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PROMOTING AND MAINSTREAMING SUSTAINABILITY PRACTICES IN AGRI-FOOD SUPPLY CHAINS

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Abstract

Sustainability consists one of the biggest challenges that the agri-food supply chains have to face. Examining agri-food supply chains from a "life-cycle" perspective has been promoted as an effective way to move towards more sustainable food production systems. The adoption of such viewpoints in the agri-food sector has a great impact on the environmental, the economic, the social and the institutional dimensions of agri-food supply chains. Relevant technical and managerial solutions have been gaining increasing relevance in the agricultural activities, and stakeholders have a variety of alternative solutions at their disposal to increase the efficiency of the agri-food supply chains. This review examines and categorizes the strategies that have been followed towards promoting sustainability in agri-food supply chains 'from farm to fork'. Moreover, our aim is to shape an analytical framework to accommodate decisions concerning supply chain design and operation towards sustainability.

Key words**:** *agri-food, supply chain, sustainability, strategies, stakeholders*

INTRODUCTION

In the last decades, sustainability has gained increasing interest worldwide and has become a focal strategic priority. The agri-food sector has a challenging role in this new canvas. The growing population, the continuous change of nutritional habits, the feeding challenges and the water crisis suggest the creation of more sustainable agri-food networks from the sides of all stakeholders [18].

Sustainability affects the agri-food supply chain in environmental, economic, social and institutional dimensions [15]. A sustainable agri-food supply chain aims to retain the environmental balance and not to adopt practices that negatively affect ecosystems. All those should be achieved while enhancing long-term economic growth of all stakeholders of agri-food supply chains. A sustainable agri-food supply chain system also benefits the society through the creation of synergies among stakeholders with different objectives and through fostering the well-being of the society. The institutional dimension is about the activities of institutions related to the facilitation of decision-making and putting sustainability policies into practice.

International efforts for the adoption of a "life cycle" perspective have been made, such as the Sustainable Development Goals (SDGs) 2030 Agenda, which includes 17 aspirational objectives with 169 targets about all dimensions of sustainable development [29]. The agri-food sector is linked with the SDGs in an important way since FAO's strategic framework is aligned with the SDGs, promoting an integrated approach to sustainability [12]. At the same time, a growing number of sustainability approaches are linked to the bio-based economy model and the strong sustainability paradigm which also apply to the agri-food supply chains [4]. For this reason, the agri-food supply chains come up with solutions in order to increase their efficiency and move towards sustainable models of food production and distribution.

This paper aims to provide a framework for the analysis, categorization and monitoring of approaches followed throughout the agri-food supply chains towards sustainability by focusing on primary production, processing, distribution and retailing.

MATERIALS AND METHODS

This paper presents the results of a selective study of the available literature concerning the sustainable strategies followed by the stakeholders during primary production; processing; and distribution and retailing of products of the agri-food supply chains. The results of this study were categorized in each stage depending on their target, range, and level of application. Finally, gaps in the application of the sustainable approaches described in the literature were detected and a framework was shaped in order to propose solutions towards the improvement and the adoption of new practices towards sustainability.

Primary production

The primary production is the first stage of the agri-food supply chain. The decisions taken in this stage have a great impact on the sustainability of the whole supply chain. The main issues that arise are food loss, especially in less developed countries with a high population where the availability of technical and economic resources is limited [10] and the excess use of natural resources and energy until the stage of manufacturing.

Examining the pre-harvest stage, especially for crop cultivation, food losses mainly occur due to changes in weather conditions which lead to disease and insect infections [21] and sometimes pre-mature harvesting [9] affecting both the quality and safety of the products. As a result, products are not appropriate for either consumption or further processing and in a lot of cases they do not meet the requirements of other stakeholders, which leads to an increase in food losses. Another potential cause of food losses that are connected to pre-harvest activities is the poor forecasting of demand which leads to the overproduction of crops [5] that remain in the field, especially in developed countries [10]. In order to manage the uncertainties that commonly exist in primary food production, stochastic programming and robust optimization models have been developed recently, helping to optimize agricultural activities [3]. Agricultural activities also involve the use of natural resources, such as soil and water. A small amount of the resources that are used in agriculture actually remains in the product since most of them are lost [14]. That is why water management is one of the main issues that farmers have to take into consideration. During harvest, the food loss often increases, due to the lack of technical skills and equipment, causing damages to the products. Post-harvest food losses mostly happen due to poor storage conditions. The lack of appropriate storage equipment especially in the case of fresh product supply chains can affect the product quality making it inappropriate to enter the manufacturing and consuming stage [13].

Food loss management has been approached from different points of view, most of them focused on the reuse of food that has been excluded from being part of the agri-food supply chains. The use of sub-products for animal feed is regarded as the most convenient way to manage food losses. There are cases where it is applied, like Japan and Korea [20] but in most countries, it is forbidden due to health and safety reasons. Recently, studies about the use of by-products on the encapsulation process and thus as an ingredient of new functional food have been gaining increasing interest in the agri-food sector. The application of converting food loss into food ingredients, which is still under research, is promising but still far from happening.

The consumption of energy is also an emerging issue since the need of the preservation of the quality of products, usually under low temperatures, leads to higher consumptions before, during and after transportation [19]. Although in the case of fresh products the model of short supply chains is mostly applied, the food losses can still reach up to 60% of the total volume [34].

The food losses and energy consumption problems are also affected by the way agricultural activities are practiced. In many countries a primary issue that farmers have to face is the fragmented agricultural activities due to the small landholdings [25]. The fact that a lot of farmers own one or more small parts of the land and not undivided parts, happens either due to the topography of the

area or law limitations of each country [25]. In such cases, small-scale farmers do not possess the means to follow an integrated framework in agricultural activities as the technological equipment at their disposal is limited and the production is lower and in some cases not enough to cover the demands [18]. That is why small-scale farmers try to create opportunities for cooperation with others and create a network of producers in order to achieve their sustainable goals [11]. The integration of different sectors of agricultural activities, such as livestock, tree cultivation, fish and crops is also a way of creating synergies in the primary production since these agricultural systems can exist at the same time taking advantage of each other due to their complementary needs by re-using nutrients and resources. Similar techniques are mostly applied in the case of greenhouses, where there is the re-use of carbon dioxide emissions of power plants as a booster to the plants' growth, but not in a wide range.

Innovative agricultural systems have been studied and applied during the last decade in order to optimize the agri-food supply chains and increase their efficiency using technological innovations and proposing new frameworks for organizing the stakeholders [30]. The scientific research behind this perspective is valuable and it has contributed to achieving its targets. The precision technologies that already find application in the agricultural sector have promoted and supported this perspective by updating the quality and increasing the efficiency of agricultural activities [7]. Besides, a multi-level perspective has also been developed within the agri-food supply chains, considering mostly the energy management and describing ways to move towards socio-technical changes, approaching a more sustainable system. The application of such socio-technical changes is difficult to be achieved in the case of highly institutionalized systems, where the rules and regulations provide stability and make them difficult to change and adapt to the new socio-technical circumstances [23].

Processing

In the case where products are not distributed for direct consumption, they enter the next level of the agri-food supply chain which is manufacturing. There is a lot of research on the sustainability approaches of the stakeholders at the level of food processing and packaging, alongside an interest in food safety and quality.

Examining the manufacturing stage of different kinds of products we observe that inappropriate handling during manufacturing and transportation is one of the main reasons for the food losses and quality degradation of the products [1] which leads to reduced profit. The lack of appropriate storage equipment, poor packaging and quality defects of products that emerge, lead to food losses even before transportation at both developed and less developed countries[10]. The use of these by-products has become an emerging issue for the agri-food supply chains as they negatively affect the environment in case they remain unused [2]. That is why the stakeholders in this stage tend to use new technological equipment, where possible, and use advanced packing and handling systems in order to avoid food losses [17]. Mechanical preservation technologies are widely used in food manufacturing aiming to extend the shelf life of the products and preventing their quality degradation [7]. The adoption of technologically advanced systems and materials especially during the stage of packaging has also a positive role towards achieving traceability, since high-quality packaging protects the quality of the product and gives all the necessary information about its background [22].

Distribution and Retailing

Depending on the kind of food product and its safety and quality standards, the procedures and requirements of the agri-food supply chain change. For example in the case of frozen products the energy needed to process, transport and store them is higher than in the case of fresh products, ending up though to a product with a longer shelf-life, giving the retailers the chance to create a stock [35]. The case of perishable products is also interesting. Even though in some cases the manufacturing stage slightly exists, such as the case of fresh

fruits, the handling and transportation of the products has a great impact on their quality and self-life [26]. On the other hand, the transport of non-perishable products is easier but still affects the quality of the products and possible losses in the next stages [26].

During transportation, there are temperature and humidity standards that have to be followed. Long-distance transportation and the lack of the appropriate equipment and trained staff causes losses of food due to pathogens and quality degradation [10]. As a result, traceability should also be assured at this stage. The requirements to achieve safe transportation include appropriate infrastructure, such as warehouses and equipment like packaging boxes but most importantly the technological capability of monitoring the transportation procedures in order to access all the information needed. Information sharing is highly important since the condition of each product should be accessible to all stakeholders in order to enhance the trust in the relationships between them [17].

Food losses also occur from the retailers' side. In some cases, the standards of each retailer are strict in order to offer products with higher quality and sometimes added value and as a result, products that do not have quality and safety problems are often rejected. Moreover, the bad storage conditions can expose products to microbiological dangers leading to non-confirmation of the food safety standards imposed by the law of each country. The inaccurate forecasting of the demand and the over-stocking of products in retailers' storage can lead to expiration before being sold and then rejection. In some cases retailers use methods of chemical preservation of products in order to avoid food losses due to expiration [7].

RESULTS AND DISCUSSIONS

Examining the strategies followed by the stakeholders of the agri-food supply chain we observe that even though there are some organized frameworks for sustainability, there is ground for substantial improvements. Some of the approaches described in the previous sections are still in an immature level or even not yet actually applied at the industrial level. In Table 1 there is a categorization of the strategies followed throughout agri-food supply chains considering the evolution of their application using the product/service life cycle curve, which is presented in Figure 1. The following continuum is used in order assess the level of application:

(1)Development: researchers have identified the potential of certain applications which are still under investigation.

(2)Introduction: the researched solution is regarded to have potential application and has been recently adopted by practitioners.

(3)Growth: the researched solution is adopted by a growing number of stakeholders.

(4)Maturity A: the researched solution is widely adopted and recognized by stakeholders.

(5)Maturity B: the researched solution is well established and recognized by stakeholders.

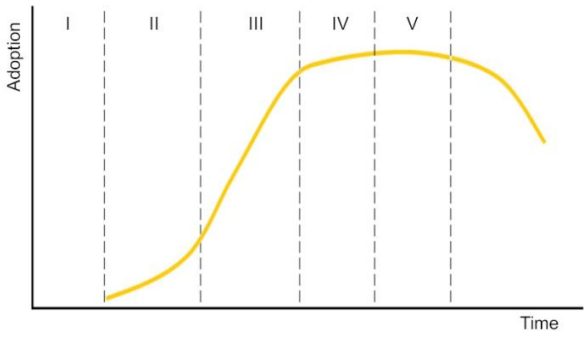

Fig. 1. The product/service life cycle curve
Source: Adapted and modified from [31].

Sustainability in agri-food supply chains is a focal priority. There is increasing interest in research around this topic, from environmental, economic, social and institutional points of view. In the last decade the increase of the published works on sustainability is remarkable [10, 32]. Most of the research is focused on environmental, economic and managerial aspects of sustainability and less on the social impact of it [8, 33]. However, a holistic approach is necessary in order to make fundamental changes towards sustainability in the agri-food supply chains focusing on overall efficiency and not dealing with the different

stakeholders as separate units, but as interdepended parts of a system.

Table 1. Evaluation of strategies followed throughout agri-food supply chains

Stage	Problem	Solution	Level of application
Primary Production	Weather conditions	Optimization models	III
	Use of natural resources	Water management	IV
	Food losses	Re-use of by-products	I
	Fragmented agricultural activities	Cooperation between farmers	II
Processing	Food losses	Technological equipment	V
		High quality packaging materials	V
Distribution	Quality degradation	Technological equipment	V
	Traceability	Information sharing	II
Retailing	Food losses	Better storage conditions	IV
	Over-stocking	Demand forecasting	III

Source: Authors' own analysis.

Although the technology in agricultural activity has been developed, the focus of the evolution lies in the post-harvest sector. As proposed by [7] the development of precision agriculture can reinforce the pre-harvest activities and manage uncertainties. In addition to this approach, the update of the skills of those who work in the primary production is necessary in order to adopt new practices and take advantage of the new technological implementations.

The environmental impact of the agricultural activities is increased since the managing of natural resources is highly involved. The preservation of soil and water, as the main sources of energy used in agriculture, and reduction of emissions have been a priority for the agricultural sector since climate change is a worldwide topic of discussion. For example, manure management has started to be applied, as it can reduce greenhouse gas emissions by being used in other agricultural activities, such as fertilization [16]. The governance has just started reinforcing eco-friendly activities and a lot of countries have committed to follow green practices [14]. Nevertheless, institutional changes are necessary, and the regulation should be modified in order to make the application of these frameworks easier for the stakeholders and motivate even small-scale farmers to align with the evolution in the agricultural sector. The cooperation between farmers, although being promising, it is not frequently adopted. As mentioned, mixed systems in agriculture slightly exist. The intensification process could help the stakeholders to increase the efficiency of the agri-food supply chain, deal with the problems caused by the limited land and equipment availability and meet the needs of the customer demand. The convergence of interests among farmers could be achieved by formal contracts and agreements, even in short agri-food supply chains and secure the commitment to achieving the goals from the sides of all coordinators [28]. All these strategies aim to increase the agri-food supply chain efficiency by achieving at the same time the best combination of safety and quality of products for the customers and thus provide products with added value. In order to monitor the condition of the products and ensure they retain their properties, we need a system of following the product through all the stages. Traceability is a very convenient solution for the agri-food supply chain and it can be achieved through the use of information technology systems that improve information management, such as blockchain technology [27]. The problem of food loss through all the stages of agri-food supply chains is dominant. The economic, environmental and social impacts are self-evident. The use of by-products from the stakeholders themselves or from their coordinators gives them the chance to utilize this food waste. In addition, when the food losses are increased as the products go through the agri-food supply chain stages, retailers may end up having at their disposal the less quantities than necessary, which in turn may lead to increases in the products' prices [24]. A decrease in food losses increases the number of the products available

for selling. There are several proposals for using the co-products, as it has already been described, but not all of them are applied in the same range. Depending on the reason why the products have been rejected, different methods of usage can be applied. In the case where the products are rejected due to inappropriate handling and not spoilage and the product cannot be used for its original purpose, they could be processed and be turned into another functional food or an ingredient for other kinds of products. For example, in the case of fresh fruits the use of them as an ingredient for juice or fruit-flavored snacks could be a way to reduce fresh food waste. On the other hand, when the product is not safe for further processing or use, this sub-product could be used for other purposes such as feed, as it has already been proposed [20]. Another way to reduce food waste and at the same time help to solve the major problem of poverty and feeding challenges is food donation. The regional donation of products that retain their quality and safety is a way to manage food waste and at the same time reduce social inequalities. However, bureaucracy is still an obstacle to this action [24].

The ability to apply this strategy at international level is not easy, as transportation among countries is difficult, mainly due to technical reasons. Opening new markets in countries where the food crisis is increased could be a way to increase food availability and at the same time reduce food waste in developed countries. To achieve this, an adjustment of laws and regulations is necessary in order to keep up with the local legislation of each country.

Examining the possible frameworks for sustainable practices in agri-food supply chains we notice that investments are required from all stakeholders. Sometimes, an investment in sustainability could reduce short-term profits [6].

CONCLUSIONS

Sustainability is linked to long-term strategic planning as it represents a change towards a different way of approaching the efficiency of agri-food supply chains. As a result, a change of perspective among stakeholders is necessary in order to take the next step towards the evolution of the agri-food supply chains and invest in a model adapted to the contemporary needs of the market. There still is room for improvement in the strategies that have already been followed by the stakeholders. Their adaption to new problems that emerge and their combination with new frameworks of solutions is the key to achieving sustainability in agri-food supply chains. This research was rather focused on the crop cultivation systems and the different kinds of products involved in such agri-food supply chains. The shape of new frameworks is an ongoing research examined from different viewpoints in order to achieve an integrated approach to sustainability.

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