FoodIntegrity Handbook

A Guide to Food Authenticity Issues and Analytical Solutions

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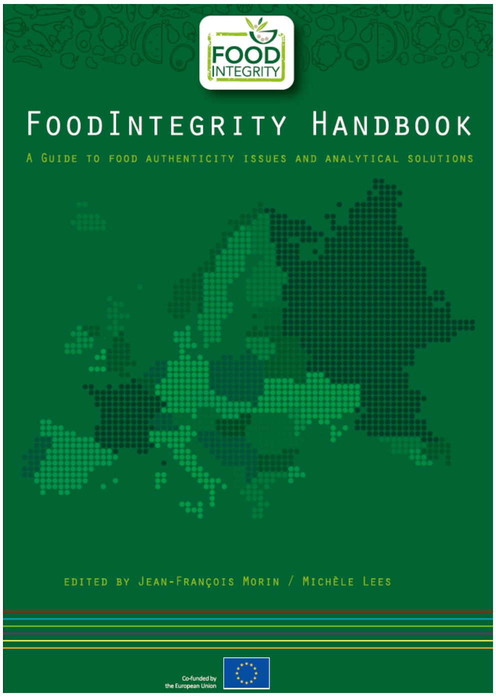

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Additional tools for mitigating the risk of food fraud

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General overview

The primary incentive for carrying out food adulteration and other fraudulent practices is economic and a desire by the dishonest producer or distributor to make money by passing off inferior product as one of a higher value. Unlike food defence where tampering of food is carried out with the aim of harming a company, its employees and even the consumer, the intention of the food fraudster is not directly to cause a public health threat, although in some cases this may be an indirect consequence.

There are a large number of potential types of fraud as described in the introduction to this book. However, they have one aspect in common: their unpredictable nature. This differentiates food fraud from food safety concerns, where contamination is often unintentional and can be linked to a specific source (microbiological contamination in food, excessive use of pesticide residues, mycotoxin production during storage, and so on). Food safety has been the main focus of the food industry over several decades leading to the globally used HACCP (Hazard Analysis and Critical Control Points) approach, a documented food safety system to identify and control biological, physical and chemical hazards in food production. Food fraud on the other hand can occur outside the company's processing and distribution system, and therefore outside the scope of the its food safety management plan.

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There is growing awareness in the food sector for the need for a preventive approach to mitigate the risk of food fraud. Whilst analytical methods such as those described in this handbook play an important role in detecting adulteration, they are not the only solution to preventing food fraud and sometimes provide no solution at all. A more efficient approach is to look at the entire value chain and identify not risks but vulnerabilities in the supply chain and of the product itself. This means taking into account various aspects of the whole chain:

Figure 1: Main aspects to be considered in a comprehensive supply chain analysis

As shown in the above figure, a comprehensive strategy of food fraud mitigation requires placing the food product or ingredient in an all-round context which includes taking into account previous food fraud occurrences, where the product has been sourced from, the complexity of the supply chain involved and the adequacy of traceability within the chain.

Various approaches dealing with all or part of such a strategy have been documented and are available either as guidelines or as specific vulnerability tools. Details of these are given in Section 2 below.

The area of fruit juice fraud has been addressed over the last 30 years and a sophisticated and global approach to controlling this sector has been set in place by the industry itself. Section 3 of this chapter describes the SGF Product Control system, an excellent example of incorporating supply chain monitoring and appropriated analytical testing on an international scale.

Supply chain traceability is an essential part of the overall strategy to mitigate the risk of food fraud. Considerable technological progress has been made in this area. A description of the concept of traceability and the latest tools is given Section 4 of this chapter.

1. Different approaches available to evaluate vulnerability

1.1. General description

Over the past few decades, food safety and quality has greatly improved in the food and food ingredient sectors. Among the main driving forces for this improvement have been the various food safety standards that have provided food operators with a framework for managing product safety throughout their entire manufacturing process. There are currently several food safety management scheme owners, now known as food safety Certification Programme Owners (CPOs), available internationally, all of them recognised by leading retailers and manufacturers worldwide. Examples of CPOs include IFS (International Featured Standards), BRC (British Retail Consortium) Global Standards, SQF (Safe Quality Food), GlobalG.A.P. (Good Agricultural Practices). A food operator can be certified compliant to one or more of these standards through regular audits carried out by a Certification Body (CB), itself authorised to conduct the audit through a formal agreement with the CPO.

Given the number of different schemes in place, many food operators have found themselves having to undergo multiple audits, each one associated with a different standard. Faced with this situation, leading food companies got together to see how they could help manage costs for food businesses by reducing duplication of audits whilst still continuing to provide safe food to consumers across the globe. In the early 2000s the Global Food Safety Initiative (GFSI) was created with the aim of harmonising standards across the global supply chain; its goal “once certified, recognised everywhere” [1]. This was achieved by establishing equivalency between the different CPOs through a set of clear benchmarking requirements that each CPO must include in their standard in order to obtain GFSI recognition.

GFSI’s primary mission is to provide safe food to consumers, and as such its main focus has been on reducing food safety risk. However, with a growing awareness that food fraud was on the increase and could have possible detrimental effects on public health, the GFSI took steps to include this concern in their remit.

In 2012, a ‘Food Fraud Think Tank’ [2] was set up with the support of GFSI, to explore how food fraud could be incorporated into existing CPOs. The work of the Think Tank gained further credence when, in early 2013, the horsemeat scandal hit the headlines. In 2014 GFSI published its position on “Mitigating the Public Health Risk of Food Fraud” where it accepted the Think Tank’s recommendations to include two key elements as part of its Benchmarking Requirements. These are:

1. Companies should perform a Food Fraud Vulnerability Assessment – in which information collected at specified points in the entire supply chain (supply chain mapping) is evaluated on the basis of the potential for food fraud
2. Companies should put in place a Food Fraud Control Plan – consisting of a set of mitigating measures including a monitoring and testing strategy, specifications management, supplier audits and anti-counterfeit technologies.

These recommendations have since cascaded down into the CPOs via the GFSI’s benchmarking process and published in 2017 (GFSI Benchmarking Requirements Version 7.1 [3]).

With these requirements now in place, food companies have been seeking help with implementing the Vulnerability Assessment required by the CPOs. There are now a number of tools available to help companies with this that have been developed either independently from or specifically in reply to the new GFSI requirements for food fraud mitigation. The two main tools that are freely available to food operators are the US Pharmacopeia (USP) Food Fraud Mitigation Guidance Document and SSAFE/PwC Vulnerability Assessment tool. These are described below.

It is worth noting that in all cases the tools that been developed are described as “living” or “dynamic” tools. Food fraud and associated vulnerabilities do not remain static but evolve over time, often influenced by changing environmental conditions, the opening up of new markets, fluctuating economic conditions, the appearance of new adulterants, and so on. It is therefore important that the vulnerability assessment process is carried out on a regular basis.

1.2. USP Food Fraud Mitigation Guidance

The United States Pharmacopeial Convention (USP) published a General Guidance on Food Ingredients as an Appendix to its Food Chemicals Codex. It was developed by the USP Expert Panel on Food Ingredients and Intentional Adulterants to help food companies set up a preventive management system for food fraud [4].

These USP guidelines for Food Fraud Mitigation Guidance (FFMG) are available as a document at www.foodfraud.org and provide a practical framework for companies to follow in order to identify areas throughout the supply chain where their business may be vulnerable to fraud. The document, which has been designed to be generally applicable to any type of food ingredient, describes both a vulnerability and an impact assessment set out in four main steps as shown in Figure 2.

In Step 1, the main factors that may be useful for identifying the susceptibility of a food ingredient to fraud are identified. These contributing factors may be either controllable by the food operator, and include the following:

- Supply chain and its complexity.
- The company’s relationship with its supplier and associated audit strategy. Does the audit specifically address anti-fraud measures?
- The frequency and type of analytical methods used to detect fraud and ensure compliance with specifications. Are the methods used able to detect known adulterants?

Other factors may be outside the user’s control such as:

- The fraud history of the ingredient in question. Has it been implicated in any recent, validated, reports?
- Geopolitical considerations linked to where the product is sourced from.
- Unexpected price fluctuations.

Each factor is then assessed on its contribution to vulnerability (low, medium-low, medium, medium-high, high) in order to build up a “contributing factors assessment matrix”. The USP FFMG document provides guidance on how to categorise each vulnerability factor using illustrative examples from food businesses, and references to where information can be sourced from.

Step 2 then identifies the impact that the food fraud event might have both on the food company and on its wider environment; the premise being that while all foods and food ingredients are possible targets of fraud, not all will impact either public health, consumer confidence or the company's economic situation.

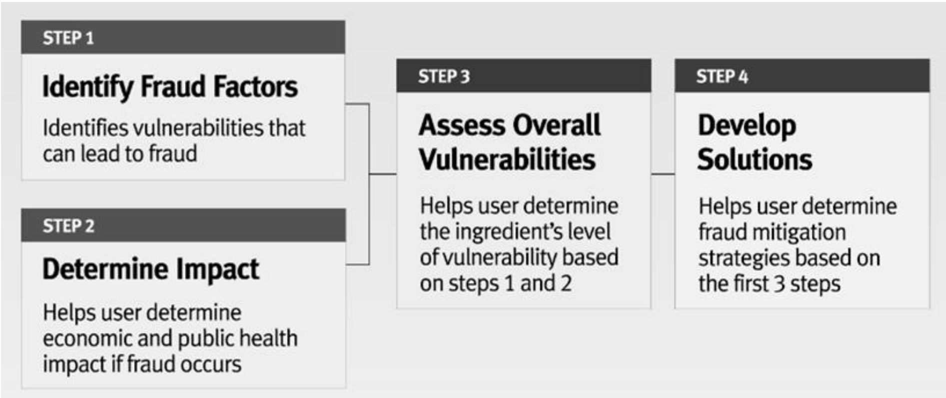

Figure 2: Four steps of the USP Food Fraud Mitigation Guidance Document. ©2015 U.S. Pharmacopeial Convention (USP)

The results of steps 1 and 2 are then brought together in a "Vulnerability Characterization Matrix" (see Figure 3) to assess overall vulnerabilities and provide an indication of where further fraud mitigation measures are required (Step 4).

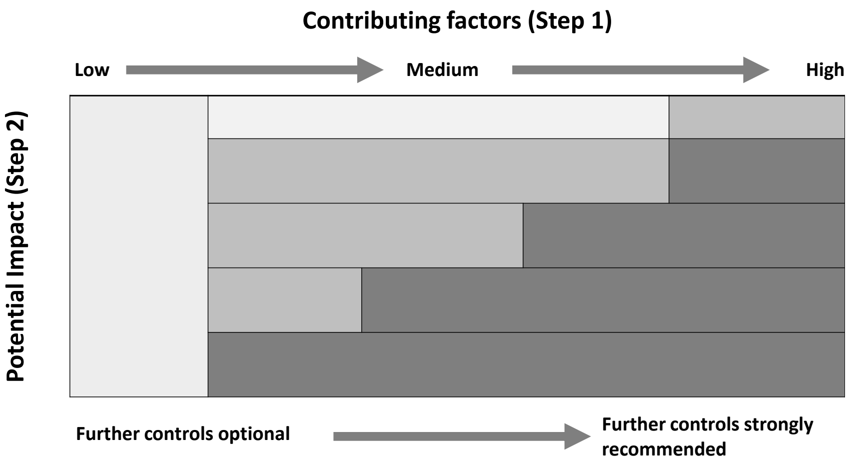

Figure 3: Vulnerability Characterization Matrix (adapted from USP Food Fraud Mitigation Guidance Document, Food Chemicals Codex Appendix XVII 2016)

1.3. SSAFE / PwC Tool

The SSAFE/PwC vulnerability assessment tool was developed specifically to help companies implement the new GFSI requirements. SSAFE is a non-profit organisation with global food companies as members, and together with PwC (PriceWaterhouseCoopers) and in collaboration with Wageningen UR and VU University Amsterdam they developed a science-based tool to assess a company's food fraud vulnerabilities. This is available as a free tool, to be used by food operators across the food supply chain, irrespective of size, geographical location or type of food business. It can be downloaded as an Excel file from www.ssafe-food.org or completed online by visiting www.pwc.com/foodfraud.

The SSAFE/PwC Tool has several components starting with a general information sheet in which the user can enter details of the company and the person or team responsible for filling in the questionnaire. It also provides a decision tree that can be used as a pre-filter to help prioritize where the tool should be applied. Its main part is a set of fifty assessment questions structured in two dimensions.

The first dimension explores those elements linked to potential criminal behaviour:

- **Opportunities**: these include the potential for fraud such as the type of product or process and previous fraud history, and the nature of the supply chain.
- **Motivations**: these relate to organizational aspects such as the business culture of the company, its economic situation and that of its customers and suppliers, and any evidence of previous offenses.
- **Control measures**: these include mitigation and contingency control measures, with questions on whether internal or external controls are in place, and whether these are hard or soft controls.

The user provides answers to the different questions by assessing their associated risk levels (low, moderate, and high).

The second dimension brings into play the company and its external environment, such as its suppliers, customers, and supply chain. How these two dimensions the key elements link together is shown in Figure 4.

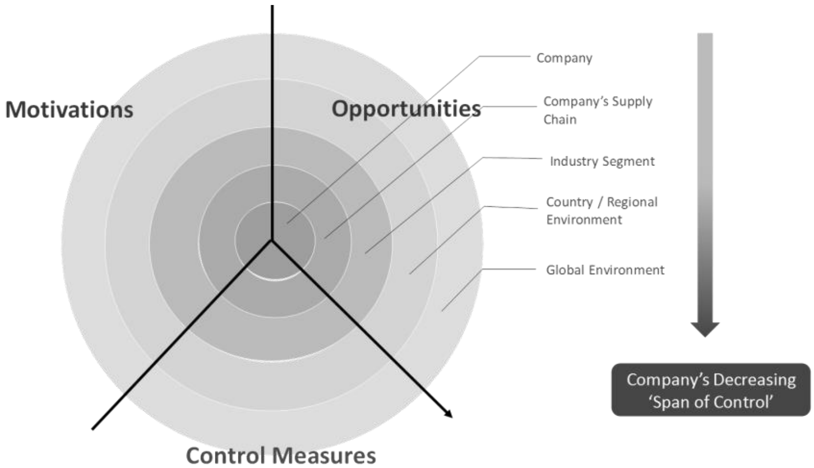

Figure 4: The SSAFE VA tool showing the environment of the company and the three elements of food fraud
Sourced from: Introduction to SSAFE Food Fraud Vulnerability Assessment Tool, December 2015

Once the questionnaire is complete, the tool provides a set of spider webs giving both an overview and a detailed assessment of the findings. Although it does not provide specific recommendations for mitigation techniques, an overall final report does identify certain areas of vulnerability and this can point the company in the right direction to address the potential risks.

Documentation accompanying the tool vulnerability assessment tool also has a full list for further reading, providing references to other tools and to external sources where more information can be found.

1.4. Other approaches

Other tools or approaches to food fraud vulnerability assessments are described briefly below.

EMAlert™ – Economically Motivated Adulteration Vulnerability Assessment Tool

EMAlert™ is a software tool developed by Battelle in partnership with GMA (association of Food, Beverage and Consumer Products Companies). It can be accessed at www.EMAlert.org. As an interactive tool which is continuously updated, the software provides a company with a quantitative assessment of its vulnerabilities to food fraud in its specific commodity sector. It works on a subscription basis [5].

FDF Food Authenticity Guide – Five Steps to Help Protect Your Business from Food Fraud

This simple guide was developed by the Food and Drink Federation (FDF) in the UK, primarily with the interests of small and medium food business in mind [6]. It can be accessed at www.fdf.org.uk.

The guide describes five key steps to help food operators identify, prioritise and manage upstream supply chain food authenticity risks. These are:

1. Map your supply chain
2. Identify impacts, risks and opportunities
3. Assess and prioritize your findings
4. Create a plan of action
5. Implement, track, review and communicate

For each of these steps, the guide provides a set of questions to consider and guidelines on how to get started. The document is concise and to the point, its main advantage, while still covering the principle aspects a small business needs to address the problem of food fraud.

1.5. Places where information can be found

All the Vulnerability Assessment tools described above rely on obtaining up-to-date information on previous food fraud incidents and possible mitigation measures. Below are some areas where such information is available.

RASFF: Rapid Alert System for Food and Feed

This is the European Commission’s online database of food and feed safety notifications. It can be accessed at www.webgate.ec.europa.eu. Information can be searched by date, type of product and, under the Hazard/Category, by selecting adulteration/fraud [6].

USP Food Fraud Database

The USP Food Fraud Database is a continuously updated collection of food fraud records, gathered from around the world. It is available through an annual subscription from www.foodfraud.org [7].

FAIR: Food Adulteration Incidents Registry

FAIR is compilation of historical and current events involving economically motivated and intentional adulteration of foods on a global scale developed by the Food Protection and Defense Institute (FPDI), a department of Homeland Security Centre of Excellence in the United States. Information of events that occurred over 5 years ago are accessible free of charge, more information is available for subscribers only. Information available at https://foodprotection.umn.edu/fair [8].

The FPDI has also initiated a further project, **FIDES (Focused Integration of Data for Early Signals)** which is collating and integrating data specifically to monitor potential food threats around the world. See link at https://foodprotection.umn.edu/innovations/food-systems.fides [9].

Food Integrity Knowledge Base

The Food Integrity Project [10] has built up a comprehensive Knowledge Base linking each food product and its potential fraud or integrity issues to appropriate analytical strategies that can be used for food fraud detection or authenticity testing. The Knowledge Base contains information on the type, frequency and impact of the fraudulent practice, the analytical methods available, including their use and performance criteria. More details on the Knowledge Base are given in a separate chapter of this book.

FARNHub: Food Authenticity Research Network Hub

The “Food Authenticity Research Network Hub» (FARNHub) is an online information hub for resources pertaining to food authenticity. The FARNHub contains an updated overview of scientific publications, past- and ongoing research projects, online resources (databases, web tools, etc.), funding bodies, regulations, and news stories, all concerning food authenticity. The FARNHub was developed in the EU-funded research project Authent-Net, is open access, and can be accessed through http://farnhub.authent.cra.wallonie.be/.

2. Best practice example of sector specific food fraud mitigation by SGF International e.V.

Food fraud is a recognized safety risk for consumers and effective strategies to mitigate this risk are required, including a vulnerability assessment of purchased ingredients and suitable analytical checks. However, food fraud detection calls on particular competencies and means which are not always available at the different links in the supply chain. Criminal energy is often spent on reducing the detectability of fraud and special intelligence is necessary to stay ahead in a constant race between the fraudster and control techniques. Thus there are good arguments to centralise the necessary competencies in a pre-competitive approach to assist raw material purchasing companies as much as possible in this task. Although processing companies are not completely dispensed from carrying out any fraud control, sector specific monitoring systems can reduce significantly the risk of purchasing falsified products and assure fair competition. As a best practice example the control system which is operated by SGF International e.V. (SGF), formerly “Schutzgemeinschaft der Fruchtsaftindustrie e.V.” [11] is discussed in this paper.

The Voluntary Control System (VCS) of SGF was established as a company certification system. It started much earlier than other international food certification systems such as the GFSI certified standards or ISO 22000 [12,13] which have gained importance since the scandals such as dioxin and BSE in the nineties. The non-profit organisation SGF [14] was founded in 1974 in Germany by the fruit juice industry. The initial motivation of fruit juice companies to set up the VCS was the wish to combat unfair competition in the marketplace and avoid negative headlines when food fraud incidents came to light. Therefore, control structures were established which have focussed on authenticity and legal compliance right from the very beginning.

It soon became obvious that major food fraud risks were linked to processed semi-finished goods purchased from third parties. For this reason the VCS extended controls along the whole value chain from the first fruit processing step to the distribution to consumers. Farming activities have less potential for food fraud and were not included. Checks of traceability and plant specific technology were intensified successively as support for the interpretation of analytical results. A worldwide unique combination of product and system control thus developed. This includes co-operating independent control systems for consumer goods in a number of European countries.

This paper will focus on food fraud control and not discuss the positive effect of the VCS on other quality aspects, food safety and hygiene.

2.1. Control activities and infrastructure

In the following the operational system of SGF is described. Respective rules are given in the implementing provisions of the VCS which are mandatory for the control body and participating companies which are members of SGF.

All controls are covered by the SGF membership contribution. No additional costs are charged with the exception of reimbursement for investigation costs if fraud incident is proved to have occurred.

The contribution order of SGF considers the companies’ turnover. Thus, smaller companies benefit from a lower contribution fee but get full service.

Companies agree to both announced and unannounced audits during normal working days. They also allow SGF auditors to check any production or traceability record.

SGF is in charge of scheduling the control plan and orders audits. Every supplier is audited at least once a year. If considered necessary, for example, if any doubt about the conformity of products from any producer exists or if post controls for already solved issues should be carried out, SGF can increase the frequency of audits or inspections for one specific supplier.

Auditors are trained by SGF and follow an integrity programme.

Every participating company keeps a retained sample from every production unit, every reception of semi-finished goods and every delivery to customers, from which the auditor selects samples for analytical controls. Advice on what to sample is provided by SGF headquarters in function of the specific situation of a company. Specially targeted sampling is carried out when an investigation is underway. An average of about 10 samples per audit are sealed by the auditor and send to SGF headquarters. Analyses are carried out in different independent qualified laboratories to stay flexible in the choice of methods and to benefit from the judgement of independent experts. A legal evaluation is requested from laboratories for analysed samples. If there are reasons to doubt the authenticity of any product, a previously defined procedure for further analytical confirmation is applied.

By covering all links in the supply chain, the identity of retained samples along the whole value chain can be counter checked by comparison with samples taken at both supplier and customer from the same batch. The interpretation of analytical data can be fine-tuned if it appears that the processing conditions have influenced the analytical profile and can be taken into account.

Furthermore, auditors are instructed to take authentic reference material from the running production and to document their history. These samples are used to maintain a worldwide unique analytical reference data base for fruit and vegetable juices. Such samples can also be provided to laboratories to help them develop and test new analytical approaches. The support of analytical development is part of SGF's tasks.

Both analytical results and traceability documentation are evaluated by specialists at SGF's headquarters.

If controls are considered as satisfactory or if required corrective actions have been carried out, the producer is listed as an approved supplier on the SGF-internet member portal which is updated daily.

VCS rules for participating companies also include the purchase of semi-finished goods from SGF approved suppliers with priority or alternatively to apply an extended analytical scope to assure conformity. Such analyses create significant costs and are an additional motivation for suppliers to join the system and to benefit from a list of additional services which are not discussed here.

Products from companies which are not actively participating in the certification scheme are controlled too. Sampling of semi-finished goods from non-participants of the VCS can be carried out during audits at participants who purchase from these sources or who have received commercial samples. Finished products are taken from retail outlets.

In other certification systems food fraud is seen as one safety and quality risk to be controlled by a single company. Thus, only products from one company and their direct suppliers are submitted to controls.

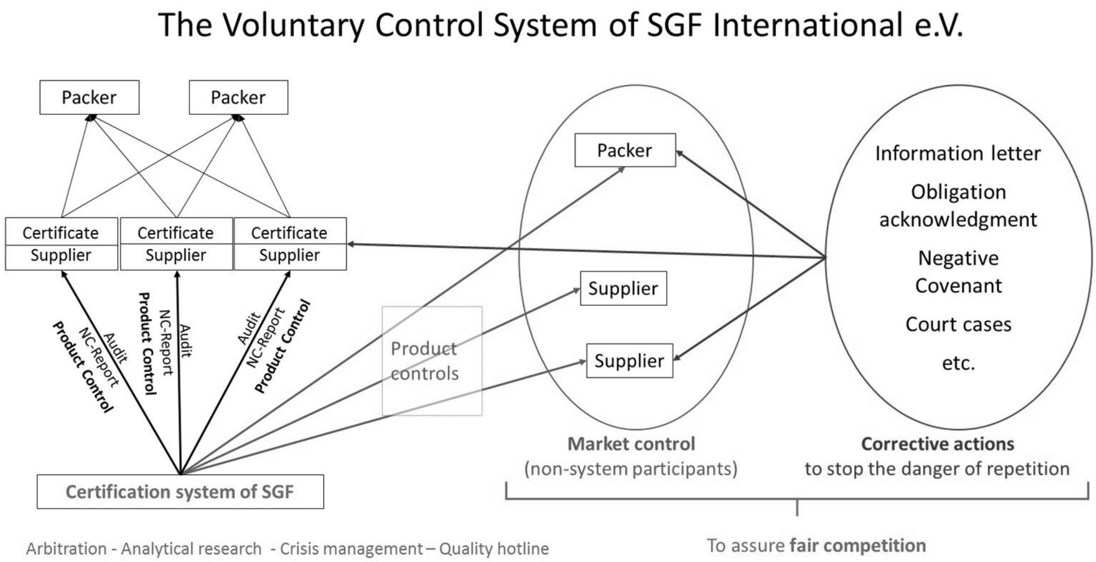

Figure 5: Control activities and corrective actions of the VCS

The major advantage of centralised and independent controls combined with corrective actions is the assurance of fair competition and a clean market. When a purchasing company detects food fraud, the subsequent consequences generally only have an effect on a single supplier-customer-relation. Unscrupulous suppliers remain in the market with adulterated products and harm fair competition and food safety. Therefore general market controls are part of the mandate that SGF had received from VCS participants. The matrix in Table 1 summarises the economic impact of possible frauds.

The VCS is recognized by the industry as control body because the system acts independently. The management and administration of the system must be structured accordingly. Other functions of an industry association such as lobby work in legislation processes and standard setting cannot be carried out by the control system if it is to maintain its neutrality and trust within the industry. The size and economic status of any company should not make any difference when food fraud is detected. For SGF the structure as shown in Figure 6 guarantees this requirement.

Table 1: Impact of food fraud to individual companies and the whole industry

	Fraud not detected	**Fraud detected Source remains active in market**	**Fraud detected Source removed from market**
Company related risks	Liability Food safety risk Official reprimand Recalls Damaged brand image	Less competitive purchasing conditions	No negative impact
Industry branch related risks	Public scandal Damage brand image for product type		No negative impact

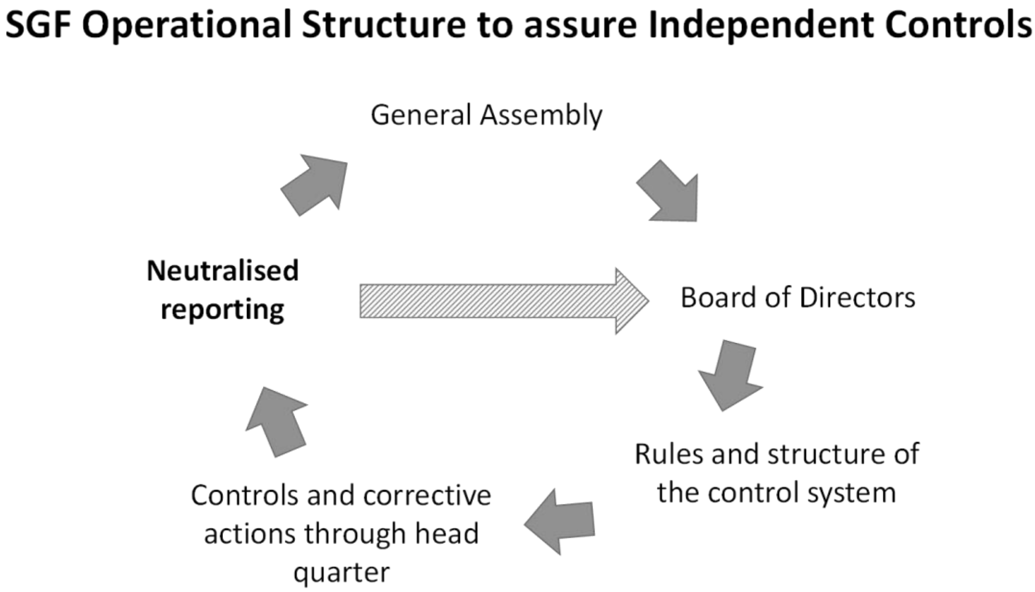

Figure 6: Operational structure of SGF to run an independent control system

As an overriding principle, all company related control results and corrective actions remain confidential between the company concerned and SGF operational headquarters and any problems are discussed solely between these two parties. No names or details are reported or transmitted to third parties. Thus, no direct relationship with the company's customers or with the authorities are affected. This allows constructive solving of any problem to assure that fraud practice is stopped. Furthermore, a tight and targeted follow up through SGF post controls ensures the effectiveness of corrective actions.

Only in a very few cases, for example if in a court case or if official notification for a detected health risk is required, does it become necessary for the operational headquarters to break confidentiality. These exceptional decisions are the responsibility of the board of directors who would be informed about the identity of parties involved.

2.2. Analytical strategy

In well-controlled sectors like the European Fruit Juice Industry, fraudsters need to put in place increasingly elaborate strategies to hide adulteration. This in turn raises the economic threshold for profit from fraud. As a consequence, less opportunistic and more systematically installed fraud can be expected. The higher probability of systematic fraud is considered for the design of control plans. Figure 7 shows a realistic flow of a systematic fraud process including the camouflage of analytical deviation. Experienced and trained auditors are able to identify and report different elements of this type of fraud process, which helps to focus controls.

The VCS adopts its analytical strategy by combining large screenings with selective and specific methods. Beside the widespread monitoring of the market, a risk-based sampling focussed on identified hot spots is necessary to get the best protection for the branch.

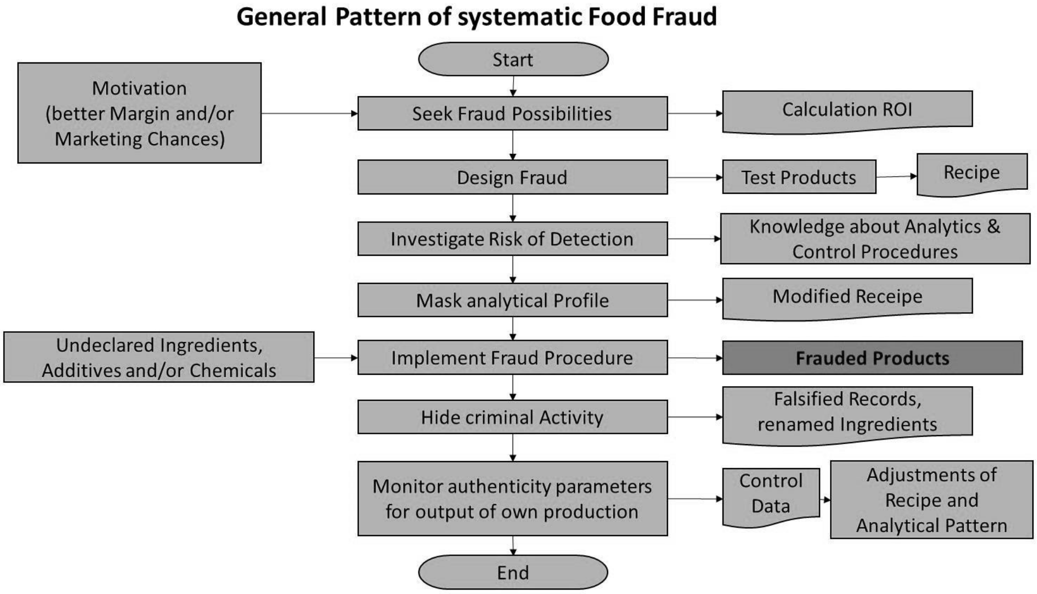

Figure 7: Graphic flow chart for systematic food fraud

Principle analytical objectives are:

- Monitoring of product groups with low fraud risk to maintain a clean market.
- Enforced controls on product groups which are more vulnerable for fraud

One important element to assure the first aspect is the application of proton-NMR-screening (SGF Profiling^{TM}) which covers a number of authenticity aspects for main product types in the fruit juice industry. Every sample taken during plant inspection is submitted to the SGF-Profiling^{TM} first. The method is a non-targeted fingerprint analysis [15,16]. Based on these results SGF decides on the applicable analytical scope.

Since not all authenticity aspects are covered by this screening technique, and for those products for which no reference models exist, other methods must complete the general quality screening. Due to the complexity of possible frauds the approach has a more or less spot check character. Continuously varying the selected checks makes it difficult to predict for the unscrupulous producer which fraud would be checked and which technique would be applied.

The VCS makes it possible to shift resources over company borders to control more intensively where a higher risk of adulteration is expected. This is important in particular for the second analytical objective to set a focus on vulnerable product groups.

Where possible, the analytical methods applied are preferably officially-recognized methods. A number of fruit and vegetable specific methods are recognised as valid by the International Fruit and Vegetable Juice Association (IFU) [17]. Often the best state-of-the-art methods are not referenced as such due to the time required to become an official method. In such cases laboratories must be able to demonstrate their suitability and/or have participated in cross validation checks with authentic and spiked samples organised by SGF.

2.3. Corrective actions

Being an industrial association SGF cannot replace national authorities and does not have the same competencies. However, the control system fulfils similar tasks and keeps the market clean. The system is also more efficient than those carried out by regulatory authorities, since it concentrates specific product know-how and control activities across borders along the entire production chain.

SGF activities follow strict rules that are controlled by external audits. An own management system (ISO 9001:2015) assures continuous improvement, integrity and equal treatment of all market participants.

The key drivers for efficiency are the corrective actions that the system imposes on any participant (see Figure 5) identified as responsible for the marketing of any falsified or adulterated product.

When a case of fraud is detected, confirmation of the analytical results and their evaluation by independent experts are required to avoid unjustified claims. After confirmation, SGF handles the case according to a catalogue of corrective actions which can be divided into internal and external measures. The normal case is the application of internal measures, handled between SGF and the company concerned to ensure confidentiality. This helps to maintain a constructive discussion. Different internal measures are possible:

- Information letter / warning letter
- Acknowledgment of obligation
- Negative covenant with penalty fee agreement for each case of repetition

For exceptional cases and only if internal measures have not had the desired effect, external measures are applied. External measures are all measures where other parties in addition to the co-workers of the SGF secretariat and the concerned company would be informed about the deviation and the identity of the concerned company. As the first step, the board of director is informed and takes the decision for further actions. Possible measures include:

- Formal infringement procedure: Information provided to authorities / Court case
- Information provided to the retailer and/or customers
- Information provided to a consumer organisation or public

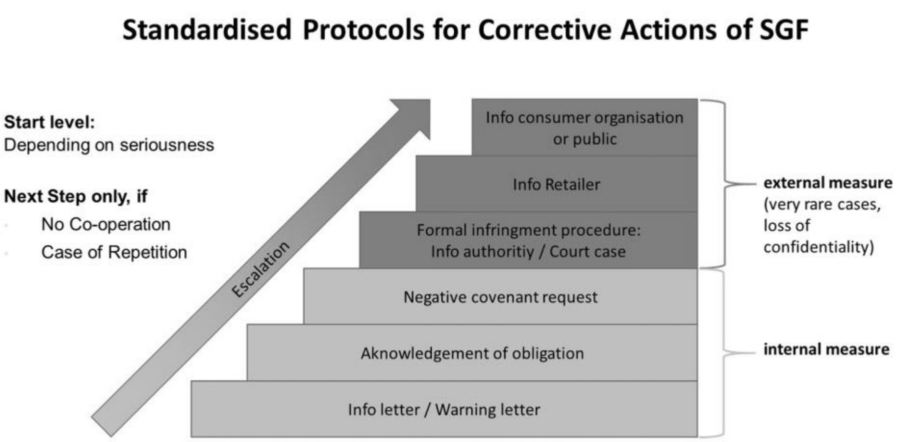

Figure 8: Corrective actions applied by VCS for quality problems

The non-respect of VCS system rules by participants leads also to corrective actions.

Figure 8 shows the different corrective actions. Depending on the seriousness of the case, first one of the internal measures is applied. For food fraud, this is generally the request to sign a negative covenant independently if the company is an SGF member or not. With such a covenant the company confirms that it will refrain from the detected fraud practices and agrees to a dissuasive penalty fee for each case of repetition. If a chosen measure is not successful the next stronger step is initiated. The system is also applied for other quality problems than food fraud, e.g. production errors or increased food spoilage.

2.4. Control results

Even though fruit juice has a high potential for food fraud, the market of consumer goods in VCS covered regions has not been marked by negative headlines due to fruit juice fraud in the last decades. No official statistics exist but in the European Union, it can be estimated that more than 80 % of semi-finished goods come from SGF certified companies. In countries with high fruit juice consumption like France and Germany the figure is even higher. National market coverage above 95 % is not unrealistic.

The control results have remained relatively similar over a number of years. Depending on the market situation some shifts and variations have been observed. About 450 audits per year are carried out by SGF auditors, the number of plants to be controlled is about 400.

As a very rough rule of thumb, from about 4 500 - 5 000 analyses per year, for 10 – 15 % of samples some analytical indicators have led to further investigation. With help of the extended SGF reference data base most cases can be explained by regional, seasonal or process technological particularities. Less than 1 % of samples analysed have shown real detectable authenticity deviation. Because SGF is working with enforced sampling for vulnerable hot spots the real percentage of detectable authenticity problems in the whole industry is likely to be lower than 1 %.

The risk of food fraud is several times higher for products which are marketed from non-VCS participants than those from SGF-approved supplier [18]. On the global level, fruit juices form part of the group of foodstuffs that have a high risk of fraud.

An anonymised overview of control outcomes is published in regular newsletters for SGF members and in annual activity reports, providing companies with information on observed authenticity problems so they can adjust their own food fraud protection measures accordingly.

2.5. Implementing of a centralised control system in other branches

The VCS of the fruit juice industry has been in operation for a long time and a wealth of knowledge encompassing analytical science, market structure, control operations and product specific intelligence has been built up. The experience gained has led to an efficient management of the available budget. Implementation of a similar system in any other branch is principally possible and is definitely recommended for products with a high food fraud risk.

However, the setting-up of a control system would require a certain starting investment and, above all, its acceptance by the industry branch. Only if a major share of market players is in support of its implementation and accept to abide by the rules of conduct, can such a system be rolled out successfully. To limit costs, benefitting from experience of existing control infrastructures is recommended. Limiting it to a defined region for finished goods and/or a reduced product scope could facilitate the start of a new system.

At the end of the day, companies will minimise their own costs incurred in carrying out vulnerability assessments and product control thanks to the advantage of centralisation. Additional market controls would lead to fair competition and fewer risk of scandals. System rules and control mandate must be defined exactly and agreed by all participants. Important points are listed in Table 2 and Table 3.

Table 2: Important characteristics of system rules in a sector specific control system

Rule characteristic	Comment
Rules are defined and agreed by active participants	Rules must be accepted by a major share of the market. Industry reality must be taken into account.
Stimulation to trade and purchase products from participants of the system	Participants must have an interest to purchase semi-finished goods from system approved suppliers preferably.
Enhanced controls when purchasing from outside of the system	No system can be hermetically closed. Therefore the system must include goods from non-controlled suppliers to ensure sufficient protection against food fraud.
Whole chain approach	Authenticity control is more efficient with cross checks along the whole supply chain.
Assure pre-competitiveness	Antitrust rules are prerequisite.

Table 3: Typical points for a mandate of a sector specific control system

Mandate	Comment
Analyses (product checks)	Analyses are necessary to check products and confirm frauds.
Audits (system checks)	Traceability data and knowledge about applied technology and specific circumstances allow refined evaluation of analytical results.
Whole market control	Controls must cover the whole market to assure fair competition.
Positive communication	Blacklisting harms the willingness of defrauding companies to carry out corrective actions. Only publication of achieved certification or approval of companies is recommended.
Maintain confidentiality	Constructive work on corrective actions is possible only if the companies concerned are sure about their anonymity with respect to customers and competitors.
Corrective actions	The system must tend to stop the danger of repetition for any detected source of food fraud.
Development of analytical methods	The system must support the best use and development of applicable analytical science. Access to efficient methods and updated information for market players is important. (e.g. publication of reference databases).
Development of control intelligence	Horizon scanning of fraud possibilities is required for efficient control work. Product specific experience to investigate and to detect fraud must be built up.
Combination with other services (facultative)	Synergies with other branch specific services can be useful. Therefore, pre-competitive character must be maintained.

3. Traceability tools to mitigate food fraud risk

3.1. Traceability

Traceability is the principle of keeping track of and connecting all the recordings that are made, and the existence of some degree of traceability underlies all the supply chain methods for verifying food item property claims.

There are numerous definitions of traceability, most of them recursive in that they define traceability as "the ability to trace" without defining exactly what "trace" means in this context. An attempt to merge the best parts of various existing definitions while avoiding recursion and ambiguity is "The ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications" [19]. This emphasises that any information can be traced, that traceability applies to any sort of object or item in any part of the life cycle, and that recorded identifications need to be involved.

Traceability depends on recording all transformations in the chain, explicitly or implicitly. If all transformations are recorded, one can always trace backwards or forwards from any given food item to any other one that comes from (or may have come from) the same origin or process. In addition, traceability requires relevant information to be recorded and associated with every food item in the supply chain. This makes it possible to find the origin of a given food item (the "parents"), the application of the food item ("the children"), and all properties of every food item (when and where was it created, weight or volume, what form is it in, what species, fat content, salt content, etc.). For the other supply chain methods to work, traceability needs to be present, and the efficacy of the supply chain methods is limited by characteristics of the traceability system. Food items need to be identified in some way (uniquely or as a group), the transformations that the food items go through need to be documented, and the attributes need to be recorded. The specifics of the identification and the documentation of transformations and attributes will decide how much data is present, how well it is connected, and how accurate it is, which in turn will be a limiting factor for the other technologies and methods outlined below.

3.2. Traceability systems

Traceability systems are constructions that enable traceability; they can be paper-based, but more and more commonly they are computer-based. Several detailed descriptions of traceability systems in various food sectors have been published, and there is general agreement on what requirements a traceability system should fulfil:

- It should provide access to all properties of a food product, not only biochemical properties that can be verified analytically.
- It should provide access to the properties of a food product or ingredient in all its forms, in all the links in the supply chain, not only on production batch level.
- It should facilitate traceability both backwards (where did the food product come from?) and forwards (where did it go?).

This means that the following activities must be carried out:

- Ingredients and raw materials must be grouped into units with similar and defined properties, commonly referred to as traceable Resource Units (TRUs)
- Identifiers / keys must be assigned to these units. Ideally these identifiers should be globally unique and never reused, but in practice traceability in the food industry depends on identifiers that are only unique within a given context (typically they are unique for a given day's production of a given product type for a given company).
- Product and process properties must be recorded and either directly or indirectly (for instance through a time stamp) linked to these identifiers.
- A mechanism must be established to facilitate access to the recorded properties.

Practically all food businesses have an internal traceability system; often using software with ample opportunity for browsing data, visualising dependencies (which TRUs are based on which TRUs), and creating reports related to what happens within the company. Implementing a similar functionality for an entire supply chain, examining the whole chain of transformations from raw material source to consumer, is a (and probably "the") major challenge, and requires effort, motivation and cooperation, in addition to the presence of technical solutions that build on well-proven and widely adopted standards. Verification and validation of the data in the traceability system is of course also very important, but these are external processes and not part of the traceability system itself.

3.3. Claims and methods for verification of claims

It is important to keep in mind that a traceability system is made up of statements that are claimed to be true, but it is not known for sure that they actually are true, so that is something that needs checking. Figure 9 illustrates the relationship between food item properties on one hand, and the claims in a traceability system on the other. Claims may be explicitly stated in the traceability system, or they may be implicit in that if the food item had that property (contained nuts, was made from genetically modified material), it should have been declared. The claims, whether implicit or explicit, fall into two categories; those that can be verified by analytical methods, and those that cannot. To verify a claim in the first category ("this product is made from cod"), analytical methods can be used to provide a true/untrue answer, or sometimes a likely/unlikely, answer. To verify a claim that is not related to a biochemical property ("this TRU came from the farm of Jim Jones"), the data recordings in the system have to be investigated, especially the transformations ("Did Jim Jones deliver to the food business that made this TRU?"). Using methods based on analysing data recordings cannot verify the claim, but they can often indicate if the claim might be true or not ("No, according to the records, Jim Jones has never delivered anything to the business that made the food item in question").

This means that analytical methods are very important when we are dealing with traceability, but they do not in themselves provide traceability. What they do provide is a way of verifying most of the claims relating to biochemical attributes of the food item in question. While these claims are only a subset of the total number of claims in a traceability system, they are among the most important ones, because if there is a food safety problem related to a food item, it will be detectable through application of analytical methods, and food safety, as it has been seen, is strongly linked to traceability.

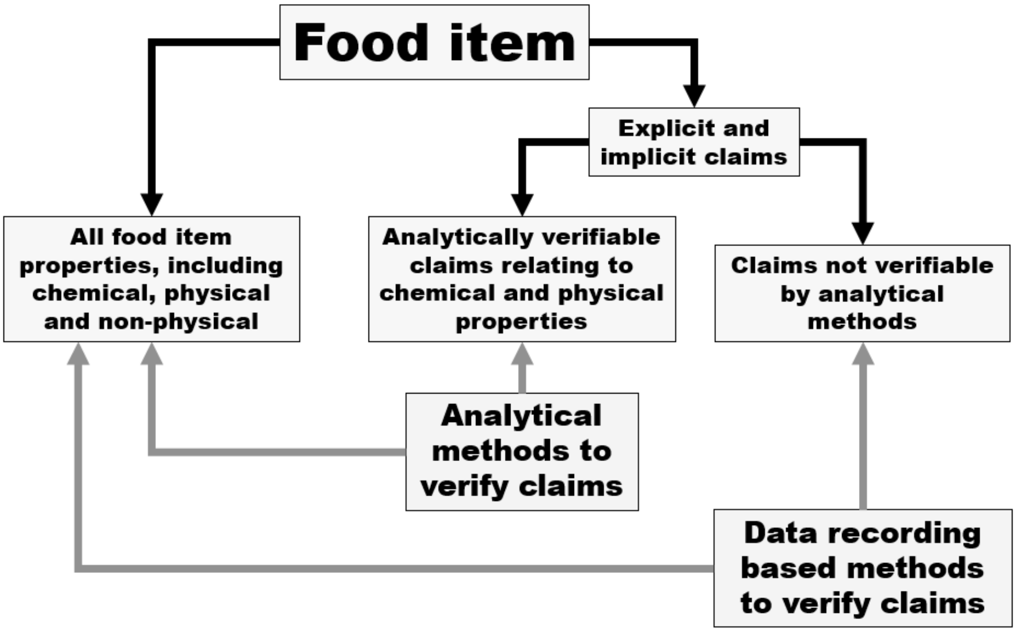

Figure 9: Relationships between claims and methods to verify them

3.4. Blockchain technology

Blockchain technology is not a method for verifying claims in itself, but it is a way of increasing transparency and accessibility of the recordings in the traceability system, and thus for increasing claim veracity, and so indirectly it contributes to verifying claims about food items. Blockchain technology in its current form has been around since 2008; it is what underlies the digital currency known as Bitcoin, and it can be used to document transformations in the supply chain in a secure and transparent manner. Blockchain technology is best described as one that enables records to be shared by all network nodes, updated by miners (system users who, for a fee, keep track of transaction records), monitored by everyone, and owned and controlled by no-one [20]. A significant problem in traceability is that it is difficult to verify that the stated transformations actually took place. Using blockchain technology, the record of all transformations would be in the public domain, openly visible to anyone (although most of the food item attributes would not be visible) [21]. If a buyer received a food item where the transactions were documented using blockchain technology, every single transaction from the food item in question back to the original farming or harvesting would be available for inspection, together with the other food items that came from the same source. This to some degree prevents food businesses from introducing undocumented raw materials or products into the supply chain; if they did, the mass-balance accounting would not add up (a 1200 kg fillet cannot be produced from 1000 kg meat or fish). It also prevents anyone from overwriting the transaction once it has been recorded, which means that if the original data recorded is correct (and it is normally in the interest of high quality producers to record the initial data correctly, to protect their brand and to justify the higher price they get) it becomes very difficult for foods businesses later on in the chain to counterfeit or dilute the product. Blockchain technology will not guarantee accurate recordings, but it will certainly remedy some weaknesses that currently exist.

3.5. Mass balance accounting

Comparing numbers and equalising them has been stated as a way of verifying claims related to large quantities. Material flow analysis is (MFA) is one approach related to mass balancing. This is a methodology developed to assess the flows and stocks of goods and materials within a set time and space [22]. The method is based on the mass balance principle; that matter is conserved in any system, and thus input is equal to output mass. It was developed to describe the metabolic processes of large and complex systems like cities, regions, nations and industrial companies. MFA is based on accounts in physical units (e.g. tons) quantifying the inputs and outputs of those processes [23].

Material flow analysis has often been used as a synonym for material flow accounting; in a strict sense, the accounting represents only one of several steps of the analysis and has a clear linkage to economic accounting. Two basic types of MFA can be distinguished. Type I is concerned with the environmental impacts of certain substances, bulk materials, or products, and therefore the flow of substances and materials linked to these entities are studied. Type II is interested in the performance of firms, sectors, or whole regions or national economies, and thus the throughput of substances and/or materials of these entities is analysed [24]. Whereas the first type is often performed from a natural science or technical engineering perspective, the second type is more directed towards the analysis of socio-economic relationships.

One limitation in using methods such as the MFA is the measuring of the qualitative aspects of material flow [25]. Quantitative changes that are measurable, for instance weight, can be accounted for using a mass balance approach.

3.5.1. Mass balance in fisheries: a study of the Norwegian cod fisheries

The Norwegian seafood industry is regulated by international standards combined with national regulations. The industry is tightly regulated as there are numerous registrations related to catch, landings, production, feeding, slaughtering, storage, transport and export. Despite the wealth of regulatory requirements, periodically there are confirmed incidents of fraud and misreporting [26], as well as accusations and rumours, especially in the cod fishery coastal fleets. Usually the fraud relates to misreporting of the total amount of landed fish. However, there is no agreed assessment suggesting the extent of the fraud, only disputed indications. A 2013-survey among fishermen and buyers conducted by Nofima indicated that the misreporting that year might have been around 5 % of the total catch [27].

In a forthcoming report [28], an analysis of the regulatory framework shows that the whitefish industry in Norway is subject to a complex list of registrations to different authorities that can be used as source data in analysis. When using the data in a material flow analysis, a gap between input and output of cod is found.

The MFA for cod was carried out on a national level for the years 2010-2017. Except for 2012, the output was higher than the input. In 2014, the discrepancy between input and output was as much as 9 %. In total for this period, the output was 5 % higher than the input.

While a certain portion of the gap is likely due to fraud, the discrepancy might also be caused by factors not related to fraud, but rather to the complexity of the production and supply chain. One challenge is that weight is recorded as living weight (round weight) in the landing phase and in product weight upon export. The numbers therefore have to be processed using a national conversion factor to get them in the same format. To obtain more information about the errors in the conversion factors and other possible sources of discrepancies, an interview was conducted with a company that produces and sells various types of fish products. Among other factors, the interview revealed that the discrepancy in product properties is largely dependent on the product in question. The discrepancy relating to weight, condition and conservation is much higher in the production of highly processed products such as saltfish and clipfish (cod that has been both salted and dried) with a long storage time, than in the production of fresh fish. In general, the more complex the production, the higher the discrepancy. It is also in the production phase of the product that discrepancies are most likely to occur, not in the export and sale of products.

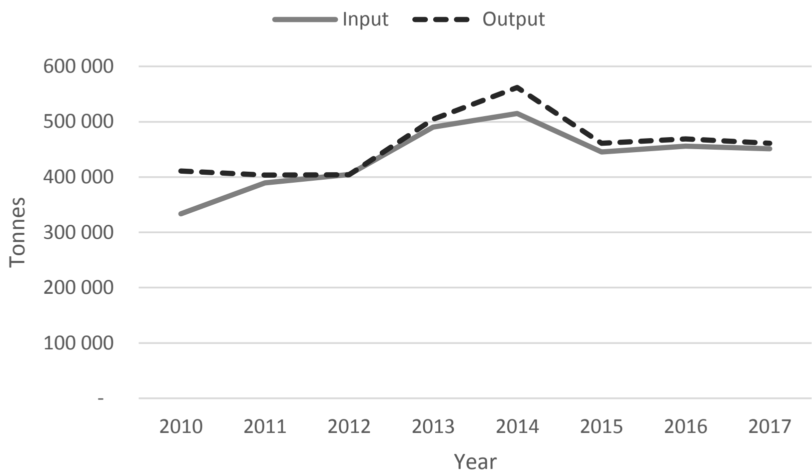

Figure 10: Discrepancy in tonnes between input and output when mass balancing cod in Norway

The conversion factors used to convert product weight into living weight stands out as a significant source of error, but there are also several other factors that can explain why this discrepancy seems to appear annually. Table 4 shows the identified main sources of discrepancies, the different reasons why they occur and the associated responsibility.

Table 4: Sources of discrepancies and associated responsibilities

Source of discrepancy	Reasons	Responsible
1) Errors in source data	Errors in electronic systems Human errors Methodical errors Hidden flows Information gaps Lack of control	Operator and/or Authority Operator and/or Authority Authority Actor and/or Authority Authority Authority
2) Errors in the MFA	Methodical errors Human errors Time lag/storage Conversion factors Alternative data sources	Study Study Method limitation Method limitation/authority Statistics supplier/authority
3) Fraud	Making profit Survival	Operator Operator

The findings from this case study shows that while public record requirements in the Norwegian fishing industry covers a wide range of topics, only a few can be used to trace a product or to identify a discrepancy. The case study shows that tracing claims like origin, time/date and ownership through the production is possible provided there are good systems for recording these properties. Properties like weight, conservation and product condition are more difficult to trace as they may change during the production. As weight often is related to catch volume and illegal, unregulated and unreported (IUU) fishing, this claim is of special interest.

If there are recordings of both input and output in a production, a MFA is of high relevance. However, the case study shows that the reliability is highly dependent on industry structure, the complexity in production, data availability, and data quality. Further, whilst the analysis shows that there is a gap between input and output, it does not identify whether this gap is due to unintentional actions (e.g. production errors, manual error, etc.) or if it is due to criminal activity. As the quantitative approach described above does not identify the source of the discrepancy, it must be supplemented by a qualitative approach, either in-depth interviews with industry actors or more cost-effective methods such as questionnaires or phone interviews, the former used in [27]. These methods can be used to identify weak points in the supply chain, such as those described above, relating to production complexity, conversion factors between product types, etc.

With the MFA-approach being highly dependent on data availability and data quality, it is useful within industries with many control points, but less so in cases where product registrations are few. As the case study shows, the discrepancy can be comparatively higher for highly processed products than products that undergo a much simpler production. For products that undergo a relatively substantial transformation during production, control points throughout the production process itself would be necessary to better account for discrepancies due to inherent product characteristics.

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