as unacceptable KMO MSA and Bartlett’s test of sphericity results. This led to the use of IRT analysis and EFA on polychoric correlation in subsequent questionnaire refinement steps.

4.2.2.4 Refinement and validation of the questionnaire

Refinement and validation of the questionnaire was carried out by adding new questions based on the limitations revealed in the pilot test and initial validation stage. IRT analysis revealed that the 2PL model had the best fit for the data, this indicates that responses to the knowledge questions were determined by the difficulty and discrimination of the questions as well as the respondent’s knowledge level. K6 was removed as it had difficulty and discrimination parameters that were not acceptable. Modified parallel analysis revealed that the knowledge section is unidimensional, while the test information showed that the question adequately covered different levels of ability. Exploratory factor analysis after the removal of one question (A12) led to the retention of a two-factor solution. The two factors related to positive and negative disposition towards SQC. Questions (except P6) in the practices section formed one-factor. P6 was not included as all respondents selected the same option, however it was retained in the questionnaire to preserve the content validity (Román and Sánchez-Siles, 2018). Cronbach' alpha was 0.703 and 0.683 for the knowledge and practices sections, respectively.

The one-factor model for the knowledge section showed a good fit, CFI = 0.946, TFI = 0.940, RMSEA = 0.020 and SRMR = 0.106. The one-factor model for the practices section also had good fit, CFI= 0.978, TFI= 0.968, RMSEA= 0.066 and SRMR = 0.068. However, the two-factor model for the attitude section did not fit well, CFI = 0.825, TL1 = 0.777, RMSEA = 0.112 and SRMR = 0.104.

Known groups comparison revealed that respondents with sensory evaluation training had a significantly higher total knowledge score than those without. Furthermore, the total knowledge scores of participants with sensory related work experience were significantly higher than those without. This indicates that training and experience lead to knowledge gains. The total practices score however did not differ for companies of different sizes nor for companies for which the respondents reported a higher frequency of customer complaints. Examination of the data revealed that the nature of the products and affiliation with a larger company may have positively impacted on a company's SQC practices. The results may also indicate that the frequency of complaints may not be a true reflection of good product sensory quality practices.

4.2.2.5 Guidelines for administration of the questionnaire

Practitioners should follow these guidelines when administering the questionnaire.

i. Decide and specify the reason/s for using the questionnaire e.g., research, determining the KAP of company employees.
ii. Determine which demographic and identifying information should be collected from respondents. These questions will form the employee characteristics section. Consider the regulations stipulated by the general requirements of the protection of personal data legislation.
iii. Choose a format for the administration of the questionnaire based on the needs and resources of the company (Online surveys are easier to collate, interview style may be more relevant for low literate employees, while paper surveys may be considered for administration of the survey during face-to-face training sessions).
iv. Completion of questionnaire by the relevant employees.

v. Collation of data and calculation of the total scores of each respondent on the different sections of the questionnaire

Responses to the knowledge section should be awarded zero (0) points for an incorrect/ I don't know answer and one (1) point for a correct answer. Responses to the attitude section should be awarded one (1) point for the most negative answer and five (5) points for the most positive answer using the five-point scale. Responses to the practice section should be awarded (1) point for the worst practice among the three options and three (3) points for the best practice.

vi. The performance of respondents for each section can be classified based on their total score: poor for < 50%, good for 50- 74% and excellent for ≥ 75%.

vii. Individual and group performances can be reviewed to identify areas of poor performance, such as the most difficult knowledge questions or the practice questions scoring <3.

viii. Appropriate interventions can be introduced to address any gaps revealed by the findings from the questionnaire.

Where possible the sequence of the questions per section should be randomised so that all employees will not answer the questions in the same order. This randomisation is usually supported by online survey collection tools such as Qualtrics. Some questions related to SQC of a specific product may be added to the relevant sections of the questionnaire. The questionnaire should be validated where it is modified. The assessment of the SQC practices of a food company by an independent (third-party) organisation may be carried out by observation (in the form of a factory audit) rather than the completion of the questionnaire by company employees. This will reduce misreporting as self-reported practices may differ from observed practices (da Cunha et al., 2019). Furthermore, future studies may also seek to compare observed practices with reported practices using the questionnaire to understand the difference between them as well as the effect of literacy level and reporting bias.

4.3 DEVELOPMENT AND ILLUSTRATION OF THE SENSORY ANALYSIS CRITICAL CONTROL POINTS SYSTEM

4.3.1 Development of the sensory quality system

The development of a preventive system-wide approach to sensory quality control, the sensory analysis critical control point (SACCP) was described. The system was developed over two phases using a case study of the production of chocolate mousse. First, the sensory indicators that drive consumer preferences were identified through preference mapping. Then the manufacturing process was examined to identify the likely sensory defects occurring at each step and the definition of the control and monitoring actions that can be applied to ensure that the sensory indicators are kept within acceptable limits. The steps taken in the development of the sensory system are summarized in Table 4.1.

Table 4.1 Description of the steps for development of the sensory analysis critical control point (SACCP) quality system

No.	Steps in SACCP Development	Description
	Preliminary steps	
i	Assemble the sensory quality team	A multi-disciplinary team responsible for the development, validation and maintenance of the sensory quality system is assembled
ii	Draw production flow diagram	The manufacturing steps are identified and described. Onsite verification of the production flow is carried out
iii	Definition of target sensory quality	The sensory quality indicators that are critical to consumer preference are identified and used to develop the sensory quality specification
	Main steps	
1	Sensory quality defect analysis	This is carried out to identify the significant sensory quality defects that is/ are likely to occur that needs to be controlled or else the final product will not be acceptable to the customer/consumer
2	Determine the critical control points (CCPs)	Critical points at which control can be applied to prevent/ eliminate or reduce a sensory defect to tolerable levels are identified
3	Establish critical limits	This determines the maximum and/or minimum values within which the control measure must be kept at the CCP
4	Establish monitoring procedure	This determines the observations and measurements that can be used to establish whether the CCP is under control
5	Establish corrective action	These are actions or steps that can be taken to prevent undesirable products from reaching the customer/ consumer once a deviation from the CCP is detected
6	Establish verification procedures	These procedures determine the validity/ effectiveness of the SACCP plan ad system operation
7	Establish record keeping and documentation procedures	These are record and documentation procedures for the SACCP plan

4.3.1.1 Preference mapping

Preference mapping is a group of techniques commonly used in product development studies to identify the relationship between hedonic data and the characteristics of the product to understand consumer preference (Cariou et al., 2014). Preference mapping has been used to compare descriptive data to consumer data to validate a scoring system for SQC of date fruit (Ismail et al., 2001). Partial least squares regression (PLS) is a method that simultaneously uses consumer preference data and instrumental or descriptive sensory data to develop a perceptual map of the products. This allows the map to be based on components that explain both the consumer liking and product characteristics, thus, ensuring that the perceptual space is relevant to consumer liking (Liggett, 2010).

Quantitative descriptive analysis (QDA) by a trained panel is usually the method of choice for objective and comprehensive identification of the nature of difference between two or more food products. The QDA of six commercial chocolate mousses (M1- M6) was conducted by a trained panel of eight members (six females and two males). Two samples of the case study products were included for profiling, and four competing products were included for preference mapping purposes. For the case study, the competing products were also considered as variations in the product due to the company's manufacturing process. One of the case study product (M2) was purchased from retail stores and the other was collected from factory retention samples (M1). The four competing products were purchased from retail stores, they were selected based on availability and to capture variation in the product range.

The validity of the QDA data collected depends on the performance of the trained panel, hence considerable effort is usually applied to the selection and training of the panel. The panellists in this study had been screened for their sensory acuity and ability to describe the sensory properties of products. The panel was trained for nine hours over three days to familiarize them with the products and the evaluation protocol. Then the panellists individually generated sensory descriptors that best differentiated between the chocolate mousses. The final list of sensory descriptors (k=21) for the characterisation of the chocolate mousse was selected by consensus among panellists. Panellists evaluated the six chocolate mousses over three replicate sessions using a nine-point unstructured intensity line scale (Torri et al., 2015). Most sensory studies have reported the use of three evaluations (Djekic, Lorenzo, Munekata, Gagaoua, & Tomasevic, 2021). Furthermore, a third evaluation did not improve the statistical analysis of the results compared to two evaluations, and one evaluation provides good information on the data (Peltier, Mammasse, Visalli, Cordelle, & Schlich, 2018). Principal component analysis (PCA) was carried out to develop the sensory map of the chocolate mousses.

Preference test was carried out on five of the chocolate mousses (all purchased from retail stores) by 79 regular consumers of chocolate mousse. Consumers rated their preference for the chocolate mousses using a nine-point hedonic scale (1= dislike extremely- 9= like extremely) (Masson et al., 2016). The number of consumers used is similar to that in previous studies (Bernstein, 2015, Janiaski et al., 2016), and also within the minimum sample size (40 – 100) commonly recommended (Gacula Jr and Rutenbeck, 2006). Consumers also made free comments about liking/ disliking the products.

All Sample evaluations was carried out in individual booths, at room temperature (25 ± 2 °C), and under artificial white day light. The samples were served at 4 ± 2 °C, the order of sample presentation was randomized using the Williams Latin square design.

Prior to applying preference mapping, the consumers were clustered into groups based on their overall liking rating of the chocolate mousses using hierarchical cluster analysis. There are multiple recommendations for performing cluster analysis, a cluster can contain at least 20% of the total number of consumers (Liggett, 2010; Meullenet, Lovely, Threlfall, Morris, & Striegler, 2008) or at least 50 consumers (MacFie, 2007). The former recommendation was followed in this study. Preference mapping was carried out by the PLS regression of the average intensity of the sensory attributes from the trained panel and the average liking scores of the products from the consumer groups (Liggett, 2010). All analysis were carried out using XLSTAT 2020 (Addinsoft, Paris, France). The fit of the PLS model was assessed using R^2 and Q^2 cumulative (Q^2 cum) (Tenenhaus et al., 2005), the model was automatically selected by XLSTAT using the default Jackknife Leave-one–out (LOO) method. The PLS regression for each group of consumers was analysed and the variable importance of projection (VIP) output used to identify the critical sensory quality indicators that drive consumer liking, sensory attributes with VIP greater than 1 were considered critical (Cariou et al., 2014).

Consumer comments were prepared for analysis by identifying the sensory attributes described and their valence (liking/ disliking). Similar comments were grouped together and the frequency of the sensory attributes for each product collated (Symoneaux et al., 2012). Chi square test of independence was used to identify significant differences between the frequency counts for each product (Mahieu et al., 2020). The critical sensory attributes were defined as those with the highest frequency (top three) that also differed significantly between the products as it is logical for consumers to comment on the sensory attributes that are important to them.

The sensory specification of the target chocolate mousse product was described using the critical sensory quality indicators and the mean intensity for the sensory attributes for the product obtained from the trained panel. In this study, preference mapping served multiple purposes. It enabled the comparison of the sensory properties of the product with that of competitors, the identification of drivers of consumer liking/ disliking for the product, and the identification of potential areas of product improvement.

4.3.1.2 Determination and control of the critical control points

Some preliminary steps were carried out before the determination of the critical points in the manufacturing system that must be controlled to ensure that the sensory quality of the final product is acceptable to consumers. A multidisciplinary team was created, this comprised of the production manager, quality manager, product development specialist and the PhD student. The team was responsible for developing the sensory quality system.

The SACCP team developed a production flow diagram for the chocolate mousse. Production of the chocolate mousse was accomplished through nine steps: receipt of raw materials, storage of raw materials, weighing of raw materials according to the formulation, cooking and mixing of raw materials, cooling of in-process slurry, cooling and aeration, weighing and packaging, cold storage and dispatch into cold truck. Factory observation was carried out to verify the flow diagram.

Sensory defect analysis was carried out using a semi-quantitative method. The SACCP team identified and prioritised the sensory defects that could arise at each step of the production based on the semi-quantitative risk assessment method. Each sensory defect was classified as critical based on their likelihood of occurrence and severity of the dissatisfaction experienced by the consumer because of the sensory defect. Customer complaints data may also provide useful information to classify the likelihood and severity of the sensory defects. However, there was very low incidence of customer complaints (only 1 in over two years) at the case study factory, this related to the stability of the foam structure. Literature may also provide some guidance in the classification of the likelihood and severity of the sensory defects. For instance, texture has been identified as an important driver of preference of chocolate mousse (Duquenne et al., 2016). The sensory defect(s) was categorised as critical if the severity of occurrence was moderate to high, and the likelihood of occurrence was high or if the severity of occurrence was high and the likelihood of occurrence was medium. Steps with critical sensory defects are considered critical control points (CCPs).

The means for control of each sensory defect was determined by the SACCP team based on experience and literature review. Monitoring procedures for all CCPs were identified and documented. The important steps that are the last step where control of the sensory defect could be effected were designated as CCPs, these were identified using a CCP decision tree.

4.3.2 Research findings- sensory quality system

4.3.2.1 Description of the sensory profile of the chocolate mousses

The chocolate mousses were well differentiated by the trained panel as indicated by significant differences between the intensities of 17 sensory attributes, these were retained for further analysis. The products did not differ on hold, sourness, chocolate aroma and flavour. Panellists commented that the products had distinct cocoa and milk flavours rather than a flavour characteristic of milk chocolate or dark chocolate and this was supported by the non-significant differences between the chocolate aroma and flavour. The descriptors used in this study are similar to those in previous studies on chocolate flavoured dairy products (Thompson et al., 2004). Sensory profiling enabled the objective description of the sensory characteristics of the case study product and allowed for comparison to competitor products. The case study product was characterised by low levels of gloss, vanilla and earthy flavour, medium levels of sweetness, bitterness, cocoa and milk flavour and high levels of brown colour, aeration, smoothness and thickness. Unique points of differentiation of the case study product from the other products were its lower level of sweetness and higher levels of thickness.

Principal component analysis was able to capture the differences in sensory characteristics between the chocolate mousses, as two principal components (PCs) described 98.6% of the variance amongst the products. PC1 was characterised by cocoa and milk flavour, samples on the left had higher intensities of cocoa flavour and darker colour and samples on the right had higher intensities of milk flavour and aeration. Chocolate mousses with higher intensities of sweetness were positively correlated with PC2, while those with higher thickness and melt rate were negatively correlated. Overall, the products formed three distinct clusters on the sensory map, with the case study product well differentiated from competing products thus suggesting its uniqueness amongst the products assessed.

4.3.2.2 Identification of critical sensory indicators

The critical sensory indicators were successfully identified using PLS regression and comment analysis. The critical sensory indicators were defined as the sensory attributes that drove consumer preferences. The products were generally liked by consumers with mean overall liking ranging from 4.64 to 7.33 (1- dislike extremely to 9- like extremely). Overall liking of the products differed significantly, pairwise comparison separated the products into three groups based on liking- most liked, moderately liked and least liked. The case study product was moderately to least liked. The overall liking of the chocolate mousses is similar to that reported previous studies on other dairy products, where products are generally liked with all products rated above 4 on a 9pt hedonic scale (Thompson et al., 2004, Janiaski et al., 2016, Gaze et al., 2015b).

Hierarchical cluster analysis of consumers based on their overall liking of the chocolate mousses revealed three groups, class 1 (C1), class 2 (C2) and class 3 (C3) made up of 32, 22 and 24 respondents, respectively. Preference mapping revealed that consumers in C1 and C2 preferred chocolate mousses with high smoothness, intense milk aroma and vanilla flavour, C2 additionally preferred a chocolate mousse product with high aeration and intense milk flavour, while C1 preferred products with high sweetness. Preference mapping and subsequent inspection of the variable importance of projection for each group of consumers revealed that C1 and C2 disliked products with intense cocoa flavour, astringency and bitterness, C1 also disliked slow melting products with high astringency while cluster 2 disliked higher intensities of brown colour and gloss.

Thus, the critical sensory attributes for consumer liking were identified as smoothness, milk aroma and flavour, aeration and vanilla flavour. While those for disliking were low melt rate and higher intensities of cocoa flavour, bitterness and thickness. Some of the critical sensory indicators identified in this study are similar to those reported for other dairy products in previous studies. Flavour, viscosity, brightness and smoothness influenced consumer liking of strawberry flavoured yoghurt (Janiaski et al., 2016). Thickness, smoothness, viscosity and colour were drivers of consumer liking of French yoghurts (Masson et al., 2016).

The critical sensory quality indicators identified based on consumers comments were chocolate flavour, non-chocolate flavour, sweetness and texture. These were similar to the critical sensory quality indicators identified by preference mapping, thus supporting the results. Consumer sensory tests are usually expensive and time intensive, thus consumer preference information has previously been collected using a questionnaire (Ismail et al., 2001). A limitation of the use of questionnaire is that consumers would have to rely on their memory to identify what they liked /disliked about the product(s). Furthermore, variations in the eating context from one consumer to another may also introduce some bias. Consumer studies are usually expensive (Liggett, 2010), thus, to save costs, focus groups made up of the target consumers may be used to generate consumer preference data. The data may be subsequently regressed with descriptive sensory data from a trained panel.

The sensory specification of the product was developed by describing the average intensities of the critical sensory indicators in the case study product. The target product was described as light brown in colour, smooth, firm and spoonable with an even honeycomb structure. The product should have a moderate milk chocolate flavour, low sweetness and bitterness. The procedure for the evaluation of each sensory attribute was also described. The sensory specification may have been impacted by the limited consideration of the expected variation in the product from one batch, this was accounted for by taking products once over three weeks of production, a more robust sampling is desirable.

4.3.2.2 Identification and management of the critical control points

Two CCPs were identified, CCP 1 was related to the weighing of ingredients, while CCP 2 was related to the cooling and aeration of the in-process slurry to form a foam. Instrumental measurements were selected for monitoring of the CCPs as they could provide adequate control. Automated control, for instance in the weighing of the ingredients, will be more effective, however labour factors and cost of setup may discourage the adoption of such measures. The monitoring activity and critical limits identified should ideally be validated against sensory quality data, this was not carried out in this study. Details of the monitoring procedure such as the personnel responsible and the frequency of monitoring were identified and documented. Corrective actions to be taken if a deviation is identified is also documented.

5 CONCLUSIONS AND RECOMMENDATIONS

The first purpose of this study was to develop and validate a questionnaire for the rapid assessment of SQC related knowledge, attitudes and practices. This is the first questionnaire that assesses the KAP multi-construct with regards to SQC. The questionnaire was validated using multiple methods to ensure the relevance of the data that will be collected with it. The validation tests enabled the identification and removal of non-discriminating questions and those that were not related to the constructs. Confirmatory factor analysis provided evidence of model fit for each section of the questionnaire. Overall, the study demonstrates that the knowledge and practices sections of the final questionnaire are valid and reliable. The attitude section needs further refinement and validation as the model fit was not acceptable. Despite this, the attitude section can be used, but the results should be interpreted with caution. The study also provides evidence of the over-reliance on finished product testing in SQC. Thus, highlighting the need for alternative approaches to SQC.

This study revealed that questionnaire development and validation is an ongoing process. For instance, the questionnaire may be modified to provide a more extensive assessment of SQC knowledge, attitudes and practices. This may be done by adding questions about the SQC of a specific product and/or administering the questionnaire as an interview. Furthermore, the assessment of SQC practices by independent or third-party stakeholders using the relevant section of the questionnaire may also take the form of a factory audit (observation and document review) rather than self-reporting of SQC practices by the company employees. Future studies can also seek to compare reported practices with observed practices.

The second purpose of this study was the illustration of a system-wide approach to sensory quality management. The study is one of a very few that presents a system approach, and it is the first to illustrate how to use preference data to identify critical sensory quality indicators and prevent the occurrence of sensory defects during the manufacturing process. Monitoring procedures for each CCP were identified and documented. This clearly specifies what is monitored, how it is monitored, when, the personnel that monitors it, and the corrective action where a deviation is observed.

The sensory quality system proposed in this study was not validated, hence, future studies to validate the sensory quality system, for example, with results from regular monitoring of the finished product by a trained panel or by the ratings from consumers, are needed. One limitation of this study was the limited consumer profiling prior to the preference test, thus the critical sensory indicators identified in this study relate to regular consumers of chocolate mousse and not specifically the target consumers for the brand of interest. It is therefore recommended that future studies use the target consumers (based on the company's internal profiling) to identify the critical sensory quality indicators of the product.

In conclusion, the final questionnaire (Appendix 3) can be used by food companies and third-party stakeholders for the rapid assessment of food company employees' knowledge, attitudes and practices related to SQC. This will be useful to identify training gaps, screening of prospective panellists, and to identify practices that need to be improved to ensure the success of SQC programmes. The practices section may also be used by third party stakeholders to assess the commitment of food companies to sensory quality management.

The illustration of the development of the sensory quality system is a vital example for food companies seeking to develop such a system. The system has several advantages: it considers the preference of consumers in defining the sensory specification for quality control purposes, thus SQC monitoring will be consumer focused. The system also considers the origins of sensory defect in the manufacturing process therefore allowing for adequate control and monitoring. Data collected from monitoring of the critical steps may provide information for trouble shooting processing issues and for process improvement. Furthermore, implementation of the system should reduce the need for finished product monitoring as this becomes a validation step rather than a monitoring step. This research will serve as a base for future studies into the optimisation of sensory quality systems.

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7 PUBLICATION, PRESENTATIONS AND POSTERS

Publication

Onojakpor, O. and de Kock, H.L., 2020. Development and pilot testing of a questionnaire to assess sensory quality control (SQC) knowledge, attitudes and practices (KAP) of food company employees. Food Quality and Preference, 86, p.103996).

Conference poster

Ogheneyoma S. Onojakpor and H. L. de Kock. Development and validation of the Sensory quality control (SQC).13th Pangborn Sensory Science Symposium, Edinburgh, Scotland. 28th July – 1st August 2019.

Early career researcher (ECR) video presentation

Conference oral presentation

Development and validation of a questionnaire to assess sensory quality control practices in food companies in African countries. 23rd Biennial International SAAFoST Congress and Exhibition, Johannesburg, South Africa. 1st - 4th September 2019

APPENDICES

APPENDIX 1: Initial questionnaire showing four sections: respondents' and company characteristics, knowledge, attitudes and practices

Identifier	Question **Respondents and company characteristics section** ***(Response options)***
C1	Please choose which option best describes your main current job function? *1. Sales/ Marketing 2. Production/ Manufacturing 3. Quality Assurance 4. Research & Development 5. Others*
C2	Please choose which option best describes your current job level? *1. Entry Level 2. Intermediate 3. Middle Management 4. Senior Management 5. Owner/Executive*
C3	Is your company a part of another larger company? *1. Yes 2. No*
C4	What is the total number of employees at your location? *1. Less than 10 2. 10 to 50 3. 51 to 200 4. More than 200*
C5	In which country is your company located? *List of countries provided*
C6	Estimate the annual projected/ real gross income of your company? (Currency and response options depend on the country selected) *1. Less than 1,000,000 2. 1,000,001 – 10,000,000 3. 10,000,001 - 100,000,000 4. Above 100,000,000*
C7	How many products does your company produce? (Includes different formulations and excludes different pack sizes) *1. Less than 3 2. 3 to 5 3. 6 to 10 4. More than 10*
C8	Please select the food processing sector your company belongs to? (if more than one sector, please choose the most important) *1. Baked goods/confectionery 2. Beverages 3. Cereals and grains 4. Dairy 5. Frozen and/or chilled 6. Fruits and vegetables 7. Meat and/or fish and/or sea food 8. Oils and fats 9. Sauces and condiments 10. Others*
C9	Do you have a quality department? *1. Yes 2. No*
C10	Have you heard of sensory evaluation before this study? *1. Yes 2. No*
C11	Was there any customer complaint or reprocessing of a product due to unacceptable sensory quality in the last 12 months? *1. Yes 2. No*
C12	Which of the following sensory-related functions are you involved in? *1. None 2. Request sensory experiments 3. Plan sensory experiments 4. Run sensory experiments 5. Analyse sensory data and write reports 6. Make decisions based on sensory data*
	Knowledge Section (*Options: Yes, No, 'I don't know*)
K1	Can you smell food while it is in your mouth?
K2	Is umami one of the basic tastes?
K3	Can product feel be judged with the eyes?
K4	Should you judge product flavour if you have a cold/flu?
K5	Is palate cleansing a good sensory practice?
K6	Should food tasters know the allergens in the food they will be tasting?
K7	Is the order of presenting samples important during sensory tests?

K8	Is a triangle test a sensory discrimination method?
K9	Should preference questions be asked during descriptive sensory tests?
K10	Is a one-tailed alternative hypothesis suitable for analysing the results of a triangle test?
K11	Is a t-test used for analysing sensory results of more than two products by the same group of people?
K12	Should untrained people be used for sensory quality control tests?
K13	Are consumer preference tests suitable for sensory quality control?
K14	Does ingredient quality contribute to the sensory quality of the finished food product?
K15	Does preparation conditions contribute to the sensory quality of the finished food product?
Identifier	**Question**
	Attitude Section (*Options: Strongly disagree to Strongly agree- 1 to 5*)
A1	Taste and appearance are not important to consumer acceptance of food products
A2	I know the sensory attributes that are important for consumer acceptance of my company's products
A3	Consistent product sensory quality is not part of my job responsibility
A4	I have a clear role in maintaining consistent product sensory quality
A5	My company believes that consumer satisfaction depends on consistent sensory quality
A6	My company provides the tools needed to make products of consistent sensory quality
A7	These are common benefits of the implementation of a sensory quality control programme, please select their level of importance to your company from 1=least important to 5=most important
A7_1	Reduce customer complaints
A7_2	Increase sales
A7_3	Improve product sensory quality
A7_4	Reduce waste
A7_5	Encourage employees to take responsibility for product quality
A8	These are common barriers to the implementation of a sensory quality control programme, please select their level of importance to your company from 1=least important to 6=most important
A8_1	Low sensory expertise
A8_2	Consumes too much time
A8_3	Too expensive
A8_4	Not enough facilities
A8_5	Low company management interest
A8_6	Low employee interest
	Practices Section *(Response options)*
P1	How often is **sensory evaluation training** carried out for company staff? *1. Never 2. Once a year 3. More than once a year*
P2	How often is **sensory quality testing** carried out for each of your company's products? *1. Anytime 2. Based on requests 3. Based on planned schedule*
P3	How would you describe the sensory quality standards for your company's products? *1. No standard 2. Memorized standard 3. Standard is documented and readily available*
P4	Who coordinates the sensory evaluation activities at your company? *1. Staff with no sensory training 2. An external organisation 3. Staff with sensory training*
P5	Who carries out product sensory tests? *1. Staff with no sensory training 2. Staff with little sensory training 3. Staff that are highly trained for product sensory evaluation*
P6	What products are assessed as part of sensory quality control in the company? *1. Samples from product development 2. Raw materials 3. In-process materials 4. Finished products*
P7	Where are the products assessed? *1. No specific area(Anywhere that is comfortable) 2.Specified test area 3.Company's sensory laboratory*

P8	How are products of unsatisfactory sensory quality managed at your company? *1. No specific procedure 2. Documented procedure 3. Documented procedure with trend analysis*

APPENDIX 2: Expert recommendations and comments (n=6)

Question	Recommendations/ Comments	Actions
D1	Please include the word phrase in question 1 where it says please choose which ... best describes ...	Not adopted as the question is clear
D1	You may need to include an 'other' response for some questions	Adopted this option was included for D1 and D7
D4	Could you clarify that this refers to the number of the entire staff of the company, not e.g., the section where the person works	Not adopted as the question is clear
D7	It might also be useful to include a box like this one after some important questions to get valuable comments.	Adopted for D1 and D7
K5	Some may not know what palate cleansing is. Would it be fair to give in brackets "e.g., rinsing mouth with water")	Adopted- example given
K11	Question is complicated- rephrase	Adopted- question rephrased
A1	This question is double barrelled, select only one descriptor	Adopted
A7 and A8	Questions A7 and A8 should be rating scales instead of ranking scales as they are more informative	Adopted- Question were rephrased
P3	Question is complicated- rephrase	Adopted- rephrased

APPENDIX 3: Recommendations and comments from the pretest (intended users n=9)

Question	Recommendations/ Comments	Actions
D1	There could be an option where you combine more than 1 option. Some positions have multiple functions.	Not adopted- the main role is the focus
D1	It should have a "Management" as an option.	Adopted- management was added
D4	Not sure if you are asking how many people are employed in the company or division etc.	Not adopted- the question is clear
D5	Maybe African regions will be better.	Not adopted- the questionnaire can be used anywhere
D6	Not everyone is privileged to know this. A person working in the technical department might not have access to this information unless they are at a very high position.	The question was removed to prevent respondents from guessing
K2	Elaborate on meaning of basic tastes.	Not adopted as the question is to test sensory evaluation knowledge
K3	Will replacing the term "feel" with "texture" not be clearer and more specific?	Adopted as the researchers considered the question
K5	Elaborate on the meaning of palate cleansing.	An example was given as the knowledge of the process was the test
K8	Elaborate when stating test methods such as triangle test.	Not adopted as familiarity of the method was the test
K10	Question comes off very complicated.	Adopted- Question was rephrased
K11	Complicated question.	Adopted- Question was rephrased
K12	Question not clear- rephrase	Adopted- Question was rephrased
A3	"Consistent" is an odd word to use here. Something is either part of your responsibility and measured and controlled or it is not.	Not adopted as the term is used here to refer to product characteristics and bot respondent's job responsibility
A5	"Tools" is a bit restrictive. Maybe use equipment, procedures and environment controls".	Adopted- Some examples of tool were given
A6	Products should be replaced with materials/products in question. change flow of answers. 2, 1, 3 and 4.	Adopted- Question was rephrased
P7	Products assessed for what? answers not specific. specified test area and company sensory lab could be same.	Adopted/ Not adopted- Question was rephrased, the answer options are sufficient

APPENDIX 4: Sensory quality control knowledge, attitude and practices questionnaire

This questionnaire assesses knowledge, attitude and practices with regards to sensory quality control

Respondents and company characteristics section

1. Please choose which option best describes your main current job function?
   1. Sales/ Marketing
   2. Production/ Manufacturing
   3. Quality Assurance
   4. Research & Development
   5. Others, please specify

2. Please choose which option best describes your current job level?
   1. Entry Level
   2. Intermediate
   3. Middle Management
   4. Senior Management
   5. Owner/Executive

3. Is your company a part of another larger company (a subsidiary)?
   1. Yes
   2. No

4. What is the total number of employees working in your company?
   1. Less than 10
   2. 10 to 50
   3. 51 to 200
   4. More than 200

5. In which country is your company located?
   A relevant list of countries are provided

6. How many products does your company produce? (Includes different formulations but excludes different pack sizes of the same product)
   1. Less than 3
   2. 3 to 5
   3. 6 to 10
   4. More than 10

7. Please select the food processing sector your company belongs to? (if more than one sector, please choose the most important)
   1. Baked goods/confectionery
   2. Beverages
   3. Cereals and grains
   4. Dairy
   5. Frozen and/or chilled

6. Fruits and vegetables
7. Meat and/or fish and/or sea food
8. Oils and fats
9. Sauces and condiments
10. Others (please specify)

8. Do you have a quality department?
   1. Yes
   2. No

9. Have you heard of sensory evaluation before this study?
   1. Yes
   2. No

10. Was there any customer complaint/s or reprocessing of a product/s due to unacceptable sensory quality in the last 12 months?
    1. Yes
    2. No
    3. I don't know

11. Which of the following sensory related functions are you involved in? (You can select more than one option)
    1. None
    2. I request sensory experiments
    3. I plan sensory experiments
    4. I participate in sensory experiments
    5. I analyse sensory data and/or write reports
    6. I make decisions based on sensory data

Knowledge Section

The order of questions in this section should be randomised.

Key to correct answers: 1. (1), 2. (1), 3. (1), 4. (2), 5. (1), 6. (1), 7. (2), 8. (2), 9. (1), 10. (1), 11. (2)

Basic senses/ physiology

1. Can you perceive the aroma of food while it is in your mouth?
   1. Yes
   2. No
   3. I don't know

2. Is umami one of the basic tastes?
   1. Yes
   2. No
   3. I don't know

3. Can product texture be judged with the eyes?
   1. Yes
   2. No

3. I don’t know

Good sensory practices

4. Will a food taster be able to judge product flavour if he/she has a cold or the flu?
   1. Yes
   2. No
   3. I don’t know

5. Is palate cleansing (e.g. rinsing mouth with water) a good sensory practice?
   1. Yes
   2. No
   3. I don’t know

6. Is it important to inform food tasters of allergens in the food they will be tasting?
   1. Yes
   2. No
   3. I don’t know

7. Should preference questions be asked during descriptive sensory tests?
   1. Yes
   2. No
   3. I don’t know

8. Should people without sensory evaluation training be used for sensory quality control tests?
   1. Yes
   2. No
   3. I don’t know

Sensory/ sensometric methods

9. Is a triangle test a sensory discrimination method?
   1. Yes
   2. No
   3. I don’t know

10. Is a one tailed hypothesis suitable for analysing the results of a triangle test?
    1. Yes
    2. No
    3. I don’t know

11. Is t-test used for analysing sensory differences between more than two products?
    1. Yes
    2. No
    3. I don’t know

Attitude Section

On a scale of 1 to 5 where 1 = Strongly Disagree, 2= Disagree, 3 = Neither Disagree nor Agree, 4 = Agree and 5 = Strongly Agree, indicate the extent to which you agree with each of the following statements.

S/N		1	2	3	4	5
1	I know the sensory attributes that are important for consumer acceptance of my company's products					
2	Maintaining product sensory quality is not part of my job responsibility					
3	I have a clear role in maintaining consistent product sensory quality					
4	My company believes that consumer satisfaction depends on consistent sensory quality					
5	My company provides the tools (equipment, procedures and/or training) needed to make products of consistent sensory quality					

6. These are common benefits of the implementation of a sensory quality control programme. Please indicate the level of importance of each to your company: 1=not important to 5=extremely important

		1	2	3	4	5
i	Reduce customer complaints					
ii	Increase sales					
iii	Improve product sensory quality					
iv	Reduce waste					
v	Encourage employee to take responsibility for product quality					

7. These are common barriers to the implementation of a sensory quality control programme. Please indicate the level of importance of each to your company:1=not important 5= extremely important

		1	2	3	4	5
i	Low sensory expertise					
ii	Consumes too much time					
iii	Too expensive					
iv	Not enough facilities					
v	Low company management interest					
vi	Low employee interest					

Practice section

Does your company carry out sensory quality control?
1. Yes
2. No

If your answer was 'Yes', then please complete the rest of the questionnaire, if 'No' please do not complete the rest of the questionnaire.

1. How often is **sensory evaluation training** carried out for company staff?
   1. Never
   2. Once a year
   3. More than once a year

2. When is **sensory quality testing** carried out for each of your company's products?
   1. Anytime
   2. Based on requests
   3. Based on a planned schedule

3. How does your company define the target sensory quality of products for quality control purposes?
   1. There is no defined standard
   2. It is based on a memorized standard
   3. The standard is documented and readily available

4. Who coordinates sensory quality control at your company?
   1. Staff with no sensory training
   2. An external organisation
   3. Staff with sensory training

5. Who carries out sensory quality tests?
   1. Staff with no sensory training
   2. An external organisation
   3. Staff with sensory training

6. What materials/products are assessed as part of sensory quality control in the company? (Please choose from the list below, you can choose more than one option)
   1. Samples from product development
   2. Raw materials
   3. In-process materials
   4. Finished products

7. Where are the products assessed for sensory quality control?
   1. No specific area (Anywhere that is comfortable)
   2. A specified test area
   3. Company's sensory laboratory

8. How are products of unsatisfactory sensory quality managed at your company?
   1. No specific procedure

2. A documented procedure
3. A documented procedure with trend analysis

Thank you for participating in this survey

APPENDIX 5: Sensory quality control knowledge, attitude and practices questionnaire

This questionnaire assesses knowledge, attitudes and practices with regards to sensory quality control in food companies.

Respondents and company characteristics section

1. Please choose which option best describes your main current job function?
   a) Production/ Manufacturing
   b) Quality Assurance
   c) Research & Development
   d) Sales/ Marketing
   e) Other, please specify
2. Please choose which option best describes your current job level?
   a) Entry level
   b) Intermediate level
   c) Middle Management
   d) Senior Management
   e) Owner/Executive
3. Is the company where you work part of another larger company (i.e., a subsidiary)?
   a) Yes
      b) No
4. In which country is the company where you work located?
   A relevant list of countries is provided
5. What is the total number of employees in the company where you work?
   a) 1 to 10
   b) 11 to 49
   c) 50 to 249
   d) 250 and above

6. How many products are produced at the company where you work? (the number includes different formulations but excludes different pack sizes of the same product)
      a) 1 to 2
      b) 3 to 5
      c) 6 to 10
      d) 11 and above
7. Please select the food processing sector that is most relevant for the company where you work (if more than one sector, please choose the most relevant)
   a) Baked goods/confectionery
   b) Beverages
   c) Cereals and grains
   d) Dairy
   e) Frozen and/or chilled
   f) Fruits and vegetables
   g) Meat and/or fish and/or sea food
   h) Oils and fats

i) Sauces and condiments
j) Other (please specify)

8. Do you have a quality department at the company where you work?
   a) Yes
   b) No
9. Have you heard of sensory evaluation before this study?
   a) Yes
   b) No (display the definition below)

   Sensory quality of a product is how the product smells, looks, tastes and feels

   Sensory evaluation is the use of the human senses to evaluate a product under standardized conditions
10. Was there any customer complaint/s or reprocessing of your company's product/s due to unacceptable sensory quality in the last 12 months?
    a) Yes
    b) No
    c) I don't know
11. How often were there complaints or reprocessing of products due to unacceptable sensory quality in the last 12 months? (displayed if yes is selected above)
    a) Rarely
    b) Occasionally
    c) Often
    d) All the time
    e) I don't know
12. What were the likely causes of unacceptable sensory quality? (You can select more than one option)
    a) Ingredient issues
    b) Processing issues
    c) Quality control issues
    d) Storage and distribution issues
    e) Others (please specify)
13. Which of the following sensory related functions are you involved in? (You can select more than one option)
    a) None
    b) I request sensory tests
    c) I plan sensory tests
    d) I participate in sensory tests
    e) I analyse sensory test data and/or write reports
    f) I make decisions based on sensory tests

14. How much sensory evaluation related (requesting, planning, participating, analysis, or decision making) experience do you have?
    a) None

b) Less than 1 year
c) 1 to 5 years
d) 6 to 10 years
e) More than 10 years

15. Have you received sensory evaluation training?
a) None
b) Yes, in house sensory evaluation training
c) Yes, sensory evaluation training at an academic institution
d) Yes, Other sensory evaluation training (please specify) ________________

Knowledge Section

Scored 1 for correct (green font) or 0 for incorrect and I don't know answers

The order of questions in this section should be randomized.

Basic senses/ physiology

1. Can a person smell a food while chewing it in the mouth?
a) Yes
b) No
c) I don't know

2. Is vanilla (sweet, salty, bitter, sour, umami, fruity) one of the basic tastes?
a) Yes
b) No
c) I don't know

3. Does the sense of hearing contribute to the evaluation of texture when eating an apple?
a) Yes
b) No
c) I don't know

4. Which one of these relates to the perception of sight?
a) Rods
b) Triangles
c) Squares
d) I don't know

5. Which one of these does trigeminal sensation relate to?
a) Visual perception
b) Auditory perception
c) Flavour perception
d) I don't know

6. Which one of these is perceived on the tongue?
   a) Volatile food compounds
   b) Water soluble compounds
   c) Bud binding compounds
   d) I don't know

Good sensory practices

1. Is palate cleansing (e.g. rinsing mouth with water) between tasting different samples a good sensory practice?
   a) Yes
   b) No
   c) I don't know
2. Should sensory quality panellists be informed of allergens in the food they will be tasting?
   a) Yes
   b) No
   c) I don't know
3. Should product liking questions be asked during sensory quality control?
   a) Yes
   b) No
   c) I don't know
4. How do you reduce carry over effects from one sample to the next when evaluating many samples?
   a) By evaluating samples under red light
   b) By taking rest periods between samples
   c) By switching sides (left then right) in the mouth during chewing
   d) I don't know

5. Which one of these can be ignored when recruiting panellists for sensory quality control of dairy products?
   a) Their availability for product evaluation
   b) Their interest in sensory quality control
   c) Their level of liking of dairy products
   d) I don't know

6. Should a panellist be asked to judge the flavour of products if he/she has a cold or the flu?
   a) Yes
   b) No
   c) I don't know

Sensory quality control

1. Should employees with **no** sensory evaluation training be used for sensory quality control of products?
   a) Yes
   b) No
   c) I don't know

2. A trained sensory panel has been carrying out sensory quality testing of bread for the past seven months. Which of the following is a way to check the panel performance?
   a) Monitoring the scores for samples from different batches
   b) Monitoring the scores for control samples
   c) Monitoring the time used for product evaluation
   d) I don't know

3. Which one of these tasks must be completed individually by members of a sensory quality panel?
   a) Identification of reference standards for sensory descriptors
   b) Selection of sensory descriptors for quality control purposes
   c) Evaluation of product samples for quality control purposes
   d) I don't know

4. A product sensory specification is…?
   a) A list of ingredients that affect the sensory quality of the product
   b) The description of the target sensory properties of the product
   c) The description of the method used to evaluate the product
   d) I don't know

5. The decision to reject/accept a product for release to the market based on its sensory quality depends on …?
   a) The results of the most senior panellist
   b) The results of the most experienced panellist
   c) The results of all the panellists
   d) I don't know

6. In which order should product sensory attributes be evaluated during sensory quality control?
   a) The order of sensory attributes should be varied from one sample to another
   b) The order of sensory attributes should be the same from one sample to another
   c) The order in which sensory attributes are evaluated does not matter
   d) I don't know

Sensory/ sensometric methods

1. Is a paired comparison test a descriptive sensory method?
   a) Yes

b) No
c) I don’t know

2. Which one of the following is suitable for testing whether two samples are different?
   a) Triangle test
   b) Quad test
   c) Square test
   d) I don’t know
3. Can a t-test be used to compare the sweetness ratings of two products?
   a) Yes
   b) No
   c) I don’t know

4. Company Z‘s policy states that white bread that differs from the product specification ($p<0.01$) should be rejected. The sensory quality of Sample X differs from the product specification ($p=0.05$), should it be rejected?
   a) Yes
   b) No
   c) I don’t know

5. Which of the following is the most suitable number of panellists for descriptive sensory evaluation?
   a) 3
   b) 5
   c) 10
   d) I don’t know

6. Which of the following tests would be suitable to determine the nature of differences between two brands of apple juice?
   a) Duo-trio test
   b) Paired preference test
   c) Descriptive analysis
   d) I don’t know

Attitude Section

Indicate the extent to which you disagree/agree with the following statements from strongly disagree - strongly agree

Employee attitudes

Scored 1 to 5 for strongly disagree - strongly agree, some questions (denoted R) are reverse worded.

S/N		Strongly disagree	Disagree	Neither agree/ disagree	Agree	Strongly agree
1	Sensory quality of products is important to consumers					
2R	Sensory quality control is not reliable					
3	Employees are responsible for maintaining consistent sensory quality of products					
4R	Sensory quality control is a waste of time					
5	Sensory quality control is important					
6R	Employees do not need training on the sensory quality of products					

Indicate the extent to which you disagree/agree with the following statements about your company from Strongly Disagree - Strongly Agree

Company attitude

Scored 1 to 5 for strongly disagree - strongly agree, some questions (denoted R) are reverse worded.

S/N		Strongly disagree	Disagree	Neither agree/ disagree	Agree	Strongly agree
1	My company maintains that consumer satisfaction depends on the sensory quality of products					
2	My company provides the resources needed to make products of good sensory quality					
3R	My company maintains that sensory quality control hinders production					
4R	My company regards sensory evaluation training as unnecessary					

5R	My company is reluctant to change operations to improve product sensory quality					
6R	My company regards safe products to be of good sensory quality					
7	My company produces products of consistent sensory quality					

Practice section

Does your company carry out sensory quality control?

3. Yes
4. No
5. I don't know

If your answer was 'Yes', then please complete the rest of the questionnaire, if 'No' please do not complete the rest of the questionnaire.

Practices section

Scored 1 to 3 for worst (a) to best practice (c))

1. How often is **sensory evaluation training** carried out for company staff?
   a) Never
   b) Once a year
   c) More than once a year
2. When is **sensory quality testing** carried out for company products?
   a) Anytime (based on convenience of the quality team)
   b) When there is a problem or complaint
   c) Based on a planned schedule

3. How does your company define the target sensory quality of products for quality control purposes?
   a) There is no defined standard/specification
   b) It is based on a memorized standard/specification
   c) The standard/specification is documented and readily available

4. Who manages sensory quality control at your company?
   a) Company staff with no sensory training
   b) Company staff with some sensory training
   c) Company staff with good sensory training and experience

5. Who evaluates the products for sensory quality control?
   a) Panellist with no sensory training
   b) Panellist with some sensory training
   c) Panellist with good product-specific sensory training
6. What materials/products are evaluated as part of sensory quality control in your company? (Please choose from the list below, you can choose more than one option)
   a) Raw materials
   b) In-process materials
   c) Finished products

7. Where is product sensory quality testing carried out?
   a) No specific area (Anywhere that is comfortable/available)
   b) A specified test area
   c) Company’s sensory laboratory

8. How are products of unsatisfactory sensory quality handled at your company?
   a) No specific procedure
   b) Based on a documented procedure
   c) Based on a documented procedure with corrective actions

9. Does your company check product sensory quality before releasing products to the market?
   a) No
   b) Yes, sometimes
   c) Yes, always

APPENDIX 6: Informed consent form (Pilot study)

Welcome to this study!

Ms Ogheneyoma Onojakpor, a PhD student at the University of Pretoria is carrying out research on sensory quality control in food companies. Your response will provide valuable insight into the limitations and opportunities for implementing good sensory quality control practices. It will also facilitate the identification of training needs for the adoption of good sensory practices. This study was approved by the ethics committee of the Faculty of Natural and Agricultural Sciences, University of Pretoria (Reference number 180000041).

The survey should take you about 15 minutes to complete. Your participation is voluntary. You may refuse to take part or exit the survey at any time without penalty or having to provide a reason. Your survey responses will be collected anonymously, no one will be able to identify you or your responses. You will not receive any remuneration for your participation, however, you may enter a prize draw to win a Sensory textbook by providing your email address at the end of the survey.

If you would like to discuss about this research, please contact the investigators:
Research supervisor (Prof HL De Kock): +27 12 420 3238 or riette.dekock@up.ac.za
Doctoral student (Ogheneyoma Onojakpor): +27 78 524 2897 or u18239634@tuks.co.za

By selecting the 'I agree' button below, you acknowledge the following:

- You have read the above information and understand it
- You are 18 years of age or older
- You voluntarily agree to participate in this survey
- You indemnify the university and its employees and/or students of against any liability related to your participation in this survey

☐ **I agree (begin the study)** ☐ **I do not agree (do not begin the study)**

APPENDIX 7: Informed consent form (Validation study)

You are invited to participate in a study on sensory quality control in food companies. This is part of the PhD study of Ogheneyoma Onojakpor at the University of Pretoria, South Africa. This questionnaire should be completed by food company employees in production, quality assurance/ control and research and development roles. Your responses will provide valuable insight to improve practices in food companies.

This questionnaire will take about 20 minutes to complete. You may provide your email address at the end of the survey to win one of four R500 shopping vouchers. Your participation in this study is voluntary and anonymous. The data collected is confidential and will only be used for research purposes. This study was approved by the Ethics Committee of the University of Pretoria. The researchers and the University are bound by their legal and professional responsibilities.

If you have any questions about the research, please contact the researchers:
Research supervisor (Prof HL De Kock): riette.dekock@up.ac.za
PhD student (Ogheneyoma Onojakpor): u18239634@tuks.co.za

By selecting Yes below, you provide consent to participate and agree to the following:

- I have read and understood the information about the study.
- I voluntarily agree to participate in this survey.
- I am aware that the information obtained in the study, will be anonymously processed, and used for research purposes only.

○ Yes, I volunteer to take part in this study

○ No, I do not volunteer to take part in this study

APPENDIX 8: Online questionnaire (Qualtrics) for validation study

Start of Block: SURVEY INSTRUCTION

Start of Block: Informed Consent

Q1 You are invited to participate in a study on sensory quality control in food companies. This is part of the PhD study of Ogheneyoma Onojakpor at the University of Pretoria, South Africa. This questionnaire should be completed by food company employees in production, quality assurance/ control and research and development roles. Your responses will provide valuable insight to improve practices in food companies. This questionnaire will take about 20 minutes to complete. You may provide your email address at the end of the survey to win one of four R500 shopping vouchers. Your participation in this study is voluntary and anonymous. The data collected is confidential and will only be used for research purposes. This study was approved by the Ethics Committee of the University of Pretoria. The researchers and the University are bound by their legal and professional responsibilities. If you have any questions about the research, please contact the researchers: Research supervisor (Prof HL De Kock): riette.dekock@up.ac.za PhD student (Ogheneyoma Onojakpor): u18239634@tuks.co.za By selecting Yes, below you provide consent to participate and agree to the following: I have read and understood the information about the study. I voluntarily agree to participate in this survey. I am aware that the information obtained in the study, will be anonymously processed, and used for research purposes only.

○ Yes, I volunteer to take part in this study

○ No, I do not volunteer to take part in this study

Page Break

End of Block: Informed Consent

Start of Block: Employee and company characteristics

This questionnaire assesses knowledge, attitudes and practices with regards to sensory quality control in food companies.

C1 Please choose which option best describes your main current job function?

- ○ Sales/ Marketing
- ○ Production/ Manufacturing
- ○ Quality Assurance
- ○ Research & Development
- ○ Others, please specify ____

C2 Please choose which option best describes your current job level?

- ○ Entry Level
- ○ Intermediate level
- ○ Middle Management
- ○ Senior Management
- ○ Owner/Executive

C3 Is the company where you work part of another larger company (i.e. a subsidiary)?

- ○ Yes
- ○ No

C4 In which country is the company where you work located?

▼ Afghanistan ... Zimbabwe

C5 What is the total number of employees in the company where you work?

- 1 to 10
- 11 to 49
- 50 to 249
- 250 and above

C6 How many products are produced at the company where you work? (*the number includes different formulations but excludes different pack sizes* of the same product)

- 1 to 2
- 3 to 5
- 6 to 10
- 11 and above

C7 Please select the food processing sector that is most relevant for your company? (*if more than one sector, please choose the most important*)

- ◯ Baked goods/confectionery
- ◯ Beverages
- ◯ Cereals and grains
- ◯ Dairy
- ◯ Frozen and/or chilled
- ◯ Fruits and vegetables
- ◯ Meat and/or fish and/or sea food
- ◯ Oils and fats
- ◯ Sauces and condiments
- ◯ Others (please specify) ____

C8 Do you have a quality department at the company where you work?

- ◯ Yes
- ◯ No

C9 Have you heard of sensory evaluation before this study?

(Sensory quality of a product is how the product smells, looks, tastes and feels. Sensory evaluation is the use of the human senses to evaluate a product under standardized conditions)

- ◯ No
- ◯ Yes

C10 Was there any customer complaint/s or reprocessing of your company's product/s due to unacceptable sensory quality in the last 12 months?

- Yes
- No
- I don't know

Display This Question:
If Was there any customer complaint/s or reprocessing of your company's product/s due to unacceptabl... = Yes

C11 How often were there complaint/s or reprocessing of product/s due to unacceptable sensory quality in the last 12 months?

- Rarely
- Occasionally
- Often
- All the time

Display This Question:
If Was there any customer complaint/s or reprocessing of your company's product/s due to unacceptabl... = Yes

C12 What were the likely causes of unacceptable sensory quality? (You can select more than one option)

- ☐ Ingredient issues
- ☐ Processing issues
- ☐ Quality control issues
- ☐ Storage and distribution issues
- ☐ Others (please specify)

____

C13 Which of the following sensory related functions are you involved in? (You can select more than one option)

- ☐ None
- ☐ I request sensory tests
- ☐ I plan sensory tests
- ☐ I participate in sensory tests
- ☐ I analyse sensory test data and/or write reports
- ☐ I make decisions based on sensory tests

C14 How much sensory related experience do you have?

- ◯ None
- ◯ Less than 1 year
- ◯ 1 to 5 years
- ◯ 6 to 10 years
- ◯ More than 10 years

X→

C15 Have you received any sensory evaluation training?

- ☐ No
- ☐ Yes, in house sensory evaluation training
- ☐ Yes, sensory evaluation training at an academic institution
- ☐ Yes, Other sensory evaluation training (please specify)

____

Page Break

End of Block: Employee and company characteristics

Start of Block: Knowledge Assessment

The following questions relate to your knowledge of sensory evaluation principles and practices. Please note that your responses are anonymous.

K1 Can a person smell a food while chewing it in the mouth?

- Yes
- No
- I don't know

K2 Is vanilla one of the basic tastes?

- Yes
- No
- I don't know

K3 Does the sense of hearing contribute to the evaluation of texture when eating an apple?

- Yes
- No
- I don't know

K4 Which one of these does trigeminal sensation relate to?

- Visual perception
- Auditory perception
- Flavour perception
- I don’t know

K5 Which one of these relates to the perception of sight?

- Rods
- Triangles
- Squares
- I don’t know

K6 Which one of these is perceived on the tongue?

- Volatile food compounds
- Water soluble compounds
- Bud binding compounds
- I don’t know

K7 Is palate cleansing (e.g., rinsing mouth with water) between tasting different samples a good sensory practice?

- Yes
- No
- I don’t know

K8 Should sensory quality panellists be informed of allergens in the food they will be tasting?

- Yes
- No
- I don’t know

K9 Should product liking questions be asked during sensory quality control?

- Yes
- No
- I don’t know

K10 How do you reduce carry over effects from one sample to the next when evaluating many samples?

- By evaluating samples under red light
- By taking rest periods between samples
- By switching sides (left then right) in the mouth during chewing
- I don’t know

K11 Which one of these can be ignored when recruiting panellists for sensory quality control of dairy products?

- ◯ Their level of liking of dairy products
- ◯ Their availability for product evaluation
- ◯ Their interest in sensory quality control
- ◯ I don't know

K12 Should a panellist be asked to evaluate the flavour of products if he/she has a cold or the flu?

- ◯ Yes
- ◯ No
- ◯ I don't know

Page Break

K13 Should employees with ***no*** sensory evaluation training be used for sensory quality control of products?

- ○ Yes
- ○ No
- ○ I don’t know

K14 A trained sensory panel has been carrying out sensory quality control testing of bread for the past seven months. Which of the following is a way to check the panel performance?

- ○ Monitoring the scores for samples from different batches
- ○ Monitoring the scores for control samples
- ○ Monitoring the time used for product evaluation
- ○ I don’t know

K15 Which one of these tasks must be completed individually by members of a sensory quality panel?

- ○ Identification of reference standards for sensory descriptors
- ○ Selection of sensory descriptors for quality control purposes
- ○ Evaluation of product samples for quality control purposes
- ○ I don’t know

K16 A product sensory specification is…?

- A list of ingredients that affect the sensory quality of the product
- The description of the target sensory properties of the product
- The description of the method used to evaluate the product
- I don't know

K17 The decision to reject/accept a product for release to the market based on its sensory quality depends on …?

- The results of the most senior panellist
- The results of the most experienced sensory panellist
- The results of all the panellists
- I don't know

K18 In which order should product sensory attributes be evaluated during sensory quality control?

- The order of sensory attributes should be varied from one sample to another
- The order of sensory attributes should be the same from one sample to another
- The order in which sensory attributes are evaluated does not matter
- I don't know

K19 Is a paired comparison test a descriptive sensory method?

- Yes
- No
- I don't know

K20 Which one of the following is suitable for testing whether two samples are different?

- Triangle test
- Quad test
- Square test
- I don't know

K21 Can a t-test be used to compare the sweetness ratings of two products?

- Yes
- No
- I don't know

K22 Company Z 's policy states that white bread that differs from the specification ($p<0.01$) should be rejected. The sensory quality of Sample X differs from the product specification ($p=0.05$), should it be rejected?

- Yes
- No
- I don't know

K23 Which of the following is the most suitable number of panellists for descriptive sensory evaluation?

- 3
- 5
- 10
- I don’t know

K24 Which of the following tests would be suitable to determine the nature of differences between two brands of apple juice?

- Duo-trio test
- Paired preference test
- Descriptive analysis
- I don’t know

Page Break

End of Block: Knowledge Assessment

Start of Block: Attitude/ perception assessment

A1 Please indicate the extent to which you disagree/ agree with the following statements, from strongly disagree - strongly agree

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Sensory quality of products is important to consumers	o	o	o	o	o
Sensory quality control is not reliable	o	o	o	o	o
Employees are responsible for maintaining the sensory quality of products	o	o	o	o	o
Sensory quality control is a waste of time	o	o	o	o	o
Sensory quality control is important	o	o	o	o	o
Employees do not need training on the sensory quality of products	o	o	o	o	o

A2 Please indicate the extent to which you disagree/ agree with the following statements about your company, from strongly disagree - strongly agree

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
My company maintains that consumer satisfaction depends on the sensory quality of products	○	○	○	○	○
My company provides the resources needed to make products of good sensory quality	○	○	○	○	○
My company maintains that sensory quality control hinders production	○	○	○	○	○
My company regards sensory evaluation training as unnecessary	○	○	○	○	○
My company is reluctant to change operations to improve product sensory quality	○	○	○	○	○
My company regards safe products to be of good sensory quality	○	○	○	○	○
My company produces products of consistent sensory quality	○	○	○	○	○

Page Break

End of Block: Attitude/ perception assessment

Start of Block: SQC

Does your company carry out sensory quality control?

- yes
- No
- I don't know

End of Block: SQC

Start of Block: Practice assessment

P1 How often is sensory evaluation training carried out for company staff?

- Never
- Once a year
- More than once a year

P2 When is sensory quality testing carried out for each of your company's products?

- Anytime (based on convenience of the quality team)
- When there is a problem or complaint
- Based on a planned schedule

P3 How does your company define the target sensory quality of products for quality control purposes?

- ◯ There is no defined standard/specification
- ◯ It is based on a memorized standard/specification
- ◯ The standard/specification is documented and readily available

---

P4 Who manages the sensory quality control at your company?

- ◯ Company staff with no sensory training
- ◯ Company staff with some sensory training
- ◯ Company staff with good sensory training and experience

P5 Who evaluates products for sensory quality control?

- ◯ Panellists with no sensory training
- ◯ Panellists with some sensory training
- ◯ Panellists with good product-specific sensory training

P6 What materials/products are evaluated as part of sensory quality control in your company?
(Please choose from the list below, you can choose more than one option)

- ☐ Raw materials
- ☐ In-process materials
- ☐ Finished products

P7 Where is product sensory quality testing carried out?

- ◯ No specific area (anywhere that is comfortable/ available)
- ◯ A specified test area
- ◯ Company's sensory laboratory

P8 How are products of unsatisfactory sensory quality handled at your company?

- ◯ No specific procedure
- ◯ Based on a documented procedure
- ◯ Based on a documented procedure with corrective actions

P9 Does your company check product sensory quality before releasing products to the market?

- ◯ No
- ◯ Yes, sometimes
- ◯ Yes, always

End of Block: Practice assessment

Start of Block: Block 7

LD Would you like to participate in the lucky draw?

- ◯ Yes
- ◯ No

End of Block: Block 7
