Advancing understanding of pinch-points and crime prevention in the food supply chain
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Crime prevention in the food supply chain: addressing the pinch-points

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Abstract

Food crime detection and prevention remains a challenge when whilst opportunity for crime can be reduced by implementing certain measures; addressing the potential perpetrators, their possible actions and criminal behaviour (including their rationalisation and decision making) and the trade-offs that can occur as a result of pressure in the food supply chain that provide a motivation for such activity, still remains complex and difficult.

These factors have led, in this study, to the consideration of pinch points within the food supply chain where crime could occur as a result of capability, opportunity, motivation, rationalisation and supply chain pressure. Pinch points can be addressed using the Food Crime Countermeasures Framework (FCCF) conceptualised in this paper. The conventional anti-fraud measures: detection, deterrence and prevention are essential to support food fraud risk assessments, continuous interventions and response strategies. The implementation of countermeasures that initially drive prevention and deterrence and where required, detection, intervention and response form the basis of the approach outlined in this paper.

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1. Introduction

Illegal activity in food supply chains is not only a discrete process operating in parallel to legal activities and supply chains, instead such activity can be embedded within authorised, licensed and permitted processes that have particular elements of opacity (Gregson and Crang, 2017; Manning et al. 2017). Illicit behaviour is a contemporary and an ancient theme in food supply chains both in terms of academic research, industry awareness and in emergent food related organisational and supply chain literature. Since the financial recession of 2007-08, McElwee et al. (2017) suggest that contemporary evidence from official reports and the media shows an increase in food related criminal activity including food adulteration, mislabeling of food, sheep theft, and trading in illegal halal meat. Farm crime has been considered in terms of criminal typology such as the urban marauder (Smith, 2010) exploiting often weak levels of security and police activity in rural areas, organised criminal gangs (OCGs) that may involve a network of insider groups (such as farmers) as well as external actors who can pass on the illicit goods into wider markets and destinations (McElwee et al. 2017). However, the strategic decision to engage in informal, and criminal acts for financial gain may be motivated primarily by austerity and its impact on the food supply chain and the need to be resilient or simply survive rather than motives of profit maximization and greed (Smith et al. 2017). Farms are just one element...
of the supply chain that encompasses multiple actors and stakeholders.

Organisations do not sit in isolation; they interact with external influences in their wider environment (Winter et al. 2004). Primary producers are actors that provide raw material, such as farms and aquaculture, secondary producers (manufacturers that enhance the value of raw materials, wholesalers, distributors) and tertiary producers (retailers and food service) see Closs and McGarrell (2004); Borghesi and Gaudenzi (2013). Supply chains are socio-economic networks with inter-related strategies, activities, dynamic components (the products, processes and technical knowledge employed) and structural elements such the key actors involved including the retailer, farmer, manufacturers processor, distributors and food service. Other factors include stakeholders such as investors, shareholders, insurers, certification bodies, governments, policy makers and regulators, civil society, amongst others; the complexity of the relationships formed, the climate of the relationships in terms of collaborative or conflicting characteristics, and the type of goals each actor develops (Closs and McGarrell, 2004; Borghesi and Gaudenzi, 2013). What factors have led to this reported rise in food related criminal activity both at farm level and across the wider supply chain and how is illicit behaviour rationalised from being the exception and becoming the norm? Are the factors influenced by multiple trade-offs within the food supply chain?

Trade-offs are said to be central to economics, because in a given situation neither the decision-maker nor wider society can have everything they want so they have to compromise in some way (Campbell and Kelly,
A trade-off is a mediated form of decision-making that is often a compromise, and this type of decision-making is ubiquitous at farm level when land is managed with multiple strategic and operational objectives (Klapwijk et al. 2014). Consumer trade-offs are often defined as being based on willingness to trade some attributes e.g. quality or safety for others such as price influencing marketing strategies, economic research and guiding public policy i.e. trade-off as a means of mental exchange rate between discrete, explicit attributes (Luce et al. 1999). Trade-offs therefore occur at multiple levels in such network systems (Table 1).

**Take in Table 1**

Protected values are those values that prove resistant to trade-offs with other values, particularly economic values (Baron and Spranca, 1997). However, research on trade-offs especially with multiple attribute and/or collective decision-making has considered other attribute trades such as time versus cost trade-offs (Feng et al. 1997); time-cost-quality trade-offs (Monghasemi et al., 2015); speed versus accuracy trade-offs (Häubl and Trift, 2000; Franks et al. 2003; Dane and Pratt, 2007); accuracy versus effort (or energy) trade-offs (Johnson and Payne, 1985, Bettman et al. 1990; Häubl and Trifts, 2000; Boulis et al. 2003; Gigerenzer and Gaissnaier, 2011); accuracy and informativeness trade-offs i.e. accepting errors in return for securing more informative judgments (Yaniv and Foster, 1995); cost versus risk trade-offs (Kerstholt, 1994); and benefit versus harm as a trade-off (O’Connor et al. 2003).

Time pressure is a frequent element of trade-off. Time pressure is driven by deadlines when the time available may be perceived as too short to
make a decision and multiple studies have investigated this phenomenon (Huber and Kunz, 2007). Time pressure, for example may lead to a negative emotional response (Maule et al. 2000) which then affects decision-making. Luce et al. (1999: 144) define emotional trade-off difficulty as “the level of subjective threat a decision-maker associates with an explicit trade-off between two attributes. Thus positive (benefit) and negative emotion (fear, harm, anxiety, threat, challenge, concern) and specific emotional goals (such as protecting self-esteem, maintaining a moral value or ideal) have an impact on both cognitive appraisal and decision-making. Therefore, trade-offs that can occur are multiple, complex and interwoven and the compromise between legality and illegality is only one of multiple decisions that supply chain actors have to take.

Decision-making behaviour is affected by these dynamic aspects of a given task environment such as time pressure, feedback on the effect of own actions, uncertainty and also a trade-off between cost and risk (Kerstholt, 1994). As a result, humans adapt their decision-making behaviour to a given situation or environment often seeking to reduce the amount of associated cognitive effort required (Shugan, 1980; Häubl and Trifts 2000) either as a conscious response or as an unconscious cognitive strategy. Thus it could be posited that decision-making is a situated event influenced by a number of factors. Prendergast (2002) suggests that the trade–off of risk versus incentive is influenced by how risk is determined e.g. risk as measured by volatility or variance of returns by the executive, whereas for farmers it is the variance of profits or variance of yield in a given crop cycle.
In this context a *food crime* threat can be considered to be an agent that arises from fraud, or perpetrators taking advantage of the market opportunities to substitute or deceive as a result of weather events, harvest failure etc. that can cause loss or harm to individuals and/or organisations.

Profit maximisation in the agricultural sector is contextualized by characteristics of constant uncertainty and risk of failure due to weather, animal disease etc. and many farming organizations have limited opportunities in terms of growth orientation and business expansion (Smith et al. 2017). So what are the pinch points in the supply chain that give rise to the environment where crime could occur?

### 2. Pinch Points

The term “pinch-point” has been used to describe physical points or locations (Makwasha and Turner, 2013); the weakest necessary conditions for the problems to persist (Read and Tilley, 2000); strategic points in the supply chain (Christopher and Peck, 2004); and points of intervention (Weisel, 2003) such as where external pressure can be applied e.g. regulatory pressure or stimulus (Yakovleva and Flynn, 2004) or to disrupt criminal activity (Chon, 2016). Pinch-point mapping involves identifying potential bottlenecks and threats and manipulating and managing those points in order to ensure effective control of resources in order to meet demand (Pil and Holweg, 2006). Moreto and Clarke (2013) in their research on transnational illegal markets in endangered species highlight that crime is situational and by directing preventive measures at pinch-points then this will deliver the best results in reducing the potential for criminal activity. Further they argue different crimes will have different pinch-points. In summary, a pinch-point is
the location at which intervention might be expected to have the longest term
of action and the widest impact (Read and Tilley, 2000) and in the context of
food crime the point where interventions take place that will have the longest
and widest impact. In terms of types of crime associated with the food chain
this paper is considering inter-food supply chain i.e. between one discrete
food supply chain and another, the legal and the illicit and intra food supply
chain criminal activity i.e. criminal activity within an otherwise seemingly
legitimate food supply chain. To provide clarity the following definitions from
Closs and McGarrell (2004, p8) are used:

- A supply chain is the combination of organisations and service
  providers that manage the raw material sourcing, manufacturing, and
delivery of goods from the source of the commodities to the ultimate
users.

- Supply chain management is the inter- and intra- organisational
  coordination of the sourcing, production, inventory management,
  transportation, and storage functions with the objective of meeting the
  service requirements of consumers or users at the minimum cost.

Pinch-points can be created by supply chain pressure (Manning et al.
2017).

In a given food supply chain there are normative, coercive and mimetic
pressures from respectively lobby groups, consumer, criminal groups,
coercive and political pressures from government, buyers and sellers etc.
(Kilbourne et al., 2002), and mimetic pressures (economic), which emerge
from horizontal competition (Aerts et al., 2006; Zhu et al., 2005; Sarkis et al.,
2010) that operate at individual levels primary, secondary, tertiary production
and also at the interfaces between levels. Pressure can be specifically exerted where there is an asymmetry in supply chain power between two or more actors/stakeholders. Wolf and Hermanson (2004) argue that pressure is one element of the “fraud diamond” model, the other three elements being capability, opportunity and motivation. Indeed, trading in an environment where there are differentiated global standards for animal welfare, environmental protection and worker welfare standards can lead to trade-offs.

Borghesi and Gaudenzi (2013) considered four types of supply chain risk: market risk, process risk, supplier risk and environmental risk as well as the risks associated with transparency and information visibility. For a retailer, the degree of risk associated with a given actor is mediated by whether the actor has a given monopoly in terms of their products or service or alternatively whether the actor e.g. a farmer can be easily substituted.

Traditional supply chain response to managing and mitigating risk include using insurance, greater information sharing or outsourcing risk to other supply chain actors (Olson and Wu, 2011). Therefore, driven by shareholder or insurer demands to quantify, manage and where possible mitigate their market, process, supplier and environmental risk profile, retailers, manufacturers or food service may adopt a systems based approach to risk.

There are multiple pressure factors that can drive illicit activity in food supply chains including rapid development of systems, logistics and technology, asymmetry in information flow, data swamping and opacity; market competition and resource scarcity, inadequate policy and market governance, lack of regulatory and market sanctions, isomorphism, and ultimately low probability of discovery (Charlebois et al., 2016; Manning et al.,
This pressure can create a series of pinch-points of informal: formal and visible: invisible supply chain risk interface(s) where differentiation in actor and stakeholder approaches, goals and objectives leads to trade-offs and thus gives rise to illicit behaviour. Taking a transactional approach and simply developing formal risk prevention strategies (countermeasures or preventive measures) is not enough to address the challenge if illicit behaviour and so pressure, opportunity. Capability, motivation, rationalisation, the derived value propositions, and regulatory and market incentives for illicit behaviour also need to be considered when developing crime prevention strategies (Manning et al. 2016; Manning et al. 2017).

The actualization of this pressure, capability, opportunity and motivation dynamic can be seen through the lens of recent global food scandals such as the 2014 European horsemeat scandal; the 2017 meat fraud scandal in Brazil (Manning et al. 2017), and the 2017 fipronil in eggs and composite products scandal in Europe. The lack of early and harmonised regulatory intervention in the fipronil scandal has resulted in an incident that has affected 56 countries (RASFF Portal, 2018; RASFF 2018). Manning et al. (2017:19) outline a number of contextual factors that show the complexity of the socio-economic aspects of illicit behaviour such as resource allocation and ownership, power relations, greed, economic inferiority, need and pressure, and argue that the existing model of the two-dimensional fraud diamond is actually three dimensional and multifaceted when the socio-economic dynamics of supply chain pressure are also considered.
3. Locating and situating food crime prevention

Supply chain power is driven by the degree of power localisation or conversely distribution and each actor’s relative control of or access to resources and capital assets. Thus the risk of illicit behaviour is situational and is framed as has just been described by power structures and other socio-economic factors. Successful modes of food crime in terms of the degree of financial gain, or their impact in the case of food defense, reflect on the quality of execution and at what point, or even if, detection actually occurs.

The use of a pre-requisite program to minimise and where possible eliminate the likelihood of an unintentional food safety incident is well established in the food supply chain through the hazard analysis critical control point (HACCP) approach. The alternative i.e. the development of a countermeasures program to minimise or where possible eliminate the likelihood of a food crime threat is less well determined.

In the wake of the 2013 Horsemeat Scandal, the Elliott Review determined that a national food crime prevention framework was essential to prevent a future food crime incident (Elliott Review, 2014). Countermeasures that address food crime vulnerability include detection, deterrence and prevention and disruption (Spink et al. 2015; Spink et al. 2016; Soon and Manning, 2017). Detection measures can identify the activities associated with food crime, whilst deterrence includes the measures that focus on a specific type of attacker and their activities. Deterrence can therefore be described as the inhibition of opportunity and perpetrator activity as a result of concern over the personal consequences to themselves as a result of taking an action or the maintenance of appropriate preventive measures, or
countermeasures that will discourage their activity (e.g. concern that the
attack will fail). Prevention in this context concerns the resources employed to
minimise the potential for a food crime incident to occur and ensure disruption
mechanisms to address any activity if it occurs. Preventive measures,
deterrence and/or a lack of motivation to conduct food crime will also have
influence. Spink et al. (2017) recommended that in order to address the root
cause of food fraud – food science and technology should encompass social
science, business and understanding of criminology.

Manning and Soon (2016) compared and contrasted six existing food
crime risk assessment (FCRA) models in terms of their aims, mechanisms of
operation and practicalities of use. The risk assessment models were: threat
analysis critical control point (TACCP), vulnerability assessment and critical
control point (VACCP), the CARVER+SHOCK tool, the food protection risk
matrix (Spink and Moyer, 2011), and the United States Pharmacopeial (USP)
preventive food fraud management system.

The ability to quantify the likelihood of a threat or vulnerability in a
given situation is influenced by the degree of adoption of countermeasures
and their effectiveness (Manning and Soon, 2016). Thus whilst FCRA is
obviously of value, that preventive benefit to organizations is limited especially
with regard to emerging or new threats if the risk assessment phase does not
translate into an effective, and dynamic food crime countermeasures
framework (FCCF). The development of the FCCF is essential to embed
preventive measures, identify relevant sources of intelligence on changing
status of risk, detect illicit activity, and ensure timely and appropriate
responsive action and a countermeasures’ continuous improvement strategy.
Therefore, three factors: detection, deterrence and prevention can be drawn together at regulatory, supply chain or individual business level to underpin a FCCF of integrated risk assessment and implementation of countermeasures that initially drive prevention and deterrence and where required, detection, intervention and response (Figure 1).

Take in Figure 1

Horizon scanning can be described as a systematic way of considering evidence about future trends and scenarios in order to determine whether an organization is adequately prepared for potential threats and has implemented, or can readily adopt, means for their appropriate countermeasure control. Effective horizon scanning is a foundation for a FCCF i.e. considering intelligence from a range of sources, be it economic, social or environmental, in order to effectively map possible criminal scenarios associated with the materials and products that the organisation procures, produces and sells, in order to accurately identify the potential threat, the controls required and the mechanisms for updating such assessments if the evidence (intelligence) changes in the future. During the mapping process weak areas, pinch-points or hotspots that are vulnerable to food crime at specific stages in food supply chains or networks can be determined.

Detection, mapping and prevention activities can only be developed to address known issues or activities, making TACCP and VACCP of limited value with regard to emerging crime risk or entrepreneurial, enterprising, situational crime risk that is reactive, responsive and specific to an organisation, the products it produces and the associated supply chain (Soon and Manning, 2017).
Those individuals or teams developing FCCF (often termed *defenders*) need to recognise that the adoption of universal, general countermeasures based on historic threats as a ‘catch all approach’ to preventing and where required managing food crime is of limited value in addressing illicit behaviour that is caused by supply chain pressure as the drivers of illicit behaviour and associated opportunity, rationalisation, capability and motivation, and derived value proposition are situational and transitory.

Situational crime risk and the means to predict its occurrence been explored within criminology and contemporary food literature (Manning and Soon, 2016; McGloin et al. 2011; Perline and Goldschmidt, 2004). Situational crime risk factors include factors such as supply chain pressure, power asymmetry, type of corporate culture, the work environment and can have a multiple, compounding impact (Perline and Goldschmidt, 2004: Carson and Bull, 2003). Situational crime risk can be mitigated by strengthening environmental resilience (Clapton, 2014) especially by increasing the associated personal risks and difficulties associated with the crime and alternatively reducing the potential personal rewards of committing a crime (Spink and Moyer, 2011; Clarke, 1995).

The concept of crime prevention through environmental design is nothing new as the design of physical space has long been identified as being important in understanding and mitigating criminal behaviour (Newman, 1972). Newman proposed that defensible space can be created when the physical space is structured in a way that reinforces the social structure that defends itself i.e. a farm or factory design could in itself help or hinder the social culture of the organisation in which people work and their psychological
engagement with the space itself. Appropriate countermeasures that are
based on the concept of defensible space can be adopted in a preventive
approach to crime in the food supply chain. Newman (1972) identified four
themes of defensible space and these have been adapted in this conceptual
research to considerations of a food factory environment:

- **Territoriality** – creating a sense of legitimate and illegitimate access to
  space i.e. identifying the legitimate allocation of space to those who are
  approved to work in the area and those who should not have access.
  Protocols that address territoriality will assure that appropriate people
  are in a given space, colour coded protective clothing by location will
  create a visual territoriality that should prove a deterrent to illicit
  individuals entering that space;

- **Natural surveillance** – designing the physical space in a way that
  assists legitimate users to observe the behaviours of both employees
  and visitors e.g. temporary workers, service engineers, contract
  cleaners etc.

- **Image** – a sense that the physical space within the factory and
  externally is well cared for and developing preventive measures that
  reduce the visual appearance that areas of the farm, distribution centre
  or manufacturing site are remote, little used, or not regularly visited;
  and

- **Milieu** – which, in the context of a food supply chain, describes the
  image, natural surveillance and territoriality of other businesses that
  interface with the organization’s space. Is there a sense, for example,
that other businesses in the supply chain are not addressing defensive
space and undertake opaque practices or lack transparency?

The example given here is one of defensive space in the physical context.
The other area of defensive space is more ethereal, such as data storage,
data exchange and cyber-related space. Cybersecurity can be described as
the countermeasures taken to protect a computer system and associated
storage clouds or individual appliance against an intentional malicious target
attack and/or unauthorised access and unintentional or accidental access.
Cybersecurity countermeasures include, but are not limited to, developing
cybersecurity policies and procedures, undertaking focused FCRA, adopting
training and awareness sessions for staff commensurate with an individual
staff member’s responsibilities and developing soft or hard controls such as
specific software, firewalls, technologies etc. that can protect the
organisation’s cyber environment and their electronic assets (Manning,
forthcoming).

However, preventive environmental design to mitigate food crime risk is
of limited benefit if there is high-level insider complicity i.e. the involvement of
the business owner, management or employees in criminal activity in illegal
practices such as covert operations by running out of hours processing known
only to a select few. Therefore, consideration of the impact of the processing
environment and the wider supply chain environment is of value, but it cannot
address all potential threats and is not as a result a zero risk approach.
However the theory of defensive space does lend itself to adoption within an
overarching FCCF.
Spink et al. (2015) define **hurdles** in the context of food crime prevention approaches. Hurdles are the transactional, formal system components that reduce opportunity for food crime by either assisting detection or proving to be a deterrent (Spink et al. 2015). These would include on-line monitoring and verification activities in the wider supply chain such as audits and product sampling. Thus a **hurdle gap** can be described as a vulnerability to food crime where such mitigation activities are not in place, or alternatively are in place, but are not effective. **Guardians** are the individuals operating at national, supply chain or individual business levels (Spink et al. 2015) that have the knowledge, skills and understanding to implement a FCCF, but vulnerability can still occur even in the presence of a capable guardian.


Crime vulnerability is the extent to which an individual, organisation, supply chain or national food system is at risk from, or susceptible to, attack, emotional injury or physical harm, or damage from intentional illicit activity (Manning and Soon, 2016). Vulnerability can be assessed, using input from legal, intelligence, medical, scientific, economic, and political sources, to determine the scientific, economic, political, and social circumstances of a country in order to quantify the degree of threat and to set priorities for resources (Manning et al. 2005; WHO, 2002). Vulnerability ranking is not static and needs to be routinely reassessed to ensure that the ranking and prioritisation of risk remains appropriate and that suitable countermeasure(s) continue to be in place (Manning and Soon, 2016; Manning et al. 2017).
Food criminals are clandestine, stealthy, and actively seek to avoid detection (Spink, 2011). According to the Centre for the Protection of National Infrastructure (CPNI, 2013), the majority of insider criminal activity in organizations was carried out by permanent staff (88%), with only 7% of cases involved contractors and 5% involved agency or temporary staff. Individuals who had worked for their organization for less than 5 years represented 60% of cases and 49% of cases were by perpetrators aged between 31 and 45. More males (82%) were involved in insider activity compared to females (18%). These data were derived from 120 UK-based insider cases from both public and private organizations from a range of industry sectors, not just food, where financial gain was the single most common primary motivation (47%), ideology (20%), desire for recognition (14%) and loyalty to friends, family or country (14%). This literature and other sources lends itself to categorising food criminal according to type (see Manning et al. 2016; PAS, 96: 2017; Spink and Moyer, 2013) and by inference developing appropriate preventive strategies. McElwee et al. (2017) argue that in order to mitigate the potential for food crime in the supply chain two approaches can be followed: firstly to design food supply chains with built in risk-tolerance to crime and secondly to have appropriate strategies in place to contain the damage once an undesirable event has been identified. The magnitude of food crime risk (and to whom) will depend on the likelihood and severity of each type of incident and the degree of implementation of preventive and mitigation measures which can also be affected by the efficacy of guardians and hurdles (Spink et al. 2015). Thus as previously outlined in this paper there is no silver bullet of
solutions to address food crime instead holistic, focused and product and
process specific crime prevention strategies need to be adopted.

5. Crime prevention strategies

Countermeasures are intended to reduce criminal opportunity in food supply
chains (Spink et al. 2015). The implementation of countermeasures will not
only have a preventive aspect in terms of preventing an incident and also
more unlikely in the first place, but should an incident occur appropriate
countermeasures will lessen the impact of an incident (Mitenus et al. 2014).
Regulators seek to reduce illegal activities either through punitive command
and control measures, prosecution and detection systems or alternatively via
preventative or deterrence measures such as awareness education and
enterprise support (Smith et al. 2017). Supply chain approaches need to drive
a crime prevention strategy based on reduced opacity and more transparency
and access to information in the supply chain. Supplier monitoring protocols
need to include not only product related procurement activities but also
standard reference checks, financial status checks, and consideration of the
supplier’s surge capacity and flexibility i.e. the ability to deliver increased
quantities at short notice, if required (Beil, 2009). A financial status check can
be incorporated into a suppliers’ ranking and performance weighting and the
scoring system that can highlight and reflect financial risk associated with a
given supply base. This data will support FCRA that focuses on identifying
the suppliers who could be subject to the supply chain pressures described
earlier in this paper e.g. failed harvest, volatility in commodity price etc. and as
a result be more likely to undertake illicit activities. These “high-risk” suppliers
can then be tracked and monitored. Whilst price is one of the most important
factors used in supplier selection, but it is critical to ensure that the objectivity
of assessing product integrity and food crime risk is not lost in a purely risk:
financial reward; time versus accuracy trade-off.
Forensic accounting has been adopted as a food crime
countermeasure especially to identify “false” suppliers (Power, 2013).
Traceability tests and second party and third party supply chain audits will
provide more information for focused forensic accounting and combined
audits can be developed (Figure 2).
Take in Figure 2
Indeed, it was a recommendation of the Elliott Review (2014) that the United
Kingdom (UK) government should “support the work of standards owners in
developing additional audit modules for food fraud prevention and detection
incorporating forensic accountancy and mass balance checks.” Traceability
protocols adopt as a minimum the regulatory one step backward and one step
forward tracking and trace principle (EU Regulation No. 178/2002) or market
protocols can require traceability throughout from field to fork and the reverse
too in a given supply chain. However, with multiple ingredients used to make
composite products, and lengthy and complex food supply chains traceability
can prove difficult in practice. Additionally, if an individual business within the
supply chain deliberately and unanimously decides to behave illicitly, they can
choose to circumvent orthodox supply chain traceability countermeasures,
controls and monitoring. Therefore the value of developing a FCCF with
regard to traceability is the socio-economic aspect of the promoting food
integrity and developing an open transparent supply network. Procedural
controls for traceability in themselves are not enough to ensure consistent
compliance and prevent the opportunity for illicit activity. Further actions are needed including an effective verification (or surveillance) programme that ensures that the controls are in place and adequate.

The process of food production involves discrete production stages from farm to fork i.e. during growing, harvesting / slaughtering / catching of primary products, primary processing, secondary processing of food / food ingredients, packaging, labeling, storage and dispatch all pinch-points where food crime activities could occur. At the manufacturing stage specifically, countermeasures need to be adopted to address the process vulnerabilities that can provide opportunity for food crime earlier in the supply chain.

During processing, itself potential deliberate contamination of food products or tampering with processes can be minimised via limited accessibility through engineering design and consideration as to the accessibility of production equipment and where needed re-engineering of equipment to prevent access e.g. covered conveyors, use of sight glasses, zoning (place) and creating a buddy-system to limit lone workers at high-risk processes such as use of expensive ingredients, or for recipe use where such information is deemed confidential. Tracer ingredients can be added to high value food so that potential counterfeit product can be readily identified in production and post packing. Further supply chain preventive countermeasures include numbered and tamper-proof seals on delivery vehicles and bulk storage silos, stock control measures such as computerised fill level equipment which relay the information back to central computerised systems, reduced electronic access to specific physical zones which are deemed high-risk via fingerprint technology, codes and passwords (PAS 96,
2017) password protection of computer terminals and electronic process
management systems etc.

Appropriate assessment measures that demonstrate whether the
FCCF is effective include substitution profit assessments, suppliers' ranking
and ongoing performance monitoring, risk rating of likelihood of perpetrators
to conduct activities, assessments to determine the likelihood of detection,
severity or impact of practices, consideration of the effectiveness of
preventive countermeasures and other factors that influence the risk of food
crime such as history of occurrences, seasonality, and market prices. The
formal FCCF systems that are in place being visible and auditable provide
objective evidence to internal and external stakeholders of the organization's
commitment to combatting food crime (Power, 2013). However this approach
does not, according to Power, build the soft knowledge required in terms of
inspector skills and knowledge to interpret audit results, thus a new type of
balanced score card of soft, culture-based risk factors also needs to be
developed. This development is worthy of further study and empirical
research.

Assessing the efficacy of the FCCF encompasses both the technical
areas of responsibility within the food supply chain as equally as the
administrative areas of responsibility, so food auditors (food crime / fraud
assessors) need to work hand in hand with appropriately trained accountants,
purchase ledger administrators etc. Via processes such as forensic
accounting, the consistency of records and documentation can be assessed
and activities such as mass balance testing for batches and production runs
allow unusual and inappropriate trends to be identified. Market knowledge is
essential to undertake this assessment effectively especially as described in
this paper the risk is situational and dynamic.

Verification through documentation review and classical food supply chain
auditing provides the food crime auditor with a range of evidence or audit
observations, which can be both qualitative, e.g. interviews, observations and
records or quantitative based on measurement and test. System failure can
occur through people (human failure), process and place (design) which
provides opportunity for perpetrators to commit food crime so verification
activities need to include all of these areas in their scope.

6. Conclusion

Pinch points are not dissimilar to vulnerability points. Identification of pinch
points and applying intervention strategies within the food supply chain – will
provide positive impact in reducing food crime. One way to address the pinch
point is via the Food Crime Countermeasures Framework (FCCF). In addition
to the conventional deterrence, detection and prevention methods, the FCCF
emphasizes a circular or a feedback mechanism to ensure continuous
interventions are successfully implemented. The countermeasures cover a
range of potential pinch points and vulnerabilities or can be targeted
measures that act against unique risks and perpetrators.

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Table 1. Types of Trade-off (Adapted from Klapwijk et al. 2014)

<table>
<thead>
<tr>
<th>Trade off</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Field level</td>
<td>Production yields versus nitrate/phosphate leaching and water quality</td>
</tr>
<tr>
<td>Enterprise level (crop or animal)</td>
<td>Grain versus crop residue</td>
</tr>
<tr>
<td></td>
<td>Milk versus meat production</td>
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<tr>
<td>Farm/agricultural system level</td>
<td>Cropping plans/enterprise mix</td>
</tr>
<tr>
<td></td>
<td>Diversification</td>
</tr>
<tr>
<td></td>
<td>Maximising short-term versus long-term return</td>
</tr>
<tr>
<td>Landscape level (agricultural system versus spatial, environmental or socio-cultural objectives)</td>
<td>Land use and ecosystem services</td>
</tr>
<tr>
<td></td>
<td>Water use</td>
</tr>
<tr>
<td>Supply chain</td>
<td>Specification versus food waste</td>
</tr>
<tr>
<td></td>
<td>Cost versus risk</td>
</tr>
</tbody>
</table>
FIGURE 1. Steps in developing a food crime countermeasures framework (FCCF). *Via food crime risk assessment (FCRA), known threats may be prevented, deterred or detected. Via continuous interventions including horizon scanning, existing and emerging threats may be identified or detected and appropriate actions (response) can be taken.
Before audit, determine types of product, ingredients needed and market trends

During audit, follow detailed floor plan to confirm documented product flow matches on-site production and there are no hidden areas

Mass balance test (Input quantity [minus expected process losses] = output quantity)

Materials at incoming goods are cross referenced to purchase orders / laboratory records of tested incoming goods

Conduct forensic accounting (i.e. market price trends; are buying records always the same?)

FIGURE 2. Forensic accounting and food crime prevention audits (adapted from Jack, 2015; NSF 2014)