Chapter 1
Chemical Additives for Foods. Impact of Food-Related Quality System Certifications on the Management of Working Flows

Abstract This chapter examines the role of food-oriented (or 'food-centric') quality system standards in the modern food and beverage industry. In general, quality schemes are based on the international norm ISO 9001 and the 'Hazard Analysis and Critical Control Points' approach. However, the chapter also introduces new and improved 'food quality' schemes and other safety-oriented and preventive approaches, currently outlining that a standardisation for international equivalence (while maintaining necessary flexibility and independence) is not always easy. This chapter discusses current issues concerning food-grade additives by the chemical and quality management viewpoints. This analysis is helpful because the reliability of management systems, including traceability, the design of working flows, and other concerns related to the use of food additives, implies an external and third-party assessment. As a result, the need for independent and reliable assessment has introduced third-party certification bodies in the world of food production.

Keywords Food additive · Flow chart · GSFS · IFS Food · Processing aid · Quality system · Traceability

Abbreviations

ATS	Addition and temporary storage
BRC	British Retail Consortium
CAS	Chemical Abstract Service
EU	European Union
FS	Final storage
T1	First corridor
FAW	Food additives warehouse
FSMA	Food Safety Modernization Act
FSSC	Food Safety System Certification
T4	Fourth corridor
GMO	Genetically modified organism

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GFSI	Global Food Safety Initiative
$[MO]_{additives}$	Global multi-origin of food additives
$[MO]_{food}$	Global multi-origin of the final product
GSFS	Global Standard for Food Safety
HACCP	Hazard Analysis and Critical Control Points
HARPC	Hazard Analysis and Risk-based Preventive Controls
IFS	International Featured Standard
ISO	International Organization for Standardization
MR	Mixing room
PO	Packaging operations
PMW	Packaging warehouse
PEA	Pre-entering area
RMW	Raw materials warehouse
RSPO	Roundtable on Sustainable Palm Oil
SQF	Safe Quality Food
T2	Second corridor
TS	Temporary storage area
T3	Third corridor
USA	United States of America

1.1 Chemical Additives for Food Productions. An Introduction

Food industries cannot avoid the use of minor (and necessary) ingredients in their formulations. This simple statement may be obvious when speaking of normal food science technology because the most part of all possible foods and beverages have always been obtained by means of the use of peculiar additives or processing aids (Ames et al. 1990; Broome and Hickey 1990; Deane and Hammond 1960; Fitzgerald and Buckley 1985; Ledford et al. 1966; Lück 1985; Nuñez et al. 1989; Okigbo et al. 1985; Oser 1985; Shehata et al. 1967; Woodroof 1966). As a simple and enlightening example, cheeses cannot be obtained from the original milk without the use of peculiar technologies using precipitating enzymes such as animal, vegetable or microbiological rennet, and/or the addition of certain acids or salts (citric acid and calcium chloride are well known in this broad ambit) (Abou-Zeid et al. 1983; Keller et al. 1974).

However, the average consumer of foods and beverages is always concerned when discussing food origin in a broad sense (Kendall et al. 2018; Zarling 2018). This behaviour has encouraged industries and researchers in the public and the private sectors with reference to new possible authentication studies and analytical methods (Fadini and Schnepel 1989; Forina et al. 1987; Szpylka et al. 2018a, b; Tsimidou et al. 1987; Williams 1985).

Actually, the analytical research in the chemical and microbiological ambits has always been carried out with reference to two distinct directions at least:

(a) The assessment of the real origin of foods and beverages intended as final products, and
(b) The evaluation of the origin of food and beverage ingredients as used in the food industry.

Apparently, these directions seem identical. On the other hand, it has to be considered that certain food and beverage products are mainly obtained from one raw material corresponding to the 85–95% at least of the original raw materials, while other products may contain more that 5–10 ingredients and additives. In relation to a simple example, cheese, two similar products may be realised in different ways when speaking of the number of introduced raw materials and other ingredients (Sagara et al. 1990; Shaw 1984; Johnson 1981; Torres and Chandan 1981; Trecker and Monckton 1990; Wargel et al. 1981):

(1) A common hard cheese from cow milk (intended use: grating) can be obtained with milk, rennet, salt (sodium chloride) and water. In this situation, milk may correspond to a minimum 95% of the total mass of raw materials, while salt may slightly exceed 1%, and water may arrive to 4%. The remaining ingredient—or a technological aid—is rennet, with a really negligible amount (<0.01%)
(2) Alternatively, a hard processed cheese for grating purposes may be also obtained by means of the use of different raw materials of milk or non-milk origin: water, rennet casein, various cheeses, milk butter, carbohydrates (potato starch, etc.) and other minoritary components including stabilisers, humectants agents, melting agents, etc.

By the viewpoint of average consumers, the difference between these products is related to two different problems:

(a) The definition of ‘cheese’ (real cheese is obtained from milk only with a minor presence of non-milk components, while processed or analogous cheeses are a mixture of different ingredients of mineral, vegetable, natural or synthetic origin)
(b) The definition of the origin of all components for the purchased product.

With reference to the exigency of average consumers, it has to be highlighted that the definition of food products may be different from the definition of ingredients used for the production. In other words (Mania et al. 2018a):

(1) The identification of a food product with a common name is linked to the natural or synthetic origin of ingredients (including the nature of original sources), the production method, the geographical origin of all raw materials and so on
(2) On the other hand, the origin of each raw material or ingredient (including food-grade chemical substances) can complicate the definition of the final food product. In fact, ‘real’ cheeses (or traditional foods such as olive oils or baked beans) are easily linked to the origin of a few ingredients, probably manufactured

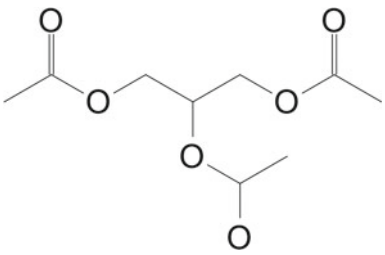

Fig. 1.1 Molecular structure of triacetin or glyceryl triacetate, a well-known additive in use in the food industry (also named E 1518). This compound—molecular formula: $C_9H_{14}O_6$, molecular weight 218.20 Da, Chemical Abstract Service (CAS) number 102-76-1—can be used in the food industry as a humectant agent

in the same region or country, and with a common or legally imposed production method (Delgado et al. 2017). On the other side, foods or beverages obtained by means of the use of a long list of ingredients should probably have a mixed or jeopardised origin.

An enlightening example may concern a well-known additive in use in the food industry: triacetin or glyceryl triacetate, named in the European Union (EU) as E 1518 (Bremus et al. 1983; Codex Alimentarius Commission 1995). This compound—-molecular formula: $C_9H_{14}O_6$, molecular weight 218.20 Da, Chemical Abstract Service (CAS) number 102-76-1 (Fig. 1.1)—can be used in the food industry as a humectant agent, and other uses are known: antifungal, plasticising and flavouring properties are reported (Quinn and Ziolkowski 2015). By the chemical viewpoint, it is generally obtained from glycerol and acetic acid. Consequently, the related use of this additive in the modern world of food production may be notable enough, in spite of its predictably negligible amount in food formulations. When speaking of the origin of this compound, it is obtained by means of synthetic processes (non-natural origin) from glycerol and acetic acid.

In relation to the origin of pre-existing components, both glycerol and acetic acids may be different (animal or vegetable sources? various geographical origins?). As a simple result, the definition—or traceability exercise—applied to the situation of E 1518 (a minor component!) can be challenging enough, and give mixed answers, which could be questioned by average consumers.

Naturally, this compound is allowed in food production, but its origin may have some impact when speaking of the final definition and claims for the food: ‘natural’, ‘100% milk’, ‘100% Italian’ (or other country origins), ‘vegetarian’, ‘vegan’ and so on.

For these reasons at least, the use of food additives, processing aids and chemical substances in general should be preventively considered in the ambit of reliable and demonstrable traceability (Barbieri et al. 2014; Mania et al. 2018a, b, c). Generally, this ambit is covered also by quality certification systems for food products and beverages.

Table 1.1 A simple table showing allowed names for food additives, processing aids and food-grade chemical compounds in general in the EU ambit[2]

Authorised additives in the European Union: declared functions and related names			
Acid	Acidity regulator	Anti-caking agent	Anti-foaming agent
Antioxidant	Bulking agent	Colour	Emulsifier
Emulsifying salts	Firming agent	Flavour enhancer	Flour treatment agent
Foaming agent	Gelling agent	Glazing agent	Humectant
Modified starch	Preservative	Propellant gas	Raising agent
Sequestrant	Stabiliser	Sweetener	Thickener

Basically, a food or beverage product including one, two, three… 'n' chemical substances without a well-known name such as a normal food ingredient has to be evaluated one, two, three… 'n' times when speaking of the origin of all possible raw materials (Barbieri et al. 2014). As a result, the matter of authenticity is—first of all—a chemical matter.

Table 1.1 shows the list of allowed names for food additives, processing aids and food-grade chemical substances in general when speaking of the European legislation (European Parliament and Council 2011). This list is exhaustive enough, and it has to be used with the aim of giving a brief overview of problems food technologists and legal representatives working in food industries have to face nowadays. A total of 24 different functions are represented in Table 1.1. As a consequence, it may be inferred that the realisation of a complex food may easily involve at least 2–3 of these functions (and one or more chemical substances for each of these functions also).

In addition, there is a class of additives without mention in Table 1.1: the group of flavourings. In the European ambit, these substances are ruled by means of the Regulation (EC) No 1334/2008; also, it should be mentioned that two peculiar flavouring agents—caffeine and quinine—have to be declared not only with their function but also with the exact name (European Parliament and Council 2008).

Each function may be related to the chemical structure or classification of several food-grade chemical substances, as reported recently. Also, the common use and declaration of food additives includes the definition of chemical substances by means of a peculiar code, as requested in the European Union by the Regulation (EC) No 1333/2008 (Saltmarsh 2000). According to this system, four groups of food-grade chemical compounds can be identified (Laganà et al. 2017; Parisi 2017, 2018; Saltmarsh 2000):

(a) Additives used for protection (antioxidants, antimicrobial substances
(b) Colourant compounds
(c) Surrogates for sugars and sweetening agents
(d) Chemical compounds able to give a good and permanent structural behaviour and peculiar technological properties to the final food or beverage).

Anyway, the classification of different food additives is interesting only because food technologists may be able to reduce the complication derived from the origin

of multiple substances by using only one (or two) different chemical substances in the same class. This behaviour corresponds to a precise technological strategy on the one side; however, each flavouring, thickener, sweetening substance and other compounds are generally prepared 'as they are named': their formulations require often the use of other substances!

As a simple result, should a peculiar food needs one, two, … 'n' different additives in the formulation, the following equation showing the 'global multi-origin of food additives' or $[MO]_{additives}$ of the complete mass of additives (with the exclusion of main raw materials) would be easily verified if each of these additives is also a carrier of one, two, … 'm' 'second-level' additives as shown in Eq. 1.1:

$$[MO]_{additives} = n \times m \tag{1.1}$$

Consequently, should this hypothetical food product have 'x' raw materials with 'y' origin features (geographical areas, natural sources, etc.), and 'n' additives/processing aids/food-grade chemical substances with 'm' possible origin features, the situation shown in Table 1.2 would be observed, where the global multi-origin of the final product—$[MO]_{food}$—can be obtained by means of Eq. 1.2. $[MO]_{food}$ corresponds to the global multi-origin of the final product assuming that $x = 1$, $y = 1$ and 'm' is $\leq$ 'n':

$$[MO]_{food} = x \times y + [MO]_{additives} = x \times y + n \times m \tag{1.2}$$

The complexity of the problem is determined by both the raw materials (generally representing 85–95% of the total mass of the food or beverage) and the used additives (minor components). Naturally, the importance of food-grade chemical is inversely proportional to their abundance when speaking of jeopardised origin…

This situation can be solved by means of traceability systems (Bosona and Gebresenbet 2013; Charlebois et al. 2014; Ene 2013; Lupien 2005; Mania et al. 2017, 2018a, b, c; Tian 2017). On the other side, the reliability of these systems implies an external and third-party assessment of the traceability procedures into food industries. The need for independent and reliable assessment has introduced third-party certification bodies in the world of food production.

1.1.1 Quality Certification Systems in the Food Industry

The world of foods and beverages has not initially been linked with the sector of quality management systems, although many companies and related representatives have followed the way of 'total quality' since 1990. The concept of quality assurance was initially related to food and non-food environments at the same time, with a peculiar fraction of customers seeking for accreditation in the non-food sectors. In

Table 1.2 Global multi-origin of food and beverage products $[MO]_{food}$ may be calculated by means of Eq. 1.2, where 'x' are raw materials, 'y' concern origin features and 'n' represent the number of additives/processing aids/food-grade chemicals with 'm' possible origin features

n	m	$[MO]_{food}$
1	1	3
2	1	4
2	2	5
2	1	4
2	2	5
2	3	6
3	1	5
3	2	6
3	3	7
4	1	6
4	2	7
4	3	8
4	4	9
5	1	7
5	2	8
5	3	9
5	4	10
5	5	11
6	1	8
6	2	9
6	3	10
6	4	11
6	5	12
6	6	13

Should $x = 1$, $y = 1$ and 'm' is $\leq$ 'n', $[MO]_{food}$ could be really challenging

other words, the possible advantages in terms of process improvement, higher profits and customer satisfaction were not an exclusive matter for food companies.

The birth of the ISO 9000 series of standards by the International Organization for Standardization (ISO) was a milestone when speaking of quality management systems. The above-mentioned norms aimed to set up recommendations and non-legally binging advices for companies and organisations seeking to ameliorate their results in terms of 'quality'. In brief, the goal of ISO was to help organisation in relation to the design, creation, delivery and continuous amelioration of supplied products and services by means of the demonstrable (reliable) prevention of 'non-conformities' (Brown et al. 1998; Buttle 1997; Dick 2000; Martínez Fuentes et al. 2000; Vloeberghs and Bellens 1996; Yung 1997).

However, the development of quality certification systems according to ISO 9000 norms has not been perceived positively by all possible institutions, including food and beverage operators. This behaviour has not been related to the complexity of quality systems or requirements, or to the comprehensible resistance against new and non-legally binding obligations. In addition, the existence of similar quality certifications based on the reliability of a quality management system located in a food company has generated some doubts when speaking of the dualism requested to the 'quality management responsible' (the subject responsible for quality improvement also directly chosen by the company direction).

On the contrary, many food and business operators have progressively questioned the general structure of quality management systems based on the 'Vision 2000' strategy (Conti 1999a, b; Renzi and Cappelli 2000). In detail, mass retailers above all have often considered the common structure of ISO 9000-based management systems as instruments without a strong connection with food quality, safety and integrity. For these and other reasons, the majority of food companies have voluntarily chosen (or have been forced) to comply with more 'food-centric' quality management systems (Stilo et al. 2009; Balasubramaniam et al. 2012; Bilska and Kowalski 2014; dos Santos Costa 2014; Filipović et al. 2008; Johnson 2014; Krieger and Schiefer 2007; Laux and Hurburgh 2012; SSICA, Certiquality, and Mobilpesca Surgelati SpA 2009; Sinha 2014; Trienekens and Zuurbier 2008; Van der Spiegel et al. 2003). This process towards the 'food quality management system' worldwide has progressively established a small number of related standards under the Global Food Safety Initiative (GFSI). At present, the most known certification standards in the broad ambit of food and packaging producers at least include (BRC 2018a; FSSC 2017; IFS 2017; ISO 2018; RSPO 2014; SQF 2017):

- The Global Standard for Food Safety (GSFS) by the British Retail Consortium (BRC)
- The International Featured Standard (IFS) Food, by the IFS
- The ISO 22000 norm, by the ISO
- The Food Safety System Certification (FSSC) 22000
- The Safe Quality Food (SQF) by the SQF Institute, USA
- The Roundtable on Sustainable Palm Oil (RSPO) certification scheme, by the homonym organisation.

In general, these systems have a common point: the partial or total adherence of the chosen procedures and instructions to basic principles of the Hazard Analysis and Critical Control Points (HACCP) assessment, although another US-related approach—the Hazard Analysis and Risk-based Preventive Controls (HARPC)—has to be considered before if its introduction some years ago (Bai et al. 2007; Baines 1999; Channaiah et al. 2017; Davidson et al. 2017; Grover et al. 2015; Parisi 2009, 2012, 2016; Gurnari 2015; Schulze et al. 2008; Stilo et al. 2009). Clearly, the basis of similar systems is always the 'old' ISO 9000 approach, but differences between food- and non-food environment have justified dissimilar strategies in response to the most part of consumer's worries (Askew 2018; Baş et al. 2007; Belik et al. 2001;

Fig. 1.2 Structure of quality management strategies in the food and beverage ambit is based on ten main pillars

Botonaki et al. 2006; Fulponi 2006; Knaflewska and Pospiech 2007; McMeekin et al. 2006; Wu et al. 2011).

In practice, the structure of these—and other—possible strategies when speaking of food quality management is based on the following pillars (Fig. 1.2) (Akkerman et al. 2010; Barone et al. 2015; BRC 2018b; Brunazzi et al. 2014; Escanciano and Santos-Vijande 2014; Fulponi et al. 2006; Mukundan 2005; Parisi and Luo 2018; Singla et al. 2018; Steinka et al. 2017; Zaccheo et al. 2017):

(a) The commitment of senior management
(b) The trend and research for continuous amelioration
(c) The elaboration, development and improvement of the 'food safety plan' (also intended according to the US Food Safety Modernization Act (FSMA)
(d) The performance of the organisation when speaking of internal audits, non-conformities and preventive/corrective actions
(e) The evaluation and re-assessment of raw material suppliers. There is no difference between edible materials and 'accessory' items such as packaging materials and objects

(f) The traceability, as legally binding requisite, with controls concerning labels and packaging integrity
(g) The attention to layout design, flow charts, processing operations and particular requisites concerning segregation
(h) Sanification and site hygiene
(i) The safe management of allergen and genetically modified organism (GMO) risks
(j) Dedicated training and attention to safety culture.

In particular, two of these pillars concern traceability and labelling procedures: these two points include the matter of food additives, processing aids and chemical substances in general. Substantially, the management of raw materials and 'secondary' (minor) ingredients can have an important impact on traceability and labelling requirements, and the general reliability of food industries can be notably enhanced by means of quality management systems (Coff et al. 2008; Opara and Mazaud 2001; Wognum et al. 2011). The real question should be: How should any quality management system be structured if traceability and labelling of food-grade chemical substances have to be assured?

By a general viewpoint, the problem of ingredients—both main and minor food and beverage components—should be managed with care when considering four key factors at least:

(1) The problem of food additives and chemical compounds in general (Asensio et al. 2008; Lindsay 2007; Lupien 2005; McEntire et al. 2010; Singhal et al. 1997): traceability, authenticity, position in the flow chart of a process
(2) The contrast to intentional adulteration (Fennema et al. 2017; Johnson 2014; Moore et al. 2012): fraud-related risk assessment and related mitigation strategies, supplier evaluation and continuous surveillance, new or improved analytical strategies, and economic studies and researches
(3) The examination of technical data sheets in the food and beverage industries by the viewpoint of external auditors (Crossland 1997; Panisello and Quantick 2001)
(4) The risk of declared and undeclared allergens BRC l 2017a, b; Nikoleiski 2015; Stein 2015) with a focus on 'masked' risk carriers (lubricants used for food processing equipments).

Actually, the management of foods and beverages by a global perspective is surely more complex than the above-shown list. However, the simple management of these points may be difficult enough: consequently, the aim of this book has been to give an overview of the current state of the art in these areas.

The first of these key factors is examined in this chapter, while:

(a) The contrast to intentional adulteration is discussed in Chap. 2
(b) The examination of technical data sheets in the food and beverage industries by the viewpoint of external auditors is examined in Chap. 3

(c) The risk of declared and undeclared allergens with a focus on 'masked' risk carriers such as lubricants used for food processing equipments is evaluated in Chap. 4.

As a premise, and in connection with main 'pillars' of food quality management systems (Fig. 1.2), it has to be considered that:

(1) The discussion concerning food additives and chemical compounds in a quality management ambit should at least include considerations related to: the commitment of senior management; the 'food safety plan'; the performance of the organisation when speaking of internal audits, non-conformities and preventive/corrective actions; the evaluation and re-assessment of raw material suppliers; traceability; flow charts, processing operations, and particular requisites concerning segregation; and sanification procedures
(2) The contrast to intentional adulteration (Chap. 2) concerns the following quality management areas: the commitment of senior management; the trend and research for continuous amelioration; the 'food safety plan' (risk assessment and dedicated procedures); the performance of the organisation (internal audits, non-conformities and preventive/corrective actions); the evaluation and re-assessment of raw material suppliers; traceability and labelling requirements; processing operations and related flow charts, with peculiar attention to site design; peculiar segregation and sanification procedures; training and attention to safety culture
(3) The examination of technical data sheets in the food and beverage industries (Chap. 3) has to consider at least: the 'food safety plan'; the performance of the organisation (internal audits, non-conformities and preventive/corrective actions); the evaluation and re-assessment of raw material suppliers; traceability; the safe management of allergen and GMO risks
(4) Finally, allergen risks and the use of peculiar lubricants (Chap. 4) should concern the following areas: the commitment of senior management; the trend and research for continuous amelioration; the 'food safety plan'; the performance of the organisation (internal audits, non-conformities and preventive/corrective actions); the evaluation and re-assessment of raw material suppliers (including accessory materials such as lubricants); traceability, layout design, flow charts, processing operations and particular requisites concerning segregation; sanification and site hygiene; and dedicated training and attention to safety culture.

Several of the above-mentioned areas are discussed in detail, while other points are briefly discussed because of their non-chemical adherence to the related factor (food additives and chemical compounds; food frauds; technical data sheets; and allergen risks).

1.1.2 How Can Food Additives Be Managed Correctly in a Quality-Oriented System? Main Requirements

The Global Standard for Food Safety, Issue 8, mentions 'additives' many times, and the importance of these minor ingredients is considered in many ambits of the quality management system (BRC 2018b). The same thing is observed in the IFS Food, version 6.1 (IFS 2017), and in other quality standards (Sect. 1.2).

First of all, the position of entering additives and chemical compounds in the process has to be clearly defined when speaking of flow diagrams, as required by GSFS (clause 2.6.1) and also the Codex Alimentarius Commission (BRC 2018b). More specifically, food additives have to be incorporated in the flow diagram when used. A critical point in this ambit is also related to the updated information concerning flow diagrams, because possible ameliorations of a food processing operations may require—or may exclude—the use of a particular food ingredient, depending on its function (Sect. 1.1). Consequently, information correlated to the presence or absences of a raw material have to be constantly updated. A similar request is implicitly stated in IFS Food, version 6.1: food processing plans should describe clearly the flow of all materials and products entering and exiting the process, also including waste, operators and water (clause 4.8.1). Interestingly, the requirement also cites the existence of a site map concerning also the design of flow charts (because of the obvious link between layout design and food processing design).

A really challenging point concerning the use of food additives and food-grade chemical substances in general is tacitly cited by GSFS in the clause 5.3.1 when speaking of raw material assessment for possible allergen contamination (BRC 2018b). Actually, the presence of food additives would not immediately linked to the control of raw materials in relation to possible allergen contamination. On the other side, it is recommended that raw material features (with their inner composition) are preliminarily discussed and agreed with raw material suppliers. Because of the possible and often verifiable presence of different chemical substances and mixtures (flavouring agents, processing aids, carriers, etc.), it has to be noted that the assessment and agreement of raw materials concerns also their previous history in terms of production. The presence of food additives should be considered by food producers not only in their process, but also in all pre-existing processes out of their surveillance (possible dangers: deliberate presence or potential cross-contamination). The basic example in Sect. 1.1 (Eqs. 1.1 and 1.2) concerns only the multi-variegated origin of a food product; however, this example highlights the role—on a numerical level—of all possible raw materials, including negligible amounts of additives, and their previous history. In relation to IFS Food, clause 4.20.1, the requirement is tacitly present when speaking of raw materials containing allergens.

Another good point when speaking of management of food additives and food-grade chemical substances in general concerns dedicated storage structures for all materials, including processing aids and additives, as requested by IFS Food, clause 4.14.4 (IFS 2017). Interestingly:

(a) The management of storage facilities should consider technical data sheets and related recommendations for food additives (Chap. 3)
(b) The packaging materials used for food additives have to be considered when speaking of safe storage
(c) Sanitisation procedures have to consider the presence of food additives on site because of possible packaging damages caused by improper sanitisation, and/or because of intrinsic features of some additive (e.g. hygroscopic food-grade chemical compounds should be adequately stored, protected against humidity and reprotected when speaking of opened packages)
(d) Training is needed when speaking of safe storage for operators? Clearly, the answer should be positive.

In relation to IFS Food, version 6.1, it should be also noted that a particular recommendation for auditors concerns the critical closure 4.2.1.2 concerning raw materials and their specifications. More in detail, auditors are requested to clearly identify the name of specifications for checked materials (including additives also). This observation appears obvious; however, there are many situations concerning peculiar additives and processing aids, or mixtures of them (with carriers, flavourings, etc.) and named with commercial names instead of their specific name. As a result, it may be assumed that a generic product defined briefly as 'potato starch preparation' is intended as 'potato starch' only, while the formulation includes also different additives. The identification of specifications means (i) the use of technical data sheets and (ii) the definition of the used preparation 'as it is' instead of a common definition for similarity… Another mention is made in IFS Food, version 6.1 (clause 4.19.1) in relation to each possible chemical substance (flavourings, additives and so on) which could be derived from GMO, even if labelling norms do not require their mention (IFS 2017).

Finally, the problem of traceability concerns all raw materials, including food additives also (the exact definition does not matter). According to GSFS Issue 9, clause 3.9.2, all possible ingredients (and food contact packaging materials also) are 'raw materials; for this reason, they have to be traced and mentioned even if their mention on labels is not needed (BRC 2018b). Consequently, traceability systems have to consider always mentioned and not-mentioned ingredients for a food or beverage product!

1.1.3 Working Flows and Flow Charts in the Food Industry. Reliable Accounts

Ideally, the production in food and beverage industries would be a dynamical process along a theoretically one-way direction. This simple declaration is easily questionable in the real world because of the following elements (BRC 2018b; Mania et al. 2017, 2018a, b, c; Parisi 2005):

(a) There are more than one possible exiting materials from the process for one, two, … '*n*' entering raw material, additive and/or packaging material: the final and desired products, various sub-products and discarder pieces (and packaging discards)
(b) In addition, various processes use in some step fluid carriers such as simple water. As a result, should this fluid serve only as a carrier (without absorption or incorporation in the final product, or in one of by-products), the exiting flow of materials would also include the fluid itself
(c) Depending on processes, certain materials can be elaborated with the intra-processing recycling of discarded products (on condition that safety, legality, integrity and quality of the product remain guaranteed). The recycle or re-use may involve discarded pieces during the process itself at the same date, or in different dates.

On these bases, there is not a one-way direction, from raw materials to finished products, but a fragmented process including one or more entering materials and one or more exiting materials, in different points of the flow.

The 'geographical' position of entering and exiting materials in the process is critical, also in connection with the creation of logical and reliable flow charts (Alli 2003; Ibarz and Barbosa-Cánovas 2002; Sun and Ockerman 2005; Tanner 2000). In other words, the logical flow of processing operations should aim at the reduction of contamination episodes by means of the limitation of all possible risks, following the broad FSMA (or HARPC) approach (Alli 2003; Grover et al. 2016; Koenig 2011; Kowalska 2018; Johnson 2014).

This result, extremely difficult to achieve in a chaotic environment, has been obtained by means of the classification of all possible risks, their localisation into the site (and off-site also) and the management of these dangers by means of dedicated countermeasures. The first—or one of the main—of these measures should be the definition of one way only when speaking of processing directions: from raw materials to finished products, without deviations in the opposite direction (Luning et al. 2006).

Moreover, the spatial localisation of steps composing the entire flow diagram is critical. In general, and in relation to all possible sites realised years ago, the most frequent situation concerns food plants without a well-defined layout, if observed with the eyes of the food technologist (Amjadi and Hussain 2005; Anonymous 1977; Moerman and Wouters 2016; UNECE 1981; Waldron 2009). In other words, and with specific relation to entering raw materials (including food additives), the best strategy should be the limitation of entering possibilities: ideally, one single enter point would be desirable, while more than one exit points may exist because of the occurrence of one or more sub-products (and fluids) (Bindi et al. 2009; Wanniarachchi et al. 2016). This objective can be obtained by means of logical and predesigned layout projects (Daf and Zanwar 2013; Drira et al. 2007; Holah 2003; Shahin and Poormostafa 2011).

In addition, a new and emerging menace should be considered: the possibility of deliberate and malicious acts against food companies, also intended industrial sabotage (Kanai et al. 2015; Van Donk and Gaalman 2004; Wanniarachchi et al.

2016). One of the most known possibilities, when speaking of deliberate attacks to food companies, concerns sabotage of processing operations. As a consequence, raw materials should really be monitored on site in relation to the following possibilities at least:

(a) Deliberate substitution of one raw material with another one
(b) Malicious contamination of one raw material with another one
(c) Manumission of the processing flow by means of the augment of one raw material if compared with normal formulations, with labelling implications also
(d) Manumission of the processing flow by means of the diminution or the complete elimination of one raw material if compared with normal formulations, with labelling implications also.

With reference to raw materials, contamination may be prevented but dangers are real; on the other side, the augment or the diminution/elimination from the operation formula is difficult enough because of the predictably notable amount of main raw materials in the product.

On the other side, food additives and food-grade chemical substances in general are negligible in terms of formulation amounts: these compounds may globally range from 0.5 to 5.0% of the total formula in many situations. As a result, food defence plans have to be considered in relation to food additives in general because malicious attacks in this ambit might be unnoticed.

Anyway, processing flow diagrams should tend to the limitation of all possible entering accesses when speaking of raw materials. A simplified example can be shown in Figs. 1.3 and 1.4.

In brief, Fig. 1.3 shows a simplified food production site subdivided in the following areas (all areas, rooms and corridors are identified with specific identification codes):

(a) Raw materials (warehouse), code: RMW
(b) Food additives (warehouse), code: FAW
(c) A pre-entering area (needed for opening operations and safety inspections before transport to food production areas), code: PEA
(d) A first corridor from the pre-entering area to a dedicated mixing room, code: T1
(e) The mixing room (where raw materials and additives are used together and processes), code: MR
(f) The second corridor between mixing room and a temporary storage area, code: T2
(g) The temporary storage area, code: TS
(h) The third corridor between the temporary storage area and the ‘addition and temporary storage’ room, code: T3
(i) The ‘addition and temporary storage’ room where the process requires the addition of a second food additive and immediately another temporary storage, code: ATS

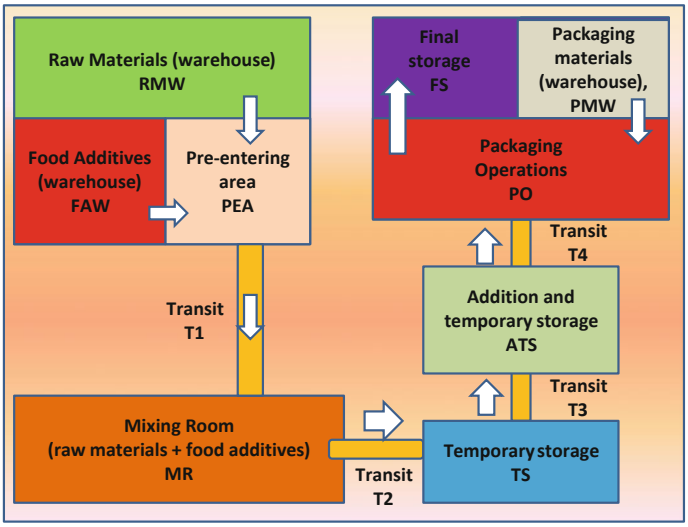

Fig. 1.3 A food production site is subdivided in different areas and rooms, depending on the specific function. This picture shows a simplified site subdivided as follows (all areas, rooms and corridors are identified with specific identification codes): raw materials (warehouse), code: RMW; food additives (warehouse), code: FAW; the pre-entering area, code: PEA; a corridor from the pre-entering area to the dedicated mixing room, code: T1; the mixing room, code: MR; another corridor between mixing room and a temporary storage area, code: T2; the temporary storage area, code: TS; another corridor between the temporary storage area and the 'addition and temporary storage' room, code: T3; the 'addition and temporary storage' room, code: ATS; another corridor between the 'addition and temporary storage' room and the 'packaging operations' area, code: T4; another warehouse containing packaging materials only, code: PMW; the 'packaging operations' area, code: PO; and the 'final storage' area, code: FS

(j) The fourth corridor between the 'addition and temporary storage' room and the 'packaging operations' area, code: T4
(k) The packaging warehouse containing packaging materials only (these materials are transported to the 'packaging operations' area), code: PMW
(l) The 'packaging operations' area, code: PO
(m) The 'final storage' area, code: FS.

Figure 1.4 shows a simplified flow diagram for the example process, taking into account Fig. 1.3 and specific codes. The simplified flow chart shows only mixing, addition and temporary storage, and packaging operations because these procedures concern only entering materials, and one exiting product (in the PO area). Each ingredient entry is highlighted with a peculiar ENTRY symbol. Our example shows:

(1) Three raw materials and one food additives entering the process in MR
(2) One additional food additive entering the process in ATS
(3) Three packaging materials entering the process in PO.

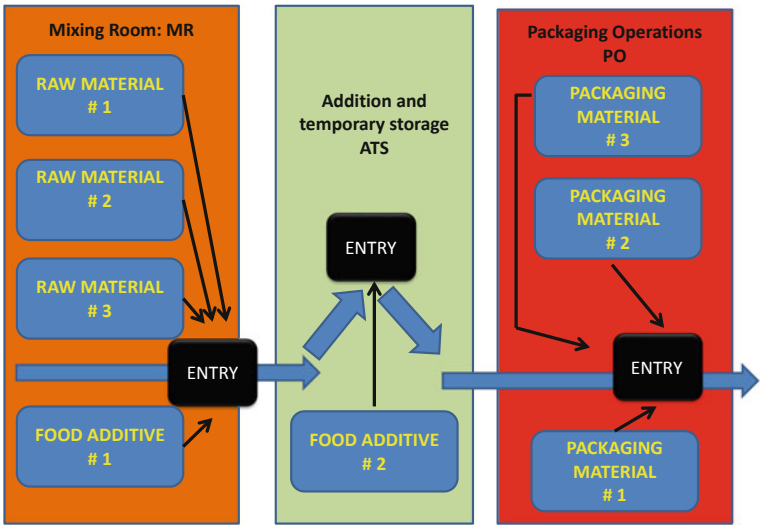

Fig. 1.4 A simplified flow diagram for the example process, taking into account Fig. 1.3 and specific codes. The simplified flow chart shows only mixing, addition and temporary storage, and packaging operations because these procedures concern only entering materials and one exiting product (in the PO area). Each ingredient entry is highlighted with a peculiar ENTRY symbol

The simplified process shows only three raw materials, two additives and three packaging materials, but the position in the process needs three entry places. On the one side, this situation can explain well reasons for limiting the number of possible entry places in the process. Unfortunately, certain processes cannot be modified in this direction, forcing food industries to search for the most important limitation of entering possibilities in terms of ingredients and entry areas. It has to be noted that malicious food attacks can easily occur in the three entry areas at least. The higher the number of raw materials and food additives, the higher the possible risks concerning HACCP/HARPC risks, identity loss and malicious attacks. At the same time, the higher the number of entry areas, the higher the possibilities for sabotages, identity loss and food safety.

Moreover, the simplified process does not show a two-way process, but an 'ideal' one-way process (from raw materials and ingredients including packaging materials to the final product). Should the process have one deviation from the ideality—for example, a portion of processed intermediates in ATS (Fig. 1.5) may exit temporarily from the process and be recycled immediately in MR as a secondary raw material or 'off-line' product (Mania et al. 2018b, c, d)—some possible formulation error could occur because the initial formulation does not contemplate secondary raw materials. In this situation, the number of entry nodes is not modified; however, should the possibility of recycling occur in different areas (more than one single node, differently from our example), the risk of non-conformities and malicious attacks would increase dramatically. A simple example (Fig. 1.6) showing four different entry areas or nodes

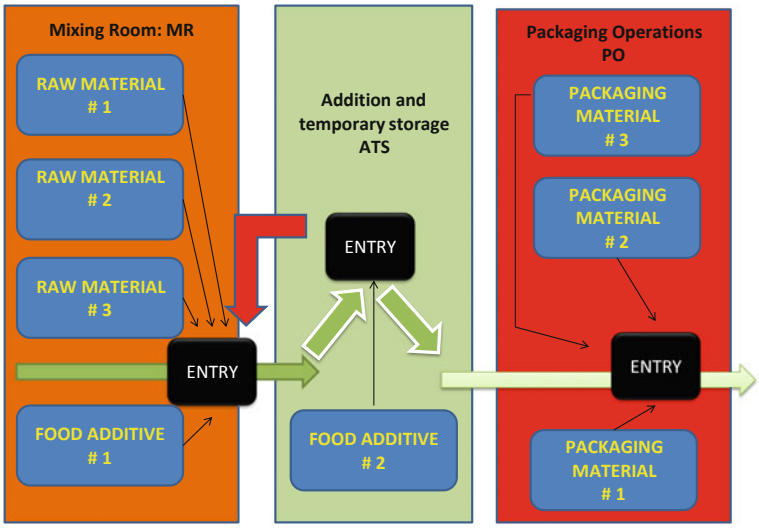

Fig. 1.5 Simplified process shown in Fig. 1.4 does not show a two-way process, but an 'ideal' one-way process (from raw materials and ingredients including packaging materials to the final product). Should a portion of processed intermediates in ATS exit temporarily from the process and be recycled immediately in MR as a secondary raw material or 'off-line' product, some possible formulation error could occur because the initial formulation does not contemplate secondary raw materials. In this situation, the number of entry nodes would not be modified but the risk of non-conformities and malicious attacks would increase dramatically

can highlight the complexity of the problem in food industries: the first of these nodes does not contemplate entering 'off-line' raw materials (containing used food additives), while entries 2, 3 and 4 (the second entry is really challenging) may receive secondary raw materials or intermediates. It has to be noted that entry 2 can receive:

(a) One intermediate from entry 1 (direction: start → end)
(b) One secondary intermediate (direction: start ← end) from entry 4

and send:

(c) One intermediate to entry 3 (direction: start → end)
(d) One secondary intermediate to 'start' (direction: start ← end).

In other words, the complexity of the whole network may be calculated in terms of number of exiting and entering 'movements' or 'connections'—the displacement of one intermediate food or material from one node to another node, without mention of the direction—into the network.[3] However, complexity of networks does not

[3]These and other information are discussed in the 'Food Traceability' lecture for the Faculty of Agricultural Technology, Al-Balqa Applied University, Al-Salt, Jordan, by Salvatore Parisi, first course 2018–2019.

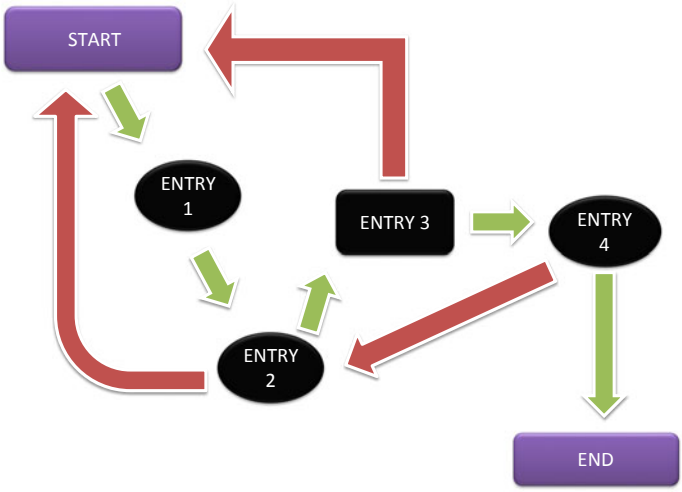

Fig. 1.6 A simple example showing four different entry areas or nodes can highlight the complexity of the problem in food industries: the first of these nodes does not contemplate entering 'off-line' raw materials while entries 2, 3 and 4 may receive secondary raw materials or intermediates. This network has eight connections while the total expected number of connections may be. In this situation, the % complexity of the network is only '8/30 × 100' = 27%

necessarily correspond to the complexity of accesses. In the first example (Fig. 1.3), this number is small (four connections) while the total expected number of connections may be 'three (nodes) × two (theoretical possible connections = number of nodes—1)' = 6 movements. As a result, the percentage of possible nodes—also considered as the 'complexity' of the network—would be '4/6 × 100' = 67%. In relation to Fig. 1.5, the number of exiting and entering connections into the network (five) demonstrates that the % complexity is augmented if compared with Fig. 1.3: '5/6 × 100' = 83%. Finally, the basic network shown in Fig. 1.6 has eight connections while the total expected number of connections may be 'six (nodes) × five (theoretical possible movements)' = 30 movements. In this situation, the % complexity of the network is only '8/30 × 100' = 27%.

On the other side, the access number corresponds to the entire number of all raw materials, foods additives, secondary raw materials and packaging materials which can enter into an 'entry node'. The network complexity cannot give an idea of risks correlated to entering and exiting materials. The above-mentioned calculations should not only consider the number of access nodes (entries) and all possible interconnections between nodes, but also the possibility that one interconnection can concern one, two, … '*n*' possible entering and exiting materials! As a consequence, and as a basic conclusion, the work of food technologists on logic networks should initially aim at (a) the reduction of entry or access nodes, (b) the reduction of connections for each node and finally (c) at the limitation of entering and exiting ingredients in the flow diagram. The last point could be considered first of all, but it

can be often placed in the end of this design work because of limited options allowed when speaking of certain processed foods.

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