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Fruit and Vegetable Loss in Markets in the North of Lebanon: Drivers, Challenges, and Prevention

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Abstract

Food loss and waste are critical global issues, particularly in developing economies where they exacerbate food insecurity and environmental degradation. This study focuses on fruit and vegetable loss (FVL) in retail and wholesale markets in North Lebanon, a region marked by socio-economic challenges and infrastructural deficiencies. The research aims to identify the underlying drivers of FVL, assess current management practices, and identify aspects impacting it. Data was collected through surveys of seventy wholesalers and retailers employing descriptive statistics and multinomial logistic regression for analysis. The findings reveal that 85.7% of the sample generate little or no FVL. Being a retailer or wholesaler, operating on a small or large scale, or being open 24/7 or part-time does not affect FVL. Conversely, inadequate display and storage, hot weather, and pricing practices significantly impact FVL. The market faces challenges such as low consumer purchasing capacity, financial difficulties, legal constraints, and lack of knowledge. Various practices are used to prevent FVL, including strategic supply chain decisions, price reductions, and donations to charities. The study underscores the need for improved infrastructure, financial support, and regulatory frameworks to mitigate FVL, thereby enhancing food security and environmental sustainability in North Lebanon.

Keywords: food system; food waste and loss; food security; environmental sustainability; green economy; retail; wholesale



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1. Introduction

Food loss and waste (FLW) as defined by the High-Level Panel of Experts on food security is a decrease, at all stages of the food chain from harvest to consumption, in mass of food that was originally intended for human consumption, regardless of the cause [1].

Annually, one-third of global food production is lost and wasted, equating to 1.05 billion tons or 132 kg per person per year in 2022 [2–4]. FLW leads to financial, ethical, environmental, social, and economic issues, including significant greenhouse gas

emissions and increased food insecurity [5–8]. Addressing these issues is crucial to advancing Sustainable Development Goals (SDGs) 2 and 12. SDG 2 aims to “End hunger, achieve food security and improved nutrition, and promote sustainable agriculture,” while SDG 12 focuses on “Ensuring sustainable consumption and production patterns,” particularly target 12.3, which seeks to halve per capita food waste [9].

It was estimated that the world’s food losses in 2017 would be enough to feed about 940 million adult individuals [8]. FLW is a particularly critical issue in low- and middle-income countries, where food security remains a major challenge compared to high-income nations [10]. According to Keating et al. (2014) [11], food security is the balance between the supply of food and the demand for that food. This may require an increase in food production and efforts to reduce losses throughout the supply chain. Reducing FLW is essential for strengthening food security, as it minimizes losses along the supply chain, ensuring that more food reaches consumers and becomes accessible to those in need [12–15].

Additionally, FLW significantly impacts the environment by contributing to greenhouse gas emissions, resource depletion, and pollution [16–21]. More specifically, FLW generates substantial greenhouse gases from landfills and agricultural activities, exacerbating climate change [22–24]. M. Crippa et al. (2021) stated that the food system contributes a third of the global greenhouse gas (GHG) emissions [25]. More in depth, food loss and waste contribute to half of the global annual GHG emissions from the whole food system [26], highlighting the urgent need for effective food loss and waste reduction strategies.

Fruit and vegetable loss (FVL) is defined here as the surplus of fruits and vegetables that is not used or reused in any form for feeding humans. It can still be valorized for feeding animals or undergo recycling or recovery activities in a circular economic perspective. Due to their high perishability, fruits and vegetables generate significant waste throughout the supply chain, from production to consumption [2,27]. Globally, FVL constitutes the highest percentage of FLW, with up to 50% of fruits and vegetables being lost from farm to fork [27]. A systematic review published on food security indicates that in the European Union, an estimated eighty-nine million tons of food waste are generated annually, with fruits and vegetables being the predominant contributors [28].

Limited shelf life, aesthetic standards, and variability in demand are significant factors contributing to food loss (FL) at the retail level [29]. Various drivers contribute to these causes, including technological, managerial, behavioral, and structural aspects. Technological drivers include issues such as infrastructure, equipment, and packaging. Managerial drivers consist of inadequate food management practices, limited skills or knowledge, and inadequate procurement practices. Behavioral drivers include intentions, norms, attitudes, awareness gaps, and risk concerns. Structural drivers encompass demographic conditions, climate, policies, regulations, economics, and financing [30,31]. Additionally, the literature [32–35] identifies specific causes such as inadequate handling, packaging, and transportation, poor planning and accounting, inadequate storage (including refrigeration and physical factors), quality and cosmetic standards, short shelf-life, lack of proper training for staff, communication issues, economic decisions, and inefficient marketing strategies.

Retailers employ a series of actions to reduce and prevent FVL in their stores [27,28,36,37]. These include installation of natural barriers and shade protection, promotions, inventory control, production forecast and planning, FLW awareness campaigns among employees, and donations to charity organizations (retailers donate unsold products with good aesthetic quality but low demand to charity organizations, minimizing losses while supporting those in need). Donations to employees help prevent discarding unsold or excess products: the retailers provide the opportunity for employees to take them home.

In Lebanon, up to 40% of food is lost and wasted at various supply chain stages, posing a significant challenge recognized by the Lebanese Government and international

organizations [38]. The Lebanon food security assessment report recently indicated that fruits and vegetables represent the value chain with the highest loss by volume, resulting in significant financial and energy losses [39]. Other studies have shown that retail and wholesale markets are critical sites for food loss specially in developing countries [29]. Both retailers and wholesalers are integral to the distribution network, linking local and global producers with urban and rural populations. In Lebanon, the retail and wholesale markets for fruits and vegetables serve as key nodes in the food distribution system. There are nine well-established wholesale markets located in major municipalities across Lebanon, including Akkar, Tripoli, Halat/Jbeil, Beirut, Sin Al Fil, Ferzol, Kab Elias, Saida, and Sour. Wholesalers operate within these markets, while retailers (traditional stores) are distributed throughout all municipalities. These markets also face challenges related to food loss and waste, with significant amounts of perishable produce being discarded. Reducing food loss in these markets is essential for enhancing food security, as it would directly increase the availability of produce to consumers. Furthermore, despite efforts in the field of waste management, organic waste from fruit and vegetable markets is collected as municipal waste [40]. Thus, food waste in Lebanon is disposed of in landfills [38,41], where it contributes significantly to environmental pollution and methane emissions.

Despite the growing literature on food loss and waste, a knowledge gap remains regarding food waste and loss in food service and retail outside high-income countries [4]. The absence of data hinders understanding of the full extent of the problem and limits the possibility of designing effective interventions. Lebanon has been classified as a lower-middle-income country since 2021; before that, it was classified as an upper-middle-income country [42,43]. Previous research conducted in Lebanon has tackled food waste and loss at the household level [44,45], as well as in hospitality (restaurants) [46,47], healthcare (hospitals) [48,49], and retail settings [50]. However, none of the studies specifically investigated food loss at fruit and vegetable wholesale and retail markets. This study was conducted to explore and answer the following research questions: What are the perceived quantities of FVL? What are the factors that contribute to FVL generation? What methods are used to prevent and mitigate it, and what challenges are encountered? The goal of this study is to enhance knowledge of FVL in Lebanon and contribute to the development of adequate methods for mitigating the problem, fostering a more resilient and sustainable food system in Lebanon.

2. Materials and Methods

2.1. Overview of the Methodology

Identifying the factors leading to food loss in fruit and vegetable markets necessitates the use of both qualitative and quantitative methodologies. These commodities are highly perishable and influenced by intricate supply chain dynamics. Approaches often used include semi-structured interviews, focus groups, and direct observation to gather insights from stakeholders, such as farmers, wholesalers, and retailers [34,51,52]. To find correlations and analyze dependency between factors affecting it, quantitative methods such as surveys and statistical modeling are used [52]. In 2021, the United Nations Environment Programme (UNEP), in collaboration with the Waste and Resources Action Programme (WRAP), published the Food Waste Index Report [53]. The report introduced a standardized methodology for countries to measure food waste at the household, food service, and retail levels. Owing to insufficient data, the fruit and vegetable market in Lebanon remains an area warranting investigation. The absence of a clear institutional description detailing the operational mechanisms, governance responsibilities, and hierarchy in these markets, along with concerns about potential government inspections (related particularly to pricing strategies), poses challenges in entering the markets and conducting daily measurements

as required by the UNEP measurement model. Additionally, this measurement method requires a significant investment of time and commitment from market actors. As a result, and to address the research questions posed in this paper, an initial literature review was conducted to understand the drivers of FVL and the prevention practices applied by retailers and wholesalers globally. Following the literature review, data was collected from retail and wholesale markets through a pilot survey. The fruit and vegetable markets in Lebanon are categorized as wholesale or retail. Consequently, two questionnaires were developed, one specifically for retailers and the other for wholesalers. The first included forty-three (43) questions, and the second included forty-six (46) questions. The questionnaires were designed based on the literature review and adapted to the local conditions and context. The survey included both single-choice and multiple-choice questions, allowing respondents to select one or more options, as appropriate. This approach is particularly common as it helps to minimize the time required to complete the questionnaires. The questions were drafted in Arabic. The results were translated into English. The two questionnaires encompassed four sections, as presented in Figure 1.

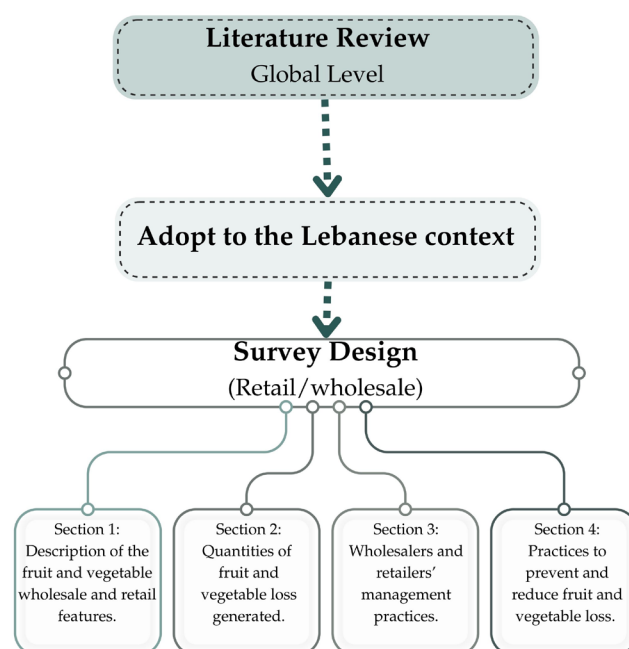


Figure 1. Survey development and structure.

The survey was designed to capture a comprehensive understanding of FVL in the retail and wholesale market. Section 1 included five questions for retailers and eight for wholesalers, gathering descriptive information on business characteristics such as location, type (retail/wholesale), and size, with an optional field for contact details. Section 2 comprised seven questions focused on FVL quantities, addressing both the amount generated and the underlying causes through multiple-choice responses. Section 3, with twenty-one questions, examined logistics and management practices, covering transportation and distribution, product display and storage conditions, pricing strategies, surplus handling, data collection practices, and return policies, alongside aspects such as business hours, procurement practices and frequency, supplier characteristics, and quality control procedures. Finally, Section 4 contained ten questions exploring surplus management approaches, FVL prevention strategies, the main challenges encountered by businesses, and the methods used for disposal.

2.2. Sampling Methods and Data Collection

In this pilot study, a total of seventy (70) participants (26 retailers and 44 wholesalers) were surveyed through non-probability sampling methods, specifically convenience and snowball sampling. Convenience sampling entailed selecting individuals who were readily accessible and willing to participate in the research, while snowball sampling relied on initial participants referring others within their networks, representing retail and wholesale fruit and vegetable markets in the North Region of Lebanon. These sampling methods were selected because of the lack of a clear and concrete population count (number of formally registered and non-registered retailers and wholesalers) and the exploratory nature of the research. Although these methods do not permit the calculation of sampling probabilities and may constrain the generalizability of the findings, they are effective for generating initial insights and identifying patterns within the target population. The use of non-probability sampling is acknowledged as a limitation; however, it is deemed appropriate for the preliminary objectives of this study.

The survey was conducted in June and July 2023, covering wholesalers in Akkar and Tripoli wholesale markets, and retailers across the North region were surveyed, engaging with the stores' managers. Each survey took approximately 15 min to complete. Most of the surveys were conducted face-to-face, but some were conducted via telephone interviews.

2.3. Data Analysis

Following this, the data underwent cleaning, coding, and analysis using the R program version 4.3.3 (March 2025). In line with the research's objectives, descriptive statistics were initially conducted, followed by multinomial logistic regression analysis. A multinomial logistic regression was employed to examine the relationship between retailers' and wholesalers' perceived generated FVL, along with their characteristics and practices. This analysis is suitable for situations involving a categorical dependent variable with two or more unordered levels (i.e., multiple discrete outcomes). It closely resembles logistic regression, except that there are multiple possible outcomes instead of just one. One level of the dependent variable is selected by the program as the reference category, typically the most common or frequent category. The R software runs a series of individual binomial logistic regressions for $M - 1$ categories (one calculation for each category, except the reference category). When M equals 2, multinomial logistic regression, ordered logistic regression, and logistic regression are equivalent. In multinomial logistic regression, p -values help determine the statistical significance of each predictor variable in relation to the outcome variable (perceived FVL). A p -value less than 0.05 typically indicates that the predictor variable has a significant effect on the outcome variable.

2.4. Study Area: Akkar and North Governorates

Akkar and North governorates are located geographically in the North of Lebanon, as shown in the map (Figure 2). According to the latest Registration conducted in 2024 [54], the populations of Akkar and North Lebanon are 320,000 and 949,000, respectively.

The regions face unique socio-economic and infrastructural challenges, being two of the most deprived regions in the country, with high poverty levels [41,55]. These socio-economic factors contribute to food insecurity. Additionally, the region lacks formal waste management, resulting in large amounts of organic waste in landfills [40].

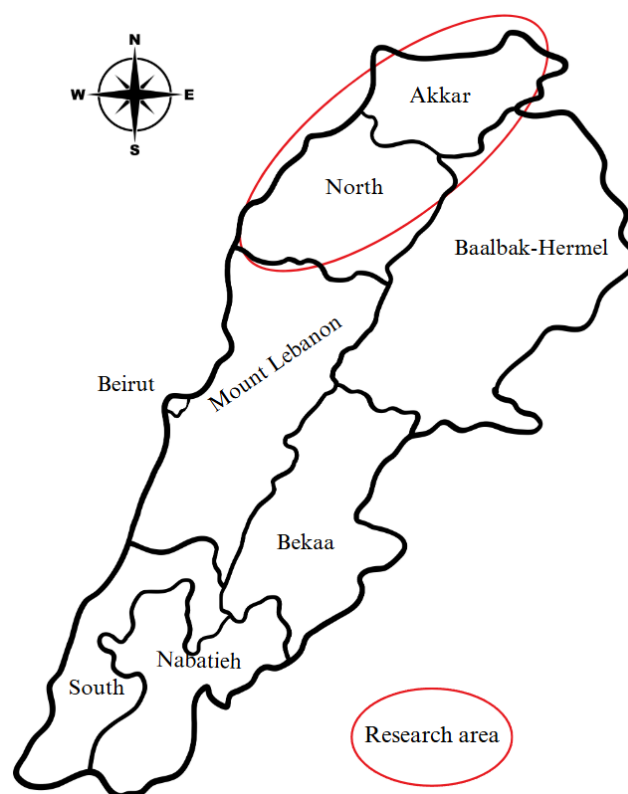


Figure 2. Map of Lebanon showing the study area.

3. Results

3.1. Significance of Factors on the Loss Generated

Due to the absence of precise and standardized measurements of FLW and the lack of standardized measurement systems in the target market, this study employed qualitative descriptions: “Rare”, “a little”, and “a lot”. The perceived quantities of FVL are presented in Table 1. Most wholesalers and retailers (85.7%) reported generating FVL at least occasionally (rare and a little). However, only 14.3% of them reported generating large amounts of FVL.

Table 1. The quantity of fruit and vegetable loss generated.

Quantity of Fruits and Vegetables Loss Generated	Percentage Answers
Rare	45.7%
A little	40.0%
A lot	14.3%

The results of the multinomial logistic regression varied between variables, including both significant and non-significant findings. The results where variation in significance exists across categories are presented in Table 2. The *p*-value indicates the significance of a variable’s role. FVL ranged from ‘a little’ to ‘rare’ and from ‘a lot’ to ‘rare’.

Table 2. Selection of the multinomial logistic regression results—*p*-values showing the results with significant values.

Variables	Factors (Level)	A Little Waste <i>p</i> -Value	A Lot of Waste <i>p</i> -Value
Return to supply	Do return	0.99	0
Supply source	Local production and import	0.99	0

Table 2. Cont.

Variables	Factors (Level)	A Little Waste <i>p</i> -Value	A Lot of Waste <i>p</i> -Value
Purchase frequency	Daily and randomly	0.99	0
	Daily and based on supply and demand	0	0
	Daily, Weekly, and based on Supply and demand	0	0
	Randomly	0	0
Pricing and sales	Price increase	0	0
Transportation and Distributions	Refrigerated trucks and private cars	0.99	0
	Refrigerated trucks	0	0.99
Display	In the fridge, on shelves inside the store	0.90	0
	In the fridge, on shelves inside the store, and on shelves outside	0	0
	On the ground and in the fridge	0	0
	On the ground and on shelves inside the store	0	0
	On the ground, on shelves inside the store, and on shelves outside	0	0
	On shelves inside the store and on shelves outside	0	0
	On shelves outside	0	0
Storage conditions	Inside the store with air-conditioning	0	0
	On the ground, in refrigerators, inside the store with air-conditioning, on shelves, and in a large storage room	0	0
	On the ground, and on the shelves	0	0
	In refrigerators	0.95	0
	In refrigerators and inside the store with air-conditioning	0.99	0
	In refrigerators, inside the store with air-conditioning, and in a large storage room	0	0
	In refrigerators and on the shelves	0	0
Measures to reduce losses	Do nothing	0.99	0
Prevention measures	Prevention Methods (price reduction, donation)	0.99	0
	SD (supply and demand)	0.99	0
	PM and SD	0.99	0

p-value represents the probability of obtaining results as extreme as, or more extreme than, those observed in the study, assuming the null hypothesis is true.

3.2. Management of Surplus Fruits and Vegetables to Reduce FVL

In this paper, we defined surplus as fruits and vegetables that did not sell at the original price for various reasons. Table 3 presents the surplus management measures employed by retailers and wholesalers to prevent losses. The measures used were grouped into three categories. The first category, labeled “Second Chance,” includes attempts to sell products that were not initially sold under normal conditions, e.g., price reduction and storing the product for sale the next day. This category accounts for 43.63% of responses. The second category involves using fruits and vegetables as animal feed, which, based on the definition used in this study, is classified as fruit and vegetable loss. This category constitutes 20.13% of responses. The final category focuses on ensuring the product’s potential for human consumption and includes measures such as distributing the product to employees, donating to charities and individuals in need, or selling to manufacturers and juice companies. This category represents 36.24% of the responses.

Table 3. Management of surplus fruits and vegetables.

Management of Surplus Fruits and Vegetables	% of Responses	Categories (Weight Percentage)
Price Reduction	78.57%	Second chance (43.63%)
I do not get rid of it, but keep it for the next day	14.29%	

Table 3. Cont.

Management of Surplus Fruits and Vegetables	% of Responses	Categories (Weight Percentage)
Sold as animal feed	42.86%	Animal feed (20.13%)
Sold for food manufacturing and juice stores	15.71%	Sold or donated for human consumption (36.24%)
Donate to charities or persons in need	41.43%	
Distribution to employees	10.00%	

The total percentage of responses exceeds 100% because respondents were allowed to select multiple answers. The percentages represent the proportion of respondents who chose each option. However, the percentages used in the categories are weighted according to their frequency, thus the total sums up to 100%.

3.3. Key Drivers Contributing to Fruit and Vegetable Loss

Fruit and vegetable loss is caused by several factors. The answers are presented in Figure 3. The figure shows the percentage of respondents who identified each factor as contributing to losses. As multiple responses were allowed, the total exceeded 100%. The percentages reflect how frequently each factor was selected by respondents.

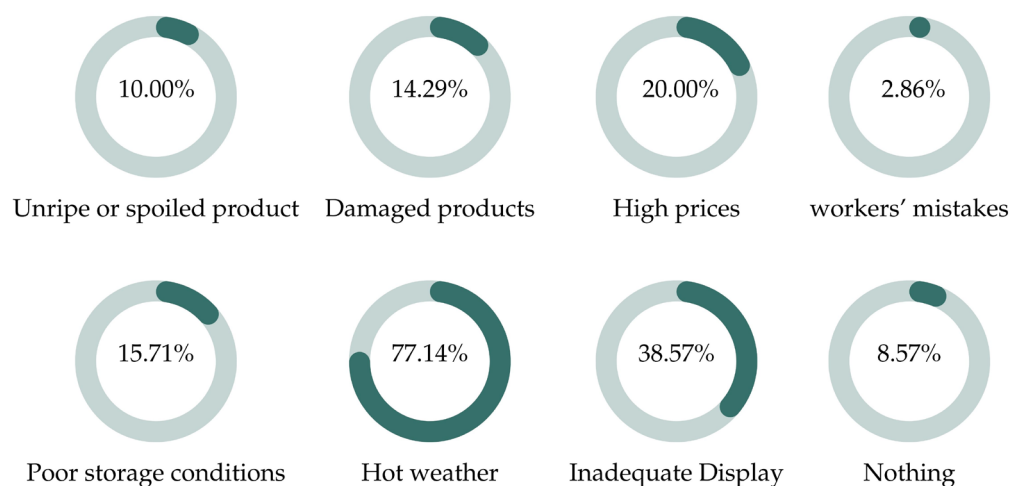


Figure 3. Percentages of the share of respondents identifying each key driver contributing to fruit and vegetable loss.

The results indicate that the most prevalent issue is hot weather. FVL is higher in summer, as claimed by 98.6% of the individuals surveyed. This is followed by inadequate storage, with 38.57%.

3.4. FVL Prevention Measures and Their Efficiencies

The results presented in Figure 4 highlight various measures employed by wholesalers and retailers to prevent FVL. The most frequent practice, adopted by 74.29% of respondents, is purchasing on request, which helps align supply with demand and reduces excess inventory. Price reduction is another widely used measure for quickly selling perishable goods before they spoil, with 58.57% of respondents choosing this option. Other measures include preserving the quality of goods through cooling or other methods, ensuring that the produce remains fresh for a longer period (25.71%); selling to food manufacturing companies, allowing the produce to be used in processed foods; and donations, which help in reducing waste while supporting communities. A minimal number (2.86%) of wholesalers and retailers choose to do nothing with the goods.



Figure 4. Percentages of respondents identifying each prevention method used by retailers and wholesalers.

When queried about the efficiency of these measures, the surveyed population expressed varied opinions. However, a significant majority of both wholesalers and retailers concurred on the effectiveness of these methods, with 95.45% and 92.31%, respectively.

3.5. Challenges to Preventing Fruit and Vegetable Losses

Many challenges face the food supply chain actors as they try to prevent losses. Figure 5 shows that the most common challenge faced by both retailers and wholesalers is the poor economic situation of consumers; low purchasing capacity is a challenge faced by 57.14% of consumers. A lack of finance for improving the infrastructure is a challenge faced by 40% of respondents. Competitive pricing is another major challenge, affecting 25.71% of the retailers and wholesalers. The respondents also reported challenges associated with a lack of information on preventing waste (14.29%), laws regarding quality and food safety (5.71%), and a lack of regulations to reduce food waste and loss (17.14%). A small proportion of the respondents (2.86%) reported no challenges.

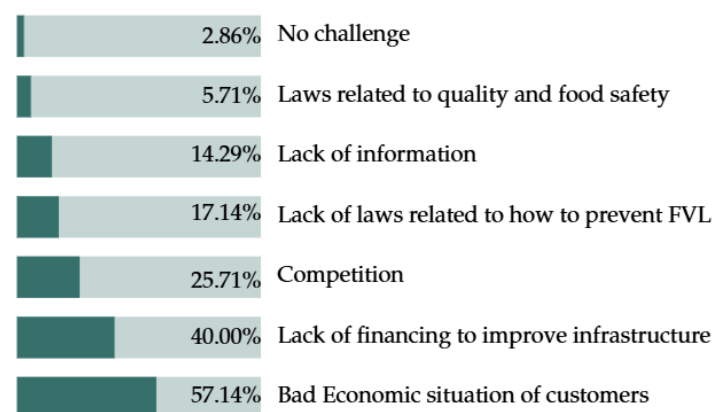


Figure 5. Percentages of respondents identifying each challenge faced by retailers and wholesalers.

3.6. Clearance/Disposal of Fruits and Vegetables

When surplus fruits and vegetables cannot be sold for human consumption, wholesalers and retailers select various clearance/disposal methods. The common alternative (64.29%) is to sell or donate the products for animal feed; 57.14% of retailers and wholesalers tend to dispose of their surplus fruits and vegetables. Neither retailers nor wholesalers reported resorting to landfilling, which is likely due to regulations prohibiting private entities from using landfills for such waste, and only 1.43% composted.

The wholesalers and retailers stated that they disposed of their fruits and vegetables in municipal solid waste containers or at designated collection points near their stores. Collection occurs daily, and the municipality or the Union of Municipalities is responsible for monitoring this process.

4. Discussion

The quantity of food waste generated in the wholesale and retail markets in the North of Lebanon is mainly considered 'rare' or 'little'. A total of 85.7% of the wholesalers and retailers acknowledge its existence, suggesting that food waste is a common issue in this market; however, only 14.3% of them report generating large amounts of FLW, indicating that extreme FLW is not the norm in Lebanon. Even when present, the quantity is not perceived as significant. Compared to available data from neighboring countries, including rural retail markets of El Jadida and Sidi Bennour in Morocco, vegetable losses accounted for the largest proportion of unsold food (45.7%), followed by fruits (27.4%) [56]. However, in a study of six Swedish retail stores, the total loss of fresh fruits and vegetables was found to be 4.3% of the delivered quantity [57]. Comparing the two values, North Lebanon can be considered to have a similar performance as the European market, such as in Sweden, with low FVL. A quantitative measurement following international standards should be conducted to confirm this performance.

The results associated with the factors affecting FVL indicate that certain variables, such as business type, size, operational hours, and inventory management (keeping records), are not significant (p -values above 0.05, not presented in the table). This means they do not significantly distinguish between 'wasting a little or a lot' and 'rarely wasting'.

While wholesalers and retailers have different business models (in terms of product quantities and diversity) and deal with different types of actors in the chain (suppliers and customers), factors such as being a retailer or wholesaler, being small or big, opening 24/7 or part-time had no effect on FVL in this study. Conducting comparative analysis is challenging, as the literature lacks information and statistics from markets similar to Lebanon. Information and data sharing are important in reducing and preventing food loss and waste [58,59]. However, this study showed that keeping a record of purchases and sales in North of Lebanon does not significantly affect the generated FVL. This may be due to a lack of further analysis of the recorded data and a deficiency in measuring FVL losses. None of the wholesalers and retailers surveyed was able to provide a precise quantity of FVL for any specific period. Due to the lack of significance, altering these variables will not result in a significant change in the quantity of FVL; however, it is still valuable to keep and analyze records, as they highlight their importance. The measurements will provide concrete data, enable informed decisions, and serve as a benchmark for analyzing the effect of any intervention and corrective actions.

On the other hand, the results show that certain factors have a strong influence on FVL, with p -values below 0.05 and close to 0. This indicates that these variables significantly increase the likelihood of food waste either a little or a lot compared to rarely wasting. These aspects should be prioritized to mitigate FVL.

In the fruit and vegetable market, returns to suppliers are not frequent and typically occur soon after inspection. The main reasons for returns include insufficient maturity, over-ripening, physiological defects, or old and damaged goods. Not returning these products significantly affects FVL, as wholesalers and retailers may end up with unsellable items. This study supports the argument of Eriksson et al., who suggested that reclamation and returning to suppliers represent a potential hotspot for waste reduction [60]. However, the focus of the discussion then diverges to who bears the responsibility for preventing the loss and covering the associated costs.

A low p -value indicates that pricing practices significantly impact FLW, influencing consumer purchasing behavior [61]. While higher prices may increase profits, they also raise the likelihood of higher FVL. Understanding and adapting pricing practices is crucial for boosting sales and preventing losses.

Transportation and distribution methods impact FVL, with varied p -values indicating significance. This is aligned with the existing literature, as improper handling and extended transit times can lead to spoilage. From the surveyed population, only 10.71% use temperature-controlled trucks, and this is usually for products that are imported; the remaining use trucks with no refrigeration. Using temperature-controlled trucks reduces microbial growth and nutrient degradation, minimizing food loss [62]. Thus, upgrading transportation and distribution with adequate trucks will have a positive effect on preventing FVL.

Display and storage conditions also influence FLW generation. Proper presentation and storage, including adequate temperature and humidity and shelf management, help maintain freshness and reduce spoilage [63,64]. This is particularly important in the North of Lebanon, where electricity limitations and high costs restrict refrigeration use, thereby contributing to FVL. Further analysis could compare retail and wholesale contexts, as differences in product shelf timelines and storage practices may lead to varying impacts on FVL. During the summer season, Northern Lebanon experiences warm temperatures and moderate humidity. World Weather Online [65] indicates that nighttime temperatures are slightly cooler, averaging around 21 °C to 24 °C. Humidity levels during the summer are generally moderate, averaging around 60% to 70%. Additionally, the limited availability of air-conditioned and refrigerated storage facilities exacerbates the impact of hot weather, confirming that hot weather is the primary driver of FVL, particularly when combined with an absence of adequate display and storage conditions. In addition, during summer, local fruit and vegetable production increases in Lebanon, as this is the harvest season for many products, leading to an excess supply in the market. The surplus may not all be sold and is instead discarded. Demand forecasting and planning can help align production. Collaboration among actors in the value chain is necessary, and the use of data and technology can be useful planning tools for assuring adequate production and preventing overharvesting [51,66,67]. These interventions should be carried out alongside national-level reforms, where public policies—such as implementing an agricultural production calendar that schedules harvest optimization—can help mitigate market surpluses and prevent overproduction.

Another significant factor is the prices and low purchasing capability of customers in deprived regions of the country, with areas such as the northern region of Lebanon having high poverty levels. This explains the practice of preventing FVL by reducing the market price of the product. While this mitigation action seems to be effective in reducing losses, its negative effect is mainly on the primary producers, farmers, who incur high costs of production and low selling prices, especially due to competition from illegally imported goods [68–70].

Wholesalers and retailers, like any other business, are inclined to increase their financial profits and decrease their losses; thus, the management of surplus fruits and vegetables often involves either reducing the price or giving the surplus more time to sell by saving it and trying to sell it another day. The second option is to sell it or donate it for human consumption, and the last favorable option is to sell it for animal feed. Selling the surplus as animal feed is specific to the markets in northern Lebanon, where animal raising is common at the household level (i.e., chickens or lambs are raised for household consumption). Additionally, this can be recognized by the way the dealers dispose of their fruits and vegetables, with 64.29% of them trying to sell or donate their products as animal feed. On the other hand, some dispose of their fruits and vegetables in municipal solid waste containers or at designated collection points near their stores. These end up in landfills due to a lack of adequate integrated municipal waste management. Here, it is important to

highlight the existing opportunities for separating organic waste from other wastes and introduce waste valorization practices [71–73]. This opportunity will lead to a reduction in municipal waste and open a new stream of income.

The economic situation of customers and the lack of finance to improve infrastructure are the main challenges. Wholesalers and retailers face significant financial barriers in upgrading or maintaining the physical infrastructure needed to reduce food loss, such as cold storage facilities and adequate display systems. This challenge was highlighted in the Expert Consultation Meeting on food losses and waste reduction in the Eastern Region held in Egypt in 2012 [74]. Another challenge is price competition due to the existence of an increased number of players in the market, including both formal and non-formal businesses, as well as the sensitivity of consumers to prices. Additional challenges are associated with information and knowledge, as well as the legal framework. Numerous academic and grey literature sources [4,13,75–79] highlight the need for education and awareness across the entire food supply chain—from farmers to consumers. This study specifically confirms knowledge gaps at the wholesale and retail levels. There is a lack of an appropriate policy and regulatory framework addressing food loss and waste in Lebanon; dealers see this as a challenge. Recent examples of regulations are the French law for fighting food waste adopted in 2016 [80], the very recent Spanish law which seeks to prevent and reduce food loss and waste by all food chain operators [81], and the newly adopted Norway’s Food Loss Act aimed at the prevention and reduction of food waste [82]. In Lebanon, Law No. 183 of 2020, Incentivizing Food Donations [83], formalizes the free redistribution of safe, surplus food to those in need through specialized charities. Its amendment provides tax incentives to food donors. In addition to its demanding administrative procedure, the law targets “All natural and legal persons whose activities in any way involve packaged food products.” Thus, it does not target only fruit and vegetable supply chain actors. This signals an opportunity for advocacy for laws or regulations that incentivize food waste and loss reduction and resource optimization in the fruit and vegetable supply chain.

Based on the analysis above, a detailed framework (Figure 6) is developed to illustrate the interconnected flow of fruits and vegetables in the retail and wholesale markets. It also presents the factors driving FVL and common measures to prevent it, along with the main challenges faced by retailers and wholesalers in their efforts to reduce FVL.

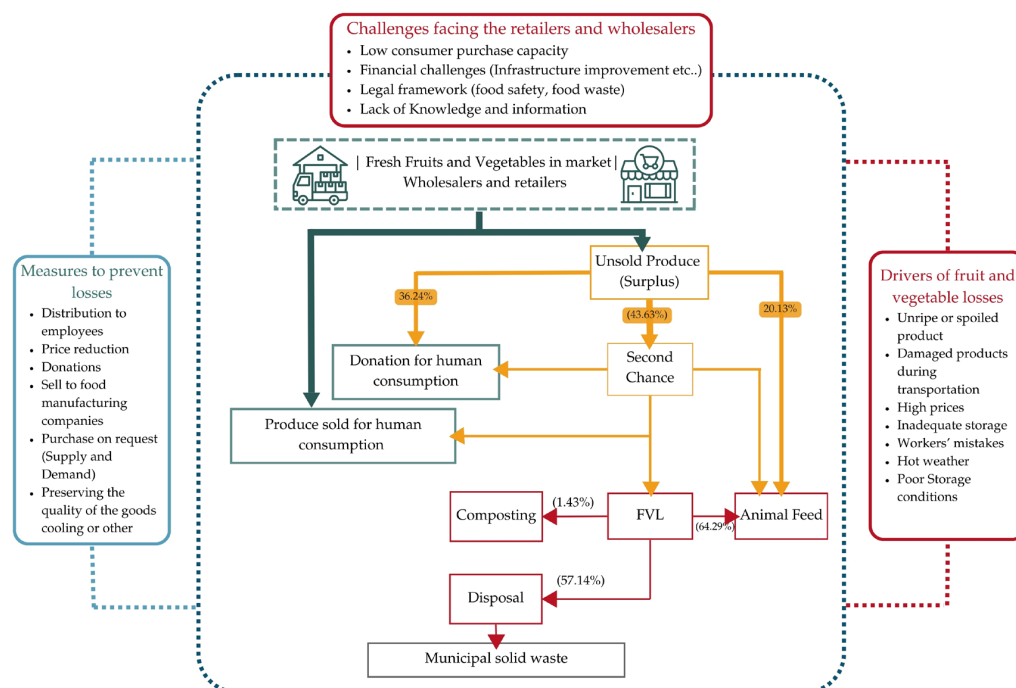


Figure 6. Comprehensive framework for addressing Fruit and vegetable loss.

5. Conclusions

This research shows that FVL is a common issue faced by fruit and vegetable retailers and wholesalers in the North of Lebanon. However, only 14.3% of them report generating large amounts of FVL, indicating that extreme FVL is not the norm. The research indicates that whether a business is a retailer or wholesaler, operates on a small or large scale, or is open 24/7 or part-time, does not significantly affect the amount of fruit and vegetable loss. Similarly, keeping records of purchases and sales in northern Lebanon does not have a significant impact on FVL. Factors such as not returning unsold fruits and vegetables to farmers and suppliers, transportation issues, pricing, and inadequate infrastructure for display and storage have a significant effect on FVL. The retailers and wholesalers identified several challenges, including a lack of information and awareness on these issues. Additionally, the current legal framework, particularly regarding food safety and food loss, and the lack of FLW regulations, was identified as a significant obstacle. The most prominent challenges, however, were financial constraints, limited consumer purchasing power, and inadequate infrastructure.

Finally, this study serves as a foundation for reducing fruit and vegetable loss in North Lebanon. By targeting the most significant factors identified and implementing tailored policy interventions and practical measures, it is possible to reduce FVL, thereby enhancing food security and promoting environmental sustainability. Collaborative efforts among food system stakeholders—policymakers, food chain actors, and researchers—are essential for developing comprehensive strategies that address the root causes of food losses and promote sustainable practices.

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Abbreviations

The following abbreviations are used in this manuscript:

FLW	Food Loss and Waste
FVL	Fruit and Vegetable Loss
FAO	Food and Agriculture Organization
USAID	United States Agency for International Development
UNDP	United Nations Development Programme
DGCS	Directorate General of Civil Status—Lebanon
OCHA	United Nations Office for the Coordination of Humanitarian Affairs

WWO	World Weather Online
R	A programming language used for statistical computing and graphics

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