

Application of Information and Technology in Supply Chain Management of Fruits and Vegetables – A Brief Overview

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Abstract:- India is the second largest producer of fruits and vegetables in the world. The supply of these materials from farm-to-fork constitute the supply chain management. This network is complex because of the perishable nature of the produce, difference in the demand and supply which affects the pricing and food safety. Information technology helps the farmer to obtain the best agricultural practices, reports about monsoon, current prices of fruits and vegetables and in overcoming poor infrastructural facilities. This supply chain also requires a continuous cold chain during various steps along its network. Currently technologies like RFID, GPS, Data recorder, Blockchain are used with Information technology (IT) mainly in tracking and tracing the products right from the field to the consumer. In food sector the IT is mainly utilized for the supply chain management, traceability, e-commerce, total quality management.

Keywords:- Fruits, Vegetables, Information and technology, Supply chain, Management.

I. INTRODUCTION

Indian food and grocery market is the world's sixth largest segment while the total production of fruits and vegetables is the second largest in the world at 985.79 and 1858.83 lakh metric tonnes (2018-2019) [1]. In India only 2% of fruits and vegetables grown goes for processing, rest is consumed or wasted. Recently, the Ministry of Food Processing Industries estimated that 23 million tons of grains, 12 million tons of fruits and 21 million tons of vegetables are lost for a total approximate value of about 4.4 billion USD in the year 2018[1]. According to another FAO report food loss and food waste constitute 1.3 billion tons, of which 44% is attributed to fruits and vegetables alone. [2].

To overcome the deficits, a multi-modal answer is required in addressing the different stages from farm-to-fork. The public private partnership (PPP) model would solve some of the issues the industry is facing. Some of the initiatives taken up by the government include foreign direct investment in food products marketing and e-commerce. An Electronic National Agriculture Market (eNAM) was created in 2016 where all the Agricultural Produce Market Committees are networked for the purpose of bringing all those involved in agriculture on a common platform. Up to May 2018, 9.87 million farmers, 109,725

traders were registered on the e-NAM platform and 585 mandis in India have been linked[3].

Computing platforms have shifted more towards a cloud-computing environment with main frame servers for back-end storage and security purposes. Smaller mobile devices such as iPad, iPhone, wearable devices can access the cloud computing using advanced communication systems Wi-Fi, mobile WiMAX technologies[4]. Information regarding supply chain management, food safety, or quality management could be introduced and accessed using devices.

According to an industry body NASSCOM, the agritech start-ups like Gobasco are using real-time data like big data analytics, artificial intelligence and remote sensing to improve agri-supply chain, improve land management, crop cycle monitoring and harvest traceability [5]. Grading and sorting is done for vegetables and fruits for creating a standard for reliable trading across country boundaries using computer technology [6]. A project called CHAMAN (Coordinated Programme on Horticulture Assessment and Management using Geoinformatics) was launched in 2015-16 by the Ministry of Agriculture. The project uses remote sensing and sample survey method to estimate the area and production of different fruits and vegetables in different states and to select alternative sites for their growth e.g. alternative sites in different parts of the country apart from the original region of Himachal Pradesh where apples are grown [7].

II. CONCEPT OF SUPPLY CHAIN MANAGEMENT AND ITS CURRENT TECHNOLOGICAL STATUS

A. Perceptions of Supply Chain Management (SCM)

Supply chain management (SCM) may be defined as a set of approaches utilized to efficiently integrate manufacturers, suppliers, warehouses, and stores, so that merchandise is produced and distributed at right quantities, to right locations, and at the right time [8]. Supply chains are concerned with the flow of products and information between members till the end user [9]. Supply chain involves continuous relationship concerning goods, money and information. Goods generally flow from upstream to downstream, money flows from downstream to upstream, while information flows both from upstream to downstream and from downstream to upstream[10]. Viewed horizontally, there are five major components in the supply

chain: suppliers, goods manufacturing factories, distributors, retailers and customers. Vertically, there are also five main components: makers, buyers, transporters, storage and sellers [11].

Currently two business models exist for fruits and vegetables supply chain in India, First is the third party logistics service model and the second is the integrated cold chain model. In the first type the third party looks after the cold chain and post harvest activities and for their service they charge a fee. The second is the integrated cold chain model from the farm –to-retail model, where the flow is instrumental in affecting the supply chain. Flow includes the product flow, the information flow and the funds flow [12]. Farmers are being assisted right from irrigation of soil, warehouse, cold storage to the transport by major industries like Reliance Group, ITC etc. in maintaining the flow across the supply chain [13].

B. Cold Chain Supply Management

A typical cold chain infrastructure consists of pre-cooling facilities, cold storage, refrigerated carriers, packaging, warehouse, traceability, retailer, and consumers, under the aegis of information management systems [Fig 1] [14]. Cold chain supply management is required for assurance of safety and security of the stored products and involves the transportation and distribution of the goods to the doorstep of the consumer [12]. Due to the availability of fruits and vegetables from different climate zones in the world, extended shipping must include cold chain for their advantage. Therefore, proper control of temperature during transport and a data managing system is essential for the proper performance of the cold chain. Interestingly, different fruits and vegetables require specific optimum storage temperature. The public private partnership in cold chain supply model would help the farmers to shorten the cost of cultivation, off-season availability and a fair competitive market place. Further, 95% of cold storages in the country were owned by private sector, 3% by cooperatives and remaining 2% were under public sector undertakings. With the application of information technology across the network, transparency and efficiency of the system can be addressed [15].

The different kinds of cold storage for storing single commodity includes cold storage with single storage items like potatoes, chillies and raisins. Multi utility cold stores with a mix of positive temperature for storing fresh fruits, vegetables, spices, etc. and a negative temperature environment for storing meat, processed fruits and vegetables are available. Pack house facility includes precooling of fresh fruits and vegetables and also a handling line for sorting, washing, drying, packing and is located close to the source of production. Ripening units are part of the supply chain which are utilized for ripening of fruits while maintaining temperature, relative humidity, supply and control of ethylene levels, CO₂ levels, etc. Refrigerated transport includes reefer ship which will carry the cargo of perishables. There are special controlled atmosphere stores for apples, pears, etc. The concept in the stores is to control percentage of oxygen and CO₂

during the storage while maintaining the desired temperature and RH. The CA storage chambers extends the shelf life of fruits and vegetables during storage and transportation [16].

A recent report from National Center for Cold Chain Development estimates that India currently needs 70,080 pack-houses (as against the current 249); the 9,131 ripening chambers (as against current 812); and 52,286 refrigerated reefer vehicles (as against the current 9,131) as per the forecast in 2015 (NCCD 2015) [17]. To ensure their integrity different products require different temperature throughout the supply process. As per data seen in 2017, there were 7645 cold storages with a capacity of 34.95 million MT in the country. Majority of them are used for storage of horticultural crops and out of the total no of potatoes cultivated around 75% was that of potatoes stored in the cold room specially [18]. To increase the 20% cold storage coverage, it would require a growth rate of 12% to achieve a capacity of 70 million tonnes by 2020 [19]. The supply chain must evolve in getting data and processing, product tracking and tracing, transport, supply-demand, marketing and its information. The internet and mobile communication can also be used to enable information and financial transfer between the different parties. All these efforts will ensure supply and traceability of products and with a fair price.

C. Modified atmosphere packaging as a part of supply chain

Modified atmosphere packaging (MAP) is used to flush out air and replace it with known-gas mixture such as nitrogen and/or carbon-dioxide in the food containers. The effectiveness of modified atmosphere packaging depends on the film and the quantity of fruit and vegetables.. The characteristics of the packaging can also be changed by perforating the film and adding additives such as ethylene absorbers. MAP-packaged foods can meet the brand standards for quality and consistency. Both the nutritional appeal and extended shelf life is taken care of in MAP [20]. Nitrogen (N₂) gas is used to displace oxygen in a sealed packet at a optimum concentration. In order to maintain the moisture content in fresh produce, a mixture of nitrogen and carbon dioxide (CO₂) are used. CO₂ lowers the pH content by reacting with moisture and creates a hurdle for bacterial growth. Overall the foods in MAP storage retain their freshness for longer duration [20].

D. Controlled atmosphere packaging as a part of the supply chain

During the transportation of fruit and vegetables, low temperature along with modified atmosphere is used and is termed as controlled atmosphere packaging (CAP). Fruits are able to respire even after harvest and if we can lower the respiration rate by refrigeration, the fruits will be fresh for longer times. For example, once the apples are chilled in the cold room, nitrogen is pumped at optimum level into the storage room. It is essential to test the oxygen levels during this phase, as it needs to be lowered from 21% to 1.2% to slow down the respiration. . With the removal of oxygen, both the carbon dioxide and oxygen levels are to

be tested. CO₂ also helps in delaying ripening of fruits during storage. Many types of apples can be preserved for 9–12 months in CA storage, as opposed to 2–3 months, if using refrigerated storage alone. The packages containing the fruits are sealed once the oxygen is removed. Different foods require different levels of gases in the packaging to stay fresh. For example, fruits and vegetables should ideally be packaged in 1-5% Oxygen, 2-15% CO₂ [21].

E. Radio-frequency identification (RFID) as a tool for supply chain management

Radio-frequency identification (RFID) has become an essential component of supply chain management. Communication within the different stages of the supply chain are effected by the RFID tags themselves. Companies such as Wal-Mart have been using RFID technology to track fresh fruits and vegetables. RFID, GPS, data recorders have reduced wastage of the food product as it moves through the supply chain. Data recorders are battery operated memory device with a microprocessor which records data over time or location. RFID tags communicate via a terminal using electromagnetic waves that monitors the various parameters, e.g. temperature and termination date and identify the contents. GPS can track products and provide real-time, in-transit data about the product's condition and location. The chip is more reliable than the barcode. The main advantage of RFID is that physical contact between the reader and tags is avoided. RFID microchips are not easily removed because they are not attached to the surface of the product [4]. By using Intel RFID technology, IBM helped design, develop and implement a next-generation manufacturing and distribution supply chain. Philips Semiconductors uses RFID Technology which would reduce the sorting and tracking by 60 % while improving its efficiency [22].

F. RFID for fruits and vegetables supply chain

In Spain, the PROCONET design of the fruit-and-vegetable collaborative network and mutual exchange of data was implemented to improve logistics and transport of perishable goods in Spain. This network includes cold storage areas and also ensures product traceability and food safety in the chain. The distributed computer networks will have access to other networks and there would be free exchange of information increasing the communication. Enterprise knowledge sharing (know-how), open source / web-based applications will help the process. Some of the best practises in the manufacturing industry is the concept of integrated and collaborative networked enterprise. The fruit-and-vegetable sector faces constant challenge to balance market preferences and agricultural reality[23].

Wal-Mart has recently begun using RFID technology to mark its pallets from fresh fruits and vegetables and made it easier to deliver them on time. Now RFID technology can monitor temperatures of various products, for example, to maintain quality, temperatures are monitored and if a spoilt product occurs it can be returned. Sensors and data recorders are used with RFID as the product moves across the supply chain. In the food industry, data recorders are extremely useful for monitoring

fresh fruits and vegetables in transit. The firms can track the shipments right from the source till the consume. GPS is used to give in-transit data in real time about the product and, thus, mitigate delayed shipments [24].

III. ORGANISING RETRIEVABLE SYSTEM FOR ORGANIC FRUIT AND VEGETABLE PRODUCTS

A. Tracing different kinds of perishables in the market

The requirement in the fruit and vegetable sector needs real-time information. This involves product, production and supportive technology. Agricultural cooperative societies and retailers use pre-harvest and postharvest data obtained for monitoring product flow. Supportive technology includes tracking and tracing links of the products at different stages. The information flow of the process supports data analysis and arrive at a conclusion.

Packaging has an important role in the identification of fruits and vegetables. Euro Pool System and Ifco System, supplies crates which can be reused and has different identification technology on every crate. The relation between box identification (BoxID), product and its origin can be recorded at the agricultural cooperative society. The distribution centre registers the incoming products with the BoxIDs and sends it to the cooperative society. This exchange can be realised by web-services [25].

The traceability system of fruits and vegetables supply chain can be based on the identification method used like the Global Positioning System (GPS) and Geographical Information System (GIS) technology, Radio Frequency Identification Technology (RFID), Bar Code Technology, Electronic Product Code (EPC) etc. Among them, the bar code technology in food traceability system has been widely used. Barcodes are used for the identification of piece of the product in the barcode reading software. They contain all the details and useful data of the product and anyone can know the information of the product by just scanning the barcode [26]. The product may have chemical, physical or biological markers on them. Physical markers may have unique signatures which can be detected by UV rays, X rays, etc. Chemical markers are reagents which are added to the product, e.g. when a vitamin is added to alcoholic beverages, it gives a distinct flavour, aroma. Among the above mentioned technologies, the most cost effective technology is barcodes [27]. An Electronic Product Code (EPC) set of digits intended to complement barcodes with digits The tidentification of the manufacturer, the product category and the individual item helps in traceability information of the fruits and vegetable so as to trace and track the product. The memory bank stores the EPC code, or the Electronic Product Code [4]. The enterprise information about the product in food safety chain has an impact on accuracy and falls within the jurisdiction laws of that place. Food traceability system includes three aspects: Data capture, Data storage which

includes how data is recorded within the retention period as prescribed by law and Data sharing [27].

The IT industry and cloud technologies have been well-developed in Taiwan. In Taiwan as per their regulations when an organic fruits and vegetables are purchased and certified it will have the details like the name and address of the farmer, location, category, validity, name of the certification body and certificate number. A unique QR code is generated and is printed on the container which can be read by on the webpage after scanning the QR code [28].

B. Administration of retrievable procedure for fruit and vegetable products: Indian scenario

More than 75 % of net margin in India during the course of the supply chain is lost due to the intermediaries and the farmer does not get the right value for his produce [29]. The combination of trade and technology like enterprise resource planning in the implementation on Indian agri-food supply chain focuses on quality assurance and tracking or tracing capability. An internet-based coffee information system has demonstrated to show the variation in coffee quality due to efficient management [30]. Unorganized retailers supplying fruit and vegetables could make use of IT to improve their services and make them competitive [31]. Social networking sites such as Facebook and Twitter, manufacturers web page and a better database management are important for online transactions in the supply chain [4].

In India, generally there are three types of supply chain models followed in fruits and vegetables sector, i.e., traditional supply chain model, hub and spoke model, and value chain model. In other words, a supply chain consists of multiple parties right from suppliers, distributors and the consumers. Buying, selling, supplies and procurement of food items and other goods have gone digital. Customers, suppliers, partners and inventors can meet online and prosecute their food business ideas in an online platform [32].

E-commerce will accelerate growth, give better market access and jump in the revenue from US\$ 39 billion in 2017 to US\$ 120 billion in 2020. Online grocery though unorganized will grow to \$17.39 billion by 2022 due to changed lifestyles [33]. Facebook has inked a Rs. 43,574 crore deal with Reliance Jio platforms. Jio has a subscriber base of 300 million while the combined social platform users of Facebook, Instagram and WhatsApp have a base of 700 million Indian users. This agreement would benefit over 3 crore kiranas under a single platform using JioMart. Reliance will be providing to the kiranas merchandise, working capital, loans, digital payment solutions with Point-of-Sales machines. The online to offline model, where supply is linked with the inventory at the nearby kirana stores and not large warehouses works better with unstructured categories like grocery [34].

Information Technology should have a region specific database of information right from the soil to final pricing of the product [22]. Bengaluru-based supply chain technology firm called NinjaCart uses sophisticated supply chain algorithms that it has developed in-house to connect farmers with retailers via a network of more than 200 collection centres and 1,200 warehouses across the country in the supply chain management. This allows the farmers to get better prices and secure a consistent demand. Farmers bring in their produce to the collection centers in their respective villages. There, the items go through grading, weighing, and dispatched to fulfillment centers in batches. NinjaCart's algorithms create optimal route plans, set a dispatch schedule, and fix arrival slots. This phase involves delivering the produce from farmers to the fulfillment centers to the distribution centers. Here quality inspection of the produce in each vehicle is done, followed by queuing and then dispatching the items from the distribution centers to the customer. The company currently sources fruits and vegetables from farmers across more than 20 Indian states and delivers to over 17,000+ local kiranas and restaurants in seven major Indian cities every day [35].

IV. INFORMATION MANAGEMENT AND ITS INFERENCE

Modern horticulture is highly knowledge intensive and information driven which is used to improve the yield, and also market and distribute [36]. Supply chains are aiding organizations in today's IT in order to reduce cost, add value, extend resources. In the present age for effective supply chain management there should be increase in profitability in every step of the link while creating value for the end user. The application of IT in horticulture would leverage the common interest of the society. Information and communication technologies are especially useful for dissemination of information, for seed selection, arrival of monsoons, agricultural products, climate control, the demand and supply, pricing [37].

E-choupal experience of ITC is an electronic market place for the soybean farmers in Madhya Pradesh. ITC empowers the farmers, eliminates middle men and improves on the supply chain. The project e-Choupal is an ICT platform where business transactions are carried out at a number of places. The area at the physical level is called Choupal run by ITC. There is lead farmer an Sanchalak who acts as a liaison between the local farmer and the computer where all the information is available. The farmers will have the information of the price what ITC is quoting and the price in the local market, thereby obtaining a better remuneration[36]. Reliance Fresh assists in contract farming by getting high quality raw material at a pre-determined price irrespective in spite of the volatile nature of the market. The farm produce is collected through a central collection centre and sends it to a processing centre and distributes it to the retail outlets. ITC makes use of IT tools such as Enterprise Resource Planning (ERP) and SAP software in best possible way [36]. Kisan project was launched by the Ministry of Agriculture in order to leverage the ICT in agriculture. IFFCO Kisan Sanchar Limited was

selected to manage the Kisan call centre services. The m-kisan project uses mobile phones for disseminating information to the farmer level. Value added services such as USSD (Unstructured Supplementary Service Data), IVRS (Interactive Voice Response System) and Pull SMS gives web based services to the farmers on their mobiles without internet [38] Information centers were set up where the vendors and farmers would join together. The ease at which the information would be available is the motivating factor for the farmer to join the information kiosk [39], Concerted efforts in way of expenditure, sharing of assets, crop produce, knowledge and information sharing, marketing and R&D are needed.

V. THE ROAD AHEAD FOR THE FUTURE

The adoption and implementation of food safety and quality assurance mechanisms such as TQM including ISO 9000, ISO 22000, HACCP, GMP, GHP by the food processing industry is the need of the hour so as to maintain stringent standards of quality and face global competition [3].

The online food ordering business in India is in its early stage, but witnessing exponential growth. With online food delivery players like FoodPanda, Zomato, TinyOwl and Swiggy, the business grew at an estimated value (GMV) of US\$ 300 million in 2016 [3]. The food processing sector in India is one of the fastest growing sectors, accounting for 32 percent of the country's total food market. This sector makes up for 13 percent of India's exports and 6 percent of total industrial investment. As per the latest annual survey of industries, there are 39,319 registered food processing units in the country that employ approximately 1.7 million people in food and beverage manufacturing [40].

During 2018-19, India exported fruits worth Rs. 4817.35 crores and vegetables worth Rs. 5419.48 crores. India's exports of processed food stood at Rs. 31111.90 crores in 2018-19 which majorly included dried and preserved vegetables and mango pulp along with other processed perishables [41][33]. The Ministry of Food Processing Industries sanctioned the establishment of 42 mega food parks in the country, with nine under operation as on 2018 [40].

Blockchain technology is a structure that stores transactional records, also known as the block, of the public in several databases, known as the "chain" in a network connected through peer-to-peer nodes [42] Typically with the help of Blockchain technology, one could easily find out where a product was made, by whom, and if the quality and condition of said product or item is of an acceptable quality. Individual data files (blocks) are managed through specific softwares where the data are processed into human readable forms. Since it is a distributed database, it means that in this network every participant has access to the entire database [43].

Blockchain will show a tamper-proof historical record of dealings regarding a food product, its quality, cost and bogus detection. Government is working with Agricultural and Processed Food Products Export Development Authority (APEDA) for pomegranate exports. Blockchain will help in tracking the pomegranate exports and proving the point of origin in terms of where the pomegranate was grown and by which farmer. Another major use case will be to provide easy and fast credit to the farmers sans any middlemen involved [44].

This technology which is available right from the manufacturer down the chain to the consumer can identify the source of contamination in the complex food chain. In the case of contamination at a specific farm, for example, producers could send data to consumers about the harmful damage of that particular batch while assuring the safety of the other batches on the shelf [45]. Louis Dreyfus Co is a food trader company teamed with banks for the first soybean trade from US to China based on blockchain. Nestle has recently entered the IBM Food Trust partnership towards food traceability, for canned pumpkin and mango using blockchain[46,47]. WalMart tooks days to know the origin of its mangoes through the traditional supply chain but by using the Blockchain it just took few seconds. Hazard Analysis and Critical Control Points system in fusion with Blockchain and Internet of Things is useful in monitoring real time physical data. It is also useful in identifying food fraud and linking outbreaks to its source and maintenance of the cold chain[48]. AgUnity is one Blockchain company which uses its platform to negotiate the farmers agricultural produce based upon demand with multinational companies like Walmart, Unilever and building trust among the players.. In the year 2017 the Blockchain industry stood at \$41.2 million. RIPE, TE-FOOD, AgriDigital are other start-ups which have played a pivotal role in creating solutions for the agri-food industry[49].

VI. CONCLUSION

The food processing sector in India is one of the fastest growing sectors, accounting for 32 percent of the country's total food market. Many agri-startups are using data analytics, artificial intelligence, Blockchain technologies to overcome the limitations of the supply chain management in the food sector. GPS, RFID would continue to be used by the food industry for better supply chain. The online food ordering business in India is in its early stage, but witnessing exponential growth with online food delivery players like FoodPanda, Zomato, etc.

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