Emerging issues and Challenges in Agri-Food Supply Chain

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Summary

Globalization and free trade policies coupled with consumers' demand for safe and high quality foods have created pressure on various stakeholders (key players) attached within the agri-food supply chain. Influence, contributions and the role of socio-economic and environmental factors are huge to achieve a successful flow of supply chain. Globally, various techniques and conceptual models have been proposed to render agri-food supply chain to be effective and profitable. However, still there are several gaps and emerging challenges in the supply chain to achieve a fruitful sustainable food production. In this chapter, an attempt has been made to identify and highlight the present world scenario and challenges encountered along agri-food supply chain and future prospects.

Keywords: Conceptual Models; Sustainable Supply Chain; Price Volatility; Food Frauds; Food Waste; Food Traceability; Block Chain Technology; Information and Communication Technologies

Introduction

Consumers demand for high quality and safer foods have led to proposals on innovative approach and models to be adopted in the agri-food supply chain. On a global context, there are several sustainability challenges witnessed along the food supply chain. Several innovative solutions proposed (depending on the socio-economic and environmental factors) are practically applicable only in certain regions of the world. Sustainability challenges along the 'farm to fork' concept is well documented in the literature and available databases. However, several sustainability challenges along supply chain management still remains unresolved. These problems range from production and processing stages, until it reaches consumers. Managing the pressure exerted by consumers (regarding quality and safety) has led to potential negative and positive impacts. Even though food production has increased to meet the demands of ever growing populations, raising price and economic impacts/hardships on individual regions (low income and high income countries) remains a recurring challenge. On a global context, with free trade policies gaining higher hand, 'trade revolution' has taken up as an upper hand over 'green revolution.' Coupled with this is the changing weather patterns which has significant effect on food supply chain. Nevertheless, 'food-energy-water' nexus is vital to effectively manage agri-supply chain and the environmental stewardship. Besides, in the food supply chain context, life cycle assessment is recognized as a reliable method to evaluate environment impacts of various processes (such as farming, harvesting of raw materials, processing, packaging, etc) (Thomassen et al. 2008). Not to forget, reduction in the carbon footprint should be one of the crucial factors to ensure and create a sustainable food supply chain system (Virtanen et al. 2011). Of course key logistic decision can be of much help to ensure environmental sustainability challenges faced in food supply chain. Certain regions of the world though claim to be economically stable, a positive relationship has never been established between diversity and food self-sufficiency. Low- and middle- income group of countries are having their own problems in the food supply chain which needs to be resolved, like: feeding and meeting the demands of own population as well as compete in the global food markets. Elementary sustainability issues valuable from a socio-economic and environmental perspective has been discussed under the 'millennium' and 'sustainable' development goals of United Nations (UN, 2014). Further, the food supply chain is recognized as a series of closely working interdependent firms/companies which manages the smooth movement of agri-food products (for value addition) to provide consumers high quality products at a low and affordable prices (Folkerts and Koehorst, 1998).

In the recently published book (Bhat, 2017), a wide range of sustainability challenges faced in the agro-food sector (on a global scenario) has been discussed by leading experts. Besides, there is a wealth of literature that have focused on various sustainability issues encountered in the agri-food supply chain (Akkerman et al. 2010; Beske et al. 2014; Brandenburg et al. 2014; Borodin et al. 2016; Kusumastuti et al. 2016). Further going ahead, top priority and attention is being focused on 'sustainable food supply chains' and 'sustainable supply chain management' (Zhu et al. 2008; Ras and Vermeulen, 2009; Tseng and Chu, 2013). Concept of sustainable supply chain management involves managing of materials, information's and capital flow between parties involved in the supply chain with a common intention of socio-economic-environmental sustainable development (Seuring and Müller, 2008). Of late, Esfahbodi et al. (2016) has proposed a working model focusing on cost operations that encompasses procurement and distribution, designing and investments recovery options in a sustainable manner. Role of technological innovations and their impact on agro-food sector (market, market structure and supply chains) has been well documented by Reardon and Timmer (2007). Moreover, the concept of 'supply chain integration' encompasses mutual understanding, tactical collaborations and practical/operational strategic activities of companies along the chain. Supply chain integration has been envisaged to keep the entire network in a single loop together, thus helping in reduction of recurring supply chain challenges; such as deprived demand based management, forecasting and maintaining of consumer and suppliers understanding and relationships (Marzita Saidon et al. 2015). As a whole, supply chain is independent and involves management and movement along various individual sectors like that of aquaculture, agriculture, livestock, food supplements, organic farming, sustainable farming, cold chain management, dairy industry, minimal processing and much more.

Todays globalized food system is highly a complex mixture with the role played by industrial personnel, NGO's, farming community and stakeholders being high. Nevertheless, the relationship along the food supply chain can be expressed as an understanding between individual stakeholders (players) to meet the interest of group of consumers. Nonetheless, all the stakeholders must encourage sustainable development and should be aware of the supply chain flow (e.g. origin of the raw material/products bought, marketed, etc.). It is also opined that if the stakeholders approach in the supply chain are in a sustainable behavior, the rapport of their firm will be much higher (Carter and Rogers, 2008). So also, maintenance of transparency is vital, and both of the consumers and stakeholders should not be ignorant on sustainable production that is adopted along the supply chain (Wognum et al. 2011). Of course, apart from consumers, farming community are also under high pressure to produce high quality safer foods at lower costs. Food diversification, food culture, changing lifestyles has all led to propose several 'tailor made solutions' along the food supply chain. Linking producers and consumers is a major effort being placed on a global scale. At international market levels, several glitches and risks have been identified along food supply chain, like: food frauds, food recalls, food borne illness (emergence of new resistant microbial pathogens), illegal production of 'mimic' or 'faked' foods and many others. Indeed, there are several 'school of thoughts' who claim that while buying a food-stuff, consumers might be least interested to know what exactly happens along a food supply chain. These groups of consumers are more worried about price/cost rather than quality or health impacts. Further there are demographic challenges in the low income group of countries (with household food insecurity problems) who are rather unaware of concept of food quality supply chain. Conversely, to ensure food security, it is not the food production or consumption volumes (Barrett, 2010), but food diversity/diversification that has an impact. So also, rural populations perceptions can be quite different from urban populations for food supply chain issues. Trust in the food supply chain varies among populations from region to region too. Along the supply chain context, the distance travelled by a agri-food commodity from farm (producers) up to table (consumers) is referred to as food miles. In majority of the developed countries consumers demand for minimally processed foods which have undergone less processing along the food production chain. As such, new agricultural policies and models being proposed for food supply chain (globalization of food chain) have been of high success only in certain regions. So also, challenges facing imports and exports in international market chain are several9nned for certification, maintenance of international standards, quality assurance, etc).

There are several terms and concepts being proposed by various researchers relevant to supply chain. The term 'supply chain responsibility' has been used by Spence and Bourlakis (2009) and 'ethical supply chain' concepts have been referred (by Carter and Easton, 2011; Walker and Phillips, 2009). Way behind during eighties, 'supply chain management' concept was introduced by Oliver and Webber (1982). Supply chain management is a direct representative of demand chain management wherein production, handling, processing manufacture, distribution as well as marketing are tailored designed to meet consumers' desires. There is a high level of uncertainty for a food products quality and safety in comparison to the market-driven transaction cost like information, negotiation or monitoring (Hobbs, 1996). Food trade and internationalization of supply chain management have led to competitive market approaches at individual national levels. At international levels, for an imported food, consumers are much interested to know on the country (geographical origin), certifications of international standards, ethical issues followed and overall a sustainable food production has been adopted or not. In the preceding text, certain vital parameter that influences a food supply chain is being discussed.

Issues, advantages and challenges

Several interesting sustainability challenges is being faced along the agri-food supply chains which encompass various socio-economic and environmental aspects. Socio-economic issues are mainly related to local populations or consumers, and this is related to household income, price variations of food commodities, gender inequality, health issues and many others. Some of the other challenges like: food shortages, pre-/post-harvest losses, imbalance in demand versus supply gaps, small land holdings, price rise, consumers demand for safe and quality foods, nutritional security, access to market information for farmers, exposure to global opportunities for free trading or technology transfer, lack of updated information and intelligence, unorganized and inadequate market infrastructure and supply chains, climate change issues, unsustainable land-water- energy use practice, and much more. Globally, a wide range of heterogeneity in household food insecurity has been witnessed in various regions (Headey et al. 2013; Verpoorten et al. 2013) creating imbalance in the regional economy. With regard to environmental aspects, this covers those dealing with waste disposal (on farm or off farm), food industrial wastes, 'on table' food wastes, etc. Li et al. (2014) have opined that in the low income and high income countries, food industry contributes to elevated levels of wastes and greenhouse gas emissions. As such, increased knowledge and concerns among consumers with available updated databases have pressurized agri-food industries personnel to emphasize on enhancing the quality and safety along supply chains (Matopoulos et al. 2007). The role of partnerships between farming community to work along with supply chain stakeholders (government organizations, NGO's, research scientists, academicians, industrialists, and others) are vital (Hamprecht et al. 2005). With rapid changes being witnessed in climate and weather conditions world over, this can have a significant impact agri-food supply chain. Imbalance in crop productivity, reduction in annual yields, depletion in water resources, impact on soil quality, and variations in nutritional qualities are some of the expected climate induced changes that can influence smooth functioning of the agri-food supply chain. These in turn can stress the overall marketing system with imbalance, in the supply versus demand systems.

Food price volatility: Any change in the market food price can highly influence a household food security, especially in middle- and low- income group of countries. Last decade has witnessed rapid changes in the food price in both agriculture and aquaculture sectors. Import and export business have suffered with detrimental long-term effects affecting normal living styles. Of course, it is a well acclaimed fact that volatility in price can affect the continuous flow of food supply chain and is a highly undesirable trait. According to Dawe and Timmer (2012), changes in price can lead to inefficiencies, low confidence in market/ investments as well as hampering of overall economic growth. Transaction cost theory and contract theory have been proposed and applied (Hobbs, 1997; Goodhue, 2000) to deliver various economic principles for designing supply chain. In addition, contract theory proposed which states providing contracts to agents (Bolton and Dewatripont, 2005), the pros- and cons being well understood.

Price, cost reduction and quality are main pointers to examine the performance of a supply chain (Cai, 2009; Fynes, 2004). High prices have been linked with increased food insecurity and poverty, especially among the non-urban/rural consumers/populations (Headey and Martin, 2016). Moreover, changes in lifestyle, food habits, preference by consumers for vegetarian/plant based diets have all led to a temporary imbalance being created in the supply chain and market demands. This in-turn affects normal price of a food commodity. Nevertheless, movement of rural populations, especially those of farming communities to urban regions can also contribute to price volatility. This holds true mainly in the Asia-Pacific, South-East Asia and North African regions. Converting of local agriculture farms and plantations to produce export oriented crops is also of much concern, especially for small scale farmers (Rullia et al. 2012). So also, emergence of new pests and vectors, lack of appropriate logistics can also have an impact on price. Though several working models are being proposed, not much information's are available on how these models contribute to the success to manage price volatility in the agri-food market supply chain. Besides, as indicated earlier, changes in the weather/climatic conditions can results in imbalance between supply and demand, thus pressurizing supply chain and marketing system and subsequently giving rise to price alterations. Influence of climate variability can affect yield pathways as well as relative price changes. In Figure 1, conceptual linkages between climate and price variability, adaptation options and food security has been depicted (Source: Wossen et al. 2018). As per the author, climate-induced price variability can significantly affect household decisions. So also, price variability can have an impact on food security wherein purchasing power in household can be compromised.

Quality and safety issues: GAP (Good Agriculture Practice), GHP (Good Handling Practice), GMP (Good Manufacturing Practice) along with HACCP (Hazard Analysis and Critical Control Points) approach and practice of international benchmark standards have been a success story in majority of the countries world over. However, still several issues which emerge from time to time on quality and safety of various agri-food commodities (both in fresh and processed ones). Emerging issues on food quality and safety in agri-food supply chain has been excellently documented by leading researchers in recent publications (Bhat et al. 2012; Bhat and Gómez Lopez, 2014).

Globalization of agri-food markets coupled with free trade policies have tremendously enhanced inspection of food origin, their quality, safety, nutritional and health properties as well as ethics followed to achieve a sustainable food production. Among all, labelling on the origin and processing of products can be considered as highly important from both consumers and stakeholders point of view. Implementation of strict policies, legislations and trade agreements for safer agri-foods have their own detrimental effects. Cheap and low quality food commodities have been marketed among inter-continents with lots of traceability issues. Presence of banned chemicals and contaminants, presence of spoilage/pathogenic microorganisms, new insect vectors pose, etc pose serious problems. Opportunistic behavior of middle men or suppliers along the supply chain can be dangerous too. Management and functioning of food supply chain emphasizes more on food quality (Rong et al. 2011). In the supply chain, the identified gaps are not entirely from the farming land, but contributions from other driving force institutions (like transport, storage, marketing, middle men, stake holders, suppliers, etc) are equally high. Hence, building up of mutual trust and positive business partnerships is of paramount importance for various stakeholders involved in the food supply chain. Mutual relationship, trust, extended partnership, effective communications, commitment and consumers' satisfaction are vital for maintaining high quality standards and safety of foods along the supply chain rather than investing in modern day technologies (Keller 2002; Beth et al. 2003; Fynes et al. 2004; Ding et al. 2014; Swinnen et al. 2015). So, bottom line being, food quality and safety are particularly of paramount importance to an individual country to overcome concerns relevant to increased cases of food recalls, economic loss, increased food frauds and faked foods, etc along the supply chain. In addition, bio-terrorism threat, increased reports of loss in consumers' confidence, increased pressure for regulation and guidelines and increased imports and trading of agri-food commodities from regions with less stringent food safety laws pose serious concerns.

Issues of food frauds, block chain technology and traceability are being discussed later on in the preceding text.

Food wastages and loss: The major reason of concern in agri-food supply chain is food wastage and loss. Alterations in the physical characteristics of a food (non-edible and reduction in weight) can be considered as food loss while inability for consumption of edible foods can be considered as waste. Nevertheless, food loss has been considered as a sub-category of food waste. As per the United Nations Environment Programme, one of the main constraints for imbalance in the supply chain is the relation between production and consumption versus food waste and loss. Even though 'Zero Hunger Challenge' has been taken up seriously by the United Nations (UN), if this imbalance occurs, then it can be an issue leading to food insecurity. The UN by taking all of the stakeholders into confidence (involved in food supply chain), has developed sustainable food system model to eliminate food wastage/loss to ensure global food security (United Nations, 2012; Wickramasinghe, 2014). Food loss can occur at 'on farm' or 'off farm' levels. This might be due to inappropriate storage environments, logistic problems, pest and contaminants, mismatch in supply vs. demand, and much more. 'On table' wastes can also be considered as food loss. Regarding food waste, this mainly happens due to negligence and mishandling and knowingly disposing of edible food stuffs (mainly by consumers in house or restaurants). In general, along the supply chain-food loss occurs in during initial stages while food waste occurs later-on (Parfitt et al. 2010). As per the FAO (2011), in developing and developed countries, in the food supply chain food loss and waste occurs mainly at consumers' level, while in underdeveloped or low income countries waste occurs during initial or middle stages. It is worth to note that in developed countries, post-harvest loss in agri-food supplies are much lesser and this is owed to modernization of the supply chain. Over here, the loss can occur only at consumer or retailer levels only (Priefer et al. 2016; Teng and Trethewie 2012). In the supply chain route, loss and wastage can occur irrespective of an agri-food commodity involved (fresh or processed). It is universally agreed that upgrading the conventional marketing system with modern technologies (waste disposal or reuse/value addition) can reduce wastage. Lack of market infrastructure and modernized facilities coupled with poor policy and regulatory frameworks and quality regulations can have long standing unwarranted influence on supply chain. As per the Food and Agriculture Organization (FAO) of the UN, nearly one third of worlds food production is wasted (FAO, 2017). According to UNEP, nearly 300 million tons of food is wasted annually owed to irresponsible approach either from a producer, retailer or consumer (UNEP, 2015). The food waste can lead to environmental issues/burdens and if remains unmanaged, then it can have an impact on achieving success in the smooth flow of supply chain (leading to food insecurity) (FAO, 2014). Raak et al. (2017) have proposed a conceptual model of drivers for 'processing-related' food waste (Fig. 2). This model proposed is self-explanatory which highlights more on processing related food wastes and losses. Kibler et al. (2018) have recently proposed conceptual model to characterize food waste within the 'Food-Energy-Water nexus' (see Fig. 3). Accordingly, the mechanism with which food waste executes itself along the nexus is directly influenced by human behavior and decision making process (this nexus is discussed in detail by the author).

To prevent loss and wastage many strategies have been put-forth by researchers and institutions world over. In general, along the supply chain, it is opined that stake holders need to work out and check for a balance in the 'loss versus prevention' costs, invest in setting modernized marketing facilities, upgrade agri-food processing facilities, undertake measure to reduce carbon emission, set-up a working model for logistics such that the product reach consumers in minimal time (food miles), etc. It has been reported that vertical cooperation can contribute to reduction in food loss (deterioration) and carbon emission wherein appropriate strategies of forward and backward integrations can help a stakeholder (here retailer) for making investment in preservation technologies to reduce food loss or deterioration (Huang et al. 2018). So also, developing models for optimization of sale forecasting process can be a vital step which can have an impact on the expansion and growth of a representative supply chain (Dellino et al. 2018).

Food frauds: Food adulterations related health issues are regularly reported from many regions of the world. Adulteration can be intentional or unintentional and not necessarily for economic gain. However, on the other hand, food fraud is defined as deliberate and intentional addition, substitution, tampering, mislabeling and making false claims of a food product mainly aimed for economic gain. Food frauds being intentional, it is more about cheating consumers for economic gains in the market. In majority of the food fraud cases, serious health effects have been reported. Some recent examples of food fraud scandals include: marketing of fake eggs, plastic rice, intentional adulteration of herbs and spices, horse meat scandal, melamine in milk, mislabeled olive oil, liquefying of fruit juice, reuse of drainage oil, mislabeling on the origin of fresh produce and processed foods-stuffs, and more. Once the fraud is detected along the supply chain, consequences are highly damaging, like company rapport being at stake, losing of consumers' confidence, product recalls, volatility/collapse in the local and international market, and in extreme cases leading to imprisonment as serious criminal offence. Understanding the individual agri-food supply chains at the primary producer levels can improve forecasting of fraud vulnerability. It is highly recommended that evaluation of the food fraud vulnerability along the supply chain can help in understanding key potential drivers (Spink et al. 2017). Of late, food fraud vulnerability and their key factors have been detailed by van Ruth et al. (2017). Accordingly, authors have identified food fraud vulnerability elements and have detailed various factors involved (see Fig.4). Factors sub-grouped were 'opportunity related' factors, 'motivation related' fraud factors and 'control measures' related factors.

Moreover, assessments and data generation have been performed in milk, spices, sea food (fish), meat and olive oil (Silvis et al. 2017). Recently, Moyer et al. (2017) have opined that fraud vulnerability needs to be assessed both at the micro- and macro- factorial levels. According to Manning and Soon (2016), vulnerability can be minimized via implementation of appropriate control measures. Working on food frauds policy and food chain, Manning (2016) has opined that fraud in food supply chain can be owed to integrity of food item, various processes employed for production of the food items, personnel involved as well as information's (labelling) accompanying the food items. The author has also stated that food fraud mitigation can transfer from a stand point perspective of detecting fraud to preventing food fraud. As shown in Fig. 5, Manning (2016) has proposed 3 vital constituents namely: food integrity (product, process, people and data integrities), drivers of supply chain linking food frauds and mitigation methods (operating at organizational, supply chain and global measures). Even though several invasive and non-invasive tools (including those of analytical and biotechnological methods) have been recommended for detecting food frauds, majority of the times it has remained underexplored owing to cost effectiveness as well huge volumes of samples to be analyzed in short time interval. On the other note, gaining access to market intelligence can be a key factor for identifying food authentication and frauds. Proposing innovative models to forecast risks involved in food frauds can be of much benefit. To protect global consumers interest, instantaneous efforts need to be done to develop universally acceptable models for each of the food commodity which are in high demand and vulnerable for frauds. Maintenance of transparency and validations along the supply chain should be of paramount importance. Involvement of producers, suppliers, marketers, risk assessment researchers, food safety inspectors, and experts from industry and academia and finally consumers are important to prevent food fraud in the supply chain.

Food traceability and block chain technology: Traceability literally means tracing the movement of a agri-food commodity along the supply chain. CODEX Alimentarius defines food traceability as the '*ability to follow the movement of a food through specified stage(s) of production, processing and distribution* (Codex, 2006), while as per the ISO standard 22005:2007 food traceability is explained as '*a technical tool to determine the history or location of a product or its relevant components*' (ISO, 2016). The concept revolves around 'one step ahead' and 'one step behind' at any given point in the supply chain. Traceability in simple words are appropriately documented transparency of the supply chain (Opara and Mazaud, 2001) of a agri-food commodity to ensure success for sustainable agriculture and food systems.

As indicated by Petersen and Green (2005) tracing and tracking are two different concepts. Tracing involves backward process wherein origin of a commodity can be determined via maintenance of records along the supply chain, whereas tracking involves the forward process wherein end users or the consumers are identified via location in supply chain. According to Bechini et al. (2008), tracking follows a downstream path of a agri-food commodity along the supply chain, whereas tracing refers to upstream referring to records in the supply chain to identify origin and characteristics features of a commodity. According to Rábade and Alfaro (2006), both tracing and tracking requires 'managerial decisions' to be taken along the supply chain to enhance efficiency, improve processing skills, risk management, value addition and enhance relation between supplier and stakeholders. According to Rijswijk and Frewer (2008), product tracing helps to regulate and understand (physical and sensorial) conditions, a produce at any given point of time. Traceability on its stand alone can help in assuring and overcoming sustainability challenges in the agri-food sector. Being transparent in the supply chain, traceability system can be a value addition to maintain food quality and safety and overcoming challenges of management system (provide direct communication linkages at micro levels with consumers and market).

Further detailing, traceability involves movement tracking from farm to table (raw materials originating farm, all of the geo-environmental conditions, harvesting, post-harvest handling, processing, manufacturing, technological intercessions, logistics/transportation involved, preservation, labelling and market sales) and is important to achieve success in food security of a region. Tracking of agri-based foods at the production and processing stages as well as during the marketing and distribution stages along the entire supply chain can be of benefit to identity food frauds, maintain transparency, reduce food safety risks, minimize food recalls, reduce wastes and economic losses. Agri- food supply chain traceability can involve those of a product (raw and finished) or process involved or origin (geographical source, genetic constituent, supplier, etc). As an example, Lim et al. (2011), consumers are much likely to opt for products from a particular geographical location of their preference compared to those which have their origin from an undesirable location. According to Larsen and Lees (2003), novel and well-organized traceability systems can manage human errors and create better awareness on food quality standards along the supply chain.

Aung and Chang (2014) have proposed various drivers or the motivating factors of traceability in food supply chain. A range of motivational factors is identified with reference to food safety, quality and visibility; traceability as a reliable a tool replies for simple queries raised like "*who (i.e., actor/product), what (actor/product's information), when (time), where (location) and why (cause/reasons)"* (see Fig.6). Proceeding further, the same authors have proposed conceptual framework of food traceability system (see Fig. 7). As per this framework all of the players (stakeholders or personnel involved) involved in the entire supply chain are deliberated to encompass both internal and external traceability. Emphasis is laid on safety regulations and quality assurance systems that are enforced by all the players in order achieve efficiency in a standardized way.

Besides, for successful operation and performance in supply chain, modern technologies (wireless technology, sensor technology, location mapping technology, information and communication technology, internet/web technology) are referred to as facilitators serve as a channel to all of the players (stakeholders involved) permitting them to have an access to information systems of food traceability.

Traceability can be imperative to gain confidence of consumers and stakeholders. Nevertheless, food traceability can also be considered as a preventative strategy in management of food quality and safety. On occurrence of health hazards or food scare in the society, maintaining a reliable food traceability system can enable timely recall of a particular batch of food products and minimize risks involved. Of late, many techniques have been routinely used to identify a particular product, like bar codes, QR codes, sensors, radio frequency tags, etc. Though consumers and public health related personnel are demanding food traceability in the supply chain, at the end of the day it is the personnel involved in agri-food business (as main economic drivers) who need to sustain this and are going to be benefited. Further going ahead, as of today, the word ‘block chain technology’ is gaining much importance to minimize food frauds.

Block chain technology: Block chain technology is a new invention which has been in focus in the supply chain management (mapping and scanning). This technique encompasses a sharing a traceable and transparent document for record keeping purposes. All of the vital information are collected at each of the transaction steps (traceability) in the food supply chain. This technology includes approval from all of the stakeholders involved in supply chain. Block chain technology is easier and can be assessed (sharing of documents, intelligence, data mapping, recommendations, etc) by all of the stakeholders at any given time frame. Block chain technology enhances transparency (digitalization of tracking and storage of information’s, can reduce food frauds, enhance consumer confidence, etc), enhance food safety (reduce cross contamination issues, product recalls, reduce food waste and loss, minimize or cut-down costs, etc) and improve overall efficiency (logistics, distribution, marketing, treatability, consumer confidence). As this technology is still in infancy stages, there are certain issues that needs to be sorted out like, who will be the key person who retains or manages vital information's, what exactly is the role of an individual stakeholder, cross-checking for authenticity of the details documented or included, readiness of the market for this technology, and much more. Aschemann-Witzel (2017) by working on 'planned behavior theory' concept (proposed originally by Ölander and Thøgersen, 2013) has provided an overview of how initiatives are localized in the up/downstream end of the supply chain, the main success key and MAO factors involved (see Fig. 8). The MAO factors originally proposed by Ölander and Thøgersen (2013) are motivation (M), personal ability (A) and externally identified opportunity (O).

Information and communication technologies in food supply chain: Revolution in information/digital technology has led to a newer phase in agri-food technology field. Digital technology has gained high attention and has changed the way people communicate, interact and exchange details with each other in the society. These technological innovations are in the form of mobile phones, smart phones, smart watches, drones, notebooks, computers, broadband internet facilities, and much more. As of today, even the agri-food supply chain is highly influenced by digital technology revolution. Information and communication technology (ICT) applications have bene applied to monitor climate changes and their impact on agriculture (Ospina and Heeks, 2011). ICT has benefitted global food supply chains by providing vital data on innovative techniques that can be employed during pre- and post- harvest operations (Coley et al. 2011). A wealth of literature is being published on ICT, artificial intelligence, geospatial science, etc and their role in agri-food sector. Wang (2016) has detailed on the importance and application of E-Logistics in managing supply chains. ICT's efficiency has been best trapped in agriculture trade, extension programmes and for imposing good agricultural practices (Rao, 2007). Selecting appropriate planting season, disease and pest controls, irrigation management, livestock management, selecting best seeds and plant varieties, planning for storage facilities are just a few examples on the ICT role/advantages in supply chain. ‘Drones’ usage in agricultural fields are well known and popular. So also, sensors usage has been used to get information’s and meteorological data from isolated or remote rural farming areas. According to Sylvester (2013) sensors can help in conservation of highly valued agri-food products too. Farming communities especially in developing countries have been benefited by getting better price for agri-food commodities in international trade market (Golan et al. 2004). So also, application of ICT in rural farming areas have provided benefits due to raised awareness and technical skills on new policy frameworks (Grant, 2003). Besides, farming community is expected to get better access towards understanding the demand for particular crop varieties, pest and disease forecast, alternative market channels, better decision-making process, post- harvest management practice, managing risks involved in production and logistics, and other supply chain demands. Nevertheless, ICT can also directly benefit and help in product identification, food fraud vulnerability, quality and safety measurements, etc. Büyüközkan and Göçer (2018) have recently proposed an integration framework for the development of digital supply chain (DSC) (this is rather self-explanatory) with expected practical application the near future (see Fig. 9).

Some of the popular software programme developed to identify traceability includes Enterprise Quality Management, Food Trak-2 and Qual-Trace. As with other technologies, ICT also has its own barriers like shortage in technical experts and support staff, chances of mis-communication in long distances or remote regions, lack of signal access (band width), uncertainty in predicting agri-food supply chain trends like demand versus supply, and much more (Huggins and Izushi, 2002; Smallbone et al. 2002; Deakins et al. 2003). However, in the coming days these hindrances are expected to be easily overcome.

Conclusions and future outlook:

Agri-food supply chain success remains critical unless efforts are made by the involved stakeholders (from personnel involved in farm up to table) to seriously understand the underlying issues and problems. Some of the vital factors in supply chain management among the participants (stakeholders) are linkages, collaborations, belief, teamwork and transparency are. As far as unethical trading psychology persists, food frauds can be expected in the global market in the near future too. However, emerging techniques like traceability and block chain, food laws and legislation, conceptual models are expected to contribute for smooth flow of agri-food supply chain, at least to some extent. In the following days, market driven agriculture and food production needs to be given higher priority by keeping in mind consumer demands. International support needs to be extended for low- and middle- income groups of countries for understanding and achieving success in supply chain. Climate change, agricultural diversification, overcoming logistics issues, feeding the world's population, emerging pests and diseases, creating alternative rural markets and overcoming terrorism based threats are some of the challenges that are expected to influence the smooth flow of agri-food supply chain.

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References:

Akkerman, R., Farahani, P., Grunow, M. 2010. Quality, Safety and Sustainability in Food Distribution: A review of quantitative operations management approaches and challenges. OR Spectrum, 32 (4):863-904.

Aschemann-Witzel, A., Hooge, I.E. de., Rohm, H., Normann, A., Bossle, M.B., Grønhøj, A., Oostindjer, M. 2017. Key characteristics and success factors of supply chain initiatives tackling consumer-related food waste-A multiple case study. Journal of Cleaner Production, 155:33-45.

Aung, M.M., Chang, Y.S. 2014. Traceability in a food supply chain: Safety and quality perspectives. Food Control, 39:172-184.

Barrett, C.B. 2010. Measuring food insecurity. Science, 327: 825-828.

Bechini, A., Cimino, M., Marcelloni, F., Tomasi, A. 2008. Patterns and technologies for enabling supply chain traceability through collaborative e-business. Information and Software Technology, 50(4):342-359.

Beske, P.A., Land, and S. Seuring. 2014. Sustainable Supply Chain Management Practices andDynamic Capabilities in the Food Industry: A Critical Analysis of the Literature. International Journal of Production Economics, 152: 131–143.

Beth, S., Burt, D.N., Copacino, W., Gopal, C., Lee, H.L., Lynch, R.P., Morris, S. 2003. Supply chain challenges- Building relationships. Harvard Business Review, 81: 64-73.

Bhat, R. 2017. Sustainability Challenges in Agro-food sector (Editor: Rajeev Bhat); Wiley Blackwell Publishers, U.K.; ISBN: 978-1-119-07276-8; total pages, 720, April, 2017.

Bhat, R., Gómez Lopez, V.M. 2014. Practical Food Safety: Contemporary Issues and Future Directions (Editors: Rajeev Bhat, Vicente Manuel Gómez Lopez; Published by Wiley Blackwell Publishers, U.K.; ISBN: 978-1-118-47460-0; total pages 632, May, 2014.

Bhat, R., Karim, A.A., Paliyath, G. 2012. Progress in Food preservation (Editors: Rajeev Bhat, Karim AA, Gopinadhan Paliyath) published by Wiley Blackwell Publishers, U.K.; ISBN-13:978-0-470-65585-6, total pages 656, February, 2012.

Bolton, P., Dewatripont, M., 2005. Contract Theory. MIT Press, Cambridge, Mass, pages 1-744.

Borodin, V., Bourtembourg, J., Hnaien, F., Labadie, N. 2016. Handling Uncertainty in Agricultural Supply Chain Management: A State of the Art. European Journal of Operational Research, 254 (2): 348–359.

Brandenburg, M., Govindan, K., Sarkis, J., Seuring, S. 2014. Quantitative models for sustainable supply chain management: developments and directions. European Journal of Operational Research, 233 (2):299-312.

Büyüközkan, G., Göçer, F. 2018. Digital Supply Chain: Literature review and a proposed framework for future research. Computers in Industry, 97: 157-177.

Cai, J., Liu, X., Xiao. Z., Liu. J. 2009. Improving supply chain performance management: a systematic approach to analyzing iterative KPI accomplishment. Decision Support Systems, 46:512-521.

Carter C. R., Rogers, D. S. 2008. A framework of sustainable supply chain management: Moving toward new theory. International Journal of Physical Distribution and Logistics Management, 38: 360-387.

Carter, C. R. and Easton, P. L. 2011. Sustainable supply chain management: Evolution and future directions. International Journal of Physical Distribution and Logistics Management, 42:4662.

CODEX Alimentarius. 2006. Principles form Traceability/product tracing as a tool within a food inspection and certification system. http://www.fao.org/fao-who-codexalimentarius/sh-proxy/ru/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCAC%2BGL%2B60-2006%252FCXG_060e.pdf, Access date: 26th June, 2018.

Coley, D.A., Howard, M., Winter, M. 2011. Food miles: time for a rethink? British Food Journal 113 (7): 919-934.

Dawe, D.C., Timmer, P.C. 2012. Why stable food prices are a good thing: lessons from stabilizing prices in Asia. Glob. Food Security, 1: 127-133.

Deakins, D., Galloway, L. and Mochrie, R. 2003. The Use and Effect of ICT on Scotland's Rural Business Community. Stirling: Scottish Economists Network, pp. 1-62.

Dellino, G., Laudadio, T., Mari, R., Mastronardi N., Meloni. C. 2018. Microforecasting methods for fresh food supply chain management: A computational study. Mathematics and Computers in Simulation, 147:100-120.

Ding, M.J., Matanda, M.J., Parton, K.A., Jie, F. 2014. Relationships between quality of information sharing and supply chain food quality in the Australian beef processing industry. International Journal of Logistics Management, 25:85-108.

Esfahbodi, A., Zhang, Y., Watson, G. 2016. Sustainable supply chain management in emerging economies: trade-offs between environmental and cost performance. International Journal of Production Economics, 181:350-366.

FAO. 2011. Report on Global Food Losses and Food Waste. Study conducted for the International Congress SAVE FOOD! at Interpack2011, Düsseldorf, Germany. http://www.fao.org/docrep/014/mb060e/mb060e02.pdf; Access date: 26th June, 2018.

FAO. 2017. Food Loss and Food Waste. http://www.fao.org/food-loss-and-food-waste/en/Acess date: 26th June, 2018.

Folkerts, H., Koehorst, H. 1998. Challenges in international food supply chains: vertical co-ordination in the European agribusiness and food industries. British Food Journal, 100 (8): 385-388.

Fynes, B., Búrca, S., Marshall, D. 2004. Environmental uncertainty, supply chain relationship quality and performance. Journal of Purchasing & Supply Management, 10(4-5):179-190.

Golan, E., Krissoff, B., Kuchler, F. 2004. Food Traceability: One ingredient in a safe and efficient food supply, https://www.ers.usda.gov/amber-waves/2004/april/food-traceability-one-ingredient-in-a-safe-and-efficient-food-supply/ Accesses date: 26th June, 2018.

Goodhue, R.E. 2000. Broiler production contracts as a multi-agent problem: common risk, incentives and heterogeneity. American Journal of Agricultural Economics, 82 (3), 606-622.

Grant, J. (2003), ''Growing rural female entrepreneurs: are they starved of ICT skills?'', paper
presented
at the ICSB World Conference, Belfast

Grant, J. 2003. Growing rural female entrepreneurs: are they starved of ICT skills? paper presented at the ICSB World Conference, Belfast.

Hamprecht, J., Corsten, D., Noll, M., Meier, E. 2005. Controlling the sustainability of food supply chains. Supply Chain Management International Journal, 10:7-10.

Headey, D. 2013. The impact of the global food crisis on self-assessed food security. World Bank Economic Review, 27(1):1–27.

Headey, D., Martin M, W.J. 2016. The impact of food prices on poverty and food security. Annual Review of Resource Economics, 8:329-351.

Hobbs, J.E. 1996. A transaction cost approach to supply chain management. Supply Chain Management, 1(2): 15-17.

Hobbs, J.E. 1997. Measuring the importance of transaction costs in cattle marketing. American Journal of Agricultural Economics, 79(4):1083-1095.

Huang, He, Y., Li, D. 2018. Pricing and inventory decisions in the food supply chain with production disruption and controllable deterioration. Journal of Cleaner Production, 180: 280-296.

Huggins, R., Izushi, H. 2002.The digital divide and ICT learning in rural communities: Examples of good practice service delivery. Local Economy, 17(2): 111–122.

ISO 22005:2007. 2016. Traceability in the Feed and Food Chain -- General principles and basic requirements for system design and implementation. https://www.iso.org/standard/36297.html; Access date: 26th June 2018.

Keller S. B. 2002. Internal relationship marketing: A key to enhanced supply chain relations. International Journal of Physical Distribution & Logistics Management:649-668.

Kibler, K.M.., Debra, R., Christopher Hawkins, C., Motlagh A.M., Wright, J. 2018. Food waste and the food-energy-water nexus: A review of food waste management alternatives. Waste Management, 74: 52-62.

Kusumastuti, R. D., Donk, D. P. V., Teunter, R. 2016. Crop-related harvesting and processing planning: A Review. International Journal of Production Economics, 174:76-92.

Larsen, E., Lees, M. 2003. Traceability in fish processing. Food authenticity and traceability, 507-517.

Li, D., Wang, X., Chan, H.K., Manzini, R. 2014. Sustainable food supply chain management. International Journal of Production Economics, 152:1-8.

Lim, K. H., Maynard, L. J., Hu, W. and Goddard, E. 2011. *U. S. Consumers' Preference and Willingness to Pay for Country of Origin Labeled Beef Steak and Food Safety Enhancements*. Paper presented for presentation at the Agricultural and Applied Economics Association's 2011 AAEA and NAREA Joint Annual Meeting. Pittsburgh, Pennsylvania, 24–26, July 2011.

Manning, L. 2016. Food fraud: policy and food chain. Current Opinion in Food Science, 10:16-21.

Manning, L., Soon, J. M. 2016. Food safety, food fraud, and food defense: A fast evolving literature. Journal of Food Science, 81: 823-834.

Marzita Saidon, I., Mat Radzi R.M., Ab Ghani, N. 2015. Food Supply Chain Integration: Learning from the supply chain superpower. International Journal of Managing Value and Supply Chains (IJMVSC), 6 (4): 1-15.

Matopoulos, A., Doukidis, G.I., Vlachopoulou, M., Manthou, V., Manos, B. 2007. A conceptual framework for supply chain collaboration: empirical evidence from the agri-food industry. International Journal of Supply Chain Management, 12: 177-186.

Moyer, D. C., DeVries, J.W., Spink, J. 2017. The economics of a food fraud incident e case studies and examples including melamine and wheat gluten. Food Control, 71: 358-364.

Ölander, F., Thøgersen, J. 2013. Informing or nudging: which way to a more effective environmental policy? In: Scholderer, J., Brunsø, K. (Eds.), Marketing, Food and the Consumer: Festschrift in Honour of Klaus G. Grunert. Pearson Longman, London, pp. 141-155.

Oliver, R.K., Webber, M.D. 1982. Supply-chain management: logistics catches up with strategy. Outlook 5 (1), 42-47.

Opara, L.U., Mazaud, F. 2001. Food traceability from field to plate. Outlook on Agriculture, 30(4): 239-247.

Ospina, A. V., Heeks, R. 2011. ICTs and climate change adaptation: Enabling innovative strategies. Strategy Brief 1. Climate Change, Innovations and ICTs Projects: 1-9.

Parfitt, J., Barthel, M., Macnaughton, S. 2010. Food waste within food supply chains: quantification and potential change to 2050. Philosophical Transactions of the Royal Society B: Biological Sciences, 365 (1554):3065-3081.

Petersen, A., Green, D. 2005. Seafood traceability: A practical guide for the US industry. http://seafood.oregonstate.edu/.pdf%20Links/Seafood%20Traceability%20-%20A%20Practical%20Guide.pdf, Assess date: 26th June 2018.

Raak, N., Symmank C., Zahn, S., Aschemann-Witzel, J., Rohm, H. 2017. Processing-and product-related causes for food waste and implications for the food supply chain. Waste Management, 61: 461-472.

Rábade, L., Alfaro, J. 2006. Buyeresupplier relationship's influence on traceability implementation in the vegetable industry. Journal of Purchasing & Supply Management, 12: 39-50.

Rao, N.H. 2007. A Framework for Implementing Information and Communication Technologies in Agricultural Development in India. Technological Forecasting & Social Change, 74: 491-518.

Ras, P.J., Vermeulen, J.V. 2009. Sustainable production and the performance of South African entrepreneurs in a global supply chain. The case of South African table grape producers. Journal of Sustainable Development, 17: 325-340.

Reardon, T., Timmer, C.P., 2007. Transformation of markets for agricultural output in developing countries since 1950: How has thinking changed? Handbook Agriculture Economics, 3:2807-2855.

Rijswijk, W.V., Frewer, L.J. 2008. Consumer perceptions of food quality and safety and their relation to traceability. British Food Journal, 110 (10):1034-1046.

Rong, A., Akkerman, R., Grunow, M. 2011. An optimization approach form managing fresh food quality throughout the supply chain. International Journal of Production Economics, 131:421-429.

Rullia, M.C., Savoria, A., D 'Odorico, P. 2012. Global land and water grabbing. PNAS, 110 (3): 3: 892-897.

Seuring, S., Müller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production, 16(15):1699-1710.

Silvis, I. C. J., van Ruth, S. M., van der Fels-Klerx, H. J., Luning, P. A. 2017.Assessment of food fraud vulnerability in the spices chain: An explorative study. Food Control, 81: 80-87.

Smallbone, D., North, D., Baldock, R. and Ekanem, I. 2002. Encouraging and Supporting Enterprises in Rural Areas. London: Small Business Service/DTI.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.534.6380&rep=rep1&type=pdf Access date: 26th June, 2018.

Spence, L., Bourlakis, M. 2009. The evolution from corporate social responsibility to supply chain responsibility: The case of Waitrose. Supply Chain Management, 14(4):291–302.

Spink, J., Ortega, D. L., Chen, C., Wu, F. 2017. Food fraud prevention shifts the food risk focus to vulnerability. Trends in Food Science & Technology, 62: 215-220.

Swinnen, J. (ed.), 2015. The Political Economy of the 2013 Reform of the CAP, Brussels: Centre for European Policy Studies Publication.

Sylvester, G. 2013. Information and communication technologies for sustainable agriculture Indicators from Asia and the Pacific, http://agris.fao.org/agris-search/search.do?recordID=XF2017001375; Access date: 26th June, 2018.

Teng P., Trethewie S. 2012. Tackling urban and rural food wastage in Southeast Asia: Issues and interventions. Policy Brief No 17. Singapore: RSIS Centre for Non-Traditional Security (NTS) Studies. https://www.rsis.edu.sg/rsis-publication/nts/2377-tackling-urban-and-rural-food/#.WzHAr_l96M8, Access date: 26th June, 2018.

Thomassen, M. A., van Calker, K. J., Smits, M. C. J. et al. 2008. Life cycle assessment of conventional and organic milk production in the Netherlands. Agriculture System, 96 (1-3):95-107.

Tseng, M.L., Chiu, A.S. 2013. Evaluating firm’s green supply chain management in linguistic preferences. Journal of Cleaner Production, 40, 22-31.

UNEP. 2015. Sustainable Consumption and Production and the SDGs. https://sustainabledevelopment.un.org/topics/sustainableconsumptionandproduction. Assess date: 26th June 2018.

United Nations. 2012. The Zero Hunger Challenge. http://www.un.org/en/zerohunger/challenge.shtml, accesses date: 26th June, 2018.

United Nations, 2014. A/69/700 Follow-up to the outcome of the Millennium Summit, The road to dignity by 2030: ending poverty, transforming all lives and protecting the planet. Synthesis report of the Secretary-General on the post-2015 sustainable development agenda.

van Ruth, S.M., Huisman, W., Luning, P.A. 2017. Food fraud vulnerability and its key factors. Trends in Food Science & Technology, 67:70-75.

Verpoorten, M., Arora, A., Stoop, N., Swinnen, J. 2013. Self-reported food insecurity in Africa during the food price crisis. Food Policy, 39: 51–63.

Virtanen, Y., Kurppa, S., Saarinen, M. et al. 2011. Carbon footprint of food: Approaches from national input-output statistics and an LCA of a food portion. Journal of Cleaner Production, 19: 1849-1856.

Walker, H. and Phillips, W. 2009. Sustainable procurement: Emerging issues. International Journal of Procurement Management, 2(1):41-61.

Wang Y. 2016. E-logistics: Managing Your Digital Supply Chains for Competitive Advantage, Kogan Page, pp. 1-536.

Wickramasinghe, U. 2014. Realizing sustainable food security in the post-2015. Development era: South Asia's progress, challenges and opportunities. South and South-West Asia Development Papers 1402. http://www.unescap.org/sites/default/files/Realising%20sustainable%20food%20security%20in%20South%20Asia%20Upali%20Wickramasinghe%20_August%202014_FINAL.pdf; Accesses date: 26th June, 2018.

Wognum, P. M., Bremmers, J., Trienekens, J. H. et al. 2011. System for sustainability and transparency of food supply chains: Current status and challenges. Advanced Engineering Informatics, 25: 65-76.

Wossen, T., Berger, T., Haile, M.G., Troost, C. 2018. Impacts of climate variability and food price volatility on household income and food security of farm households in East and West Africa. Agricultural System, 163:7-15.

Zhu, Q., Sarkis, J., Lai, K. 2008. Confirmation of a measurement model for green supply chain management practices implementation. International Journal of Production Economics, 111: 261-273.

Legend to Figures:

Fig. 1. Conceptual linkages among climate and price variability, adaptation options and food security (Wossen et al. 2018; **Journal**: Agricultural Systems; License Number; 4375640298518; Permission from Elsevier, dated: 24 June 2018)

Fig. 2. Conceptual model of drivers for processing-related food waste (Raak et al. 2017;

License Number 4375651260723; **Journal**: Waste Management; Permission from Elsevier, dated: 24 June 2018)

Fig. 3. Food loss and waste impact to the Food-Energy-Water (FEW) nexus in food production and waste management phases (Kibler 2018; Journal: License Number 4375641353554; Waste Management; Permission from Elsevier, dated: 24 June 2018)

Fig. 4. Overview of the food fraud vulnerability main elements and detailed factors (van Ruth et al. 2017; License Number 4375650542424; **Journal**: Trends in Food Science & Technology; Permission from Elsevier, dated: 24 June 2018)

Fig 5. Food integrity management and mitigation model (Louise Manning 2016; Journal: License Number 4375660718008; **Journal**: Current Opinion in Food Science; Permission from Elsevier)

Fig. 6. Drivers for traceability of food supply chain. (Source: Aung and Chang 2014; **Journal**: Food control; License Number: 4375630869300; Permission from Elsevier, dated: 24 Jun20 18).

Fig. 7. Conceptual framework of food traceability system. (Source: Aung and Chang, 2014; **Journal**: Food control; License Number: 4375630869300; Permission from Elsevier, dated: 24 June 2018).

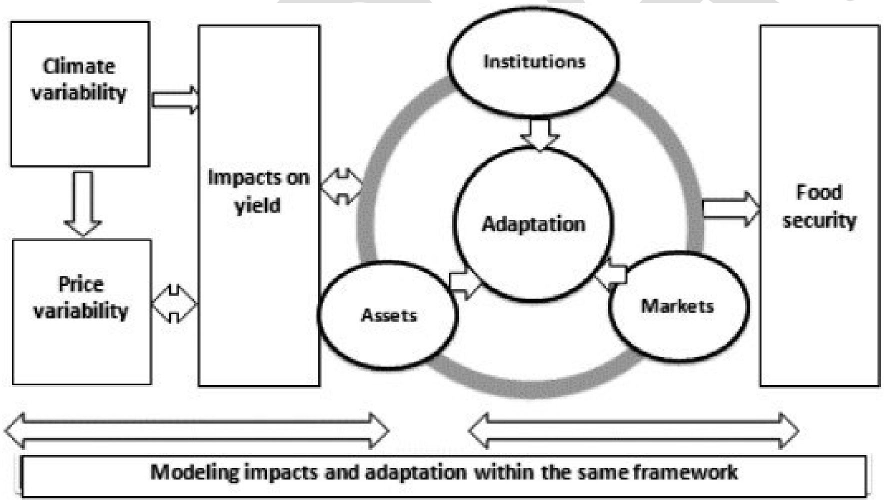
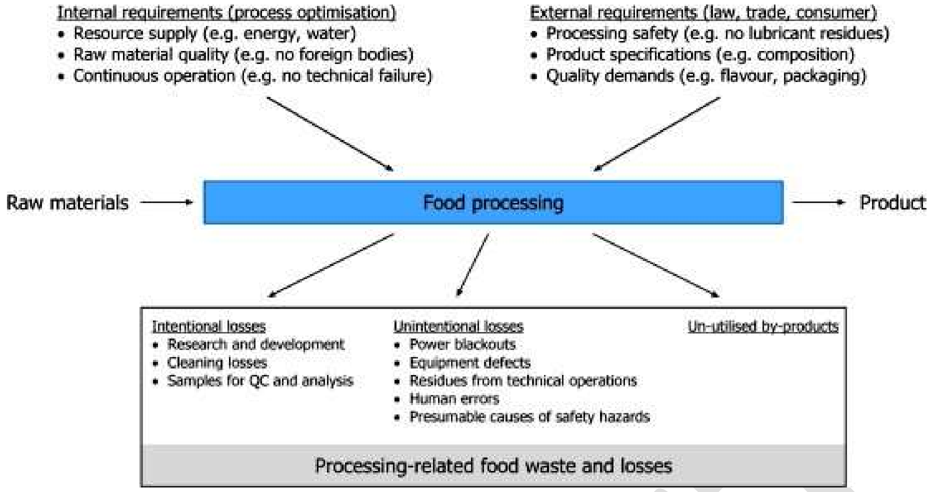
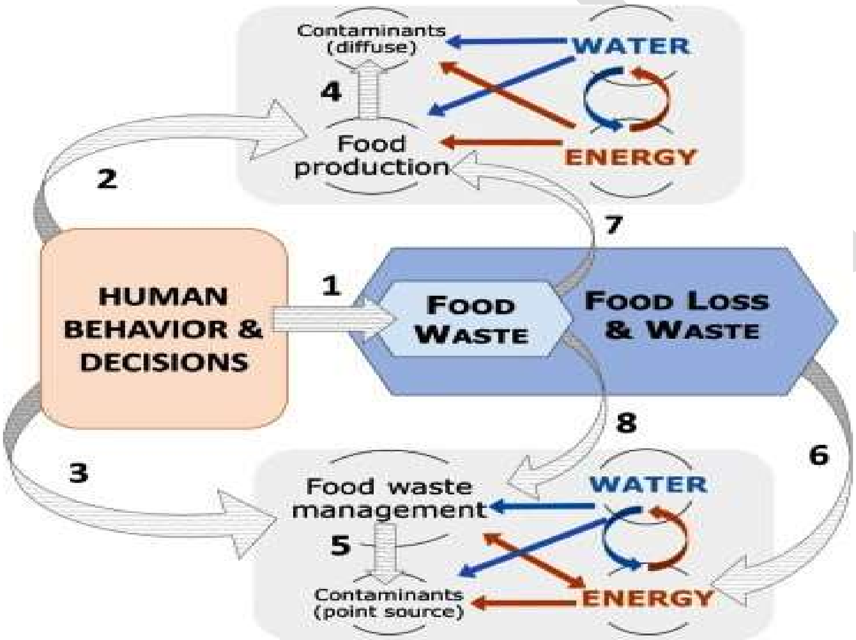


Fig. 1.



Internal requirements (process optimisation)
• Resource supply (e.g. energy, water)
• Raw material quality (e.g. no foreign bodies)
• Continuous operation (e.g. no technical failure)
External requirements (law, trade, consumer)
• Processing safety (e.g. no lubricant residues)
• Product specifications (e.g. composition)
• Quality demands (e.g. flavour, packaging)
Raw materials
Food processing
Product
Intentional losses
• Research and development
• Cleaning losses
• Samples for QC and analysis
Unintentional losses
• Power blackouts
• Equipment defects
• Residues from technical operations
• Human errors
• Presumable causes of safety hazards
Un-utilised by-products
Processing-related food waste and losses

Fig.2.



Contaminants (diffuse)
WATER
4
Food production
ENERGY
2
7
HUMAN BEHAVIOR & DECISIONS
1
FOOD WASTE
FOOD LOSS & WASTE
8
3
6
Food waste management
WATER
5
Contaminants (point source)
ENERGY

Fig.3.

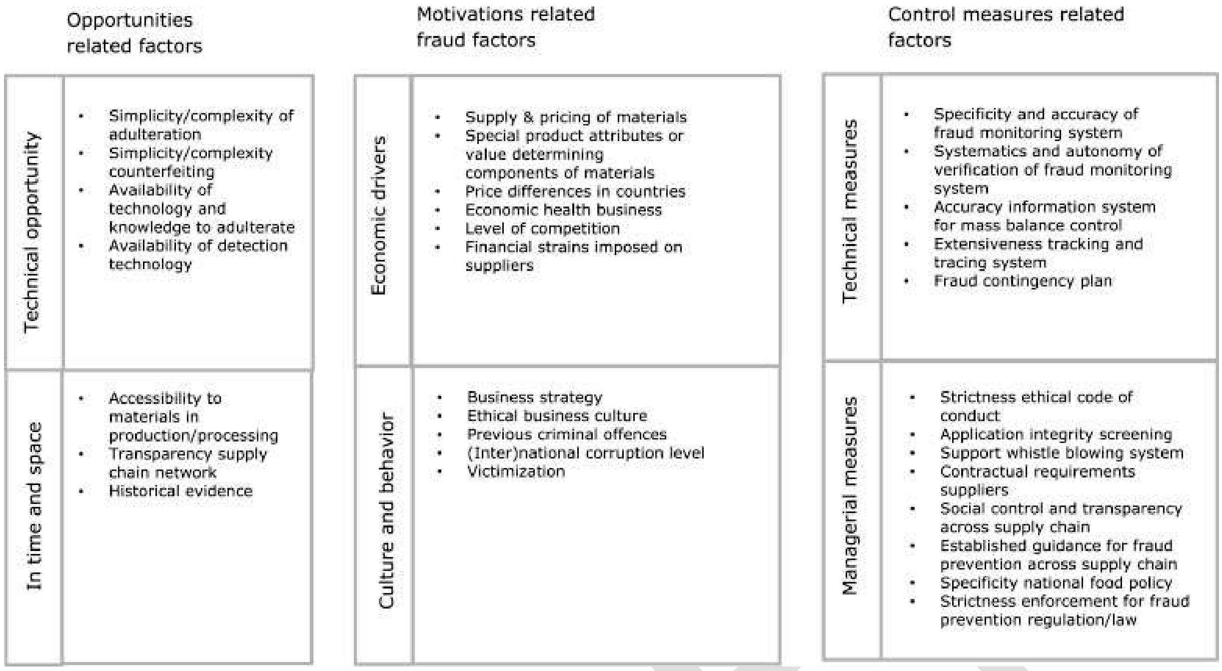
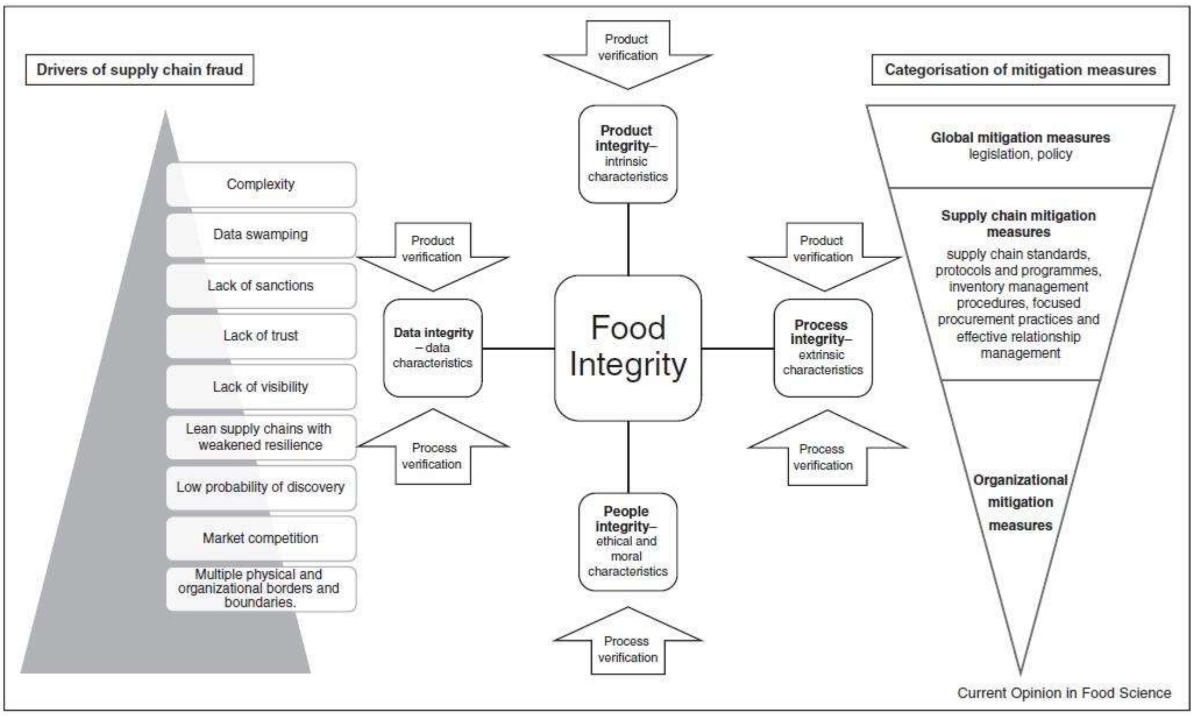


Fig.4.



Food integrity management and mitigation model.

Fig.5.

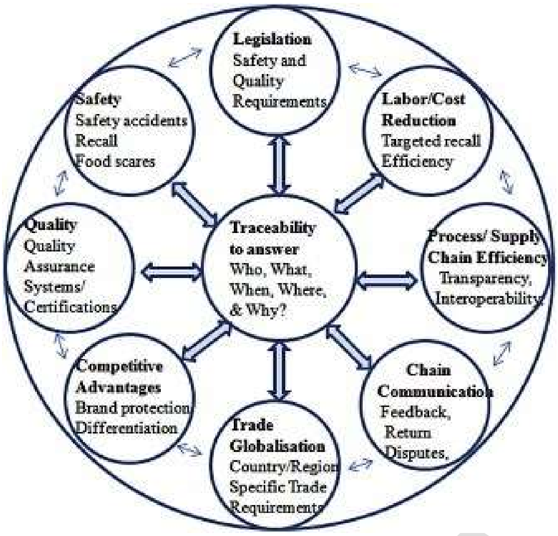


Fig.6.

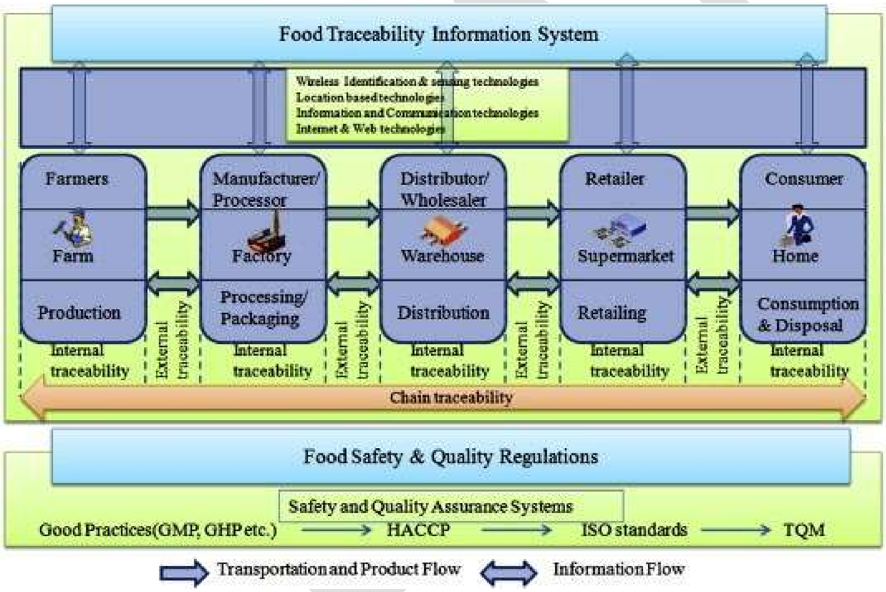


Fig.7.