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Modeling the causes of food wastage in Indian perishable food supply chain

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ABSTRACT

Wastage in the perishable fresh produce fruits and vegetables supply chain from harvesting stage till it reaches the consumer is very high in emerging markets like India. Studies are inadequate in analysing the causal factors of food losses in this context. This study intends to identify the causes of food wastage, as well as the driving power and dependence of these causes and to analyse the interactions among them. This work proposes to use fuzzy MICMAC and total interpretive structural modeling (TISM) based approach which is a novel effort in this sector, to study the interactions. Based on review of literature and brainstorming among experts in the food industry and academia, this study identified 16 variables as the super-set of causal factors of food wastage which can represent all other causes within them. It is found that the lack of scientific methods in harvesting and a large number of intermediaries in the chain have high driving power and can be considered as the root causes of the food losses. This work categorises the causes into several levels that give an idea regarding the cause which needs more attention than others. Thereby it provides practical insights into how to improve efficiency, competitiveness, and profitability of the food supply chains. For a developing country like India, in addition to the economy, it can have greater implications on food security and conservation of environment resources. This work can be utilized by supply chain designers, managers, and policy makers.

1. Introduction

The Food and Agriculture Organization (FAO) defines food waste as "wholesome edible material intended for human consumption, arising at any point in the food supply chain (FSC) that is instead discarded, lost or degrade" (Gustavsson et al., 2011). Food losses or waste are the quantities of edible material wasted or lost in the food supply chain at various stages, including harvesting, post-harvest storage and material handling, processing, distribution and consumption. A large amount of energy and other resources are consumed for food production and distribution. Examples of food loss in the supply chain include losses due to mechanical damage, spillage and degradation due to threshing, improper handling and packaging. Food losses bear a direct influence on food quality, food security and safety, economic development and environment (Gustavsson et al., 2011). It also has a direct and negative impact on the farmer and consumer. Food losses represent the wastage of natural resources which are inputs for food production. These losses lead to needless CO_2 emissions, which further add to the environmental problems. To meet the global food demand for increasing population, it is important that not only the food production be considerably increased but also it is equally important that the causes of food waste be addressed (Halloran et al., 2014). This paper analyses the causes of food wastage in Indian fruits and vegetable supply chain from harvesting stage till it reaches the consumer. Though the terms food loss and food waste are interchangeably used, food losses refer to the losses in earlier part of the chain as in production and processing stages whereas food waste refers to the loss in the later part of the food chain as in retail and consumption stages (Thyberg and Tonjes, 2016). In this paper, food losses or food waste both means the same and refers to the loss of edible food material.

According to National Horticulture Database 2014, India is the second largest producer of fruits and vegetables next to China. India produced 88.97 million metric tonnes of fruits and 162.98 million metric tonnes of vegetables during 2014, which constitutes around 12.6% and 14% of the total world production of fruits and vegetables respectively (Handbook on Horticulture Statistics, 2014). Despite this enormous volume of production, the amounts

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of exports are only 1–2%. As high as 18% of the total amount of fruits and vegetables produced are wasted beginning from the post-harvest stage until they reach consumers (FASAR, 2014). Both the lack of an integrated approach and poor management of the supply chain are attributed to this wastage. As a result, a humongous loss of more than INR 440 billion per year is reported due to poor management of supply chains (Times of India, 2014). In 2013, Associated Chambers of Commerce and Industry of India (ASSOCHAM) highlighted that India incurs post-harvest losses worth over INR 2 trillion each year mainly owing to the lack of food processing units and cold storage facilities as well as a general disregard for handling the critical issue of post-harvest losses (ASSOCHAM, 2013). Food loss can be minimized by the efficient supply chains (Shukla and Jharkharia, 2013). There is ample scope to study the efficiency in fruits and vegetables supply chain particularly in the Indian context. The major contributors to food waste in the supply chain are processing waste, lack of cold-storage facilities, process contamination, improper packaging, transportation losses, higher inventory due to poor forecasts (Papargyropoulou et al., 2014). When these inefficiencies in the fruits & vegetable supply chain are addressed leading to the minimum loss of food from harvesting to the point of consumption, it has enormous economic, social and environmental benefits. There is scantiness of studies on food wastage along the food supply chain (Mena et al., 2011). Given the significance of the problem, this paper aims to address this gap by analysing the interactions among the causes of the food wastage in the perishable food supply chain. Analysing the interactions among the elements is very useful in dealing with the system efficiently and better decision making (Nasim, 2011). Given the complexities involved in the Indian agricultural ecosystem, a detailed and well-structured analysis of the causes of food wastage along the chain and the ways in which each variable affects the other would bring better clarity in dealing with the challenges. Further, interpreting the relation through the opinion of experts' for each couple of variables will make the structural models explicit and more transparent.

Interpretive Structural Modeling (ISM) is a proven technique for identifying the interactions or relationships among the elements which address a problem under study. ISM helps in translating the mental models into structural models, thereby the relationships are very useful in solving the problem under study. Total Interpretive Structural Modeling (TISM) approach is an upgraded, extended version of ISM, which gives meaningful insights much better than ISM approach by interpretation of the links (Singh and Sushil, 2013). Using TISM, we found and labeled 89 interactions among the 16 causes of food wastage in fruits and vegetable supply chain for complete interpretation. The various causes of losses in fruits and vegetables supply chain, need to be studied in terms of their driving power and interdependence. The traditional approach of "Matrice d'Impacts Croises – Multiplication Applicqnce a un Classement" (MICMAC) uses binary values of either 0 or 1, whereas Fuzzy MICMAC uses a fuzzy scale in determining the weights of the relationship between any two variables in which the linkage relationships can be inferred in detail. This study attempts to model the interactions among the causes of food wastage in fruits and vegetables supply chain from the harvesting stage till it reaches the consumer using TISM and Fuzzy MICMAC approach. Fuzzy MICMAC output ranks and classifies the 16 causes of food wastage in the supply chains based on their driving power and dependence. This model would help policymakers in reducing the food losses successfully and contribute both to their organizations and to the society to improve productivity and performance. Application of TISM and Fuzzy MICMAC approach in fruits and vegetables supply chain is a novel contribution, particularly in the context of developing countries like India.

The main objectives of this research are:

- to identify and rank the causes of food wastage in fruits and vegetables supply chain in the Indian context
- to establish the interrelationship among these identified causes using TISM and Fuzzy MICMAC and
- to provide the key insights to the practitioners

The remainder of this paper is organized as follows. The following section discusses the literature review on food losses in the perishable food supply chain. Section-3 deals with research methodology and explains the procedure for doing TISM and Fuzzy MICMAC analysis. Section-4 identifies the variables for losses in fruits and vegetables supply chain in the Indian scenario. Then an ISM-based structural model is developed. The ISM model is upgraded to TISM, by entirely interpreting the structural model in Section-5. In section-6, fuzzy MICMAC analysis is performed to classify the causes based on driving power and dependence and in Section-7, the results are provided. Section-8 provides suggestions for the improvement of fruits and vegetables supply chain in India and we conclude the paper in Section-9, with the limitations and issues for further research.

2. Literature review

In this section, the relevant literature on food wastage in perishable fresh produce supply chain has been reviewed.

Managing fresh food supply chains is very complex with the recently increased concern of public health, food safety, food quality, demand and price variability, and the limited lifetime of these products. Due to the short shelf life and product perishability, inventory management for agri-food supply chains is important (Beshara et al., 2012). Apaiah and Hendrix (2005) proposed a methodology for designing efficient food supply chains and identifying problems in supply chains. Supply chain design plays a crucial role, in dealing with the products which have short shelf life and higher quality degradation.

Fruits and vegetables (F&V) have a very short shelf life and are the most perishable agricultural produce. Managing fruits and vegetables supply chains is highly complicated due to the product specific attributes. One of the critical parameters of fresh produce F&V supply chain is food quality which degrades over the period depending upon the environmental conditions of storage and the transportation facilities. This quality degradation makes food items perishable in a short span of time, resulting in the value loss of the food items. This dynamic nature makes the F&V supply chain very challenging for its integrated management approach. An efficient F&V supply chain would effectively manage the dynamic interrelationships between shelf life, food quality, food wastage and would result in increased profitability. Waste reduction is the principal factor in achieving sustainability of the food supply chains (Kaipia et al., 2013). Carter and Rogers (2008) proposed the triple bottom line for sustainability. They argued that a firm has to do well in the areas of economy, society and environment to achieve sustainability and that sustainability should be part of an integrated strategy for managing the firm. Van der Vorst et al. (2007) proposed the quality controlled logistics that integrate the quality dimensions with the logistics operations. Jedermann et al. (2014) proposed intelligent food logistics by better quality supervision and prediction models to address the food loss. Kaipia et al. (2013) demonstrated using pilot projects on the benefits of information sharing, including demand and shelf-life among producers, wholesalers and retailers to accomplish enhanced fresh food supply chain performance. They argued that improved visibility along the supply chain would enhance the supply chain performance. Manzini and Accorsi (2013) presented a conceptual framework for the assessment of integrated food supply chain. They proposed an integrated