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Behind the scenes of taste: an exploratory study of non-compliance in Italian artisanal bakery and pastry laboratories

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Abstract
This study aimed to identify critical issues in artisanal bakery and pastry production in Italy that could improve food safety and quality. Fifteen voluntary Italian companies underwent on-site inspections and interviews from 2018 to 2021. The inspection concerned the production site characteristics, processing flows, materials, and personnel to pinpoint potential product contamination and record objective data collection through a 126-question demerit scoring system. The examined areas encompassed various aspects, such as the point of sale, management of raw materials and packaging, hygiene practices, finished product quality, sanitization procedures, external spaces, personnel, and other factors impacting food safety and hygiene. Additionally, assessments of the microbiological air quality were carried out. Two cohorts (six and nine companies in 2018-2019 and in 2020-2021, respectively) revealed critical issues in warehouse/packaging (70% non-compliance), finished product/cooling (50%), and people/products flow (38%). Site visits identified pest management and raw material handling challenges. Significant airborne mold and yeast contamination (30-50 colony-forming units/plate/h) was observed in areas near processing sites or with air turbulence. This study facilitated constructive discussions and proposed solutions with the participating companies.

Introduction
In Italy, artisan bakeries and pastry shops (Italian Republic, 1985 - Law 443/85), in addition to producing bread and desserts, also offer an assortment of savory products, such as sandwiches and pizzas, often filled with sauces, vegetables, *etc*.
Additionally, many of these businesses extend their range of services to include beverages, coffee, and bar services, showcasing a broad spectrum of offerings to their customers. These businesses operate locally and represent an essential sector in the production of typical Italian gastronomic products (*e.g*., Christmas sweets like *Panettone* and other traditional cakes), with an estimated 31,000 retail outlets offering integrated and varied services (Businesscoot, 2023).
Italian artisanal companies have a very low number of employees and carry out part of their activities manually (Italian Republic, 1985). In Italy, bread takes the lead in bakeries, constituting 70% of artisanal production, followed by other savory bakery products (such as pizza) at 23.5%, whereas sweets account for less than 10% of the overall production. Nevertheless, there is an ongoing shift away from traditional bread and baked goods sales towards diversification. This involves not only a broader range of raw materials, with an increased variety of flours but also a varied product offering. These products reflect considerations related to dietary preferences, with a focus on healthier options, as well as factors such as seasonality and offerings with enhanced added value (Businesscoot, 2023). These marketing-related factors and new consumer trends lead to the introduction and development of new bakery or pastry products characterized by hygienic-sanitary risks that are often different from customary ones. Based on technological aspects related to shelf life, quality, and potential hygienic-sanitary aspects, bakery and pastry products are classified based on their intrinsic characteristics such as pH, water activity (a_w), and percentage moisture content (Smith *et al*., 2004). Based on the a_w value, bakery products can be classified as low moisture (<0.6), intermediate moisture (0.6-0.85), and high moisture (>0.85, generally between 0.95 and 0.99). Although the chemical and physical alteration of baked leavened products is crucial in many baked goods, microbial deterioration (*e.g*., mold and yeasts) is often the major limiting factor for shelf life. Especially products considered to have a medium and high level of a_w are the most susceptible to microbial proliferation (Smith *et al*., 2004). The influence of a_w levels on microbial alterations holds substantial importance. Specifically, in products characterized by a_w surpassing 0.9, exemplified by bread or items containing various fillings, there is a discernible prevalence of the primary development of spoilage bacteria and pathogens. In the context of pH classification, bakery products exhibit distinctions based on acidity levels: those with a pH <4.5 are categorized as acidic, low-acid products fall within the pH range between 4.6 and 7, and products designated as non-acidic/alkaline have a pH exceeding 7. This is affected by added ingredients of both animal and vegetable origin (*e.g*., dairy, egg creams, fruit). In general, baking conditions, intrinsic factors such as acidic pH, and storage methods in cake or

intermediate product production can limit the proliferation of potential pathogens (Smith *et al*., 2004). However, instances of cross-contamination, incorrect handling by staff, and initial contamination of ingredients (milk products, wheat, spices, or dehydrated eggs) by spore-forming bacteria have led to cases of foodborne illness following the consumption of such products induced by various agents such as *Bacillus cereus* and non-spore-forming bacteria such as *Staphylococcus aureus* and *Salmonella* (Smith *et al.,* 2004). In addition to potential biological hazards, bakeries and pastry shops increasingly must deal with a diversification of products and activities, as well as numerous other hygienic-sanitary issues such as allergen management, and they are subject to productive management stresses, especially in certain periods of the year such as special occasions like Easter or Christmas. Depending on the different products, the diversification of services that can involve a lot of handling, and the presence of perishable ingredients, the artisanal business could be characterized by a different level of risk (Newbold *et al*., 2008).

Similar to other segments of the food industry, bakeries and pastry labs should proactively mitigate hazards through the implementation of a range of fundamental hygienic management systems, including prerequisite programs (PRPs) and good manufacturing practices (GMP) (Özçakmak, 2019). As outlined in the scope of the European Commission (2004), the food business operator (FBO) is tasked with the responsibility of reinforcing the application of good hygiene practices. A comprehensive understanding of these prerequisites forms the basis for the maintenance, evaluation, and implementation of the HACCP system. Furthermore, various aspects such as the design evaluation of processes, structural criteria for buildings, and surface hygiene falling under PRPs should be well-defined, even in bakery and pastry laboratories (Özçakmak, 2019). Bakeries prioritize the production of top-tier bread, emphasizing the need to meticulously manage incoming raw materials, semi-finished products, and the final output. The excellence of bread is determined by a myriad of characteristics that not only influence the sensory aspects for consumers but also play a crucial role in ensuring the overall safety of the food products for human consumption (Bukhovets *et al*., 2022).

A more conscientious management of the entire production system can impact not only specific productions (*e.g*., traditional leavened sweet products) but also all other production lines (bakery, pastry, savory production, chocolate, *etc*.) that may present numerous and complex issues often underestimated by FBOs. Artisanal companies are inherently heterogeneous and diversified; hence, it is crucial to consider these diversities (Businesscoot, 2023). Moreover, few studies focus on identifying useful descriptors to pinpoint deficiencies and implementing proactive measures in the management of bakeries and pastry laboratories (Garcia *et al*., 2019; Özçakmak, 2019). Hence, the primary objective of this exploratory study was to identify vulnerabilities in hygienic-sanitary management that might jeopardize the safety of bakery and pastry productions in micro- and small-artisanal businesses. Subsequently, the study aimed to articulate the foundational principles of food safety knowledge and their practical application, laying the groundwork for fostering a culture of food safety in these sectors.

Materials and Methods

Recruitment of companies and survey planning

Two discrete cohorts of companies were included in the study, with a total of six companies recruited during the 2018-2019 period and nine companies recruited during the 2020-2021 period. The companies in question demonstrated voluntary participation, with each cohort convened for an introductory meeting to elucidate the investigative objectives. The scheduling and modalities pertaining to company entry were established through telephonic deliberations. The selection of the 15 companies, amounting to 4.3% of analogous enterprises in the Vicenza province (Italy), was predicated on predefined criteria encompassing size (micro and small) and production specialization, delineated as either predominantly pastry or predominantly bakery establishments (all actively engaged in the production of celebratory baked goods), each with a corresponding retail point. Some more structured entities also engaged in international products trade. To underscore hygiene and

safety concerns, the survey was strategically scheduled for both cohorts during the pre-Christmas period, commencing in November. This decision is tied to the heightened production of celebratory products, such as *Panettone* and various pastry items, necessitating increased dedication to work activities and occasionally the hiring of seasonal personnel. Each site visit lasted approximately 2 hours during the peak morning activity and involved the use of a checklist questionnaire paired with an interview with the production managers/FBOs of the laboratories (face-to-face approach) (Özçakmak, 2019). After each visit, there was a feedback session detailing the main observations and highlighting the primary non-compliances. Additionally, two concluding meetings took place, including a comprehensive definition of critical issues for each company and a specific training session for each FBO, in which customized solutions were also provided to resolve critical issues (*e.g*., layout of the production area).

Structure of the checklist questionnaire and basis of interviews with food business operators

Data collection was standardized through an assessment questionnaire featuring a demerit scoring system (126 questions), tailored to specific criteria for leavened product manufacturing activities. The adopted checklist questionnaire was modified and adapted by consulting various documents, such as guidelines and online checklists (MCP, 1998; Regione Lombardia, 2007; Regione Campania, 2011). Some more specific criteria were introduced concerning bakeries and pastry shops, for instance, those related to storage and use of flours or the assessment of unique production lines (*e.g*. chocolate-making; dish production). The serving phase was not analyzed, only focusing on aspects related to the retail space.

Scores were assigned based on a demerit criterion: higher scores in certain sections or individual questions imply less control over hazards and issues, hence a higher risk of product contamination due to structural problems, flow management, *etc*.

The following production areas/aspects of hygiene management were analyzed (with the respective maximum demerit scores in brackets) in *Supplementary Material*: point of sale (score ≥60); raw material management (score 169); people/production flows (score 296); packaging management (score 21); hygiene management (score 159); finished product management (score 54); sanitization and external spaces management (score 49); changing room (score 54); personnel hygiene and behavior (score 49); toilets (score 106); special cases (*e.g.*, wood-fired oven management, not included in scoring). For each production aspect, two thresholds (threshold 1: low; threshold 2: high) were set at the first and second tertiles of the maximum demerit score assignable.

Monitoring the microbiological air quality

The method employed was a passive approach for the sedimentation of airborne contamination. The air microbial index (AMI) is based on the degree of microbiological pollution from airborne fungi, expressed as the number of colony-forming units (CFUs) counted on each 9 cm diameter Petri dish. These dishes contain selective agar for molds and yeasts (oxytetracycline glucose agar, Oxoid Ltd., Basingstoke, Hampshire, England) and are left open in the environment for one hour, positioned one meter above the ground and one meter from any relevant physical obstacles (INAIL, 2010). A minimum of 10 plates were used for each site designated for the storage/cooling of the finished product. The analysis was conducted during the production of a day's worth of *Panettone*, following a one-hour cooling period after baking.

Results and Discussion

Figure 1 depicts the total number of non-compliant companies from both cohorts identified during the survey. A company was deemed non-compliant if it exceeded at least the initially proposed threshold (threshold 1; low) for a specific descriptor considered in the survey (production areas and aspects of hygiene management). Specifically, the areas exhibiting the most pronounced issues were warehouse and packaging management (observed as non-compliant in 70% of the companies), finished product and cooling management (50%), and people/production flow management (38%).

Olmedo *et al.* (2018) categorized possible non-conformities (NCs) in the sanitary inspection of food service establishments into six groups: physical structure; hygienic and sanitary conditions; control of pests, vectors, and rodents; food handlers; work processes and procedures; and others. According to the sanitary inspection of bakeries and pastry shops with in-house production (Olmedo *et al*., 2018), 77.4% of the companies highlighted NCs. Among these, 16.4% of irregularities were related to the behaviors and training of food handlers, followed by hygienic conditions of facilities, equipment, furniture, and utensils (13%), production flow, and other factors related to physical structure (11%). In contrast to findings reported in other countries (Olmedo *et al*., 2018; Ozcakam, 2019), issues pertaining to food handlers' previous training and knowledge were not investigated in the current survey. However, according to interviews with the FBOs, all laboratory teams conducted periodic training on safety management as reported in the questionnaire (*Supplementary Material* - Personnel hygiene and behavior).

Only in a few investigated companies (15%) did personnel hygiene and hygiene management NCs exceed threshold 1 (Figure 1). However, some NCs were discovered in most artisanal laboratories, such as the lack of use of protective equipment (absence of headgear), improper handling of ingredients like eggs with the potential for cross-contamination, the cooling of prepared meals (*e.g.*, *meat lasagna*) at room temperature without any protection or cover, and certain aspects related to the use of ingredients.

Garcia *et al*. (2019) assessed the adherence of bakeries to GMP, emphasizing a high level of application in hygiene practices (75% compliance with GMP). In accordance with their findings, it is imperative to exercise control over various factors to mitigate the risk of contamination in bakery products. These factors encompass the upkeep of buildings, installations, equipment, furniture, and utensils; the implementation of rigorous sanitation protocols for facilities, equipment, furniture, and utensils; vigilant oversight of food handlers; and meticulous monitoring of the exposure of prepared food. Based on these considerations, the most significant sources of contamination, as revealed by the checklist questionnaires and on-site evaluations of the studied Italian companies, are primarily associated with buildings, warehouse management, and, in certain cases, the exposure of prepared food.

One of the most critical factors observed was the lack of specific compartments for the production flow, together with packaging material and finished product management (Figure 2). Very few artisanal laboratories are aware of the importance of designing and maintaining a proper production flow to avoid the possibility of cross-contamination events. Additionally, in several cases, different food handlers are engaged in different production steps, while some individuals not included in the personnel have access to the laboratories. These findings are linked to the small size of the companies, the limitations on space availability (*e.g.*, being located in the town center in historical buildings), and the attitude of food handlers. However, as defined by Ozcakam (2019), a poorly defined flow chart of activities may lead to some insufficiencies in the evaluation of hazards and risk analysis, particularly in bakery companies, where cross-contamination, such as the presence of allergens, could be underestimated.

The most significant NC identified in the present orientative study is associated with warehouse management, particularly in connection with packaging management (Figure 2A), where one-third of the examined laboratories exceed threshold 2, with a higher number of NCs reported. The most observed issues include the mixing of raw materials or semi-finished products with packaging materials, packaging materials being dusty, the presence of foreign materials in the warehouse, or the outdated state of facilities with peeling and mold on the ceilings, or the presence of damp areas and water stagnation in the warehouse. The use of non-washable and non-sanitizable materials for surfaces and walls was also noted in a specific case (*e.g.*, polystyrene). Surface-related issues have been identified in prior investigations, as highlighted by Ozcakam (2019).

Interestingly, one of the criticisms highlighted pertains to the management of finished products (Figure 2B). Considering the cooling procedures applied to the production of large-leavened baked goods and traditional celebratory bread and pastry items (*e.g.*, *Panettone*, *Pandoro*), in most

laboratories, there was no specific room designated for the cooling and packaging of finished products. Many packaging areas are situated very close to the production rooms, and, in some instances, there was the possibility of contamination due to the inadequate environment for this production stage. Ozcakam (2019) emphasized the importance of cooling procedures and the hygiene involved in this process for bakery products to prevent and reduce hazards, considering it a critical control point. These assessments should also be coupled with an evaluation of the microbial quality of the air in contact with the final products. To simulate the fallout and contamination by airborne fungi (mold and yeasts), the AMI was evaluated at each site dedicated to product cooling and storage. In Figure 3, the box plot of contamination levels in CFU per plate per hour of sedimentation is depicted. In 30% of the laboratories, the observed level falls within the range of 30 to 50 CFU/plate/h. The Italian limit values for AMI in environments with medium risk, such as food industries, are reported as 50 CFU (INAIL, 2010). However, these values are related to the total mesophilic count and not to molds and yeasts. It is important to stress the potential presence of toxigenic fungi such as *A. flavus, A. niger,* and *A. ochraceus*, which were isolated as contaminants in the air in bakery plants (Cornea *et al*., 2011). In this case, molds and yeasts can have significant hygienic importance not only because they can alter bakery and pastry products but also because some species, such as *Aspergillus, Alternaria,* or *Penicillium* can induce allergic diseases (INAIL, 2010).

In a specific case from the interview, the issue of flour allergy emerged. In this company, the presence of flour on equipment and floors, the dusting of flour for dough preparation, and the management of its usage contributed to significant environmental contamination. The use of appropriate devices, such as masks, can help reduce certain risks of exposure. In this investigation, the corridors, cooling areas, and bakery laboratories of the companies represent the places most involved in airborne contamination. This outcome can be attributed to several factors, including turbulence resulting from personnel movement, the circulation of hot and cold air leading to convective currents, or other air movements in zones like the cooling area or the bakery laboratory. Flour and residual production materials, along with dust, are prominent vectors of airborne contamination. Consequently, the air in distinct sections of a bakery facility exhibits differing levels of mold contamination. Fermentation rooms usually have the lowest levels of contamination, while areas where leavened dough is worked, sliced, and packaged typically have the highest mold contamination levels (Cornea *et al*., 2011). In some cases, cooling was done after processing and, therefore, did not overlap temporally with the company's production lines, reducing turbulence and airborne contamination.

Certain aspects of GMP could be correlated with fungal air contamination (*e.g*., the state of the building); however, many different aspects should be taken under control to reduce this problem, which can affect the safety and shelf life of bakery products. Other aspects are related to ventilation efficiency and management. Moreover, the quality of raw materials, especially flours, could have a significant influence on the load of fungal spores dispersed in the processing air (Garcia *et al*., 2019).

The questionnaires also revealed various NCs in pest management, affecting 40% of the companies. Rodents (29% of NCs), cockroaches (14% of NCs), and flying insects (57% of NCs) were identified both as cadavers and in traces (*e.g.*, cockroach feces). NCs mainly involved the placement and types of traps used, along with a non-systematic approach to pest management in some instances.

The on-site inspections and analyses conducted provided insights into the unique characteristics of each producer, while also enabling the development of a methodological approach to assess the hygienic conditions of these establishments. The findings revealed that significant differences in approaches to production systems and hygiene were more related to distinct production types than to company sizes. Three predominant categories were identified: i) bakeries specializing in leavened sweet products for special occasions; ii) pastry shops; and iii) companies producing a variety of leavened products, pastries, and other food items.

Companies inherently involved in the production of perishable and high-risk products typically implement principles and precautions across all production lines. In contrast, in productions primarily focused on leavened/bakery products, certain managerial/structural aspects seem to have less

stringent control. Several aspects related to NCs (Figure 1) were pervasive, shared, and impactful across many companies, including issues with flow, packaging, and finished product management. Several NCs, though not prominent, require effective solutions and attention, including pest management, warehouse operations (both for raw materials and packaging), and, to a certain extent, staff training. When necessary, the reorganization of spaces (*e.g.*, the introduction of hygienic barriers) and workflows, the implementation of traceability forms, or an accurate shelf life evaluation have been suggested.

It is crucial to offer straightforward, readily available tools for individuals working seasonally or occasionally, ensuring they receive proper training comparable to that of regular staff. Basic knowledge regarding food perishability, shelf life, and allergen presence should also be integrated into the training of sales personnel. According to the interviews and sessions explaining the identified NCs to the FBOs, a keen focus on product quality and a reduced perception of hygienic-sanitary risks associated with the products themselves emerge. According to various hygiene standards and regulations, bakeries and patisseries are classified as high-risk food services (Olmedo *et al*., 2019; FSANZ,–2023). FBOs in these establishments are involved in high-risk food handling activities, dealing with unpackaged, potentially hazardous food served as ready-to-eat meals. FBOs must adhere to specific food safety measures, including supervision, handler training, and documentation of safety controls. These protocols are essential for mitigating risks and preventing foodborne illnesses, aligning with established hygiene standards and regulations. (FSANZ, 2023).

The identified issues are often related to limited space availability and the organization of flows, often requiring reorganization, especially during peak activity. It appears that the fundamentals of food safety knowledge are shared and known among food handlers, and the understanding and knowledge of hazards are clear. However, awareness, resignation, and habituation to the presence of issues without posing solutions are aspects to consider in the context of spreading the food safety culture.

The observed situations and identified NCs have been used to develop an easy-to-use document (*vademecum*) that helps FBOs assess food safety management within their company. The *vademecum* analyzes the warehouse, processing area, packaging and storage, and shop, stimulating reflection on how the hygiene requirements established by current regulations are applied, integrating other existing training tools.

Conclusions

The study facilitated meaningful discussions with the participating companies and the exploration of potential solutions to address the identified issues. The highlighted NCs provided insights into bakery and pastry artisanal productions, which represent a vital traditional system in Italy. All the companies implemented prerequisite practices, demonstrating their commitment to food safety through continuous training of food handlers. The results suggest a personalized approach to resolving NCs and implementing aspects related to the dissemination of food safety culture. Based on these findings, a *vademecum* for the sector has been developed, encompassing valuable recommendations for the hygienic-sanitary management of production systems.

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Online supplementary material:

Supplementary Material. Summary of the checklist questionnaire for artisanal bakery and pastry laboratories.

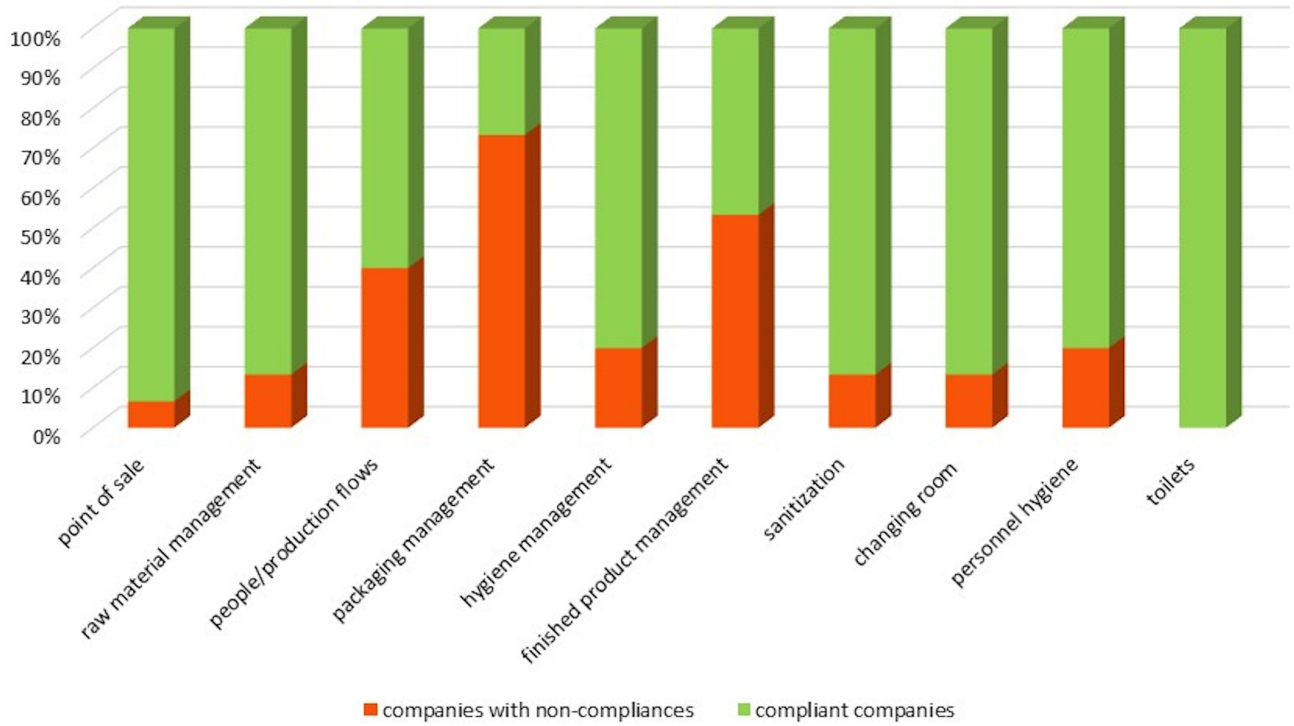

Figure 1. Results of the survey for both cohorts of companies (2019 and 2021). For each production area and aspect of hygiene management, the percentage of companies surpassing at least the threshold of the first tertile was summarized (threshold 1; low).

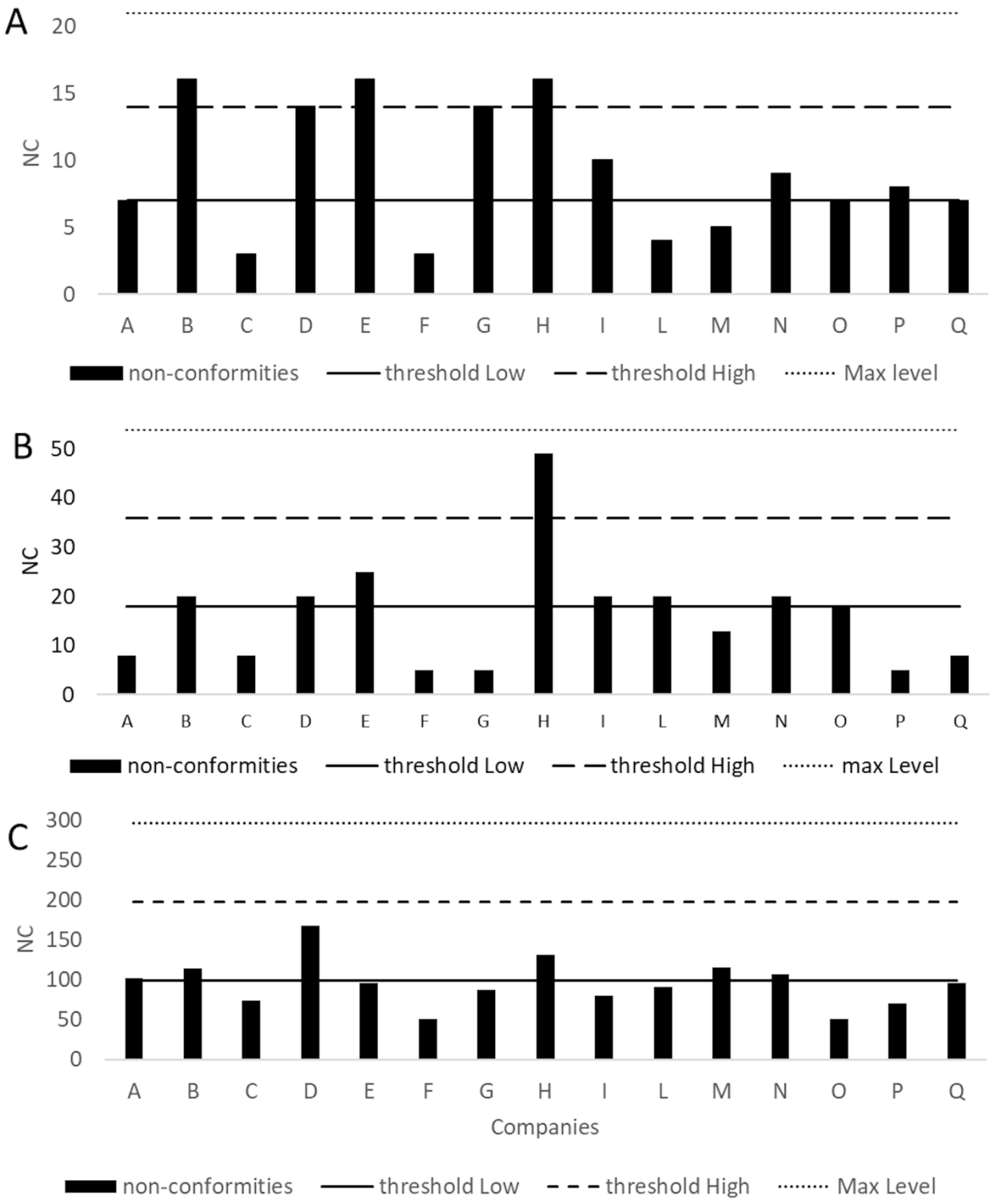

Figure 2. The figures represent the total number of non-conformities (NCs) per company in the management sectors that involve the highest number of artisanal labs. A) Packaging management and warehouse; B) finished product management and cooling; C) flows of materials and personnel. NCs are presented as demerit scores where threshold 1: low and threshold 2: high represent the first and second tertile of the total possible NCs (maximum level) for each section of the questionnaire.

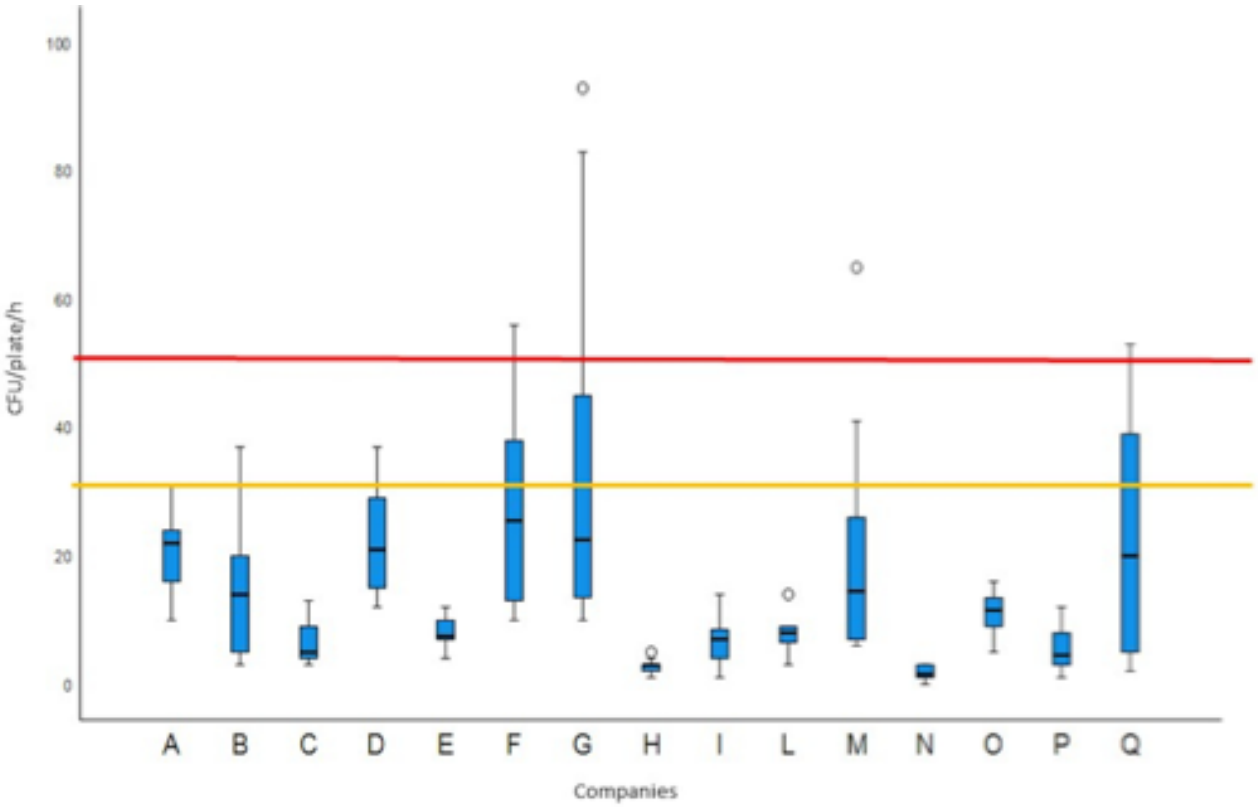

Figure 3. Box-plot of the air microbial index in various artisanal laboratories. The orange and red lines highlight contamination levels ranging from 30 to 50 colony-forming units(CFU)/plate/h.