PRELIMINARY STUDY ON FOOD LOSS ANALYSIS IN THE APPLE VALUE CHAIN: THE CASE OF KESRWAN-MOUNT LEBANON

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ABSTRACT

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Studies are done on different crops worldwide to gather data allowing on one hand policy makers to implement food loss reduction strategies, and on the other hand researchers to calculate and monitor the food loss. This article identifies and quantifies the losses in the Lebanese apples at the cold storage level in Kesrwan-Mount Lebanon and recognises the main causes of those losses. A preliminary diagnosis based on key informant interviews was followed by assessing a sample of 29 Metric Tons (MT) of apples handled by 14 traders in three cold storage facilities. The sorted apples were assessed for the type of damage and its causes. The graded apples as assessed by traders were measured. A survey was also conducted with farmers, traders, and managers of cold storage facilities. The results identified the actors, the postharvest practices, three distinct postharvest systems and cost-profit values based on the usage of cold storage and the different marketing channels. Results showed that 5% of the stored apples were lost, only grade 1 (41%) and grade 2 (26%) could get a good price while the rest (28%) could hardly cover the cost of production. Hence, improving the production and postharvest systems would lead to higher quantities of good quality apples and meet high-end markets.

Keywords: Postharvest Loss; Apples; Apple Sorting; Apple Grading; Cost-Profit; Lebanon

INTRODUCTION

Food losses are the reduction in quality and quantity of edible food along the food supply chain from harvest to right before the retail level (FAO, 2019). Prevention of these losses is economically and environmentally important, and can affect the food security, food quality, and food safety. Food

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losses are a result of several causes that are specific to the situation and the country where it is produced. The Food and Agriculture Organization of the United Nations (FAO) recognized the stages at which food losses can occur along the supply chain (FAO, 2016a). According to FAO (2014a and 2016b), food losses are the result of poor farming practices, lack of appropriate infrastructure and poor postharvest systems that occur along the supply chain. Inadequate markets and inefficient marketing systems, as well as inadequate financing, are also key factors (FAO, 2014b).

The current article presents a case study on food losses at the cold storage level. It is based on an initial assessment of the apple value chain in Lebanon carried out by the Lebanese University in collaboration with the FAO and using the FAO Methodology (FAO, 2016b). The assessment identified the main critical loss points (CLP) which are the points where food losses have the highest magnitude and impact on food security, and a significant effect on the economic result of the food supply chain. The CLPs are at (i) the on-farm level during production and during harvesting, at (ii) the off-farm cold storage level and (iii) the wholesale market. The initial assessment showed that the transportation segment of the apple supply chain is not a critical loss point because the distances from farm to packing houses and cold storages and from cold storages to wholesale and retail markets are not long and therefore not causing losses (FAO, 2017). The aim of analysing the causes of food losses is to propose concrete actions to implement food loss reduction strategies (FAO, 2016b) which falls under the Sustainable Development Goal 12 entitled “responsible consumption and production”. The Lebanese fruits subsector accounts for 26% of total agricultural production and the apple sector is chosen for its economic importance due to its production and export quantities in addition to the planted area it covers. According to FAO statistics (2020), apples in Lebanon are planted on a total area of 14,787 hectares (ha) with an annual production of around 245,152 Metric Tons (MT). Apples constitute 23% of the total Lebanese fruits production, the highest share among fruits and 20% of the total agricultural exports (Leeters, 2018). The main destination market for Lebanese apples is Egypt (70% of all Lebanese apple exports) and the rest is mainly exported to the Gulf states (Leeters, 2018).

The objective of this study is to identify and quantify food loss in the apple supply chain at the cold storage level, one of the identified CLPs, to estimate the magnitude of these losses and their causes. A survey was conducted to determine who are the actors involved and what are the postharvest practices and systems in this specific link, and to determine the possible causes of the losses.

MATERIAL AND METHODS

The following sections describe the different steps in the methodology: preliminary diagnosis, sampling and measurements.

2.1. Preliminary diagnosis

The methodology relied on a preliminary diagnosis conducted in Kesrwan district, Mount Lebanon governorate in 2015 based on key informant interviews in the apple sector:

- Two cold storages and four farms were selected in Kesrwan and assessed through interviews and observation.
- Agricultural engineers active in the apple production sector at the non-governmental organization « Georges N. Frem Foundation » operating in Kesrwan were also interviewed to further identify the main problems, determine the study area within the selected region and select the cold storage facilities of the study.

2.2 Sampling

The selected region is Kesrwan district - Mount Lebanon governorate where 26% of the Lebanese apple is produced, accounting for 31% of the total red apples (MOA, 2012). In Kesrwan, apples are placed in cold storages for six months (September - February) for the middle altitude (1,000-1,200 meters) production and for eight months (October to May) for the higher altitudes. The varieties studied are the red varieties[1] (most planted). Red apples constitute 60% of the planted areas in Lebanon whereas yellow and green apples constitute the remaining 40% (MOA, 2012). In the scope of the present study, losses at the cold storage level were assessed on a sample of red apple crates retrieved from the cold storage for the middle altitude apples. This region comprises the villages of Mayrouba, Hrajel, Kfarzebian, Bqaatouta and Ballouneh and is served by eight cold storage facilities, which are located in Dbayeh (one facility), Hrajel (one facility), Ballouneh (one facility), Mayrouba (two facilities) and Kfarzebian (three facilities). Sampling was performed in three selected cold storage facilities:

- Dbayeh with a capacity of 100,000 crates (2000 MT) while 51,000 crates (1020 MT) were available at the time of the study
- Hrajel with a capacity of 30,000 crates (600 MT) while 10,000 crates (200 MT) were available at the time of the study
- Kfarzebian with a capacity of 50,000 crates (1000 MT) while 20,000 crates (400 MT) were available at the time of the study

These facilities deal with multiple traders. The total representative sample covers 29 MT of apples equivalent to 1,450 crates which represent approximately 4% of the total production present at the end of the storage period (February 2016). The data was collected during this specific period, which is near the end of the storage period, when losses would increase and allow the estimation of maximum loss.

These 29 MT cover fourteen individual traders who store the apples in crate and retrieve them gradually for marketing. Each sub-sample is one load, or one transaction covering one Metric Ton per day and handled by one trader (representing 50 crates of 20 kg per crate). A transaction is the action of retrieving a load or quantity of crates from the storage and preparing it to reach the market. Within the framework of this study, any load exiting the storage facility was considered a representative sample of the apples stored. The sub-sample from Dbayeh cold storage covers 400 crates representing 8 MT, 5 traders, and 8 transactions. The sub-sample from Hrajel covers 700 crates representing 14 MT, 6 traders, and 14 transactions. The sub-sample from Kfarzebian covers 350 crates representing 7 MT, 3 traders, and 7 transactions. The difference in the total number of samples among the storages is due to the time convenient for the traders and their workers to cooperate at the time of the measurement. All crates were assessed based on the criteria retained for measurement which are the grades and categories of apples as sorted by the traders.

2.3 Measurements:

The methodology consisted of measuring and counting the apples of each of the selected crates based on the grades as sorted by the traders.

Since sorting is done based on damage incidence and grading is done according to size and colour intensity, measurements of the sampled apples included the following criteria: i) weight of crate before sorting and grading to estimate the weight to be measured, ii) grading by size, final

1 Red varieties include the red delicious, red chief, and double red varieties. The red varieties planted in Kesrwan region are of two types: i) old varieties: Starking and Double red; and ii) new varieties: Red delicious (including: Scarlet spur, Ace spur, Top red, and Red one); Red chief and Super chief.

weight and number of crates per grade, weight of all lost apples after sorting. In addition, the causes of damages were identified and noted in four categories: i) mechanical, ii) physiological, iii) pathological and iv) pest injuries. Basically, two main categories were measured: i) marketable apples and ii) lost apples (losses).

Along with the observations and measurements taken during the visits to the storage units, an in-depth survey with the traders and manager of each storage unit was conducted through two prepared structured questionnaires:

1. A questionnaire for traders who, on the day of measurement, were sorting their products before marketing. The survey gathered information on problems encountered and marketing channels, the number of grades, grading criteria, the percentage of each grade, and the percentage of damaged and wasted apples to discuss the causes of loss.

2. A questionnaire for the manager of each selected cold storage. Survey included i) general information on the capacity of the cold storage facility, variety of apples, temperature and relative humidity at the facility and the source of apples; details on the cost of labour for sorting and grading, cost of transportation, cost of storage, quantity lost and the different market channels.

In addition, a survey based on ten questionnaires was conducted among farmers chosen randomly from the study region to estimate the cost of production and enquire about their marketing strategies. The survey consisted of semi-structured questionnaires among 10 farmers who cultivated red apples of 10-years old, and they have been selected from four different regions comprising the highest number of apple orchards: Bqaatouta, Hrajel, Mayrouba and Kfarzebian. The questionnaires gathered information on the surface area planted, the cost of production (irrigation system, water, inputs, manpower for the cultural practices, harvesting practices, sorting, and grading of apples at field level), and their marketing channels. Each questionnaire required approximately 45 minutes.

RESULTS

The results include the identification of actors in the trade of apples and their relations, the postharvest practices, the measurements of marketable and lost apples at the cold storage level, the different postharvest systems, and their economic analysis.

3.1 Actors in the trade of apples:

The main actors in the trade of apples in the study region are the farmers, the traders, the cold storage operators, the wholesalers, and the retailers (supermarkets and retail shops). In the scope of this study, the actors taken into consideration are only the farmers, the traders and the cold storage operators.

3.1.1 The farmers

Based on the survey conducted on ten farmers, two types of farmers are identified:

- “Farmer”: This farmer sells directly to the trader. They sell the yield at the farm level either before or after harvest.
- “Farmer-trader”: This farmer is also a trader. They harvest and sell to the market. If needed they also store part of their crop for further selling.

3.1.2 The traders

The survey revealed that farmers' production is aggregated by traders/collectors, known as *dammans*. These traders are essentially intermediaries who, at a minimum, have a pick-up truck and a stock of 20 kg plastic crates. There are two different types of traders:

- Trader-harvester: traders organize labour for harvesting and supply the crates used for pre-sorted apples and transport.
- Trader-collector: traders rely on the farmers to do the harvesting and pre-sorting, but typically supply the crates used for pre-sorted apples and transport.

Both types of traders generally agree to purchase the marketable production from the farmers at a prearranged price. Farmers are paid immediately a post-dated check on a trust-based verbal agreement. The traders in their turn sell the product to the market directly after harvest and/or store it in the cold storage facilities and market it gradually during the off-peak season (from October until February) when prices are acceptable.

3.1.3 Cold storage operators:

The cold storage operators provide apple traders with storage and sorting-packing space from September through February.

3.2 Postharvest practices and damages

While all grades of apples are mixed in 20 kg plastic crates at the farm level and inside the cold storage, these apples are further sorted and graded before reaching different market outlets in different packages. Based on the preliminary diagnosis and the survey, the results show that traders and farmers pre-sort, sort, and grade apples into five categories before distribution to different market channels.

3.2.1 Pre-sorting, sorting, and damages

Pre-sorting and sorting are conducted based on fruits' appearance. It is the process of the separation of apples without blemishes from the ones showing damage. Pre-sorting is commonly practiced at the farm during harvesting, where workers pack only marketable apples. Sorting is commonly practiced at the packinghouse right before distribution to the market outlets, where workers further remove unmarketable fruits. Marketable apples are the ones with acceptable damage incidence as perceived by farmers and traders. The unmarketable apples are the malformed, the immature, the overripe, the too small, or the highly damaged fruits. Box 1 defines the damages and terms used to sort apples.

Box 1. Definition of the terms "damage, acceptable damage and lost apples" used by the actors to sort apples in the present study

"**Damaged apples**" show physiological disorders, diseases, pest injuries and mechanical injuries.

"**Acceptable damage**" is a subjective decision where the surface area covered by the damage is acceptable from the trader's point of view and based on his knowledge of the buyer's preferences.

"**Lost apples**" (*talaff* in common Arabic) are unmarketable because they are not appropriate to be consumed fresh, processed, or even fed to animals; this designation is usually reserved for completely rotten apples.

The causes of damage (Box 1) are inappropriate preharvest cultural practices leading to physiological disorders, diseases and pest injuries and undesirable climatic conditions. In addition, mechanical injuries due to rough postharvest handling and inadequate storage conditions are also important sources of deterioration. The main damages retained for the study are the visual ones and are divided into:

- Physiological disorders: bitter pit (caused mainly by calcium deficiency), malformation (caused mainly by irregular irrigation, wrong or no thinning), shrivelling (water loss during storage), aggravated cold scald (at cold storage level) due to possible harvesting at the immature stage.
- Mechanical / physical injuries: hail injury, impact injury from falling on the ground, fruit without peduncle, compression marks when harvesting (rough handling such as finger marks made on the fruit during harvest) and packing (scratches from crate edges), and other bruises.
- Pathological injuries (diseases): apple scab/sooty blotch (*Venturia inaequalis*) at farm level, rot caused by *Penicillium* spp. (blue mold) and *Botrytis* spp. (grey mold) during cold storage.
- Pest injuries: thrips (*Thysanoptera* sp.), spider mites (*Tetranichus* sp.), codling moth (*Cydia pomonella*)

3.2.2 Grading

Grading is an advanced step after on farm pre-sorting. It is the separation of the apples according to size and colour density. It is either done while sorting or after sorting at the packing area. It is commonly practiced before packing and distribution to the market outlets. The following grades are adapted by traders:

- Grade 1: diameter of apple varies from 9 to 10 cm
- Grade 2: diameter of apple varies from 7 to 8 cm
- Grade 3: diameter of apple varies from 5 to 6 cm

Within each of the above grades, apples are again separated (when judged applicable) into three categories according to the red colour intensity (dark red, red, and light red).

The remaining marketable apples that are smaller than 5 cm in diameter or showing malformation are referred to as “no-grade” (or “brara*”* in common Arabic) and as labelled by the traders.

3.3 Measurements at the cold storage level:

To assess the qualitative and quantitative losses, measurements were taken of the weight of grades 1, 2, and 3, "no-grade," and lost apples. The lost apples are unmarketable and considered as the quantitative loss. Figure 1 summarizes these measurements in percentages of the total sample weight of 29 MT.

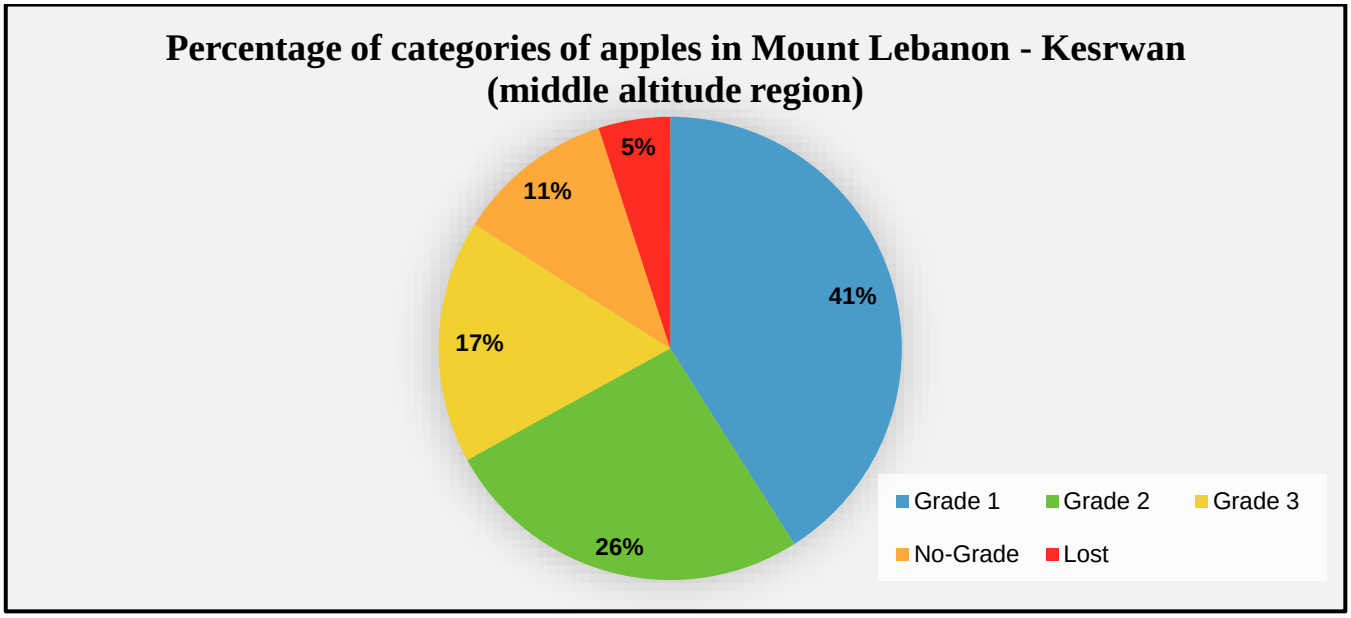

Figure 1. Categories of sorted apples at the retrieval from the cold storage facility: Percentage of total sample weight

Based on the sampled apples, the middle altitude of Mount Lebanon shows a good quality of apples since grade 1, large sized apples (9 to 10 cm diameter) represent 41%, while grades 2 and 3 represent 26% and 17% of the total sample, respectively. The no-grade apples represent 11% of the total sample and the lost apples 5%. This distribution across grades is believed to represent the general trend of the grades of sorted apples retrieved from the cold storage from the study region.

The 5% lost apples are understood to be collected from the ground, over-mature, or damaged fruits that were kept in the crates during the cold storage period. Despite the fact that the apples seemed marketable at the beginning of the cold storage period, these fruits were damaged and had a shorter shelf life then the healthy ones.

The measurements also covered the colour intensity of the apples in three shades: dark red, red and light red. This applies only for the grades 1, 2 and 3. Usually, darker colours get higher prices. No-grade apples are not sorted by colour intensity. The colour intensity within each grade showed a general trend of a higher percentage of dark red across all the grades (Table 1).

Table 1. Apples sampled based on grade and colour intensity: in number of crates and in percentage

Grades	Grade 1				Grade 2				Grade 3			
Colour intensity	Dark Red	Red	Light Red	Total	Dark Red	Red	Light Red	Total	Dark Red	Red	Light Red	Total
Weight (kg) [a]	7,490.7	2,734.7	1,664.6	11,890.0	4,297.8	2,337.4	904.8	7,540	2,366.4	1,626.9	936.7	4,930.0
Percentage (%)	63	23	14	100	57	31	12	100	48	33	19	100

[a] *Weight calculated out of the total sample of 1,450 crates sampled and at 20kg per crate*

The average percentage of all three grades mixed is 58.1% for dark red, 27.5% for red and 14.4% for light red (Table 2) covering 24,360 kg (or 1,218 crates) out of the total sample of 29,000 kg (or 1,450 crates).

Table 2. Apples sampled according to red colour intensity in number of crates and percentage of whole sample

Crates	**Colour Intensity**			
	Dark red	**Red**	**Light red**	**Total**
Weight (kg)	14,154.9	6,699.0	3,506.1	24,360.0
Percentage (%)	58.1	27.5	14.4	100

The economic loss in the apple sector before reaching the market outlets entails both qualitative and quantitative loss in terms of low grades and unmarketable apples. However, there are differences in the postharvest handling practices leading to the identification of distinct postharvest systems with disparities in their respective costs and profit.

3.4 Postharvest systems

Three postharvest systems were identified based on the handling practices applied (pre-sorting, sorting, and grading and use of cold storage). Farmers and/ or traders can diversify in their postharvest systems depending on their marketing strategies, the quantity dealt with, their capital and their need for cash.

- "Postharvest system 1" (PS1): Pre-sorting - Cold storage - Sorting - Grading - Market

This system uses pre-sorting of apples at farm level in 20 kg plastic crates. The produce is then transported to cold storage. Thereafter, it is retrieved gradually upon demand, sorted, graded and repacked before reaching wholesale and retail markets.

- "Postharvest system 2" (PS2): Pre-sorting - Sorting - Grading - Market

Similar to PS1, this system uses pre-sorting of apples at farm level in 20 kg plastic crates. The produce is then sorted, graded and repacked on-farm before reaching wholesale and retail markets. Cold storage is not used in this system.

- "Postharvest system 3" (PS3): Pre-sorting - Market

This system uses pre-sorting of apples at farm level in 20 kg plastic crates. The produce is directly transported to the wholesale and retail markets. No sorting, grading or storage are practiced in this system. Apples are sold in bulk, with all grades mixed and sold at the low-grade price.

3.5 Cost profit analysis per postharvest system

In order to compare the profit among the three postharvest systems, the costs incurred from the production to the market are calculated and deducted from the total sales. The total sale at wholesale market is calculated for each system based on the proportion of grades in each case and the respective selling price. The following details the cost of production at field level (common for the three systems) and the cost-profit analysis for each system.

3.5.1 Cost of production at field level

Based on the data collected, the total cost per *dunum*[2] for a 10-year-old orchard is estimated to be approximately LBP 1,660,000 [3] for an average production of 400 crates. The average yield for apples is around 5 crates per tree, the density of plantation is 80 trees per *dunum*; the average crate weight is 20 kg. The opportunity cost for the farmer's labour, the rental price of the land, the water fees and the harvesting cost are not considered in these calculations. The harvesting cost is included in the cost-profit analysis of the different postharvest systems as it affects the profit of the farmer at field level. These figures are also confirmed by similar studies conducted during the same period (Matta, 2016; Chahine & Tohmé Tawk, 2017). Table 3 details the cost of production.

Table 3. Production costs in LBP of 1 *dunum* of 10-year-old apple orchard

Crop:	**Apple**	***Malus Domestica***	**Family: *Rosacea***
	10 years old		
Costs	**Description**		**Cost/dunum in LBP***
Input and equipment costs	Mechanical ploughing, drip irrigation, fertilizers, pesticides, herbicides		1,300,000
Labor costs	Labor for pesticide application, herbicide application, pruning, spreading fertilizer, spreading manure		360,000
Total costs			1,660,000

3.5.2 Total sales per postharvest system

The following calculations are based on 100 crates equivalent to 2000 kg of apples, with a total production cost of LBP 415,000. This cost is used to calculate the profit per postharvest system according to the proportion of apple categories and the respective price per category for each system (Table 4). The profit is based on the total sales at the wholesale market**.** There is no price difference between fresh apples and apples retrieved from the cold storage facilities during the off-season (December, January, and February) for the middle altitude apples. According to the interviewed traders and own observations, the price at the wholesale market of grades 1 and 2 varies between LBP 2,000 and LBP 3,500 per kg (average LBP 3,000 for grade 1 and LBP 2,000 for grade 2), LBP 1,000 for grade 3 and between LBP 250 to LBP 750 (average LBP 500) for no-grade apples. These average prices are taken into consideration for the calculations and for comparison among the identified postharvest systems.

[2] 1 dunum=1000 square meters

[3] 1000 LBP = 0.66 US Dollars in 2016

Table 4. Apple categories per postharvest system: percentage, weight, and sales in LBP based on 100 crates of 2000 kg

		Grade 1	Grade 2	Grade 3	No-grade	Loss	Total
	Wholesale price in LBP per kg	*3000*	*2000*	*1000*	*500*	*0*	-
PS1 [a]	***Quantity in percentage***	*41*	*26*	*17*	*11*	*5*	*100*
	Quantity in kg	*820*	*520*	*340*	*220*	*100*	*2000*
	Sales in LBP	2,460,000	1,040,000	340,000	110,000	0	**3,950,000**
PS2 [b]	***Quantity in percentage***	*41*	*26*	*17*	*16*	*NA* [d]	*100*
	Quantity in kg	*820*	*520*	*340*	*320*	*0*	*2000*
	Sales in LBP	2,460,000	1,040,000	340,000	160,000	NA	**4,000,000**
PS3 [c]	***Quantity in percentage***	*NA*	*NA*	*100*	*NA*	*NA*	*100*
	Quantity in kg	*0*	*0*	*2000*	*0*	*0*	*2000*
	Sales in LBP	NA	NA	2,000,000	NA	NA	**2,000,000**

[a] *PS1 "Postharvest System 1": Pre-sorting - Cold storage – Sorting – Grading - Market*
[b] *PS2 "Postharvest System 2": Pre-sorting - Sorting - Grading - Market*
[c] *PS3 "Postharvest System 3": Pre-sorting – Market*
[d] *NA "Not Applicable"*

Table 4 shows that in PS1 the cold storage incurred a 5% loss of apples due to the fact that some marketable fruits developed gradual damages during the storage period (refer to Figure 1 section 3.3) while in PS2 and PS3 all marketable apples were packed and sold immediately. The total sales in PS3 are LBP 2,000,00 representing approximately half the value of the ones in PS1 and PS2. This is due to the fact that the sales in PS3 are based on the low price of grade 3. PS1 and PS2 total sales are almost equal in value (LBP 3,950,000 and LBP 4,000,000 respectively).

3.5.3 Profit per postharvest system

The profit for each postharvest system is calculated based on the production cost at field level, the handling practices, and the total sales (Table 5).

PS3 has the lowest cost of LBP 643,500 but also the lowest profit of LBP 1,356,500 since all apples are sold as bulk. This system fits farmers unwilling or with limited capacity to invest in postharvest practices and ensures low-cost marketing of surplus production per individual trader. Sorting and grading the produce ensures higher profit in PS1 and PS2. The highest profit of LBP 3,131,500 is shown in PS2 since the apples are graded and sold directly without the cost of cold storage. In PS1, apples reach a lower profit of approximately LBP 2,558,500 accounting for the cost of cold storage and two transportation segments, from farm to cold storage facility (also serving as packinghouse) and from cold storage to market outlets.

By calculating the differences among the profits in the three systems (Table 6), PS2 with the highest profit is appropriate for small-scale farmers or small quantities since it can only meet the

market demand and its capacity during a limited period which is the harvesting season. On the other hand, and despite the higher costs in PS1, this system ensures the gradual marketing of larger quantities of apples of all categories during winter while kept in the cold storage facility, hence satisfying market demand and need for a prolonged period.

Table 5. Cost and profit in LBP per postharvest systems based on 100 crates (20 kg/crate)

	PS1 (Cold Storage)	**PS2**	**PS3**
		(No cold storage)	
Cost of Activity per 100 crates in LBP			
Production	415,000	415,000	415,000
Harvesting and pre-sorting	116,000	116,000	116,000
Transportation from farm to cold storage	48,000	NA [a]	NA
Cold storage	475,000	NA	NA
Sorting, grading, and packaging (before marketing and/or after retrieving from cold storage)	225,000	225,000	NA
Transportation to market [b]	112,500	112,500	112,500
Total cost (production, harvest, and postharvest practices)	**1,391,500**	**868,500**	**643,500**
Total cost/kg reaching the market	732.37	434.25	321.75
Profit in LBP per 95 crates for PS1 and 100 crates for PS2 and PS3			
Total weight of apples reaching the market in kg	**1900**	**2000**	**2000**
Total Sale at wholesale market (accounting for the proportion of grades and the corresponding price per grade)	**3,950,000**	**4,000,000**	**2,000,000**
Net Profit	**2,558,500**	**3,131,500**	**1,356,500**

[a] *NA: Not Applicable*

[b] *Cost of transportation: from farm to storage and to market for PS1; from farm to market for PS2 and PS3.*

Table 6. Differences in profit between the 3 postharvest systems in LBP

	PS1	PS2	PS3
PS1		-573,000	1,202,000
PS2	573,000		1,775,000
PS3	-1,202,000	-1,775,000	

Looking at the net profit per kilogram generated from each grade and per postharvest system, the following tables (tables 7, 8, and 9) present the profit per grade for each system. It details the economic value of apples traded at the market level based on the total cost per kg for each system after being retrieved from the field or from the cold storage and before reaching the market outlets. It is based on the cost-profit analysis of the average weight and percentages of each grade (grade 1, grade 2, and grade 3), no-grade, and lost apples as measured and observed at the cold storage level.

Table 7. Profit per kg for each grade in Postharvest system 1

PS1	Grade 1	Grade 2	Grade 3	No-grade
Average selling price of 1kg in LBP	3,000	2,000	1,000	500
Total cost per kg in LBP	732.37	732.37	732.37	732.37
Net profit per kg in LBP	2,268	1,268	268	-232

Table 8. Profit per kg for each grade in Postharvest system 2

PS2	Grade 1	Grade 2	Grade 3	No-grade
Average selling price of 1kg in LBP	3,000	2,000	1,000	500
Total cost per kg in LBP	434.25	434.25	434.25	434.25
Net profit per kg in LBP	2,566	1,566	566	66

Table 9. Profit per kg for each grade in Postharvest system 3 ($1 = 1500 LBP)

PS3	Grade 1	Grade 2	Grade 3	No-grade
Wholesale price in LBP per kg	-	-	1,000	-
Total cost in LBP per kg	-	-	321.75	-
Net profit in LBP per kg	-	-	678.25	-

The net profit (difference between the selling price and the total cost) shows positive value for all grades except for the no-grade apples in PS1 where the value is negative (table 7).

DISCUSSION

The present study aims at identifying the postharvest losses in apples at the retrieval from the cold storage and before reaching the market level. The analysis of apple damages at the storage level in this study shows that the cultural practices and the postharvest handling practices are the main causes of lower grades and damaged apples. Good harvesting and handling practices reduced the incidence of bruising from 93.3% to 37.7% in Golden Delicious apples and eliminated the symptoms of rot (Abi Tarabay et al., 2018). Similarly, inadequate handling practices during harvesting increase physical damages in Poland (Dobrzański et al., 2006); moreover, postharvest bruising susceptibility increases due to the dehydration and weight loss during storage in Spain (Juan et al., 1999). Our results compare to a study carried out on the apple sector in India, where loss at the storage level reached 2% and was also attributed to the lack of good storage conditions and the availability of skilled labour (Sharma *et al.*, 2020).

In Lebanon, all apple grades have a depreciated value due to the physical and pathological damages they hold (Chahine & Tohmé Tawk, 2017). The best quality parameters and best marketability are obtained at optimal harvest time. However, no harvesting was based on maturity level according to the field observations of the present study. In fact, in Lithuania, fruit quality parameters such as firmness during storage were found to correlate with the stage of ripeness at which apples were picked and depending on the cultivar and the weather conditions (Kvikliene *et al.*, 2006). Production and postharvest practices require higher attention from the relevant actors in the apple value chain to meet higher standards and reach better markets. The present study shows losses at the storage level reaching 5% which are the apples who have deteriorated during storage. Hence, more attention should be given to the pre-sorting right before storage and to the removal of the low-quality fruits that appear to have a shorter shelf life.

The identified three main postharvest systems (PS) differ in the grading process and the use of cold storage. We have assessed the economic benefits of these systems and the losses at the cold storage level for PS1. As for grading and sorting, apples are separated into five categories: Grades 1, 2 and 3, “no grade”, and the lost apples that are unmarketable. Apples belonging to Grades 1, 2 and 3 might be further graded by red colour intensity with a trend of a higher percentage of dark red across all the grades. It was found that grading is a subjective activity; it is not based on standards with regards to the tolerance of damage incidence or size and colour intensity. Even though all marketable apples show positive net profit values, the stored “no grade” apples in PS1 show negative values due to the following reasons: high cost of production; cost of cold storage; and very low selling price. However, this inevitable economic loss is compensated by the overall net profit of this system which allows gradual marketing of apples and finding different domestic outlets and export market windows

over several months. Lebanese exporters benefit from a strong awareness on product quality and customer satisfaction in regional markets (IDAL, 2020). It becomes crucial to produce apples according to standards to increase the profitability of the sector. Hence increasing the percentage of Grade 1 apples and reducing quantitative and qualitative losses will insure higher income for all stakeholders. In addition, dark red apples, regardless of their grade by size, fetches better prices at the market but this criterion is not always used in pricing and depends on the market outlet. Eventually, local and export markets will be more demanding in terms of standards and norms for food safety and quality which will force Lebanese stakeholders to be vigilant in this regard. The importance of investing in extension services and small equipment can improve practices to reach high quality fruits and improve the profit by approximately 50% as suggested by Chahine and Tohmé Tawk (2017).

CONCLUSION

Amidst the COVID-19 pandemic and the economic crisis and devaluation of the Lebanese currency, supporting farmers in improving their practices and finding better marketing channels will sustain their livelihood by enhancing their production thus improving their profitability. The present study sheds the light on the main issues faced by the apple sector at the cold storage level and can lead to appropriate strategic planning and policy making to seize better local and international market opportunities. The results of this study can be used to target opportunities for investment programs and interventions, during which formulations of a wider geographical scope and the seasonality will be analysed. A multi-stakeholder approach involving public and private actors in the food supply chain is proposed to reach a consensus on a strategic agenda for this sector. With many small orchards and small-scale traders responsible for collection and aggregation, poor handling during and after harvest contributes to high losses in the marketing chain and diminishes product quality. There is a need to focus on improving the production and postharvest systems to produce Grade 1 apples in sufficient quantities to supply the fresh high-end markets. This will increase substantially the revenues from apples. The investment of the private and the public sectors in such improvements along with adequate extension services targeting the causes of apple losses, would support the farmers in adopting good practices. The results can eventually lead to more focused research, strategic planning, and advocacy for the sector. It can be used as a steppingstone for the development of business plans for fresh and processed apples.

Several measures should be considered to reduce apple loss and improve the apple sector including incentivizing grading and sorting, adding value to low grade apples through innovation in fruit processing, modernization of cold storage facilities and monitoring good cold storage practices. Further research should consider the multitude of interventions needed to increase profitability of the apple sector at the farm, cold storage and market levels.

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