14 Industrial Quality Control

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14.1 Introduction

During the last two decades the term "quality" has become one of the most stressed words in the field of food and food production. The facts behind this are, on the one hand, the traditionally different meanings of the word "quality" and, on the other hand, the advanced importance of quality and quality management systems as tools for an economical and safe production of food. "Quality" originates from the Latin language meaning as much as "property" or "characteristic". In relation to food it originally was used as a synonym for "freshness" and "unspoilt".

From antiquity up to now, many philosophers, scientists and economists have tackled with the sense and the meaning of the term "quality", leading to numerous quality models, for example metaphysical, product management, economical, ecological and cognitive approaches. To get an overview of the major quality models, see [1].

In the book *Flavor Science—Sensible Principles and Techniques*, Acree and Teranishi [2] distinguished two different meanings of the word "quality". One meaning is that of an attribute, for example sweet, bitter or floral. The second meaning depends on whether someone likes these attributes, by which quality relates to acceptance and the question how people interact with it.

14.2 Quality and Quality Management Systems

According to the International Organisation for Standardisation (ISO) "quality" is the entirety of attributes and characteristics of a product or a service which are necessary to fulfil its defined or assumed requirements. As already indicated, quality can be seen to be more or less comprehensive, for which reason many organisations define or describe their commitment to quality in a so-called *quality policy* statement. A quality policy typically is based on three fundamental principles:

1. Ensuring that the customer's needs are identified and that these are conformed.
2. Examination of all production and service processes in order to identify the potential for errors and to take necessary actions to eliminate them.
3. Ensuring that each employee understands how to do his/her job and is doing it right.

In order to implement the quality policy in the daily work, quality management systems are installed, covering quality planning, quality control, quality assurance and quality improvement. To ensure that the quality assurance system is in place and effective, external standards are used, for example the DIN EN ISO 9000 ff. standard system, commonly shortened to ISO 9000 (DIN is an acronym for *Deutsches Institut für Normung*, meaning "German Industry Standard").

The best known international quality management standard seems to be the so-called DIN EN ISO 9001 ff. standard. ISO standards are agreements developed by technical committees. Since the members of these committees come from many countries, ISO standards tend to have very broad support. Conformance to that is said to guarantee that a company provides quality services and products. This standard was amended in 2000, so the current standard is called DIN EN ISO 9000:2000.

The most important steps to follow the ISO 9000 standard are:

- Deciding quality assurance policies and objectives
- Formally writing down the company's policies and requirements and how the staff can implement the quality assurance system
- Implementation of the quality assurance system
- Examination of the quality assurance system by an outside assessor to see whether it complies with the ISO standard
- Describing the parts of the standard the company is missing and correction of any problem
- Certification that the company is in conformance with the standard

Beside the ISO standards there are some other standards which are set up by different organisations and sometimes it is really a problem to fulfil the requirements of the different partners in the food market. Not least because of this situation it is not possible here to go in more details. For further information on quality systems and quality management systems see the specific standards as well as the respective literature.

Very special quality demands and quality systems are those for the production and certification of kosher and halal products, which at the time are gaining in importance all over the world. Kashrut is the body of Jewish law dealing with what foods Jews can and cannot eat and how those foods must be prepared. "Kashrut" originates from the Hebrew and means "fit", "proper" or "correct". The more commonly known word "kosher" comes from the same roots and refers to foodstuffs that meet these dietary requirements of Jewish law. "Halal" is an

Arabic word meaning "lawful" or "permitted", and eating halal is obligatory for every Muslim. The opposite of "halal" is *haram*, which means "prohibited". Whether a company fulfils the requirements for a kosher or halal production or not can be examined and certificated by specially qualified people or organisations. For further information, see the recently published books concerning kosher [3] and halal [4] production.

14.3 Quality Control

In the frame of a quality management system, quality control is defined as a set of activities or techniques whose purpose is to ensure that all quality requirements are being met. Every raw material used, all intermediate products as well as all flavours and flavouring products which are delivered to the customers have to be controlled by appropriate physicochemical, biotechnological (e.g. enzymic or immunologic procedures), sensory or if necessary microbiological methods. The quality control of flavourings as well as their raw materials is a highly complex field and quality control laboratories in the flavour industry may have more than 500 defined analytical procedures [5].

A prerequisite for any quality control is the definition of how the characteristics of a specific raw material, an intermediate product or a final product of a manufacturing process should be described. This means that all characteristics for every single product have to be defined in adequate standards and specifications so that the results obtained can be compared with these data. Numerous standards and specifications have been established in more or less official specification collections, for example pharmacopoeias, the aforementioned ISO or DIN standards, standards of the Essential Oil Association or the American Spice Trade Organization (ASTA).

According to [6], the main objectives of the quality control in the flavour industry concern the following items:

- *Identity*: Does the raw material delivered or the manufactured product correspond with the order?
- *Purity*: Are the raw materials or the manufactured product free from unacceptable impurities, e.g. filth?
- *Contamination*: Is there contamination, e.g. heavy metals, pesticides, aflatoxins, microorganisms?
- *Adulterations*: Are the raw materials free from adulterations?
- *Quantitatively limited substances*: Are legal regulations concerning limited amounts of specific substances observed?
- *Spoilage*: Ageing and unsuitable storage conditions can lead to quality changes of raw materials or products up to the complete spoilage of the product.
- *Authenticity*: Conformity of the declared and real origin of a raw material. Are materials which are declared as "natural" really natural and not synthetic?

The extensive quality control tests of raw materials, intermediate and final products represent a flood of data which have to be evaluated and documented according to the different aims of the quality control system. Considering the fact, that quality control often has to work under deadline pressure this work can only be done by using powerful electronic labour information and management systems (LIMS).

14.4 Physicochemical Methods

Supported by the overall development in all fields of analysis during the past few decades, a precise analytical methodology has been developed for the different aspects of quality control, comprising physicochemical, biotechnological, sensory and microbiological methods. In order to meet the sense of the quality control system and by that the customers requirements, all methods applied have to be validated by adequate quality assurance tools.

In the frame of this short review it is not even possible to discuss only the major methods and techniques used in industrial quality control in detail, so they will only be summarised here [5, 7].

For sample preparation, isolation and separation traditional methods like distillation (e.g. essential oil content of raw materials) or Soxhlet extraction are still in use. Beyond that, more recent methods are employed, for example supercritical fluid extraction with liquid carbon dioxide.

Even in modern quality control laboratories you will find a number of traditional methods for the identification of single flavour compounds, for example the estimation of optical rotation, refractive index, density and melting point, since these methods are generally accepted, effective and less time-consuming. Especially for the purpose of fast identification checks of more complex systems, spectroscopic methods, above all infrared (IR) and near-IR spectroscopy, are gaining more and more importance.

Numerous analyses in the quality control of most kinds of samples occurring in the flavour industry are done by different chromatographic procedures, for example gas chromatography (GC), high-pressure liquid chromatography (HPLC) and capillary electrophoresis (CE). Besides the different IR methods mentioned already, further spectroscopic techniques are used, for example nuclear magnetic resonance, ultraviolet spectroscopy, mass spectroscopy (MS) and atomic absorption spectroscopy. In addition, also in quality control modern coupled techniques like GC-MS, GC–Fourier transform IR spectroscopy, HPLC-MS and CE-MS are gaining more and more importance.

14.5 Sensory Evaluation

Over the last few decades scientist have developed sensory testing from the earliest individual examinations into a formalised, structured and codified methodology. Subsequently, sensory tests have become valuable, important and precise tools in quality control, which are equivalent to the physical and chemical methods used. However, sensory testing is not only a tool in quality assurance, but also in grading, product development and marketing, as well as for the correlation between specific chemical/physical properties of a food and the effect on the human sensorial perception.

Besides smell and taste, the sensorial evaluation of raw materials and final products covers trigeminal impressions (e.g. hot) and visual impressions like colour, opacity and particle size.

In order to obtain reproducible results, special care must be given to panel selection and panel education, testing facilities, sample presentation and the design of each test. Modern sensory facilities display a kitchen/laboratory for sample preparation as well as separate sensory booths with controlled air and lighting. The evaluation of the sensory results can be supported by specialised computer software packages.

The most frequently used tests in quality control in the flavour industry are paired-sample comparison tests, and triangle tests, which are often combined with the description of deviation from a reference item. For the selection and training of panellists, further test methods are used, for example ranking tests for colour, taste and odour, threshold detections (taste, off-flavour), colour blindness tests and odour identification tests [6].

14.6 Specific Safety Aspects

Over the last few decades, safety has become one of the most important topics related to food. From this view, quality control of vegetable raw materials has at first to cover the following issues: natural and anthropogenic contaminants (e.g. heavy metals, pollution from industrial and private combustions, not professionally deposited waste products, radionuclides), residues of fertilisers (e.g. nitrate), plant-conditioning and plant-protective agents, filth, pests, the microbial status and the occurrence of microbial toxins. It is not possible to discuss all these aspects in detail; however, with a focus on herbs and spices, two of them should be stressed more thoroughly. For further information, see [8].

As background, it has to be remembered that a large number of our spices are imported from less-developed tropical and subtropical countries which often lack the necessary consistency in the application of a quality-oriented cultivation and adequate processing. The hot, humid climate prevailing in many cultivation countries, the mostly simple, unpretentious production conditions, and the often inadequate instruction of farmers and farm hands give rise to fundamental problems [8].

14.7 Microbial Aspects and Microbiological Methods

The fact that food-borne infections and intoxications increased during the last decade of the twentieth century in several European countries underlines the necessity of microbial investigations of food as well as their additives and ingredients [9]. However, compared with the physicochemical methods, microbiological tests play a less important role in the quality control of the flavour industry. Most of the liquid flavours contain solvents like ethanol, propylene glycol or edible oils in concentrations between 70 and 90% so that they possess bacteriostatic or bactericidal properties. Moreover some of the aroma compounds possess the same properties, so routine microbial investigations are not necessary for many of the raw materials and final products [6]. Microbiologically critical products of the flavour industry are above all emulsified, pasty or dry products as well as the agricultural raw materials of animal and plant origin.

According to [10], for microorganisms each particular type of vegetable provides a unique environment in terms of type, availability and concentration of substrate, buffering capacity, competing microorganisms and perhaps plant antagonists. So it is not surprising that every natural plant material harbours numerous and varied types of microorganisms, among which pathogenic or food-spoiling species like salmonella, staphylococci, bacilli, clostridia, enterohaemorrhagic *Escherichia coli* or moulds may occur. In the case of herbs and spices—one of the important sources for the flavour industry—the number and composition of the microflora is above all influenced by the part of the plant used for spice (leaves, seeds, flowers, etc.) and beyond that by harvesting, post-harvest treatment, the drying process as well as storage and transport conditions. In order to give an idea about the microbial load of herbs and spices Table 14.1 surveys the microbial numbers which can be found on untreated ground spices.

Among the pathogenic microorganisms which might be available, special attention has to be paid to the *Enterobacteriaceae*. A salmonella outbreak in 1993 caused by paprika-powdered potato chips showed the importance of these microorganisms even with spices [12]. Burow and Pudich [13] reported that 5.4% of 317 samples of paprika powder and 10.1% of 139 snack products investigated in 1993 and 1994 were salmonella-positive. The differentiation of the isolated salmonellae revealed a number of seldom-found serotypes, which led to the conclusion that the contamination had its origin in the producing countries.

The evaluation of the aforementioned outbreak seems to be of practical consequence for quality control throughout the food industry. On the basis of the results of this evaluation and on the basis of the knowledge that there are strains of salmonella which owing to the existence of plasmids or prophages are able

Table 14.1 Microbial counts (cfu/g) of untreated ground spices [11]

Spice	Total germ count	Coliforms	Moulds
Allspice	1×10^5–5×10^6	$<10^2$–1×10^3	5×10^2–5×10^4
Anise	2×10^5–2×10^6	$<10^2$–1×10^4	$<10^2$–1×10^3
Basil	2×10^4–4×10^5	$<10^2$	$<10^2$
Caraway	1×10^5–5×10^6	$<10^2$–1×10^3	$<10^2$–1×10^4
Cinnamon	2×10^3–5×10^4	$<10^2$	2×10^2–5×10^3
Cloves	5×10^4–1×10^7	$<10^2$	$<10^2$
Coriander	1×10^3–1×10^7	$<10^2$	$<10^2$–5×10^4
Fennel	5×10^4–1×10^5	$<10^2$	1×10^2
Garlic	5×10^4	$<10^2$–5×10^2	$<10^2$–5×10^2
Ginger	1×10^4–1×10^7	$<10^2$	$<10^2$
Laurel (bay)	1×10^3–5×10^4	$<10^2$	2×10^2–2×10^4
Mace	1×10^4–5×10^4	$<10^2$–1×10^3	1×10^2–5×10^4
Marjoram	2×10^5–1×10^6	5×10^2	5×10^3–5×10^4
Oregano	5×10^3–5×10^4	$<10^2$	5×10^2–5×10^3
Paprika	1×10^5–5×10^5	$<10^2$	2×10^2–5×10^2
Pepper black	5×10^5–1×10^7	1×10^2–5×10^4	5×10^2–2×10^4
Pepper white	1×10^4–5×10^5	$<10^2$–1×10^3	$<10^2$–1×10^5
Tarragon	5×10^4	$<10^2$–1×10^3	$<10^2$
Thyme	5×10^5–1×10^7	$<10^2$	5×10^2–1×10^4
Turmeric	1×10^4–2×10^7	$<10^2$–1×10^3	$<10^2$–3×10^3

to change their virulence and thereby their minimal infectious doses, it is assumed today that under special circumstances one single salmonella could be infectious. In this case, any finding of salmonellae in a food has to be regarded as a health risk. Consequently it was decided by the European authorities that salmonella should not be detectable in 25 g of herbs or spices.

As a consequence, the importing and manufacturing companies have established comprehensive and efficient examination procedures for raw material acceptance. The major problem in this relation is the fact that microorganisms as well as other contaminants normally are not homogenously distributed within the product. For that reason detailed sampling plans have been developed; the best known one is the Foster plan [14], which is specialised for salmonella detection.

Industrial microbiological quality control normally covers the total count of germs, the counts of yeasts and moulds, coliform bacteria and *E. coli*. In special cases these investigations are complemented by the detection of *Staphylococcus aureus*, salmonella and listeria.

The German Association for Hygiene and Microbiology has published microbial approximate and warning values for spices which should be given to the consumer or which should be used in the production of foods which do not

Table 14.2 Microbial approximate and warning values for spices which should be given to the consumer or which should be used in foods without any further germ reduction treatment [15]

Organism	Approximate value (cfu/g)	Warning value (cfu/g)
Salmonella	–	Not detectable in 25 g
Staphylococcus aureus	1.0×10^{2}	1.0×10^{3}
Bacillus cereus	1.0×10^{4}	1.0×10^{5}
Escherichia coli	1.0×10^{4}	–
Sulphite-reducing clostridia	1.0×10^{4}	1.0×10^{5}
Moulds	1.0×10^{5}	1.0×10^{6}

undergo further heat treatment. The data are summarised in Table 14.2 and can be used as a guideline for the microbiological assessment of spices. Once again, it can be seen that salmonella should not be detectable in 25 g of the spice.

The traditional microbiological methods are very time consuming and sometimes limited concerning their interpretation. For that reason fast analysis methods as well as automated methods have been developed; the latter are often used in specialised microbiological laboratories. During the last few years more and more modern biotechnological methods have been implemented into quality control, for example the enzyme-linked immunosorbent assay or more recently the polymerase chain reaction, which allows the detection of very specific microorganisms.

The occurrence of moulds on or within vegetable raw materials represents a serious problem, since the topic is of increasing interest and is doubly problematic: for one thing, in many countries mouldy foodstuffs are considered disgusting, regardless of the sanitary risk they present; secondly, the presence of moulds always implies the risk of mycotoxin formation. Besides their acute toxicity, some of the mycotoxins have been found to be teratogenic, mutagenic and/or carcinogenic. The most critical spices concerning the possible occurrence of mycotoxins are coriander, paprika, chillies and nutmeg, a special problem being that moulds growing within capsicum fruits as well as within nutmeg nuts cannot be detected from the outside.

14.8 Residues of Plant-Conditioning and Plant-Protective Agents

For several reasons, residues of plant-conditioning and plant-protective agents represent a highly complex problem. So is it often not quite clear what to look for since for different reasons sometimes substances are used which are not intended for the particular crop. This can occur when the intended preparations are not available or by crossing-over effects from intensively used plantations which may be located close to the often small spice parcels. Otherwise up to now there are no global methods for the detection of residues of plant-conditioning and plant-protective agents available, which is above all owing to the high number of active substances as well as to their multifarious chemical structures.

Another serious problem is the fact that the maximal accepted residues for the different plant-conditioning and plant-protective agents are not harmonised and that, for example, in Germany for some substances the maximum value for residues in herbs and spices is generally set at 0.01 ppm. This value was solely set by a political decision and has no proven toxicological background. Moreover in a number of cases this value is near the lowest detection value of the particular substance.

14.9 Biologically Active Substances

One critical subject concerning the quality of herbs and spices as well as of flavours is the discussion of so-called biologically active substances. Among the estimated 60,000–100,000 different secondary plant metabolites numerous substances can be found which have considerable effects on the human organism, i.e. they are biologically active. This is not astonishing, since most of the vegetables used as herbs and spices today were originally used for their pharmaceutical properties. Since Paracelsus (1493–1541) we know that it is only a question of dose whether something is poisonous or not, and so it is not surprising that among the secondary plant metabolites substances can be found which have to be seen as critical from a toxicological point of view. Often we have to ask the question how to reconcile the obvious contradiction that animal experiments with isolated substances indicate their carcinogenic potential, whereas daily experience obviously does not indicate a serious health risk for humans. Moreover, a recently undertaken comparison of the genotoxicity of estragol with that of tarragon (the plant which contains the highest percentage of estragol) showed that untreated tarragon has a genotoxic potential under the conditions of the test carried out. However, this activity is clearly lower than that observed with methylchavicol at the same concentrations. Dried tarragon, on the other hand, showed no genotoxic potential under the same experimental conditions (study conducted for the European Spice Association, 2005, unpublished).

Since the idea of a zero risk of food in principle cannot be realised, it is not least an ethical request to set the assessment of naturally occurring biological active substances on a new basis corresponding to the rules of a scientifically substantiated risk assessment.

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