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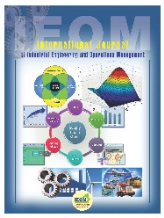

Traceability of Fruits and Vegetables Supply Chain towards Efficient Management: A Case Study from Sri Lanka

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ABSTRACT

The necessity for food traceability has been increased over the years with the expansion of food supply chains globally over these years due to stringent of food safety regulations. Enhancing the access to quality food safely is one of the essential requirements of food supply chain traceability. Conversely, significant percentages of postharvest losses available especially in developing countries due to poor supply chain and logistics practices thereby threatening food security. Unless there is a possibility to trace the Supply chain, it is difficult to take remedial actions. When it comes to Sri Lanka, currently it is harder to have the traceability in most of the foods supply chains commonly on most of the elementary supply chains such as fruits and vegetables. This has led to postharvest losses since it is harder to identify when and where damages occur, who are accountable, harvested and transient times, supply demand mismatch too. Therefore, this paper aims to investigate the feasibility of tracing of fruit and vegetable supply chain in Sri Lanka and contribute theoretically to facilitate authorities and decision makers for future traceability improvement. Availability of secondary information on fruits and vegetables traceability was examined referring to government agencies. Basic structure of supply chain was identified based on secondary data and a case study was conducted based on supply chains linked to Thambuththegama and Keppetipola Dedicated Economic Centers to gather primary data. To quantify the feasibility of tracing, a feasibility index was developed. Developed index was used to assess the feasibility towards improved traceability of selected chains where it can be applied for other food and non-food supply chains as well. The feasibility index can be used for other fruits and vegetables supply chains too to assess the feasibility prior to implementation of a traceability system. Furthermore, it can be used for non-food supply chains with some modifications. Analysis revealed that poor feasibility of wholesalers compared to farmers and retailers. Product

identification technologies, awareness and willingness for traceability improvement were ranged low to fair for all the entity categories. Hence, enhancement of record-keeping and information sharing, adopting product identification and quality measurement technologies, and strengthening of legislation were identified as key improvements for enhanced fruits and vegetable traceability and efficient postharvest management of studied supply chains

1. Introduction

World populations above 7 billion have imposed great pressure towards global food security. 'No hunger' that make sure all people have sufficient and nutritious food throughout the life has been identified as the second SDG that is aimed to be achieved by 2030. However, more than 820 million of the world population are suffering from hunger presently which is challenged of achieving this goal (FAO et al. 2019) by social, economic, and environmental factors including population growth, climate change, reduction of per capita arable land, and urbanisation (Lakhiar et al. 2020; Mbow et al. 2019; Wang 2019, Benke and Tomkins 2017).

Food safety can be considered as an integral part of food security where food security is ensured only when the community has access to a sufficient amount of food that is safer. Due to the abundance of food safety issues, an increasing trend of adopting traceability systems for food supply chains can be identified globally. And also present consumers are increasingly more concern on the information of foodstuffs that they consume. . With the technological advancement a world trend is created to use the concept of Industry 4.0 for food supply chain traceability (Cruz Introini et al, 2018). Industry 4.0 is referred to the revolutionary improvements in manufacturing industry influenced by digitalization and the Internet (Tjahjono et al.2017). Industry 4.0 includes vast range of concepts for instance 3D printing, robotics, block chain, big data analytics, artificial intelligence, internet of things, e-commerce, digitalization, smart factory etc. (Garay-Rondero et al. 2019). According to Ojo (2018) Industry 4.0 contribute to achieve Sustainable Development Goal (SDG) in any industry including food industry. However, Raj et al. (2020) has found number of barrios to implement Industry 4.0 (high implementation cost, lack of clarity regarding the economic benefit, low maturity level of the desired technology, lack of infrastructure, lack of digital technologies etc.).

Many countries have incorporated rules and regulations to ensure food safety through enhanced traceability. European Union (EU) has enforced legislations related to food traceability and they use traceability as a management tool that ensures food safety, quality, and environmental sustainability (Borit 2016). USA is attempting to improve the farm to plate traceability of food supply chain trough US food and drug administration with inclusion of new technologies such as RFID (Roberti 2019). Canada has implemented food traceability regulation, 'Safe Food for Canadians Regulations' (SFCR) under Canadian food inspection agency that came in to force on 2019 aiming to track movements of food one step back and one step forward (CFIA 2019). Though, it is at the initial stage of implementation. As per the Charlebois et al. (2014) EU is the leader in food traceability due to strong traceability legislations cover a broad range of food and animal products including domestic and imported where many other countries are successful only with regards to animal products.

Although many countries do not have strong national level traceability standards, Global Standard 1(GS1) provide a better framework to improve food traceability on global scale and achieve global food security.
Examining of Sri Lankan food safety status should be given a high priority to ensure the food safety of every citizen. Sri Lanka is ranked the 66th place in the global food security index and as the best in the South Asian region with an overall score of 60.8 averaged over three core factors affordability (65.0), availability (60.0) and, quality and safety. Nevertheless, in this paper, our interest is on ensuring the food quality and safety of the country where the Sri Lankan score for the factor 'quality and safety' is 52.4 and the highest score of 91.8 has been reported for Finland (GFSI 2019). Hence, enhancing the access to quality and safety food for all the citizens of the country should be highly prioritized.

Sri Lanka is a Middle-Income country with population of 21.67 million people (estimated midyear population – census and statistics 2018) and 1.1% of population growth rate (census and statistics 2018). Food industry of the country is rapidly expanding with respect to the growing population. Therefore, numbers of safety issues have been raised that endangers the food safety of the country.

Major food safety issues that threaten the health of Sri Lankan community can be identified as food borne infections such as bacterial infections, fungal invasions, contamination with pesticides and heavy metals and also contamination with artificial ripening chemicals (Munasinghe et al. 2015). These contaminations may occur at any point of the food chain where pre-harvest or post-harvest. Hence, identification of exact point of the cause

plays an important role in the regulatory measures of food safety issues. In that sense, the term traceability is given a huge importance.

Furthermore, postharvest losses significantly contribute to the food security in Sri Lanka. Presently, estimated postharvest loss of fruits and vegetables ranges from 20% - 46% (Sarananda et al. 2004; Wasala et al. 2014) which is significantly higher than global norms. This is primarily related to the poor handling, storage and transportation practices which do not have clear evidences to point out towards each link and actors of the supply chain due to poor traceability. The food security has further aggravated due to the climate change induced extreme weather conditions. Since Sri Lanka become one of the significantly affected country in the world according to the Global Climate risk index (Eckstein et al. 2019) which shows the necessity for the tractability of food supply chains of Sri Lanka.

As the first step towards reducing postharvest losses, traceability of supply chains is paramount important. However, depend on the context of supply chains considered feasibility of tracing them will be vary drastically. Therefore, this research was conducted to examine the feasibility to improve the traceability of fruit and vegetable supply chain in Sri Lanka. This paper describes and discusses the concept and basic requirements of fruits and vegetables supply chain traceability improvement, basic structure of the Sri Lankan fruits and vegetables supply chain, availability of secondary information of fruits and vegetables traceability and results of the case study conducted to assess the feasibility towards fruits and vegetables traceability.

2. Literature Review

Food traceability can be considered as an effective way of increasing the consumer confidence on purchasing of food by providing food alerts (Marchante et al. 2013; Andrade et al. 2019) and thus the basic for food safety. It is also considered as a risk management tool that enables recalling and withdrawal of unsafe products (Thakur et al. 2010). Traceability is a broad term where number of definitions can be found in the literature. European Communities (2007) describes the traceability as the ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing and distribution. According to ISO 22005 (2007) traceability is the ability to follow the movement of a feed or food through specified stage(s) of production, processing and distribution. Also ISO 22005 (2007) describes a traceability system as a useful tool to assist an organization operating within a feed and food chain to achieve defined objectives in a management system. Therefore, food traceability system can be considered as a managerial tool that can be used for effective management of food supply chain.

In a food traceability system, the product should be able to both traced and tracked where tracing is the ability to identify the origin and other characteristics of a product by tracing back through the upstream of a supply chain where tracking is the following of the path of the product through the downstream (Bechini et al. 2008; Dabbene et al. 2014). However, all the definitions emphasise two key requirements that enables the capturing of information on traceable elements forward and backward through the supply chain.

Furthermore, traceability is discussed under two sub categories: internal traceability and external (Chain) traceability. Internal traceability occurs between receiving and dispatch of a traceability item by a traceability partner where external traceability occurs when a traceability item is handed over by one traceability partner to another (GS1 2006). Internal traceability can be defined as the ability to follow the movement inside the organisation while external traceability can be defined as the traceability between organisations excluding final consumer. It is important to examine the necessities of achieving internal and external traceability for establishment of a supply chain management system with a high degree of traceability.

Managing the perishables (fruits and vegetables) supply chain is challenging and it is significantly different from the conventional supply chain strategies due to the value of perishables deteriorate significantly over the time (Blackburn and Scudder 2009). Modern tracing and tracking technologies such as block chain technology and Internet of things (IoT) technology facilitates the monitoring of perishable supply chain effectively by facilitating inventory and product quality monitoring (Yang et.al. 2017) where the management challenge due to the perishability is overcome.

However, in Sri Lankan context use of modern traceability technologies are far below with reference to the fruits and vegetables supply chain compared to that of global context. Therefore, Sri Lanka is ahead a challenge of developing a proper traceability system for fruits and vegetables and necessary necessities were identified as below.

Basic requirements for traceability improvement identified through literature survey mainly emphasis on the availability of information, record keeping, and product identification technologies and discussed below in more comprehensively.

ISO 22005 (2007) has defined a traceability system as a totality of data and operations that is capable of maintaining desired information about a product and its components through all or part of its production and utilization chain. Therefore, identification of traceability information is one of the main important factors prior to implement a traceability system where information has to be recorded at each segment (farmer, collector, wholesaler, retailer, food processor, exporter etc.) involved for a particular chain.

According to Opara (2003), there are six traceability elements in an agricultural and food supply chain traceability system namely product traceability that provide information on the physical location of a product at any stage, process traceability that inform what happen to the product during pre-harvest or post-harvest operations, genetic traceability that determines genetic constituents of a product such as seed, cuttings that are used, Input traceability that gives information on fertiliser, agro chemicals, irrigation etc., diseases and pest traceability that determines pests, bacteria, viruses etc. and measurement traceability on individual measurements of the product quality that provide a worthy guidance for identification of traceability items. Wilson and Clarke (1998) describes data within a traceability system under two categories; information relating to a specific consignment or collection of food material (traceability data), information on general environment that the food material is grown or processed. ISO 22005 (2007) has identified the cost effectiveness as a principle of a traceability system were information on monitory flow was identified as a critically require information element.

Therefore, traceable information for Fruits and vegetable Supply Chain can be categorised in to seven categories based on literature; General information on supply chain player, Information on monetary flow, Information on management practices, information on quality parameters, Temporal Information, Locational information, information on environmental conditions and utilities. Table 1 identifies this information in detail.

However, under Sri Lankan condition availability of this traceability information has to be reexamined before establishing of a traceability system.

Table 1. Traceability Information required for typical fruits and vegetable supply chains

Traceability Information	**Supply Chain Player**						
	Farmer	**Farmer to collector**	**Collector**	**Collector to Wholesaler**	**Wholesaler**	**Wholesaler to Retailer**	**Retailer**
General information on supply chain player	Name, Address, Contact details, Identity card numbers of players Business name, Brand name, Business registration number etc.						
Information on monitory flow	Input cost (Planting materials, Fertilizer, Agrochemicals etc.) (Arzeno 2004) Labour cost Transportation cost Selling price	Transport cost Other costs	Purchasing cost Labour cost Cost for chemicals Other costs (wrapping materials, packaging materials etc) Selling price	Transport cost Other costs	Purchasing cost Labour cost Selling price other costs	Transport cost Other costs	Purchasing cost Labour cost Other costs Selling price
Information on management practices	**Pre-harvest Practices** Plant genetic material (Hewett 2006) Fertiliser Application (Date, Type, Dose etc.) Use of Agrochemicals (Date, Type, Dose etc.) Weeding (Date, frequency) Irrigation (Date, Source, Amount) Other crop specific management practices (Earthing up, loosening of soil, planking, bagging, mulching) Maturity stage at harvesting (Weston and Barth, 1997) **Harvesting Practices**	Use of plastic crates for transportation Use of lining materials for crates Number of nuts/fruits per crate Type and condition of vehicle used for transportation (Level of vibrations)(Fadiji et al. 2016) Transportation condition (Temperature, RH)	**At the pack house** Conditions of the packing house (Sanitation, Shelter, Ventilation, Temperature, Relative Humidity) Maintaining of pack house sanitary condition Crop specific management practices (trimming, de-handing, etc.) Pre-treatments used Water source and water quality Method of ripening (Chemicals) Packaging material	Type of packing material used Type and condition of vehicle used for transportation (Level of vibrations) Transportation condition (Temperature, RH)	Conditions of the packing house/warehouse (Sanitation, Shelter, Ventilation, Temperature, Relative Humidity) Loading/unloading practices	Type of packing material used Type and condition of vehicle used for transportation (Level of vibrations) Transportation condition (Temperature, RH)	Displaying method Sanitary condition of the retail outlet Temperature regulation in the retail outlet Air circulation

	Method of harvesting Measures taken to minimise harvesting damages **Post-harvest Practices** Precooling Using field containers/Plastic crates Lining materials Prevention of contamination with soil Avoiding exposure to sun to prevent heat build-up Field heat removal (precooling) Sorting and grading Waste Management Time of harvesting		Number of nuts/fruits per package Use of lining material for packages				
Information on quality parameters	Color (colorimeter reading) Texture (penetrometer reading) Sugar content (TSS) Pest and diseases Free from defects Visual quality		Color (colorimeter reading) Texture (penetrometer reading) Presence of aromatic and non-aromatic volatiles Sugar content (TSS) Pest and diseases Free from defects Visual quality		Color (colorimeter reading) Texture (penetrometer reading) Sugar content (TSS) Visual quality Availability of defects Pest and diseases		Color (colorimeter reading) Texture (penetrometer reading) Sugar content (TSS) Visual quality Availability of defects Pest and diseases
Temporal Information	Time taken for harvesting Time taken for loading	Travel time from farm to pack house	Time at pack house Time for loading/unloading	Travel time from collecting centre to wholesale market	Time at wholesale market Time for loading/unloading	Travel time from wholesale market to retail outlet	Time duration at retail outlet

Locational information	Coordinates	Route followed (coordinates)	Coordinates	Route followed	Coordinates	Route followed	Coordinates
Information on environmental condition and utilities	Spatial distribution of daily rainfall Spatial variation of hourly temperature Spatial variation of relative humidity Wind (speed/direction) Flood situations Road conditions						

Record keeping becomes one of the major requirements to ensure the supply chain traceability. Maintenance of an internal record keeping system is vital to determine causes of problems and also to recall contaminated products efficiently through the supply chain (Thakur and Hurburgh 2009) where both internal and external traceability is reinforced by record keeping. 'One up and one down' principle is an important and widely used concept under ISO 22005 standard that empower the traceability through the supply chain. It guides the traceability partner to keep traceability information on where a particular product or a row material is purchased (immediate previous supplier) and where it was sold (immediate next customer) (Carcea et al. 2009) there by facilitate tracing back and tracking forward through the supply chain. However, it does not guarantee the traceability of the whole system unless it is followed by all the traceability partners. Hence, traceability across the whole supply chain is accomplished when only both internal and external tractability is achieved by all the traceability partners. Advanced technologies such as blockchain technology (BCT) are practiced in many developed countries (Lemieux 2016; Tian 2016) to facilitate record keeping and information sharing. BCTs can be used to enhance the traceability of fruits and vegetables supply chain through providing a platform to store traceability information, securely sharing of information among stakeholders and facilitating transactions (Bechtsis et al. 2019; Casino et al. 2019). In addition, internet of things (IoT) technologies is used in supply chain traceability improvement. IoT includes product quality measurement sensors (electronic gas sensors, RH sensors, temperature sensors etc.) that facilitate food quality monitoring (Popa et al. 2019). IoT can be integrated with BCT for efficient and reliable sharing of information in agricultural supply chain (Gunasekaran et al. 2016). IoT integrated blockchain systems can be used to remove the third-party involvement, to improve the consumer and producer trust on the quality, and to facilitate fraud detection (Aich et al. 2019).

Product identification technology is identified as another major feature of any traceability system that enables the ability to trace back and track the location of the product through the supply chain (Opara 2002). Product identification techniques have been evolved through simple tagging, barcoding, QR coding, radio frequency Identification and use of location tracking devices with the influence of technology.

Barcoding is a popular technique of labelling due to its simplicity and inexpensiveness (Gao et al. 2007). Barcoding is being used in the field of supply chain management for several decades since presence of many advantages; affordability, ease of use, reliability and accuracy and human readability (McCathie and Michael 2005). Ordinary barcodes were capable of storing limited number of characters and also static in nature where invention of 2-dimensional barcodes enabled storing of more detailed and dynamic information. However, optical nature of barcoding can be identified as a limitation, where human intervention is compulsory and full automation is incapable. Traditional barcodes are required to clearly visible to be read by scanners and damages to label may cause to loose information. Though, 2D barcode technology has been able to overcome this problem up to certain extent.

QR coding is being popularised due to its ability to store more information (Rouillard 2008) and free availability of numerous QR code generators. QR codes allow storing both strings and numbers where it can be used to keep the url of a web page, Face book page, pre-designed pdf, image, video etc (Crompton 2012). QR code readers are used to access the information enclosed in a QR code.

Subsequently, Radio Frequency Identification (RFID) was evolved that provides many benefits compared to barcoding; non-line-of – sight scanning, less labour requirement etc. (White et al. 2007). However, limitations such as lack of knowledge, cost of tags, and lack of standards can be found (Michael and McCathie 2005).

With the technological advancement of ICT, GPS and GIS the concept of geo-traceability evolved to reinforce traditional traceability systems. Geo-traceability is a powerful traceability tool that integrates the spatial component of the supply chain to traditional traceability information (Andrade et al. 2019). It is simply defined as the ability of describing the history, the use and the location of a product, allowing tracing and tracking from its product to its consumption (Ometto et al. 2007). Geo-traceability increases the confidence of buying since it provides information on the path of the product movement, safety and quality from production to consumption (Ometto et al. 2007). Also, it adds a value to product that affords competitive advantages over similar businesses thereby it may influence on sales (Oger et al. 2010). Further, Geo-traceability provides information on the environmental characteristics that the agricultural product is exposed during the pre-harvesting duration as well as post-harvesting duration.

Throughout the literature survey major requirements to establish fruits and vegetables traceability were identified. No literatures were found on food traceability in Sri Lanka where a research gap was identified to study the present situation of fruits and vegetable supply chain in terms of traceability and to identify the feasibility for traceability improvement. However, establishment of a food traceability system alone will not guarantee the food safety of a country where

continuous monitoring and regulatory actions to be taken followed by quality analysis of food products through the supply chain (Aung and Chang 2014).

Therefore, this study was started with objectives mentioned below.

- to identify information required to improve the traceability
- to identify the basic structure of the fresh fruits and vegetables supply chain
- to examine the feasibility to improve the traceability of fruit and vegetable supply chain based on a case study
- to identify suggestions to improve the traceability of fruits and vegetables supply chain in Sri Lanka

3. Research Methodology

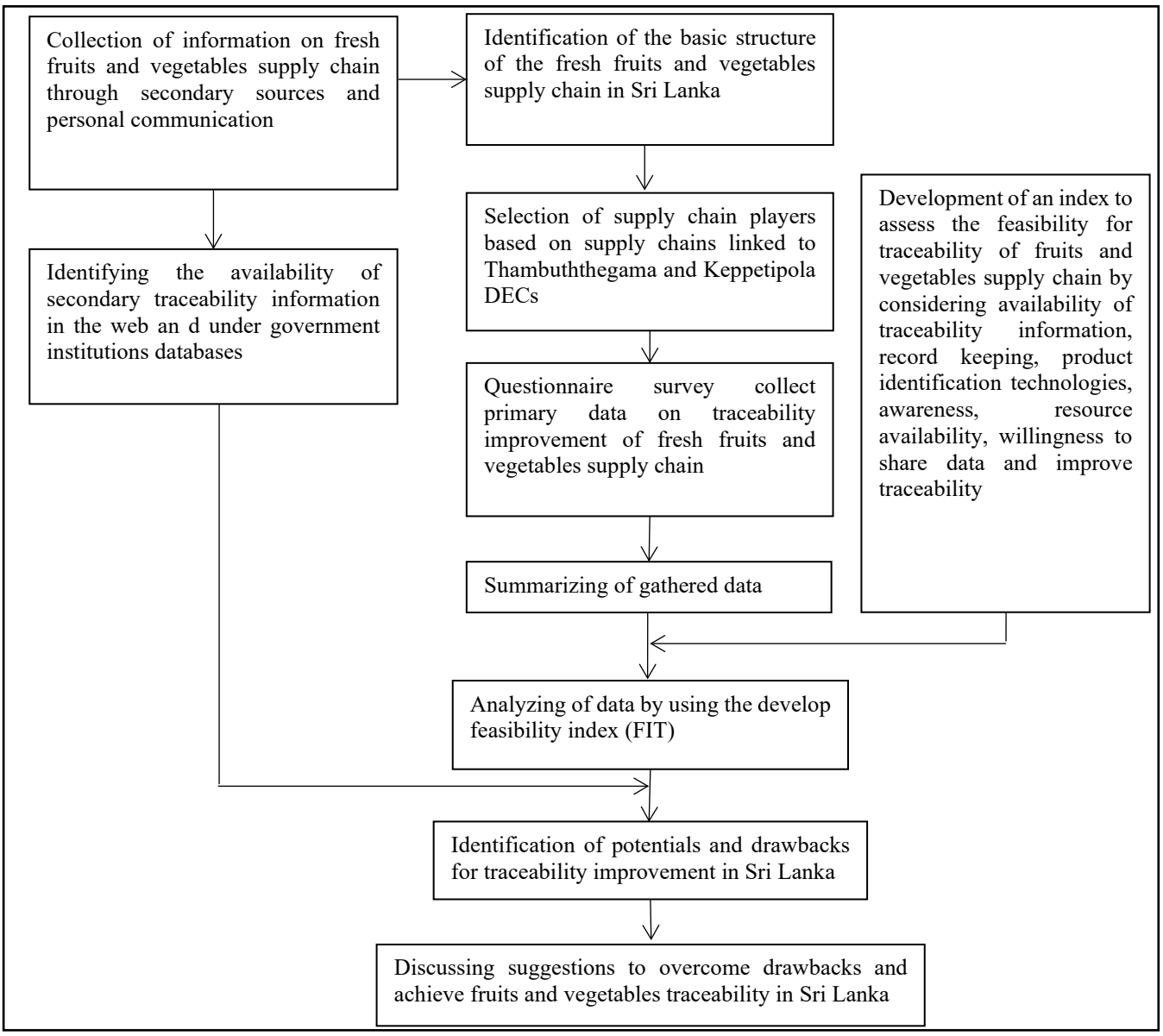

Figure 1. Methodology flow diagram

Structure of the fresh fruits and vegetables supply chain was identified based on secondary sources and through personal communications as the initial step. Potentials and limitations to enhance the traceability of fruits and vegetable supply chain in Sri Lanka were assessed by considering available secondary information and through a questionnaire survey. Thambuththegama and Keppetipola Dedicated Economic Centers (DEC) were selected for the study since these markets

are important wholesale markets that acts as farmer markets. Three major entities were identified based on economic center as farmer, wholesaler and retailers. Twenty individuals of each identified entity category were interviewed for both DECs through the questionnaire survey. Fruits (Papaya, water melon) and vegetable (Low country vegetables and Up country vegetables) cultivating farmers were located in Thalawa and Thambuththegama, Boghakumbura, Haputhale and Haliela Agrarian Service Divisions. Retailers were from Shrawasthipura, Thalawa, ambanpola, and thambuththegama Agrarian Service Divisions.

Gathered data was analysed to estimate the feasibility to enhance the traceability of fruits and vegetables supply chain in Sri Lanka. A feasibility index (Equation: 01) was developed for this purpose. Availability of traceability information is one of the foremost requirements to improve the traceability where it was a major component of the developed index. Though, improved fruits and vegetables traceability can't be improved only by having traceability information with stakeholders. As discussed in the literature review practice of record keeping and product identification technologies are important requirement to achieve both internal and external traceability along the supply chain. Also, ISO 22005 (2007) includes these factors as important factors to be considered. Therefore, those factors were included in the developed feasibility index. Apart of that it is important to identify the awareness of the concept of food traceability among stakeholders where poor awareness is a limiting factor towards improved traceability. Awareness was assessed by considering the awareness on concept and awareness certification systems (Good Agricultural Practices, Good Manufacturing Practices). Availability of resources to support traceability system was considered as the next factor. Here, only basic resources (Computers, mobile phones) were considered that required to share and store traceability information. One of the most important factors towards traceability is attitudes where willingness to share traceability information and willingness to actively participate for a fruits and vegetable traceability system through continuous data feeding was included for the feasibility index.

Weights for criterions in the feasibility index were allocated by considering the significance to improve the traceability. Availability of traceability information and willingness to share were identified as significant criterions where weighted by 2. Record keeping and willingness for food traceability improvement were identified as next significant factors and weighted by 1.5 where all the other factors were weighted by 1. Summation of weighted criterions is divided by ten to normalise the index and obtain an index range from 0-1 for the easiness of comparison.

Feasibility was rated as poor, fair, average, good and excellent between ranges of 0-0.2, 0.21-0.4, 0.41-0.6, 0.61-0.8 and 0.81-1 respectively.

$$FIT = (2*IA + 1.5*RK + PIT + A + RA + 2*WS + 1.5*WT)/10 \qquad \text{eq 01}$$

RK : Practice of record keeping
PIT : Use of Product Identification technologies
A : Awareness
RA : Resource availability to support a traceability system
WS : Willingness to share data
WT : Willingness for food traceability improvement

Availability of traceability information and record keeping were accessed considering monetary information, management practices, quality parameters and temporal information. Awareness on food traceability, labeling and certification were considered to access the overall awareness among players. Smart phones and computers were considered as resources that are required to take part a traceability system. Willingness to share data was accessed under willingness to share general information, monetary information, and information on management practices, information on quality parameters and temporal information.

Thereafter, potentials, drawbacks and suggestions to improve the traceability were discussed aiming an improved fruits and vegetable traceability in Sri Lanka.

4. Results and Discussion

4.1 Exploring the fruits and vegetable supply chain in Sri Lanka

Fruits and vegetable supply chain in Sri Lanka can be divided into four different categories such as fresh produce for local consumption, processed produce for local consumption, fresh produce for the export market, processed products for the export market. Among these categories, 'fresh produce for local consumption' is the most prominent.

'Fresh produces for local consumption' supply chain is involved with the number of players from farmer to a consumer, as illustrated in Figure 01. Dedicated Economic Centers (DEC) established by Ministry of Rural Economy (MRE) plays a vital role in the distribution of fruits and vegetables in Sri Lanka, where a significant proportion is circulated through. Currently, there are 14 DECs, namely Dambulla, Nuwara-Eliya, Thambuththegama, Keppetipola, Embilipitiya, Nawalapitiya (Nawa Kurunduwaththa), Meegoda, Welisara, Weyangoda, Narahenpita, Rathmalana, Piliyandala, Killinochchi and Ampara. These DECs can be considered as economic hubs that facilitate producers (farmers), retailers and wholesalers (Figure2). According to MRE (2020), DECs are established for providing a market place for producers to obtain a reasonable price, facilitating small scale producers to minimise transportation cost and wastage, facilitating wholesalers to purchase fruits and vegetables directly from producers, providing a competitive market place to encourage business community, creating the opportunity to area-specific agricultural products in all over the country and facilitate consumers to access food at a lower price. When considering the distribution of DECs, some of them (Thambuththegama, Dambulla, Nuwara Eliya, etc.) are established in farming areas mainly to provide better market access for farmers. The other set of centres are located in non-farming urban areas (Narahenpita, Weyangoda, Piliyandala), where consumers are benefited. However, whether the goals of establishing a network of DECs are achieved or not is questionable, mainly due to the complicated nature of supply chains. Due to the high level of intermediary involvement, supply chains become lengthier and become more difficult to trace information back. An intermediary person may mainly involve between farmer to DEC and between two DECs.

Manning market that is located in Colombo Fort is also contributed significantly for the fruits and vegetable distribution in the country by connecting with DECs all over the country. However, in the practical situation, these supply chains are very much dynamic and complicated where fixed and bounded chains cannot be identified except for supper market network. Apart from that, food processing industries and exporters are also linked to this complicated web where the complexity of the supply chain is further amplified.

In addition to DEC linked supply web, few supermarket networks also identifiable that provides fresh produces for the local market.

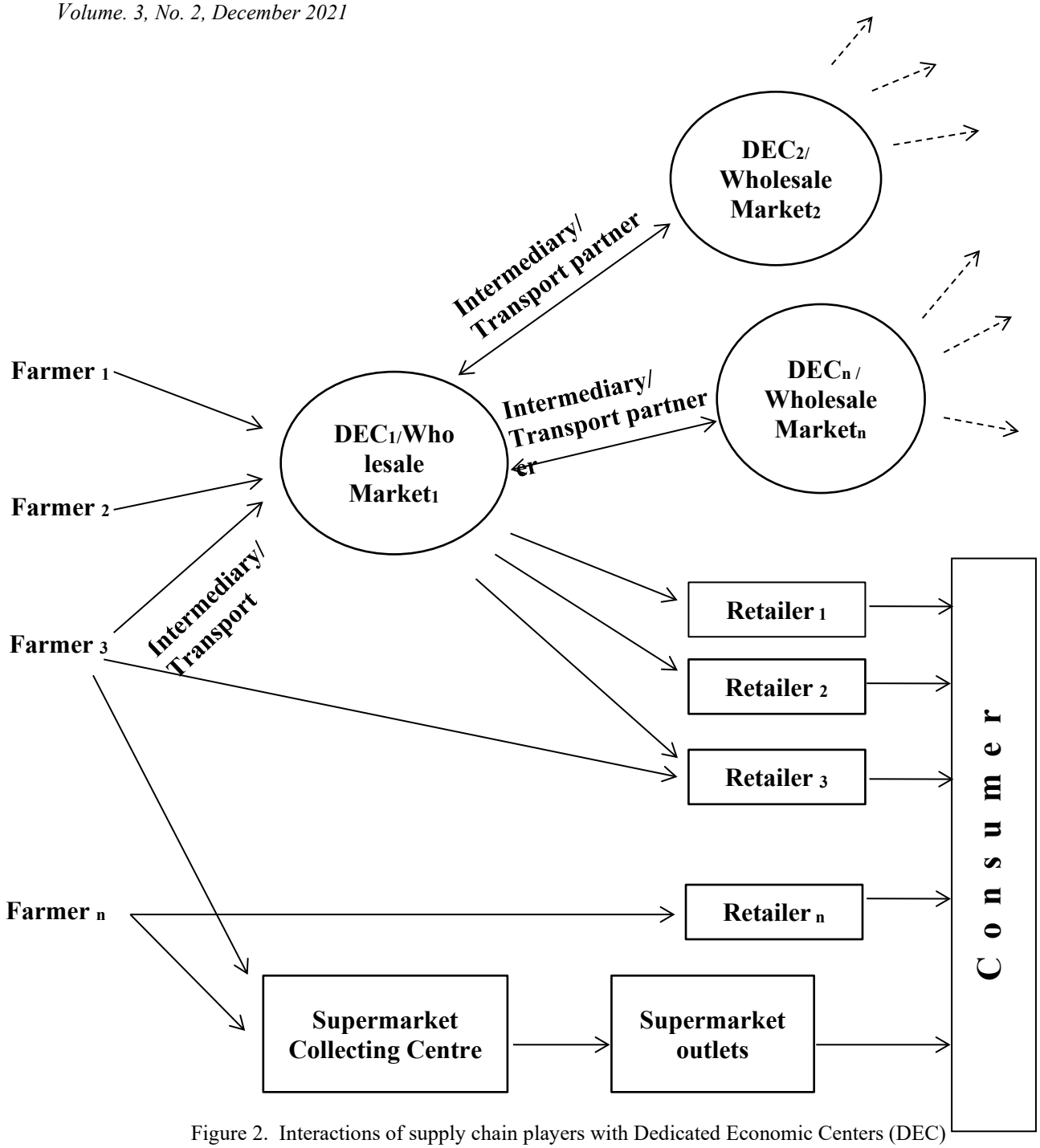

Figure 2. Interactions of supply chain players with Dedicated Economic Centers (DEC)

4.2 Identification of availability of secondary data towards traceability improvement

Lack of secondary data on fruits and vegetables that are transported through the supply chain is a significant limitation. None of the data is available for four traceability information categories namely general information on supply chain player, information on management practices, information on quality parameters, and temporal information under the seven categories discussed in literature review. Some of the secondary data is available for monetary flow, location information, and environmental condition and utilities. However, according to ISO 22005 (2007) totality of data and operations through all or part of the supply chain is a major requirement of a traceability system where it is lack in Sri Lankan fruits and vegetables supply chain.

Information on monetary flow is mainly available for fruits and vegetables transmitted through wholesale markets and not available for a farmer, collector, transporter, retailer and consumer levels. Central Bank of Sri Lanka provides a

daily price report on the wholesale and retail price of primary commodities in DECs and Pettah markets. Also, price data on fruits and vegetables transmitted through wholesale markets can be gathered by direct contact of those dedicated economic centres. However, there are several supply chains that are not linked to these main wholesale markets, and no secondary data is available.

Location information for the above mentioned major wholesale markets can be derived through Google maps. However, deriving locational information for retailers and farmers is practically impossible.

Environmental information such as rainfall, temperature, relative humidity, wind can be mainly acquired through the agro-meteorological network (42 stations) maintained under the department of meteorology, Sri Lanka. Information on road network can be obtained by the road development authority, Sri Lanka.

Accordingly, availability of secondary data is very much low with regards to the fruits and vegetable supply chain of Sri Lanka where the feasibility to gather preliminary information should be examined for future development of fruits and vegetable traceability.

4.3 Feasibility assessment to improve the traceability of fruits and vegetable traceability; case study based on Thambuththegama and Keppetipola DECs

Farmers, Wholesalers and retailers linked with Thambuththegama and Keppetipola DECs were interviewed to assess the feasibility for traceability improvement in fruits and vegetables supply chain. Table 02 illustrates the results gained by the developed feasibility index for traceability. According to the analysis, wholesalers were accounted for a poor FTI. This low index value was reported due to their less involvement for the handling of fruits and vegetables since they are acting as commission-based brokers. They may be a barrio improve the traceability of Sri Lankan fresh fruits and vegetable supply chain for local consumption. Thereby, a proper structural change followed by implementation of rules and regulations will be required to control their involvement to a certain extent and facilitate the goal towards food traceability. Farmers and retailers accounted for a fair FTI, nevertheless farmers accounted for a high FTI compared to the retailer.

Farmers had an excellent index value for availability of information while wholesalers and retailers had fair index value. This is due to the farmer is the primary entity in the chain that produce and handle fruits and vegetables. When considering record-keeping farmers and retailers had a low index value. However, wholesalers were accounted for a fair index value since the record-keeping is done for monitory information. Willingness to share data was reported a good index value for farmers while a low index value for wholesaler. DECs are dynamic places with a lot of transactions are happening, and wholesalers are reluctant to share information. However, record-keeping and sharing of information can be identified as essential requirements to enhance the internal as well as external traceability of any supply chain (Thakur and Hurburgh 2009). Unless improving the practice of record keeping on immediate previous supplier and immediate next customer, achieving forward and backward traceability is not possible (Carcea et al. 2009), Although paper based record keeping is resource consuming and time consuming (Li et al. 2010), at the initial stage it is suggested to implement a paper based record keeping system since Sri Lankan supply chain players are even very poor in paper based record keeping. Developing the habit of record keeping and information sharing can be only improved followed by continuous training and education. Therefore, application of advanced digital ledger technologies such as BCT for fresh fruits and vegetable supply chain is far ahead under Sri Lankan scenario.

Use of product identification technologies was relatively available among farmers while it was zero for wholesaler and retailer. Farmers are using a primitive level of tagging that is called “Villasan” and used to ensure the farmer identity. That information doesn’t go beyond the wholesaler, and there is no way to trace back after that. As a whole, use of product identification techniques for the supply chain ‘fresh produce for local consumption’ is very limited in Sri Lanka that is another major requirement to ensure backward and forward traceability (Opara 2002).Even barcoding is not practiced in this supply chain, one of the simplest product identification technologies. However, when considering other fruits and vegetable supply chains (‘processed produce for local consumption’, ‘fresh produce for the export market’, ‘processed produce for export market’) use of Barcoding and QR coding can be identified. QR coding can be identified as a more convenient solution to improve the traceability of fruits and vegetable supply chain of Sri Lanka due to free availability of QR code generators and readers, and also due to growing trend of use of internet, Social media and use of mobile phones among the Sri Lankan community (Thuseethan and Vasanthapriyan 2015). However, the identification of information that has to be conveyed to the consumer utilising the QR code is a critical requirement. Capability to implement RFID technology for fresh fruits and vegetables supply chain should be well studied due to its comparative advantages over barcoding and QR coding; non-line-of – sight scanning and less labour requirement (White et al. 2007).

Awareness of food traceability and certificates is insufficient for all the selected entities. Resource availability was low among farmers. Willingness for food traceability improvement was fair only among farmers based on Thambuththegama DEC, whereas all the other entities reported a low index value. The reason behind this is fruit farmers in this area are comparatively concern about increasing their income by providing their fruits to a high-value market through enhanced traceability.

Quality parameters of fruits and vegetables may alter significantly through the supply chain from farmer to consumer due to its perishable nature as well as external factors affecting (improper handling, improper packaging, adverse microclimatic conditions etc.) on the quality. Quality loss becomes a reason for the food is being rejected by the consumer (Aung and Chang 2014) thereby increased postharvest loss. Opara (2003) has also identified the measurement traceability as an important element of food supply chain traceability where a least priority is given for measurements in fruits and vegetables supply chain in Sri Lanka. According to the study no information was available on quality parameters. Hence, improving the consumer awareness on quality parameters and adopting a quality measurement system throughout the supply chain should be implemented for improved food safety in Sri Lanka.

Achieving food traceability is not only crucial for achieving food safety of the local community but also crucial for invade the export market and contribute to national economic development. Legislations play an essential role in achieving food traceability. Food (labelling and advertising) regulations 2005 does not cover traceability requirements of fresh fruits and vegetables. GS1 Traceability for Fresh Fruits and Vegetable Guideline (2016) is a globally accepted practise guide that is based on GS1 global standards for supply chain management and product identification. Also, Codex standards for fresh fruits and vegetables provide standards on quality, classification, sizing, presentation, labelling, contaminants and hygiene (FAO/WHO 2007).

Therefore, these international standards can be adopted in the national context.

Table 2. Feasibility index distribution among supply chain entities linked with Thambuththegama and Keppetipola DEC

	Supply chain entities				
	Based on Thambuththegama DEC			**Based on Keppetipola DEC**	
	Farmer	**Wholesaler**	**Retailer**	**Farmer**	**Wholesaler**
Availability of information (IA)	0.74	0.25	0.37	0.75	0.25
Record keeping (RK)	0.10	0.25	0.11	0.00	0.25
Product Identification Technology (PIT)	0.33	0.00	0.00	0.33	0.00
Awareness (A)	0.03	0.00	0.00	0.00	0.00
Resource availability (RA)	0.28	0.43	0.215	0.10	0.30
Willingness to share data (WS)	0.63	0.00	0.46	0.68	0.19
Willingness for food traceability improvement (WT)	0.31	0.00	0.05	0.00	0.04
***FTI**	**0.40**	**0.13**	**0.21**	**0.33**	**0.16**

* FTI = Feasibility Index for Traceability Improvement

By analyzing the data through secondary information, questionnaire survey and personal communications with supply chain players, several drawbacks to improve the traceability of Sri Lankan 'fresh fruits and vegetables supply chain for local market' could be identified; presence of complex and unnecessarily lengthy supply chains, unnecessary intermediary involvement, poor record keeping, poor use of product identification technologies, lack of awareness, lack of resource availability, and willingness issues. Therefore Sri Lanka has a huge requirement to overcome these limitations with a proper framework where, it is a long-term process with several stages. Suggestions to overcome those limitations can be summarised into 5 categories as.

a) Capacity building and awareness raising among all the stakeholders from farmer to consumer-
   - Improving the awareness on concept of food traceability and its importance
   - Improving the awareness of record keeping of traceability information and capacity building. (at the initial stage paper based record keeping can be promoted where high end ledger technologies can be promoted in the long run)

- Attitudes improvement towards sharing of information and thereby achieving the required level of transparency.
- Capacity building on product identification technologies (Barcoding, QR coding, RFID)
- Improving awareness on quality certifications and quality parameters, capacity building for use of quality measurement equipment
- Improving the consumer awareness for a habit of purchasing traceable products

b) Providing financial assistance for initial arrangements (providing required equipment, offering loan facilities under low interest rate)
c) Reformation of the structure of fruits and vegetable supply chain – This has to be done with the government involvement to minimise intermediary involvement, reduce the number of players and eliminate the complexity.
d) Implementation of legislations to facilitate traceability
e) Continuous monitoring and evaluation to keep the track for improved traceability

Further, implementation of modern technologies such as BCT and I4.0 technologies is a future challenge ahead Sri Lanka to improve fruits and vegetables traceability that has to be achieved in the long run after implementing above mentioned suggestions.

By considering all above facts, it is noticeable that Sri Lanka is ahead the challenge of building National Food Traceability System to assure the food safety of the population. However, it is a multistep and time-consuming task where the above-discussed suggestions should be adopted, and the collaboration of all the stakeholders, government authorities, non-government organisations, private parties will be required.

6. Conclusion

Fruits and vegetable supply chain in Sri Lanka is very much complicated. When considering the supply chain 'fresh produce for local consumption' is the most prominent fruits and vegetable based supply chain, where traceability is minimally involved and a negligible level of information is shared among supply chain players and almost no information is transferred to the consumer. Availability of secondary data on this supply chain is also limited to sales price and location information at wholesaler level and some climatic information. Therefore, this case study was conducted aiming closely observe the 'fresh fruits and vegetables supply chain' in Sri Lanka in terms of traceability.

Availability of traceability information, practice of record keeping, use of product identification technologies, awareness, resource availability to support a traceability system, willingness to share data and willingness for food traceability improvement were identified as key parameters to improve the traceability of the fruits and vegetables supply chain. A questionnaire survey was conducted to gather information on availability of above key elements. Thereafter, a feasibility index (FTI) was developed to analyze those key elements for its feasibility to improve the traceability. Gathered information were analysed with FTI to identify the feasibility as a whole as well as element wise.

According to the analysis, wholesalers were accounted for a poor FTI while farmers and retailers were accounted for a fair FTI. Index values for record-keeping, use of product identification technologies, awareness and willingness for traceability improvement were ranged low to fair for all the entity categories. Hence, enhancement of record-keeping, adopting product identification technologies, adopting quality measurement technologies, strengthening of legislation and standards, improvement of transparency through the supply chain and information sharing were identified as key improvements that are required for fruits and vegetable traceability improvement for investigated supply chains. . And also, decision makers can use the FTI value to identify which traceability element is lack in which supply chain and which supply chain entity. Furthermore, it can be applied for other fruits and vegetable supply chains to analyse the feasibility to improve the traceability of those supply chains as well. Thereby, FTI can be used as tool that supports effective decision making under this consequence.

Establishment of a national fruits and vegetable supply chain traceability system is not one step process where lots of preparatory activities to be implemented at the initial stage. In that sense, a series of awareness programmes, training and monitoring programmes, and subsidiary schemes may require to be implemented under government intervention.
This case study was limited to mainly two selected DECs linked supply chain entities where studying based on other DECs will be highly important to get a holistic perspective. Also, this case study didn't focused on consumer that is one of the major entity in the fruits and vegetables supply chain and also may having a high influence on the feasibility towards fruits and vegetables traceability in Sri Lanka. Therefore, future research activities are recommended to study on key factors such as consumer's awareness on food traceability and willingness- to-pay for traceable fruits and vegetables.

Hence, improving the traceability of fruits and vegetables supply chain may highly important to improve the consumers' confidence of purchasing. Improved traceability will ensure the access to quality products for Sri Lankan consumers and it will improve the nutritional status of the community. Also, it will provide economic benefits to all the other stakeholders by adding a value to their product through improved traceability.

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