Food Certification through Collaborative Sensory Analysis Methods and Tools

(Discussion Paper)

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Abstract

In the current global food market, there exists a vital need for data-driven tools that ensure the highest quality of food. Guaranteeing food quality demands meticulous control across the entire production chain, while adhering to best practices and legal regulations. However, beyond objective metrics for evaluating food quality, subjective elements derived from sensory analysis hold paramount importance. Sensory analysis involves assessing food through the five senses: taste, sight, touch, smell, and hearing. It significantly influences food choices and dietary preferences. The process of preparing a sensory analysis panel is complex and includes panel leaders, tasters and sensory analysis experts, who are in charge of analysing the panel results. Therefore, the process can greatly benefit from the use of specialised tools. These tools must facilitate all phases of the panel, from selecting tasters and food samples to analysing and visualising results, and must be properly integrated to maximise the outcome of the sensory analysis. They must also help in appropriately weighing tasters' input based on their experience and on-the-fly comparison against other tasters during the panel, ultimately culminating in the issuance of a food certification. To this aim, in this discussion paper we discuss a comprehensive suite of tools developed to manage sensory analysis panels. These tools are grounded on a shared conceptual data model and are specifically designed to evaluate food quality and generate a food certificate, ensuring that the highest standards are met throughout the food production and assessment process.

Keywords

Agri-food 4.0, Sensory Analysis, Smart Food, Food Certification

1. Introduction

In recent years, consumers are demanding for high-quality food, that calls for meticulous controls across the entire production chain and compliance with best practices and regulations. In this context, sensory analysis plays a pivotal role in evaluating food quality, as it provides invaluable insights into the sensory attributes that define consumers' preferences. Collected sensory data encompasses a wide range of attributes, including taste, aroma, texture, appearance, and sound perception. Nonetheless, the variability of human sensory perception adds complexity to data collection, emphasising the need for standardised evaluation methods to ensure consistency and reliability in data interpretation.

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Going beyond objective measurements on food quality and compliance, such as laboratory tests, sensory analysis has a significant role in food choice and dietary patterns [1]. Data collected for sensory analysis presents specific features [2] and requires an interdisciplinary approach to address *subjectivity and variability in perception*, ensure *data quality* through proper data analysis and interpretation, allow *data security and privacy*, implement *longitudinal data management* for continuous monitoring, and handling the volume and complexity of large datasets. Different types of users, such as sensory scientists, statisticians, data scientists, and IT professionals, could benefit from the adoption of proper tools that might support all phases of the sensory analysis process, ranging from the selection of tasters and food samples, to the analysis and visualisation of results, to outcome a food certification.

In this discussion paper, we introduce a comprehensive suite of tools developed to support a *tasters association* in the preparation, execution and analysis of the sensory analysis process. The process firstly involves panel leaders, who are in charge of preparing the product profile (i.e., a list of descriptors used to characterise a food product using five senses), select the tasters and food samples and supervise the execution of the tasting panel. Tasters are asked to assign a vote in a discrete scale to each descriptor (e.g., on a scale from 0 to 9, how much astringency is perceived or how much attractive the product appears) according to their sensory experience (stimulation caused by aromas and flavours of the product). Based on the answers collected through multiple panels, a food product certificate is prepared, to establish the quality of the product for future comparisons and quality assessment. These steps are supported by an integrated set of software tools that guide the involved actors [3]. To the best of our knowledge, this is the first attempt to provide such a completely integrated suite of tools in this domain, bridging together data management about the portfolio of tasters, statistical analysis to judge tasters according to their experience and data modelling to pursue food quality and certification. This is the first step in a project where food certificate will be correlated with Big Data collected on field during food production (implementing the so-called Agri-Food 4.0) and the feedback of the final consumers.

The paper is organised as follows: Section 2 provides a Sensory Analysis overview; Section 3 introduces the Sensory Data Model; Section 4 delves into Sensory Data Analysis; Section 5 outlines the software architecture of the tool suite; Section 6 reviews Related Work. Finally, Section 7 offers concluding remarks and future directions.

2. Sensory Analysis Overview

Figure 1 depicts the sensory analysis process, that begins with a tasters' association receiving a commission for food evaluation (for instance, from a chocolate manufacturer interested in certifying the quality of products) and culminates in the issuance of a food certificate based on the analysis results. The Panel Leader, an expert with significant experience in sensory analysis, embarks on the critical task of preparing the sensory panel. This phase is marked by a series of deliberate and well-considered actions aimed at ensuring the panel's effectiveness and reliability and improving the panel compliance to standardised procedures. The panel leader's role is pivotal, involving the meticulous selection of tasters who have received extensive training to participate in food evaluation panels. The panel leader is in charge of defining the set of

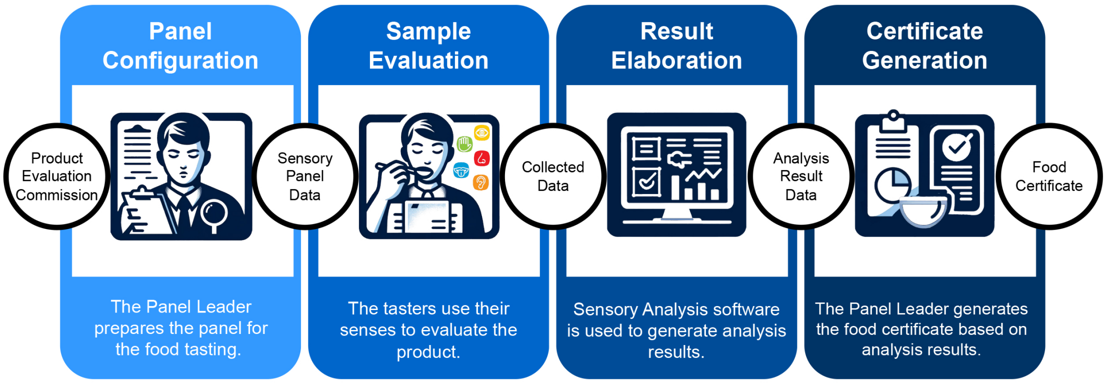

Figure 1: Sensory Analysis overview

sensory attributes (*descriptors*) that are relevant for product evaluation. For instance, in the case of chocolate, examples of descriptors could be creamy texture and floral aroma. The panel leader also selects the most suitable methodology for the session, guaranteeing an efficient and effective assessment of the product's sensory quality.

With the sensory panel in place, the evaluation of samples can begin. This phase is characterised by a structured and controlled approach, essential for maintaining the integrity of the sensory data collected. The tasters, now thoroughly trained, systematically evaluate the food product using their calibrated senses to determine its quality. To avoid any bias, samples are presented in a neutral and standardised manner. The tasting sessions are held in environments specially designed to minimise external influences and distractions. Factors such as lighting, temperature, and even the room's color are meticulously controlled, complemented by the integration of a user-friendly graphical user interface (GUI) for data collection. Employing blind testing methods, where the identity of the samples remains hidden, ensures tasters base their evaluations solely on the product's sensory attributes, thus relieving tasters from the influence of environmental factors, for example allowing the chocolate manufacturer to objectively assess the appeal and flavour profile of the product. This harmonised setting, together with the advanced collection tool, streamlines the evaluation process, allowing tasters to efficiently and accurately record their observations. Tasters assess the product using the previously defined set of descriptors, rating each attribute on scales measuring intensity, preference, or quality. The tasters' responses are compiled, resulting in a comprehensive dataset that mirrors the collective sensory experience of the product.

Advanced statistical methods are then applied to analyse the collected data. Through statistical analysis, subtle nuances and significant trends are uncovered, providing a profound understanding of the product's sensory attributes. This methodical approach enables the quantification of sensory perceptions, converting subjective experiences into objective data. A crucial aspect of the analysis involves evaluating the tasters' performance to ensure consistency and alignment with the calibration phase standards.

Ultimately, the Panel Leader utilises the analysis results to produce a food certificate. This document consolidates the sensory evaluation findings, offering a formal and authoritative

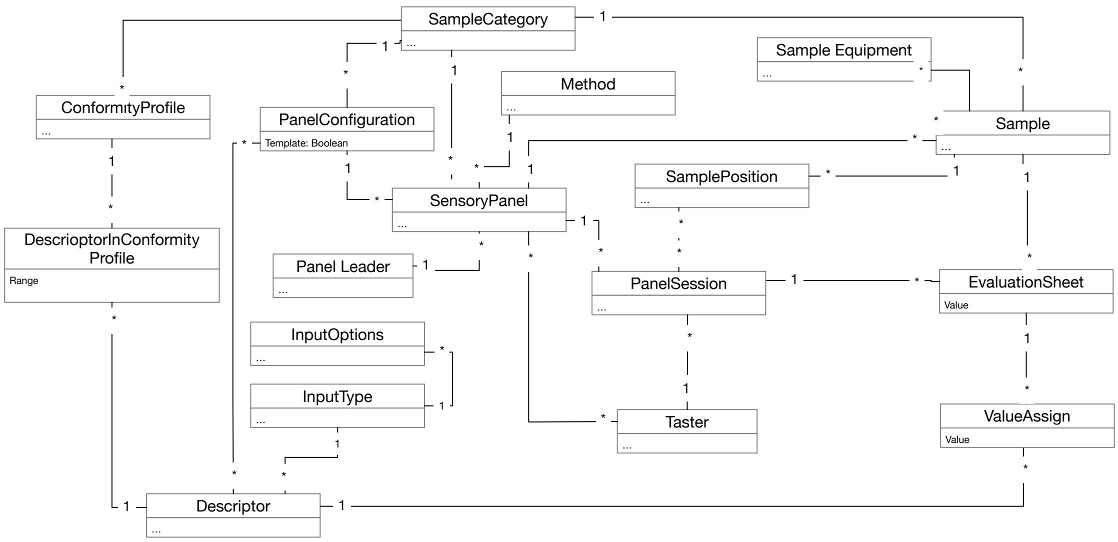

Figure 2: Sensory data conceptual model on which the suite of tools relies.

assessment of the product sensory quality, which can greatly enhance the manufacturer's market positioning.

3. Sensory Data Model

The unified view over the data exploited by different components of the tool suite is one of the strengths of the approach, with respect to the existing systems for sensory analysis. The collection of sensory data is initiated through the Input Sensory Software (ISS), designed to organise panel sessions as standard procedures. Afterwards, data is exported to be analysed using the Big Sensory Software (BSS), that implements several statistical metrics. Finally, sensory data collected over time is stored to enable longitudinal data management through the Data Sensory Software (DSS).

Figure 2 illustrates a portion of the conceptual data model which the tools suite is based on. The **Panel Leader** is in charge of creating and overseeing a **Sensory Panel**. For this purpose, the Panel Leader selects the **Samples** for evaluation, associated to a **Sample Category** (e.g. red wine or white chocolate). The evaluation **Method**, encapsulating a set of rules and guidelines, is selected to make the evaluation process compliant to best practices, such as the proper sequence in which the samples are presented to the tasters. Moreover, the Panel Leader defines the **Descriptors** set (e.g., astringency or flower aroma). A descriptor is tailored to a specific Sample Category — for instance, creamy texture and shiny appearance can be descriptors used for chocolate, whereas tannin taste or earthy aroma better suit wine. Descriptors are characterised by an **Input Type** (e.g., number, text, range, select), to enable data collection. Some Input Types may feature a predefined set of **Input Options**. Dropdowns, sliders, and other kinds of predefined input sets are tailored as usual to reduce ambiguity and enhance the precision of data entry, directly addressing the complexity of sensory data translation. Sample Category,

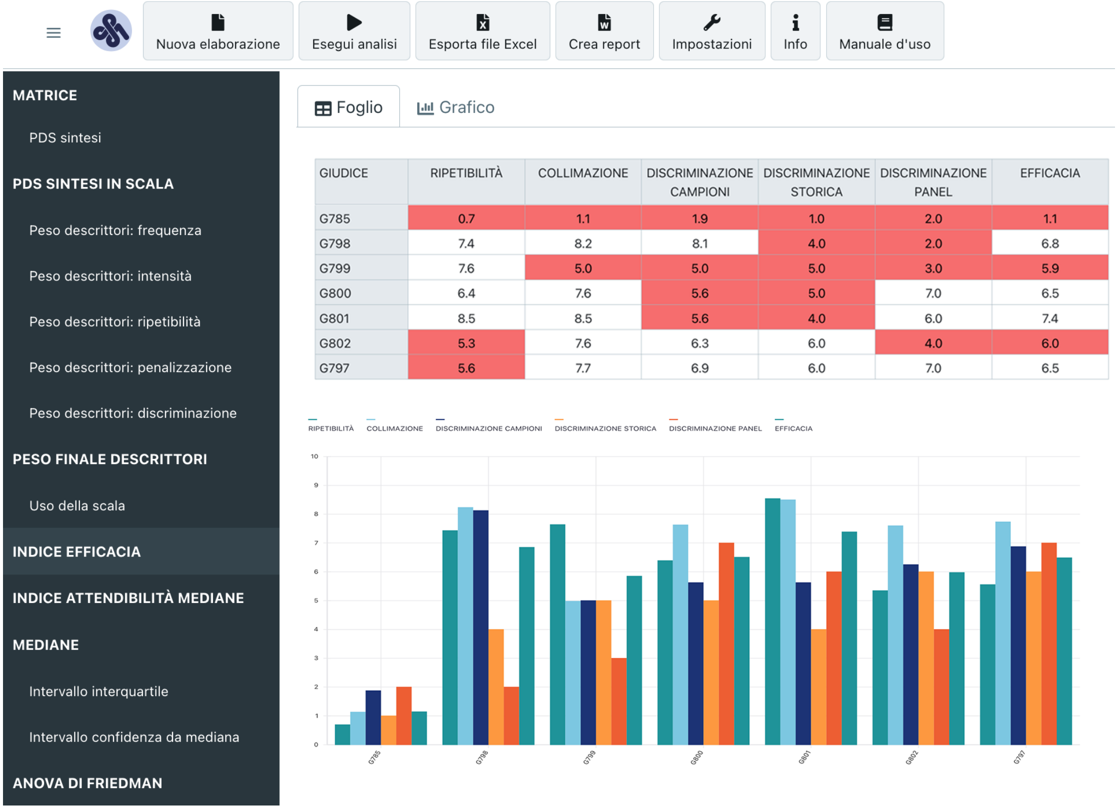

Figure 3: Sensory analysis result for tasters (tasters) evaluation.

Method and Descriptors composes the **Panel Configurations**. These configurations are crucial for loading the appropriate descriptors for the selected sample category.

After establishing the panel, the **Tasters** start the **Panel Session**. During the panel session, tasters evaluate one or more food samples. Each sample is associated with an **Evaluation Sheet**, that contains the **Assigned Values** of descriptors for the assessment. Using the ISS, tasters assign ratings to each descriptor of samples, allowing the Panel Leader to monitor the panel progress. The Panel Leader also plays an important role in sustaining the tasters' engagement throughout the session.

Once the panel has been completed, the Panel Leader exports the collected evaluations for further analysis. The analysis is aimed at preparing a **Conformity Profile** for a Sample Category. Conformity Profile ensures that the product meets specific criteria established by regulatory bodies, industry standards, or internal benchmarks. Such criteria are expressed as expected ranges of values for each descriptor. For example, in order to assure quality of the tasted chocolate, the flower aroma descriptor range should be from 6 to 8.

4. Sensory Data Analysis

Sensory analysis experts leverage the Big Sensory Software (BSS), a sophisticated web-based tool, for statistical analysis of product evaluations collected by the Panel Leader. The involved statistical techniques are tailored to handle the inherent variability and subjectivity of sensory perception. For example, the analysis of variance (ANOVA) is used for identifying significant differences between sample groups. The use of statistical techniques serves a specific purpose in analysing different aspects of sensory data, ranging from detecting differences in mean ratings to assessing the reliability and effectiveness of sensory descriptors. The BSS is designed with the overarching aim of enhancing the quality certification of each product through comprehensive sensory analysis, encompassing data collected throughout the entire product lifecycle—from production to distribution. This data, typically gathered via sensors, offers a basis for correlating product quality levels identified through sensory analysis, thereby informing potential improvements within the food production chain. As depicted in Figure 3, the BSS features an intuitive Graphical User Interface (GUI), empowered with a statistical engine, completed with an extensive array of indices for assessing the significance of panel results. This interface allows experts to meticulously examine the quality of the product and validate the accuracy of tasters' evaluations using various analytical techniques. For instance, majority-based techniques can identify and possibly exclude evaluations from less skilled tasters, ensuring the reliability of the analysis. Such a measure is crucial when tasters may not meet the requisite quality standards for reliability due to factors like distraction or fatigue, thereby mitigating the risk of compromising the analysis with unreliable data.

The BSS GUI offers diverse methods for visualising the results of sensory analysis, ranging from tables to charts, thus providing a comprehensive view of the data at hand. Moreover, it enables experts to compile and export detailed reports, encapsulating all findings from the sensory analysis. This functionality not only facilitates a deeper understanding of the product sensory attributes, but also supports informed decision-making regarding quality assurance and product development.

5. Tools Architecture and Implementation

Figure 4 presents the architecture of the Sensory Analysis Tools. This project has been designed as a microservices architecture to ensure modularity and scalability. The system uses two databases: a MySQL database for storing relational data, including Sensory Panel and configuration data, and a MongoDB database for holding all the collected through panel sessions.

On top of these databases, a suite of micro-services operates, each one belonging to different components of the tool suite. Among the ISS Services, the Panel Service is invoked to manage sensory panels. This service closely interacts with the Taster Service and the Sample Service, which are responsible for managing tasters and samples, respectively. Additionally, the Collection Data Service generates evaluation forms and compiles evaluation data to be saved on the MongoDB database.

Conversely, the BSS Services include the Sample Evaluation Service, which is in charge of starting the sensory analysis starting from data collected through ISS services. The Sensory

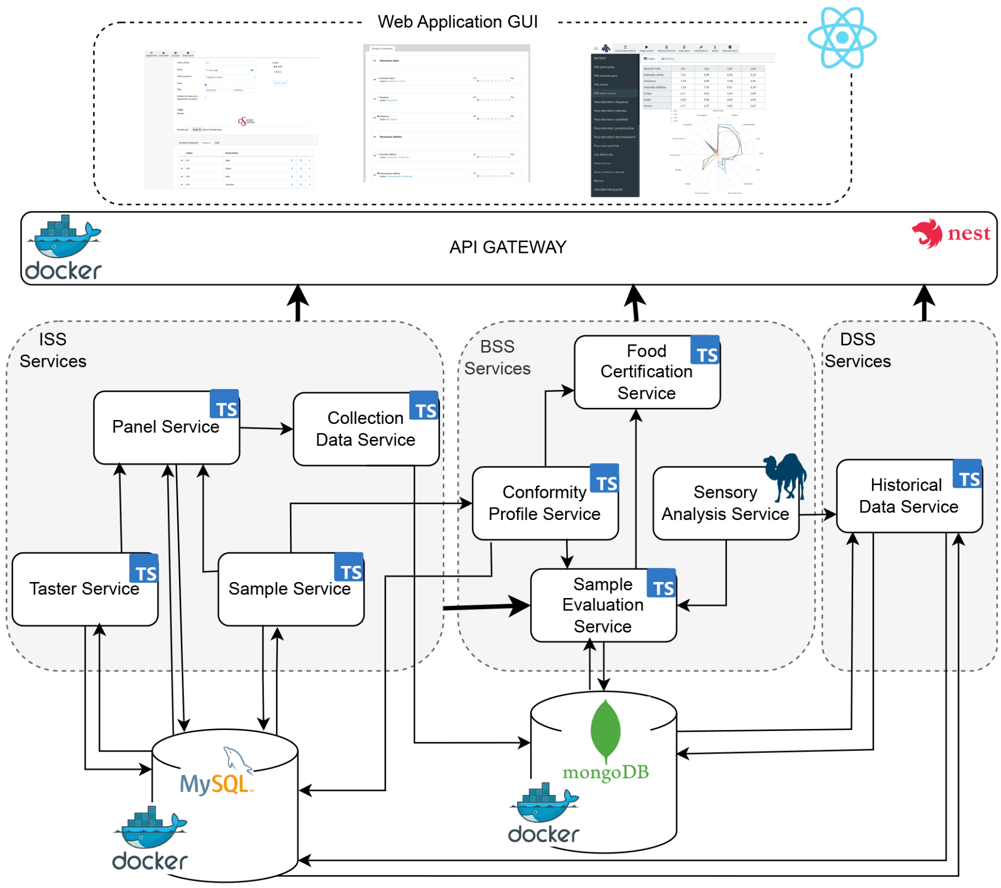

Figure 4: Sensory Analysis Tools architecture

Analysis Service is invoked to produce analysis results, and uses the Conformity Profile Service, which establishes product profiles for evaluating results and generating certifications through the Food Certification Service.

Finally, the Data Sensory Software (DSS) is in charge of managing and navigating the historical data, thought the Historical Data Service.

All the tools [1], namely ISS, BSS and DSS, have been developed in a modular way. The GUI is crafted with ReactJS, while the server-side logic employs NodeJS with TypeScript. The Sensory Analysis Service, derived from a legacy and standalone implementation of the statistical methods, was available in Perl and integrated in the overall tool suite. To booster the efficiency, reliability, and scalability of the server-side applications, the NestJs framework has been integrated. A unified API Gateway sits atop the micro-services, although the architecture permits the creation of multiple gateways for different deployment strategies.

For web application integration and management within a single development environment, the NX build system has been used. Considering the variety of technologies involved and to

[1]Tools Demo: https://youtu.be/03Mr3uXA5kg

streamline the release process of the integrated web applications, Docker containers have been adopted. The current setup comprises three Docker containers: one for each database and another deploying the APIs.

6. Related Work

Transitioning from paper to digital sensory analysis tools has been a pivotal advancement, addressing inefficiencies and enhancing data management. Platforms like Compusense, RedJade, Fizz Software, SIMS 2000, and EyeQuestion have significantly contributed to this field by offering advanced functionalities for sensory evaluation and are widely used in the field [4, 5, 6, 7, 8, 9, 10]. Moreover, the introduction of the BioSensory app, which records participants' biometric responses, represents an innovation in incorporating biometrics into sensory analysis [11]. Despite such progresses, the high costs and limited remote analysis capabilities of these tools present barriers, indicating a need for more accessible and functional solutions. Traditional tools, while capable in their own rights, often fall short in facilitating effective remote sessions. In contrast, the proposed tools suite is specifically designed to support remote analysis, incorporating features that ensure participant engagement and the integrity of data collected in such settings. This adaptability positions the suite as particularly relevant in the current global context.

The adaptation of digital tools like Zoom and Google Forms for remote sensory sessions during the pandemic demonstrates the field resilience and flexibility [12]. However, these general-purpose tools lack the specialised features necessary for detailed sensory analysis. The proposed tools suite fills this critical gap, offering both the flexibility required for remote analysis and the analytical depth needed for comprehensive sensory evaluations.

In conclusion, while the foundational work of existing sensory analysis software has significantly contributed to the field, our tools aim to build upon this foundation by addressing the critical needs of cost, data integrity, and remote analysis capability.

7. Concluding remarks

In this paper, we discussed an integrated tools suite designed to implement food quality assessment through the lens of sensory analysis. Our approach provides a novel contribution to the emerging field of Agri-Food 4.0, setting the stage for a future, where food certification is strictly linked with comprehensive big data collected throughout the food production cycle. As the tools suite is operative in test mode at the moment, current work is focused on conducting thorough evaluations of users' experience, including among users experts of sensory analysis, panel leaders and professional tasters. Moreover, we recognise the potential of blockchain technology in fostering transparency, immutability, and trust among all participants in the food quality assurance ecosystem. Therefore, our future work will explore the integration of blockchain technology to safeguard the integrity of data exchanged across the food supply chain. In this scenario, the proposed tool suite can interact directly with the blockchain. By doing so, we aim at establishing a new benchmark for data quality and security in food quality assessment, paving the way for more informed decision-making and consumers' confidence.

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