The Potential Effects of Developing Different Marketing Channels on Waste Reduction in the Leafy Vegetable Supply Chain in Kermanshah Province

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Abstract

Every year, approximately one-third of the total food produced for human consumption is lost or wasted due to various reasons. This level of wastage has substantial adverse impacts on the environment, economy, and society. Numerous studies have proposed various policies to address the issue of food waste, such as incorporating technology into existing supply chains. However, concerns about their effectiveness and unintended consequences have led researchers to emphasize market-based approaches for waste reduction. The present study was carried out to estimate waste and investigate the potential for developing different marketing channels as market-based approaches to reduce waste in the leafy vegetable supply chain in Kermanshah province. To achieve this purpose, a system dynamics modeling of the waste system in the leafy vegetable supply chain was developed by using the literature review and interviews with experts and key actors. The tool for collecting research data was a questionnaire. The statistical population of this study included two groups of subject matter experts and actors involved in the leafy vegetable supply chain. In total, 22 experts and 728 actors from different stages of the supply chain were studied. Based on the findings, around 31,000 tonnes (39%) of leafy vegetables are wasted annually across the supply chain. Projections indicate that if the current trend persists, the amount of waste will continue to rise in the coming decades. The research scenarios indicate that the establishment of processing industries will effectively decrease the overall waste of leafy vegetables from around 31,000 tons to approximately 20,000 tons annually. Therefore, it is critical that government initiatives and policies in the field of leafy vegetable exchange in the study area focus on supporting businesses associated with leafy vegetable processing industries and establishing infrastructure prerequisites for these industries.

Keywords: Food waste, Marketing channels, Leafy vegetables, Food chain, System dynamics modeling.

Introduction

A considerable quantity of fresh agricultural products, specifically fruits and vegetables, is annually lost or wasted across different operational channels and levels of the supply chain (Anand and Barua, 2022). This wastage has major economic, environmental, and societal consequences resulting from the inefficient utilization of land, water, energy, labor, and other resources (Ganesh *et al.*, 2022; Parsafar *et al.*, 2023). For instance, the inefficient utilization and wastage of agricultural products at the farm level result in increased expenses and decreased revenue for farmers (Lipinski *et al.*, 2013). Similarly, at the household level, the

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disposal of food leads to higher expenditures for consumers per unit of food purchased (Latka *et al.*, 2022). Moreover, food waste is one of the most important contributer of greenhouse gas emissions (Amicarelli *et al.*, 2021). Despite ongoing endeavors to accurately measure and implement efficient strategies to mitigate food waste, a comprehensive assessment of the current literature in this area reveals persistent gaps and limitations. The analysis of research conducted on food waste measurement reveals several key points: Firstly, studies that cover the entire food supply chain are scarce (Liu *et al.*, 2020). Secondly, the majority of research has predominantly focused on the consumption and retail sector (Xue and Liu, 2019). Lastly, a significant proportion of these studies were carried out in developed countries (Xue *et al.*, 2017). The lack of comprehensive global data on food waste, along with restricted geographical coverage, poses challenges in establishing a baseline for tracking progress towards the Sustainable Development Goals. therefore, there is a pressing requirement for additional studies into the magnitude of food waste and the implementation of effective mitigation strategies, particularly in developing countries.

In Iran, a substantial portion of agricultural products goes to waste each year for various reasons across the supply chain (Nakouzi, 2017). According to the Food and Agriculture Organization of the United Nations (FAO), approximately 35 million tons of agricultural products are discarded annually in Iran, accounting for 2.7% of the global food waste. These statistics position Iran among the top three countries worldwide in terms of food waste and loss. Based on this report, vegetables are identified as a significant contributor to food waste in Iran, alongside bread, fruit, and rice (FinancialTribune, 2017). Among these vegetables, leafy vegetables have been found to have particularly high waste rates (Moradi *et al.*, 2023). The primary obstacle in the supply chains of these products is ensuring their freshness from the time they are harvested until they reach the end customer (Kumar and Agrawal, 2023; Mohan *et al.*, 2023). As a result, any challenges or inefficiencies within the supply chain causes a substantial portion of these products to be withdrawn from the consumption chain (Parsafar *et al.*, 2023). Studies indicate that in Kermanshah province, a considerable amount of leafy vegetable production is wasted each year across the supply chain. This wastage can be attributed to various factors such as the perishable nature of these products, production challenges, inadequate marketing infrastructure, and improper consumer food consumption management (Abadi *et al.*, 2021; Moradi *et al.*, 2023). In recent years, extensive literature has focused on various strategies to address food waste in the supply chain. These strategies include the implementation of technical solutions at different stages of the supply chain (Gardas *et al.*, 2017; Kör *et al.*, 2022; Magalhães *et al.*, 2022). However, concerns about the effectiveness and potential unintended consequences of these approaches have prompted researchers to highlight the importance of market-based approaches to tackle food waste (Adebola, 2020; Aramyan *et al.*, 2016). The marketing channels that are used have a considerable impact on the waste generated within the agricultural product supply chain. Hence, recognizing the potential of these channels as a form of market-based approaches can be effective in guiding the decisions of policy makers and relevant planners to implement appropriate policies and measures to reduce waste. Given the significance of the topic, this study employed system dynamics modeling to quantify waste and assess the potential of different marketing channels in minimizing waste within the leafy vegetable supply chain in Kermanshah province. The utilization of system dynamics modeling by assessing the interdependencies among various variables within the leafy vegetable waste system provides a comprehensive overview of the efficacy of the suggested waste reduction initiatives. To achieve the aforementioned objective, the following questions were taken into consideration: 1-What is the exact structure and process of the leafy vegetable supply chain in Kermanshah province? 2- How much waste is annually generated within the leafy vegetable supply chain in Kermanshah province? 3-What will be the

projected trend of waste in the leafy vegetable supply chain in the upcoming years? 4- What impact will the development of different marketing channels have on the overall waste amount in the leafy vegetable supply chain?

Materials and Methods

The present study is classified as applied research and in terms of data analysis, it can be classified as descriptive research. The geographical area under investigation was Kermanshah province in the west of Iran (Figure 1).

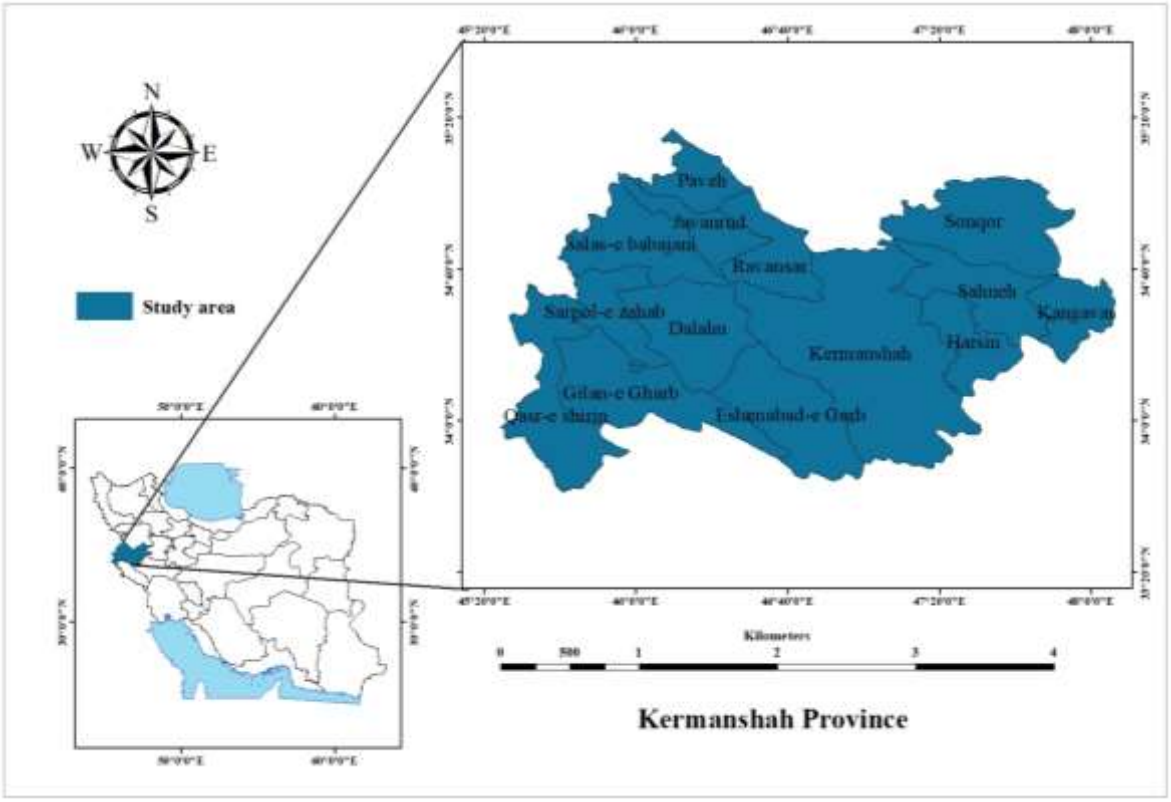

Figure 1– A map of the study area

Study Definitions and Scope

The focus of this study is on the product of leafy vegetables in the category of fruits and vegetables, which hold significant dietary value for Iranians as staple food items (in cooked form and desserts). Leafy vegetables encompass various green edible plants, including celery, spinach, leek, watercress, mint, parsley, coriander, etc. In this research, the inclusion of lettuce and cabbage was omitted due to the distinct marketing and sales characteristics of these products compared to other leafy vegetables, as well as the difficulty in monitoring their waste. This study does not distinguish between the two terms food waste and food loss and investigates waste in the leafy vegetable supply chain from farm to table. Therefore, the term "leafy vegetable waste" is utilized broadly in this study to encompass those portions of the products that are intended for human consumption but are eliminated from the supply chain due to various reasons (FAO, 2014; Parfitt *et al.*, 2010).

Statistical population and sampling method

The data collection method utilized in this study was a questionnaire. The statistical population consisted of two categories: the first category comprised national and regional subject matter experts, such as university faculty members, researchers from the Horticulture Research Center, and agricultural experts and managers from Kermanshah province. Additionally, a group of individuals with relevant executive experience were included. This group played a role in ensuring the quality of the questionnaire, identifying the structure and process of the leafy vegetable supply chain, and validating the model and its results. The total number of studied samples in this section was 22 participants who were selected purposefully. The second category focused on actors involved in various sectors of the supply chain, such as farmers, wholesalers and retailers, processing units, and consumers (both households and food services) in Kermanshah province. The data collected from this group was utilized to simulate the research model. In the farmers and households sections, samples were selected in a stratified sampling with proportional assignment, following Cochran's formula to determine the sample size. For the other groups, a full count was conducted. A total of 728 samples were chosen and analyzed, consisting of 172 farmers, 83 wholesalers and retailers, 16 processing units, 384 households, and 73 food service units. Furthermore, population data and future trends were calculated based on UN forecasts for Iran's population in the upcoming years (UN, 2018).

Analytical process and method

Identifying research variables and the structure of their interactions

Initially, studying the literature and the opinions of experts and actors using the focous group discussion technique, the structure, and procedure of the leafy vegetable supply chain were compiled.

Leafy vegetable supply chain

The supply chain can be defined as a complex network of activities, individuals, organizations, information, and resources that work together to ensure the efficient delivery of goods from the initial production stages to the end customer (Van der Vorst *et al.*, 2007). In the case of Kermanshah province, the leafy vegetable supply chain can be categorized into five main groups: suppliers, producers (farmers), marketing and distribution (retailers and wholesalers), processing industries, and consumers (food services and households) (Fig. 2).

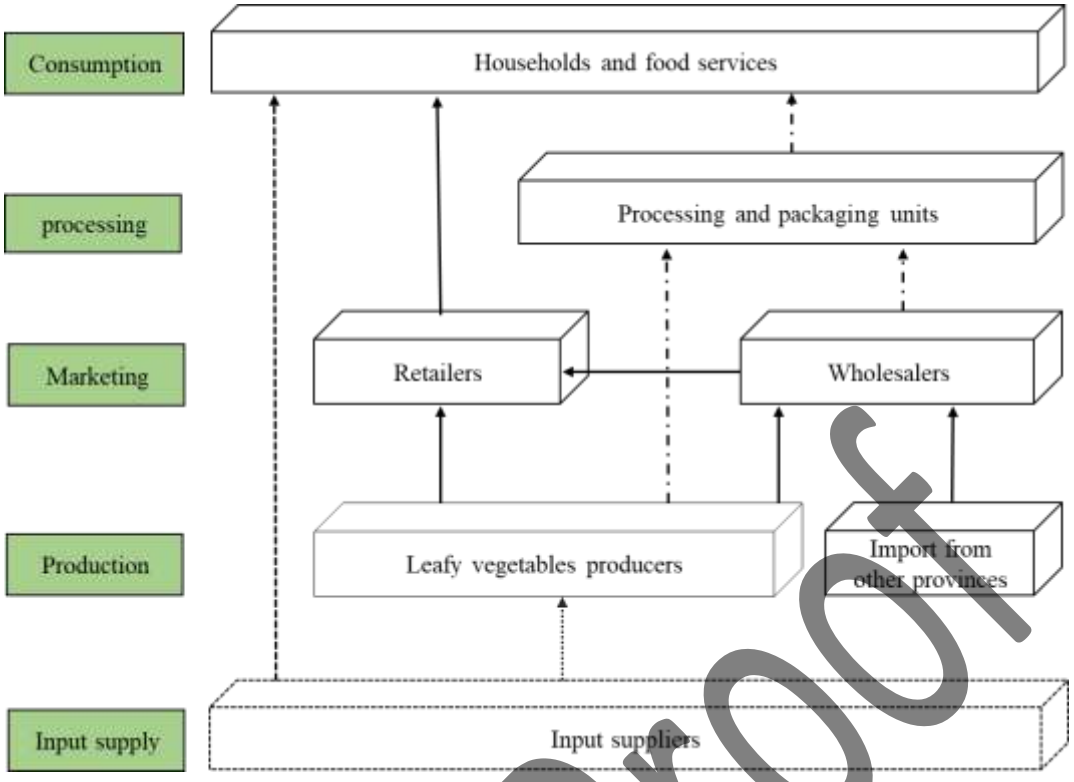

Figure 2- Leafy vegetable supply chain in Kermanshah province

Marketing channels

Marketing channels refer to the methods through which farm ers market their products to consumers. In Kermanshah province, leafy vegetable farmers employ a diverse range of marketing channels to effectively reach their target audience. One prevalent method is direct marketing, where farmers sell their produce directly to customers through stalls and stores situated within the fields or along roadsides. The second approach involves the conventional system of distributing agricultural products to consumers. Under this marketing strategy, fresh leafy vegetables are made available to consumers through various markets, including wholesale and retail stores. The third approach entails processing and preparing leafy vegetables in specialized facilities and subsequently distributing them to customers. In this marketing strategy, a portion of the leafy vegetables is transformed into frozen products, while the rest is packaged and delivered fresh to consumers. It is important to note that during the winter season, when severe weather conditions restrict local production, a portion of the leafy vegetables required in the study area are supplied from other provinces and subsequently distributed in the market (Figure 3).

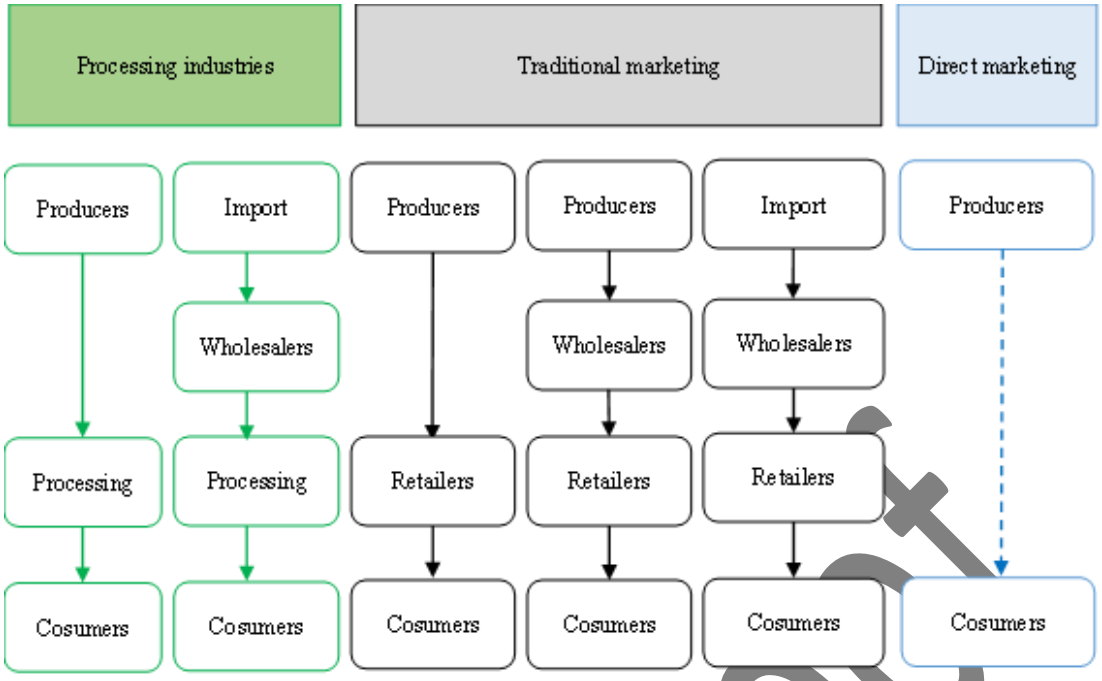

Figure 3- Leafy vegetable marketing channels in Kermanshah province

System dynamics modeling of waste within the leafy vegetable supply chain

After identifying the research variables and their relationship structure, the waste system within the leafy vegetable supply chain was modeled using the system dynamics modeling. System dynamics is a powerful methodology for accurately representing real-world events, which enables the evaluation of different policies on the overall performance of the system over time (Forrester, 1992). To develop the waste system in the leafy vegetable supply chain in Kermanshah province, the following steps were followed:

Problem Statement

The first stage in system dynamics modeling involves defining the structure and extent of the research problem (Sterman, 2000). In socio-economic research, the boundaries of a system are defined by two key factors: 1) the research purpose, and 2) the importance and effect of various factors on the elements within the boundaries of the system. The purpose of this study is to examine the effect of developing different marketing channels on waste reduction in the leafy vegetable supply chain in Kermanshah province.

Designing a conceptual model

After formulating the research problem and defining the boundaries of the system, the next step is to create a conceptual model. Figure 4 provides a structured overview of the variables and their key component interactions for testing the research hypotheses.

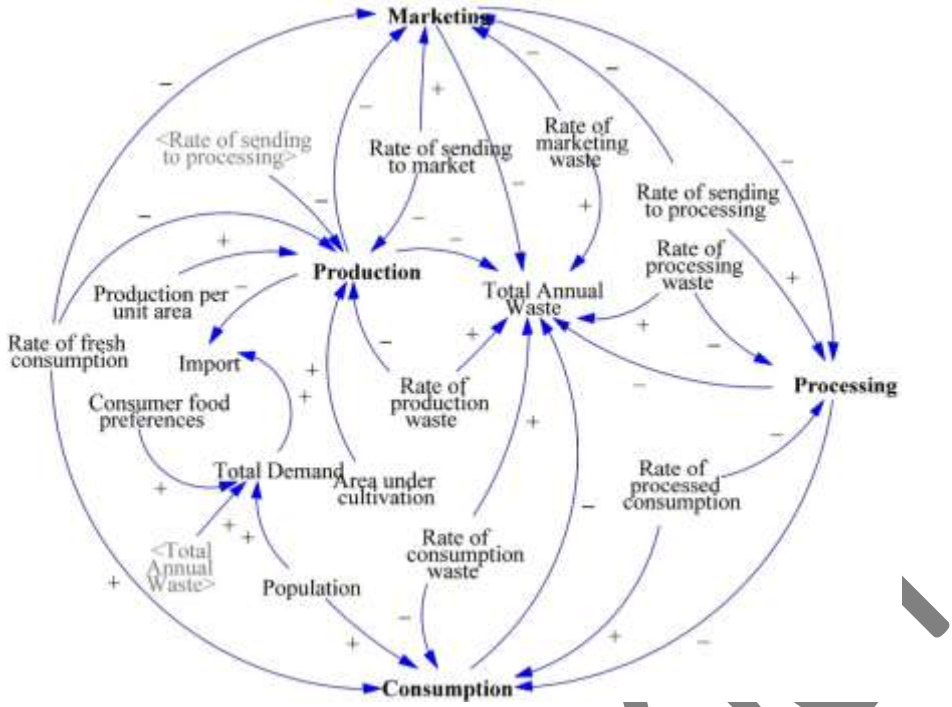

Figure 4- Causal loops diagram of waste system within the leafy vegetable supply chain

Formulation of the simulation model

To simulate the results of the model, the causal loops diagram is required to be converted into a stock and flow diagram. This part encompasses specifications of the system structure, parameter estimations, model interactions, and initial values (Figure 5 and Table 1).

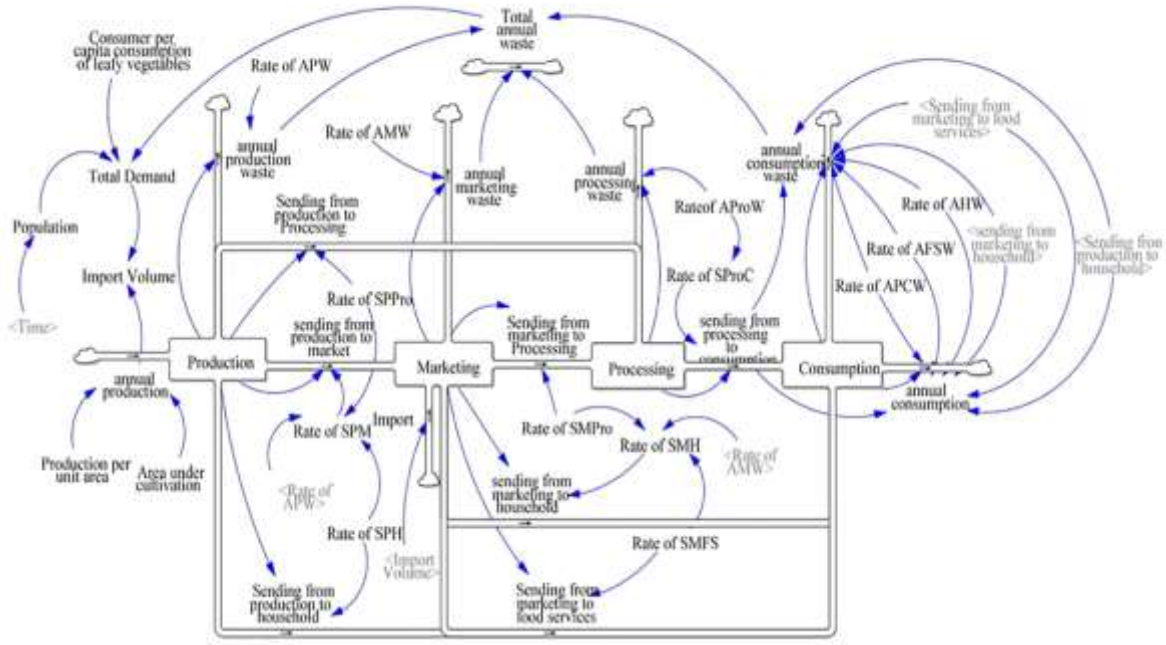

Figure 5– Stock and flow diagram of waste system in Leafy vegetable supply chain

Table 1- Initial values of research variables

Subsystems	Flows	Variables	Amount	Units
Demand subsystem	-	Population (Po)	2.070	Person
	-	Per capita leafy vegetable consumption (PLVC)	24	kg
Production subsystem	Input flows	Annual production (AP) of leafy vegetables	52000000	kg/Year
	Output flows	Sending from production to household (SPH)	25	%
		Sending from production to processing (SPPro)	4	%
		Sending from production to market (SPM)	47	%
		Annual production waste (APW)	24	%
Marketing subsystem	Input flows	Import (I)	28492000	kg/Year
		Sending from production to market (SPM)	47	%
	Output flows	Sending from market to household (SMH)	84.5	%
		Sending from market to processing (SMPro)	1.5	%
		Sending from market to food services (SMFS)	3	%
		Annual marketing waste (AMW)	11	%
Processing subsystem	Input flows	Sending from production to processing (SPPro)	4	%
		Sending from market to processing (SMPro)	1.5	%
	Output flows	Sending from processing to consumption (SProC)	93.5	%
		Annual processing waste (AProW)	6.5	%
Consumption subsystem	Input flows	Sending from production to consumption (SPC)	25	%
		Sending from market to consumption (SMC)	84.5	%
		Sending from market to food services (SMFS)	3	%
		Sending from processing to consumption (SProC)	93.5	%
	Output flows	Annual consumption (AC)	48740000	kg/Year
		Annual consumption waste (ACW)	Annual Household waste (AHW)	21	%
			Annual Food services waste (AFSW)	18	%
			Annual processed consumption waste (APCW)	5	%

Source: Research findings

The ultimate model created comprises multiple sub-models, which are detailed as follows:

1) Estimating the total demand for leafy vegetables

The total demand for leafy vegetables in this study was estimated by taking into account the population of the province, the per capita consumption of leafy vegetables, and the amount of annual waste across the supply chain. This model considers that a portion of the demand for leafy vegetables in Kermanshah province is fulfilled through local production, while during the cold seasons of the year, another portion is sourced through imports from other provinces (Equation 1).

$$\text{Total demand} = (\text{Po} \times \text{PLVC}) + \text{TAW} \quad (1)$$

Unit: kg/year

2) Production subsystem modeling

Cumulative production indicates the overall volume of leafy vegetables during the production stage over a period of a year (Equation 2).

$$Cumulative\ production = \int_{t_0}^{t} AP - (APW + SPH + SPPro + SPM) \quad (2)$$

Initial value= 52000000

Unit: kg/year

3) Marketing subsystem modeling

Cumulative marketing quantifies the overall amount of leafy vegetables in the marketing stage over a period of a year.

$$Cumulative\ marketing = \int_{t_0}^{t}(I + SPM) - (SMH + SMP + SMPro + AMW) \quad (4)$$

Initial value= 52581700
Unit: kg/year

4) Processing subsystem modeling

Cumulative processing integrates the input and output flow of leafy vegetables in the processing stage over one year (Equation 4).

$$Cumulative\ processing = \int_{t_0}^{t}(SPPro + SMPro) - (SProC + AProW) \quad (5)$$

Initial value= 2857510
Unit: kg/year

5) Consumption subsystem modeling

Cumulative consumption indicates the total amount of leafy vegetable consumption over one year, including two parts: household and food services (Equation 5).

$$Cumulative\ consumption = \int_{t_0}^{t}(SPC + SMC + SMFS + SProC) - (AC + ACW) \quad (6)$$

Initial value= 61070300
Unit: kg/year

6) Waste estimation modeling in the supply chain

The total waste of leafy vegetables was estimated through considering the cumulative waste generated at various stages of the supply chain, including production, market, processing, and consumption (Equation 5).

$$TAW = APW + AMW + AProW + ACW \quad (8)$$

Unit: kg/year

After developing and formulating the model simulation, the parameters were estimated using Vensim software.

Simulate the model to test the scenarios

The primary objective of the system dynamics modeling is to examine potential strategies aimed at enhancing the system's overall performance. In this research, four scenarios were devised based on expert opinions and the purpose of study. These scenarios include: 1) maintaining the current status quo, 2) development of processing industries, 3) development of direct marketing, and 4) development of traditional marketing. The purpose of these scenarios is to address the question of which marketing channel development can play a more impactful role in minimizing waste within the leafy vegetable supply chain. At this stage, by directing the flow of distribution of leafy vegetables in each of the marketing channels, their potential in reducing the amount of waste in the supply chain of leafy vegetables was documented. Policy scenarios were simulated based on the conditions in Table 2.

Table 2– Model variable values in four different scenarios

Variables	Baseline	Development of direct marketing	Development of traditional marketing	Development of processing industries
Sending from production to household	25	76	0	0
Sending from production to processing	4	0	0	76
Sending from production to market	47	0	76	0
Sending from market to household	84.5	84.5	86	0
Sending from market to processing	1.5	1.5	0	89
Sending from market to food services	3	3	3	0

Source: Research findings

Results and Discussion

The validation of a system dynamics model is a crucial step in ensuring its accuracy and reliability. Thus, initially, the results of evaluating the validity and accuracy of the model are presented.

Assessment of Model Validity

The purpose of validating the model is to increase confidence in its ability to accurately represent the real behavior of the system. In general, for model verification and validation in system dynamics modeling, two types of behavioral and structural tests are used (Sterman, 2000). Several specialized tests, including sensitivity analysis and expert opinion tests, were performed at this stage. Sensitivity analysis examines how changes in certain variables, which can be modified in real-world conditions, affect the behavior of other variables in the model. Throughout the sensitivity analysis process, the assumptions related to the constants of the model were adjusted in the range of +10 and -10 and the output values of the system were examined. Figure 6 presents the results of sensitivity analysis for the four main variables of the study based on four different ranges of changes (50%, 75%, 95% and 100%). These variables were selected based on expert opinions and the sensitivity of the model to their variations. Based on these findings, it can be concluded that the outputs of the model are sensitive to the changes in its inputs, which indicates the reliability of the model.

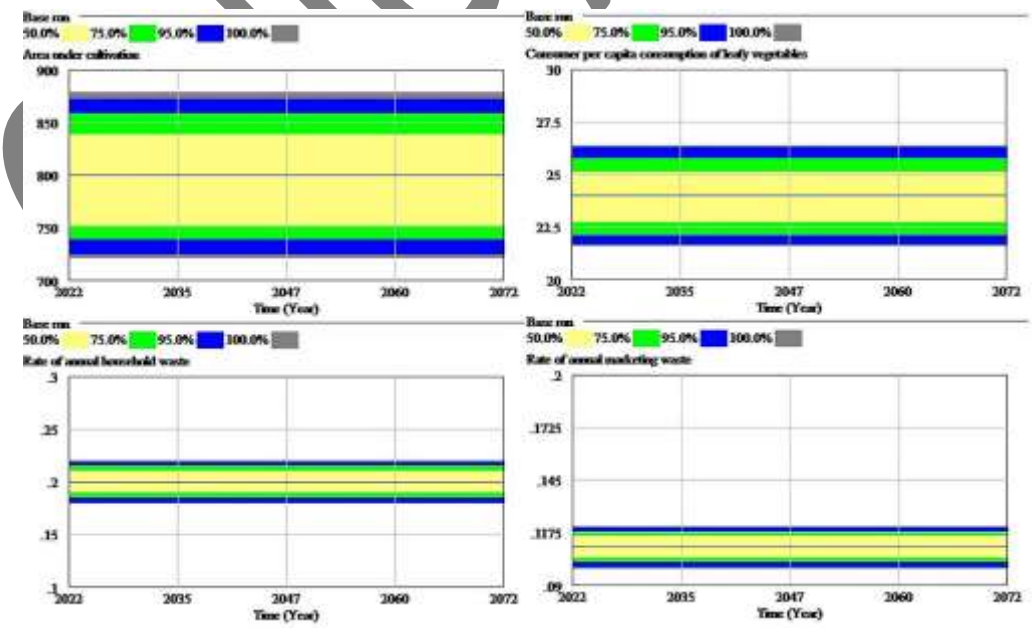

Figure 6– Confidence limits for four of the most important model variables

After confirming the validity of the simulated model, it is essential to verify the conformity of the model results with reality. This can be achieved by comparing the model outputs with available historical data. Since there is limited historical data on leafy vegetable waste in the current study, the simulated model and its outputs were evaluated by three relevant experts to validate its findings. Following their assessments, necessary modifications were made to the model.

Model simulation under different scenarios

After formulating and validating the model, it can be implemented. For this model, we selected a simulation unit of one year, with a simulation duration from 1401 to 1450. The simulation was divided into two parts: a) Simulating the model assuming the continuation of the current condition, b) Evaluating the effects of different scenarios involving the development of traditional marketing, direct marketing, and processing industries on the amount of leafy vegetable waste.

Scenario 1) Continuation of the current condition

This scenario estimates the amount of waste in the simulation period assuming no intervention to reduce waste. Model estimates show that of the total annual demand of 80,000 tons for leafy vegetables, approximately 31,000 tons (around 39%) are wasted across the supply chain. The highest amount of waste occurs during production, accounting for 12,500 tons (40.6%), followed by consumption with 12,300 tons (40.1%), and the market with 5,700 tons (18.7%). The findings of this study is consistent with global trends, highlighting the significant levels of waste during both the production and consumption stages in developing nations (UNEP, 2021).

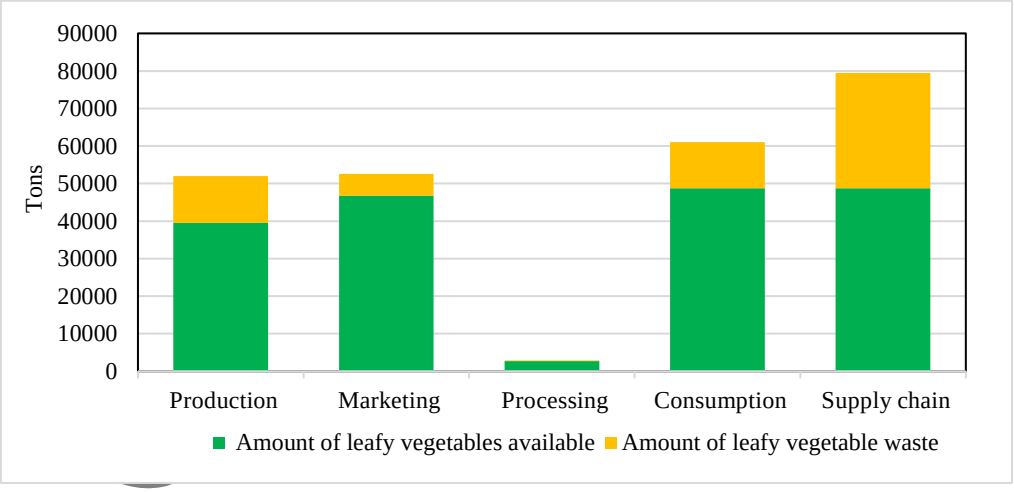

Figure 7- Amount of leafy vegetables available and waste in the leafy vegetable supply chain.

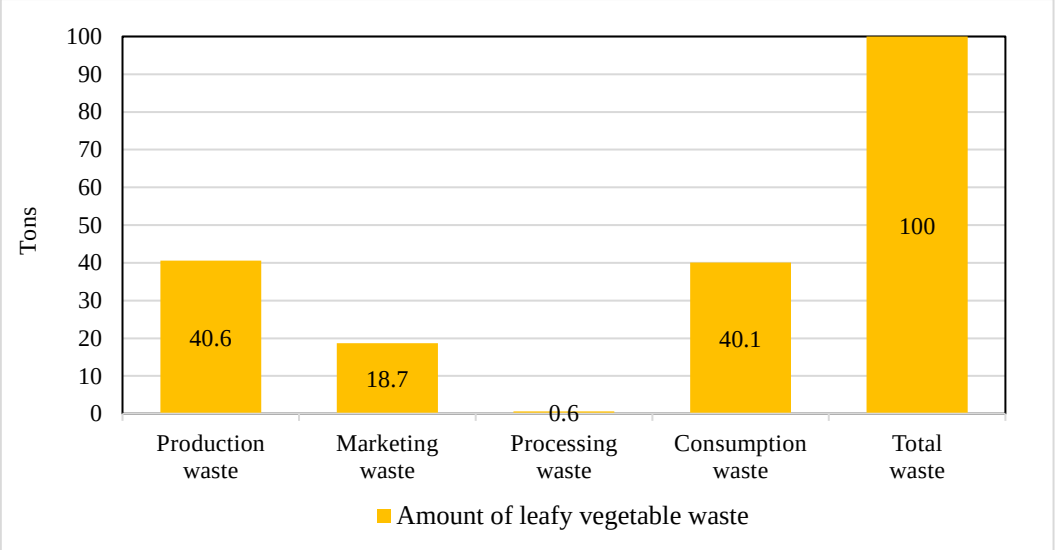

Figure 8- The proportion of waste generated in each stage of the leafy vegetable supply chain from the total waste.

The leafy vegetable consumption sector encompasses fresh vegetables consumed by households, fresh vegetables consumed by food services, and processed vegetables consumed by both households and food services. At the household level, approximately 57,000 tons of leafy vegetables are consumed, with 11,900 tons (21 percent) being wasted. In the food service sector, approximately 1,600 tons of fresh leafy vegetables are consumed each year, with 270 tons (18%) being wasted. Furthermore, approximately 2,700 tons of processed leafy vegetables are eaten in the consumer sector, with 130 tons (5%) ending up as waste (Figure 9). Although the findings of this study align with the report from the United Nations Environment Office, which highlights a significant amount of food waste during the consumption stage in developing countries, a closer examination of the data reveals a distinction between the quantity of leafy vegetable waste supplied to consumers in fresh form and that provided to households in processed form. Upon analyzing the causes of this difference, Moradi *et al.* (2023) have concluded that the primary reason for the disparity in leafy vegetable waste at the household level and food services in the studied area is the deterioration of fresh product quality across the supply chain. In fact, The high waste of fresh leafy vegetables at the household and food service level is primarily attributable to the poor quality of the product, rather than the behavioral patterns of consumers. This issue stems from the unfavorable actions and decisions made by other actors in the supply chain (Moradi *et al.*, 2023; Siddiqui, 2018).

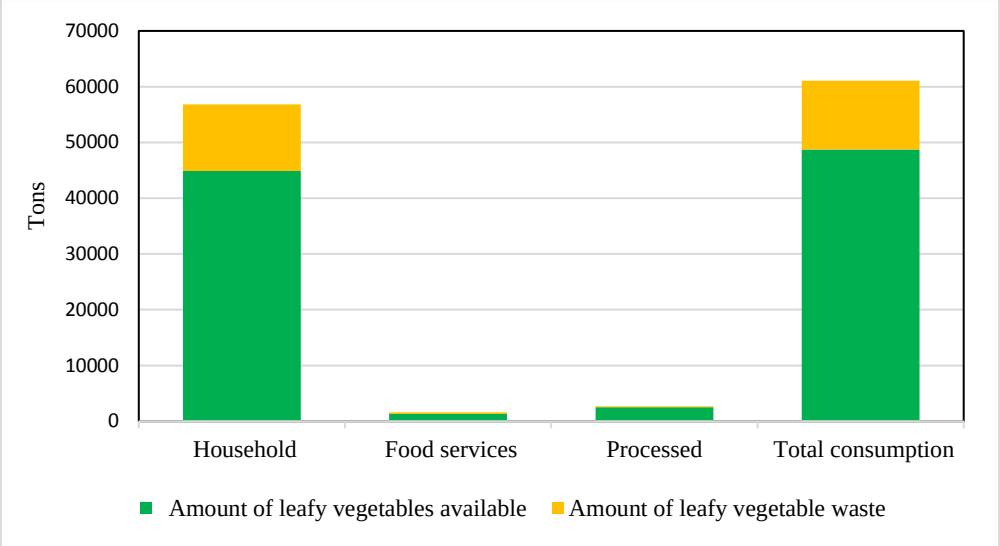

Figure 9- The amount of leafy vegetable waste in the consumption stage

The simulation of the amounts of waste at different stages of the supply chain of leafy vegetables during the simulation period showed that the annual waste of leafy vegetables is projected to increase initially and then decrease in accordance with the population growth trend (Figure 10). This trend indicates that the continuation of the current trend and lack of intervention to reduce the waste of leafy vegetables will have detrimental economic, social and environmental consequences for supply chain actors and community.

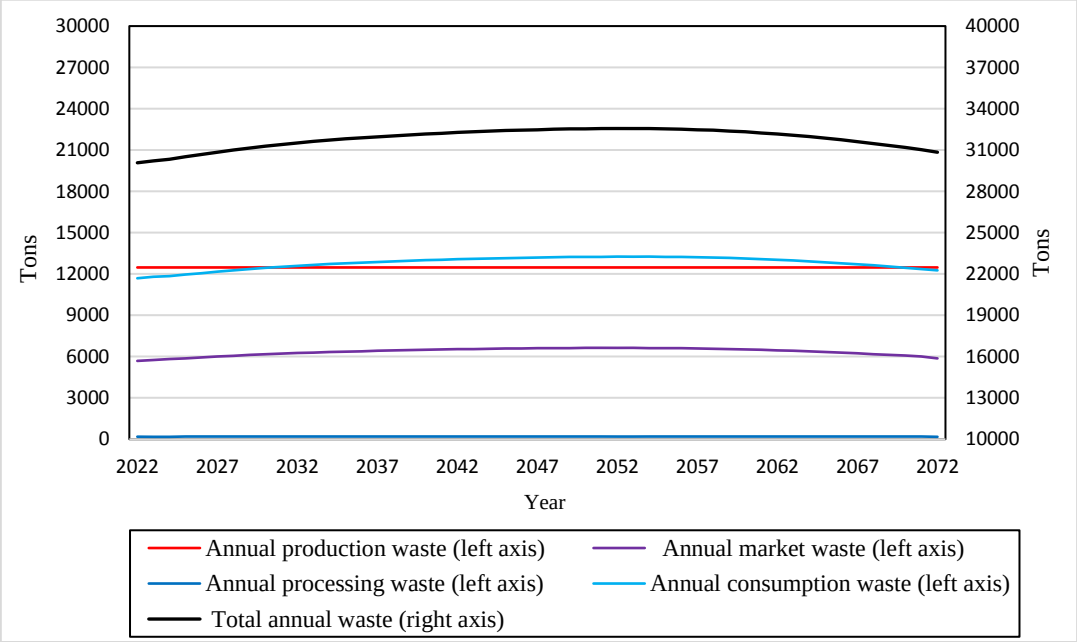

Figure 10- Waste estimation assuming the current trend continues

Scenario 2) Development of processing industries

In this scenario, it is assumed that all of the current marketing and distribution approach for leafy vegetables will be discarded. Instead, all the demand for leafy vegetables in the study area will be fulfilled through processed products (Figure 11 to Figure 14). Investigating the effects of the development of leafy vegetable processing industries on waste across the supply chain showed that implementing this scenario leads to an increase in waste during the

processing stage while reducing marketing waste. These changes occur as a result of an increased volume of leafy vegetables being processed and the elimination of marketing activities for fresh leafy vegetables in wholesale and retail stores. In addition, the effect of this scenario on waste during the consumption stage was significantly greater compared to the base scenario. According to this scenario, the amount of waste generated in the consumption stage will decrease from 12,300 tons to 3,200 tons. This reduction can be attributed to several factors. Firstly, the waste generated from processed leafy vegetables is significantly lower compared to that from fresh vegetables. Secondly, the development of processed products leads to a decrease in the consumption of fresh leafy vegetables at the household level. As a result, the amount of low-quality leafy vegetables and discarded parts, such as stems, decreases (Moradi *et al.*, 2023). Thirdly, processing units are generally less affected by the poor quality of purchased leafy vegetables compared to households. Consequently, a significant portion of leafy vegetables that was previously discarded at the household level now remains in the consumption chain. Although this study does endorse the strategy of fostering processing industries to minimize leafy vegetable waste, the limited quantity of processed leafy vegetables in the studied region implies that there are obstacles to establishing a successful leafy vegetable processing sector. These challenges can be analyzed from various perspectives. Firstly, extensive research has indicated that the majority of regions in Iran lack adequate infrastructure for the development of agricultural product processing industries (Khodayi Steyar *et al.*, 2018; Varmazyari *et al.*, 2016). The presence of an institutional gap and the absence of a clear strategy for the advancement of these industries are among the primary factors contributing to this problem (Varmazyari *et al.*, 2016). Secondly, the implementation of this approach necessitates substantial behavioral modifications from households and other stakeholders within the leafy vegetable supply chain. For instance, from the demand perspective, the establishment of leafy vegetable processing industries calls for a shift in consumer preferences towards purchasing processed and packaged products. In recent years, there has been growing concerns have been raised regarding the use of unconventional water in the cultivation of leafy vegetables and the lack of consumer confidence in compliance with health regulations in processing units. These challenges have significantly impacted the motivation of households to purchase processed leafy vegetables. Therefore, many individuals choose to directly purchase the leafy vegetables they require from local farmers. In addition, the implementation of this strategy necessitates substantial investment in cold chain infrastructure and facilities to support the distribution and marketing of processed products by market actors.

Scenario 3) Development of direct marketing

In this scenario, it is assumed that all leafy vegetables produced in the studied area will be supplied directly to consumers through stalls and stores located within the fields and alongside the roads (Figure 11 to Figure 14). It should be noted that in this senario, leafy vegetables imported from other regions are still distributed through traditional marketing methods within the supply chain. The simulation results indicate that implementing this marketing approach in the studied area would result in a significant reduction of 3,000 tons of wasted leafy vegetables at the market stage, compared to the baseline scenario. In line with the results of this study, Kirci *et al.* (2022), concluded that direct marketing is effective in minimizing product spoilage by eliminating unnecessary intermediaries in the supply chain, especially for perishable products such as leafy vegetables. This approach also minimizes losses incurred from rejected products that fail to meet the standards set by wholesale and retail centers (Johnson *et al.*, 2019). Despite the benefits offered by direct marketing approach in reducing waste, it is important to acknowledge that it cannot fully replace existing marketing systems due to seasonal limitations and limited access to all consumers (Priefer *et al.*, 2016). Furthermore, in

this particular scenario, the decrease in processed vegetable consumption and the rise in fresh vegetable consumption may lead to a slight increase in waste at the consumer stage. Nevertheless, implementing the direct marketing approach could still lead to a significant reduction of approximately 2,500 tons of waste per year compared to the baseline scenario.

Scenario 4) Development of traditional marketing

In this scenario, it is assumed that the supply of leafy vegetables through other marketing methods such as direct marketing and processing industries will cease. Instead, the entire demand for leafy vegetables in the studied area will be met by providing fresh produce to consumers through intermediaries like wholesalers and retailers (Figure 11 to Figure 14). The results indicate that implementing this scenario will lead to an increase in the total waste volume of leafy vegetables in the studied area by 2,000 tons per year. The high volume of food loss and waste in traditional marketing channels is one of the challenges of to the agricultural product supply chain in numerous countries, which has been extensively addressed in numerous studies (Anand and Barua, 2022; Kör *et al.*, 2022).

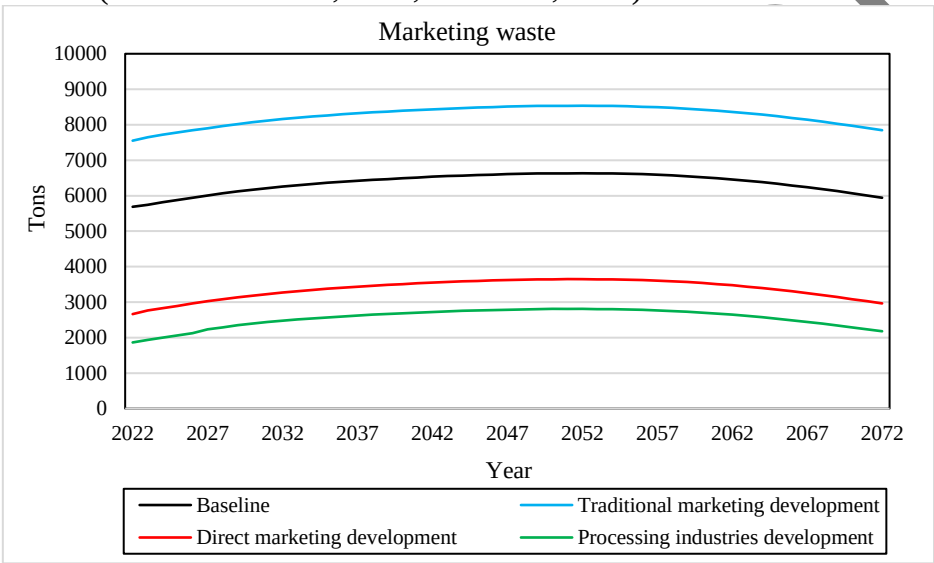

Figure 11- The effects of different scenarios on waste reduction in the market stage

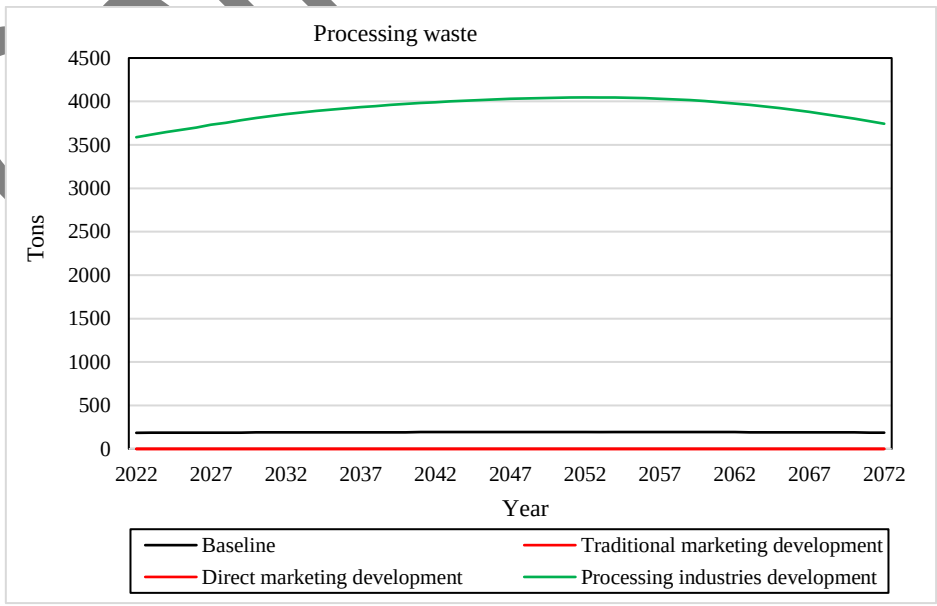

Figure 12- The effects of different scenarios on waste reduction in the processing stage

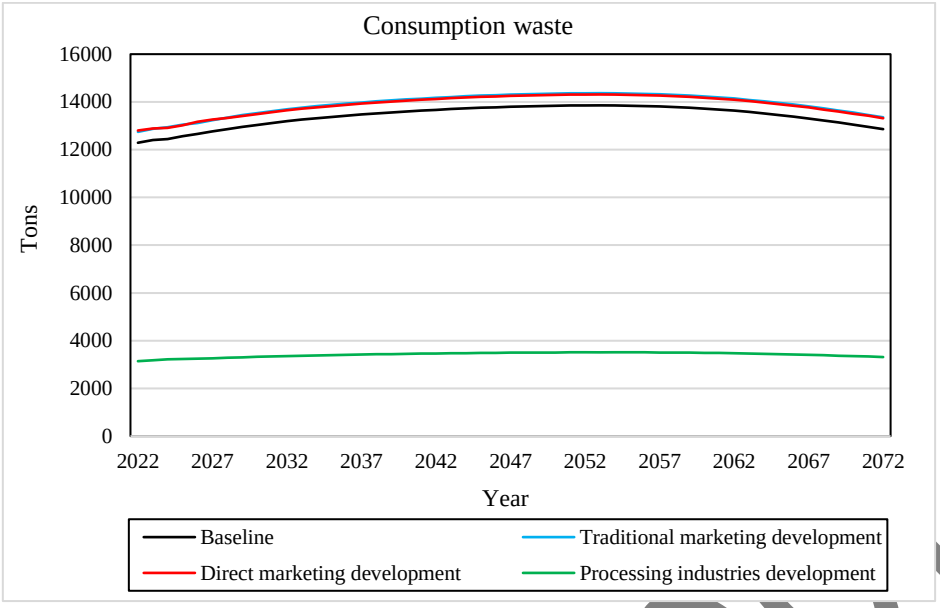

Figure 13- The effects of different scenarios on waste reduction in the Consumption stage

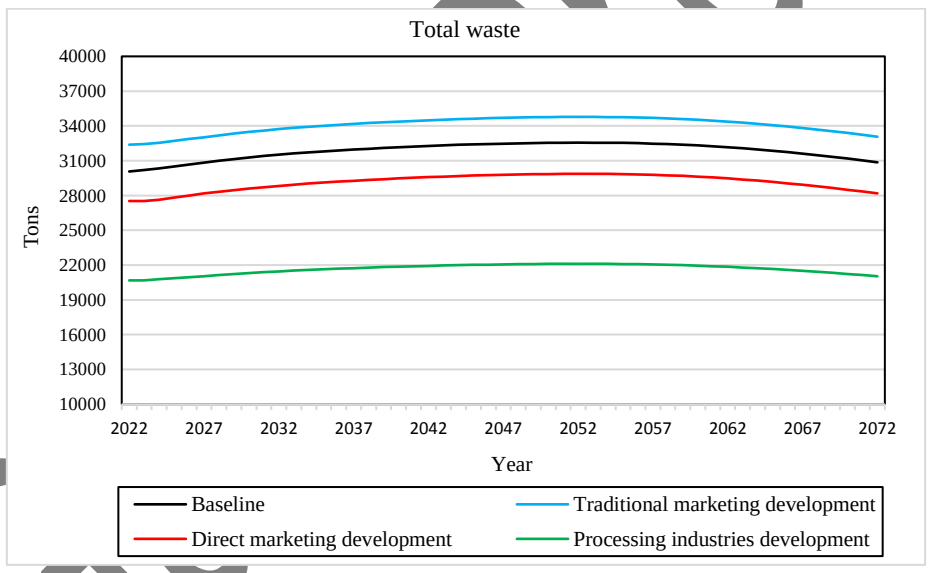

Figure 14- The effects of different scenarios on total waste

Conclusion

To achieve economic efficiency, environmental sustainability, food security, quality assurance, and meet consumer expectations, it is crucial to employ effective waste reduction strategies in the food supply chain. The present study developed a system dynamics model for the waste system across the leafy vegetable supply chain in Kermanshah province with the aim of investigating the potential of different marketing channels in minimizing waste. The findings of estimating waste at various stages of the supply chain revealed that approximately 39% (equivalent to 31,000 tons) of the total volume of leafy vegetables in Kermanshah province ends up as waste. These findings highlight the entery points where intervention and waste reduction strategies can be implemented effectively. This study examined the potential impact of three marketing channels (traditional marketing, direct marketing, and processing industries)

on waste reduction in the study area. The findings indicate that among these approaches, the development of processing industries shows the highest potential for reducing waste in leafy vegetables. By adopting this approach, it is possible to decrease total waste by a significant amount, approximately one-third or 10,000 tons per year. However, it's important to note that a single marketing channel alone may not be sufficient to meet the diverse demands of consumers due to varying interests. Nevertheless, given the effectiveness of processing industries in waste reduction, it is recommended that policy actions and programs in the studied area prioritize the development of leafy vegetable processing industries.
The following suggestions are proposed to develop leafy vegetable processing industries in the studied area:

- It is recommended that the governance structure, with the help of effective policy mechanisms and tools, establishes the framework for collaborative investments between private entities and the government in order to develop essential infrastructure for leafy vegetable processing industries. This infrastructure may include processing facilities, cold storage units, and specialized transportation networks. In addition, offering affordable facilities, subsidies, tax incentives, and facilitating the licensing process are key measures that can encourage entrepreneurs to invest in leafy vegetable processing facilities and infrastructure.
- One commonly used approach for the development of processing industries is the contract farming. To successfully implement this production approach, it is recommended that the governance structure through the development of appropriate laws and regulations to manage relations between farmers and processing units provides the basis for farmers' participation in these projects. It is important to note that establishment of processing units in rural areas and the ownership of farmers on these units, while creating a connection between farmers and processing units, can maximize the benefits of the local community from the added value of leafy vegetable cultivation in the study area.
- To implement this approach, it is necessary to invest in and provide market actors with cold chain infrastructure and facilities. One possible strategy is to utilize the existing capacity of supermarkets or equip the existing retail sector with storage facilities specifically tailored for processed and frozen leafy vegetables.
- To facilitate the development of leafy vegetable processing industries, it is essential to implement market development strategies that encourage consumer consumption of processed products. Given that 70% of leafy vegetables are consumed in cooked form, there is a significant opportunity to promote the use of processed vegetables. Educating consumers about the advantages and value of processed products through consumer awareness campaigns, media outlets, and social networks can effectively stimulate their interest in purchasing such products.
- Given the increasing concerns among consumers regarding health issues associated with processed products, it is imperative to establish robust regulatory frameworks that guarantee the quality and safety of these products across the supply chain. This entails implementing mechanisms to closely monitor the usage of water and other resources during the production process. Additionally, conducting routine health inspections in processing units is vital for upholding the safety standards of processed products.

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