Article

Quantification and use of food losses: the case of cantaloupe melon in a region of North-Central Mexico

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Abstract

According to FAO, about one-third of global food production is lost or wasted. This waste reduces the availability of foods for the population, increases their prices and generates problems of environmental pollution. A common problem in developing countries is the scarcity of data on the quantity, causes and uses of food losses. In this work, the quantification, by sowing stages, of the losses of cantaloupe melon, their causes and uses in the links of production, packaging and transportation in a region of North-Central Mexico known as the Comarca Lagunera was carried out. This region is the largest producer of cantaloupe melon in Mexico, with an area of more than 4 565 ha and a production of 165 663 t. A structured questionnaire was applied in person to a statistical sample of 47 producers and eight packers. It was found that losses, both in production and packaging, vary according to the sowing stage, with greater losses in late sowings, followed by early and intermediate sowings. The main causes of losses are inadequate fruit size (small or very large), deformed, overripe, spotted and cracked. The product that is wasted in the orchard is destined to feed domestic animals or as fertilizer to the land; while the one that is discarded in the packaging centers is resold to small local intermediaries for commercialization and for the feeding of domestic animals.

Keywords: Comarca Lagunera, late sowings, sowing stages.

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Introduction

The United Nations Development Programme adopted in 2015 the Sustainable Development Goals to eradicate poverty, protect the planet and ensure prosperity for all as part of a new agenda, known as the 2030 Agenda (UNDP, 2015). There are 17 goals, of which goal 12 refers to responsible production and consumption. Goal 12 contains goal 12.3, which proposed by 2030 to halve global per capita food waste in sales at the consumer level and reduce food losses in production and distribution chains (Fabi and English, 2018).

In a world with limited natural resources and where solutions need to be found to produce enough safe and nutritious foods for all, reducing food losses must be a priority (FAO, 2012). Globally, about 1.3 billion tonnes of food are lost and wasted annually, which represents about one-third of global production (FAO, 2012).

In high- and middle-income countries, foods are significantly wasted at the consumption stage, while in low-income countries, foods are mainly lost during the early and intermediate stages of the food supply chain (FAO, 2012). Losses occur mainly during production, postharvest, storage and transport while waste occurs during distribution and consumption, in direct relationship to the behavior of wholesalers and retailers, food sales services and consumers who decide to discard food that still has value (Parfitt *et al*., 2010).

Losses and waste differ between products and between countries. In Mexico, as in other less developed countries, losses are greater than waste (Benítez, 2018). Reducing food losses and waste is a critical means of ensuring food availability to supply the world's growing population sustainably (Chen and Chen, 2018).

In addition, reducing food losses and waste is widely recognized as an important lever for reducing the environmental impacts of food systems by reducing the use of land, water and inputs along production chains (Kotykova and Babych, 2019; Read *et al*., 2020). In a study in several regions of the world, Gustavsson *et al*. (2011) found that the causes of food losses in low-income countries are storage deficiencies, poor refrigeration and transport infrastructure and packaging deficiencies, while in high-income countries, waste has to do with lack of planning in purchases, quality standards, deficiencies in exhibition conditions and lack of coordination with suppliers.

In Latin America, it is estimated that foods that are lost and wasted reach 28% of production (FAO, 2018). Other more specific studies estimate that losses and waste by food groups in Latin America, with regard to meat, dairy products and oilseeds, reach 20%, cereals are wasted 25%, fish and seafood 33% and fruits and vegetables 55% (FAO, 2017).

Food losses should be kept to a minimum in any country, regardless of its level of economic development and the maturity of its systems; however, the problem of food losses and waste is likely to increase in the coming years unless countries adopt strict policies (European Commission,

2014). Consumer dissatisfaction with product quality is directly related to total postharvest losses. Therefore, providing consumers with good quality fruits and vegetables can significantly increase their consumption, reducing waste (Kader, 2005).

In Mexico, several secretariats of the federal government, the private sector and civil society have joined with the aim of reducing food losses and waste, which has allowed positioning the issue of waste at the highest level and formulating a comprehensive national strategy with a socioeconomic, environmental and food security vision (FAO, 2017). In Mexico, some studies on food losses and waste have been carried out, but none in cantaloupe melon.

In the state of Jalisco, Mexico, a study was conducted to quantify food losses, causes and uses. The main crops of the state, such as sugarcane, agave, corn, tomato, banana and avocado, were studied. The average loss in agricultural products was 10.75%; nevertheless, in the case of tomatoes the losses were 24.64% and in avocado 15.15%.

The greatest losses were in small producers because their processes are not very technical, and they have little transport and storage infrastructure. The main causes of losses were pests, climate variations, poor infrastructure and lack of training (SIPRA, 2019). Del Angel *et al*. (2019) did a study to analyze food losses from three fruit crops in the state of Veracruz, Mexico. They analyzed the cases of chayote (*Sechium edule*), manila mango (*Mangifera indica*) and manzano pepper (*Capsicum pubescens*).

The values of losses found in this study were 13.7% in chayote, 10% in mango and 30% in manzano pepper. INEGI (2018) conducted a nationwide study on the causes of food losses (FLW) in the primary sector. It was found that 44.2% of the production units have suffered losses due to biological causes (pests and diseases), while 74.7% of the units have suffered losses due to climatic factors such as droughts, strong winds, hailstorms, frosts and floods, among other factors.

In this work, the case of cantaloupe melon in the region of Comarca Lagunera, located in North-Central Mexico, was analyzed. The cantaloupe melon is a variety of the *Cucumis melo* species of the *Cucurbitacea* family. It is a creeping annual plant with rough pubescent stems provided with tendrils that can reach 3 m in length (Tiscornia, 1979). The weight of its fruits varies from 0.5 to 4 kg. The melon fruit is usually consumed raw in its natural state when it has reached perfect maturation.

Melon is not very nutritious, but it has an abundance of sugary and mucilaginous matter, has refreshing properties and facilitates secretions. In addition to being consumed fresh, jams, juices, smoothies, sweets and confitures are also made with it; however, it is estimated that more than 95% is consumed fresh (Tamaro, 1977). The production of cantaloupe melon in the world in 2019 was 27.5 million tonnes. China was the largest producer with 49% of the total, followed by Turkey with 6.47% and India with 4.62% (FAO, 2020).

In Mexico, the area cultivated with cantaloupe melon in 2020 was 19 104 ha with a production of 591 574 t (SIAP, 2021). The study region, the Comarca Lagunera, contributed in 2020 with an area of 4 565 ha and a production of 165 663 t, with a participation of 28% of national production and is recognized as the main melon-growing region of the country (SADER Región Lagunera, 2021).

According to FAO (2012), there are large data gaps about food losses and waste in the world. Further research is therefore needed in this field. The objective of this work was to quantify cantaloupe melon losses, their causes and uses in the links of primary production, packaging and transport in a region of North-Central Mexico.

The 'uses' refer to the destination given to the melon that no longer continues the commercialization process, mainly because it does not meet the minimum quality requirements and is rejected by marketers. It is hypothesized that melon losses, in the study region, are of economic importance, significantly affecting producers' incomes. It is a work that makes an analysis by stage of sowing (early, intermediate and late), an aspect not addressed in previous studies. Based on the quantification of melon losses and their causes, specific measures may be proposed for their reduction.

Material and methos

The study region is located in North-Central Mexico and is known as the Comarca Lagunera. It is composed of five municipalities in the southwest of the state of Coahuila and 10 in the northeast of Durango. The cities of Matamoros and Torreón in the state of Coahuila and Gómez Palacio and Lerdo in the state of Durango form the Metropolitan Area of La Laguna with about 1.5 million inhabitants.

The region is located between the meridians 102º 22' and 104º 47' west longitude and the parallels 24º 22' and 26º 23' north latitude and an average height of 1 150 masl (Orona *et al*., 2006). The climate of the region is dry desert and is characterized by an average annual temperature of 20.9 ºC, warm summers, with average maximum temperatures of 30.2 ºC (±1.9), minimum temperatures of 10.5 ºC (±3) and average annual rainfall of 287 (±98) mm (Figueroa *et al*., 2015).

There are several methods for quantifying food losses and waste, which have been reported by Hanson *et al*. (2016). Some of the methods are the weighing method, counting method, method of evaluation by volume, file method, diary method, modeling method and survey method, among others. For this work, the survey method was used, which has some advantages such as not requiring technical specialization in the food area, the investment is lower than in the other methods and no equipment, laboratories or qualified personnel are required to quantify the losses.

Surveys were applied at the producer level and in packaging centers, in which not only information on losses in their facilities was obtained but also in transport to consumption centers. To measure losses in the production and packaging stage, questionnaires were applied to 47 melon producers

from the municipalities of Matamoros and Viesca, Coahuila and eight packers established in the region. The questionnaires used with the producers were printed and their application was personal in the places where they were located: in the melon orchards or in their private homes.

The study population was determined based on the register of melon producers of SADER Region Lagunera (2021), from which the statistical sample was calculated. The questionnaires applied to producers consisted of 18 questions, with which the following information was obtained: area sown, sowing and harvesting period, percentage of losses, causes of losses, uses of the rejected product, transport methods and type of packaging, among others.

The questionnaires applied covered early (January-February sowing period), intermediate (March-April sowing period) and late (June-August sowing period) sowings. This is of great importance given that, at each stage, the climatic conditions, the availability of water and other factors such as pests and diseases are different, so when analyzing by stage, the different conditions of the agricultural year were covered.

Sample calculation was performed by simple random sampling (Lind *et al*., 2004) according to the following formula: $n=\frac{N(Z)^2(\sigma)^2}{(N-1)(e)^2+(Z)^2(\sigma)^2}$. Where: n= sample size; N= population size= 671 producers; Z^2= 1.96 (value of Z for a confidence level of 95%); e= 1 (maximum permissible error); σ^2= 6.62 (variance previously obtained based on the variable producer price of melon). The sample (n) obtained was 47 melon producers to whom the questionnaires corresponding to the production stage were applied.

As for packers, a sample of eight of them was interviewed and printed questionnaires were applied through personal visits to their operation centers. To determine the population of packers, the Municipal Presidency of the city of Matamoros was contacted to request a list since a crop mobility tax (transport waybill) is collected in that municipality.

According to the information obtained, there is a register of 13 formal packers, so 67% of the population was covered. The questionnaire was composed of 16 questions, with which the following information was obtained: the period of the year in which the packaging center operates, quantities of melon packed, losses in packaging and transport, main destinations of the melon, uses and causes of losses, among others.

Results and discussion

Characteristics of producers and owners of packaging centers

Before presenting the estimates of melon losses, some characteristics of producers and packers are shown, which will help a better understanding of the results. The cantaloupe melon producers from the Comarca Lagunera are small-scale, from the social sector, with areas between 1 and 2 ha, of advanced age and with low schooling. In contrast, packaging centers owners are younger and more educated. Generally, producers do not have their own packaging centers.

The intermediaries are the ones that own packaging centers and are responsible for the distribution of melon to the country's large consumption centers, such as the cities of Monterrey, Mexico, Guadalajara, León, San Luis Potosí, Querétaro and Puebla, among others. The age of producers is an important factor because it is related to the adoption of technologies and their negotiating power in the sale of their products. Nineteen percent of melon producers in the region are ≤ 40 years old, 51% are between 41 and 60 years old and 30% are in the 61-80 age range.

In terms of schooling, 19% have incomplete primary education, 26% complete primary education and 32% have junior high school education, this implies that 77% of producers have junior high school education. The age of owners of packaging centers indicates that 24% are between 21 and 40 years old, 63% between 41 and 60 years old and 13% between 61 and 80 years old. The level of schooling of owners of melon-packaging centers in the study region is as follows: 25% have completed primary school, 50% finished junior high school, 0% high school and 25% completed a bachelor's degree.

Melon-packaging centers operate in the region from the beginning of April of each year when the harvest begins, until the beginning of November, the month in which the cantaloupe melon harvest ends in the region due to the occurrence of the first winter frosts. Depending on the size of the packaging centers, melon marketers send to consumption centers an average between 40 and 120 t daily.

Quantification of losses, causes and uses of melon at the producer level

Figure 1 shows the percentages of melon losses in the orchard for the early, intermediate and late sowing stages. As losses at this stage, we understand the melon that the producers themselves discard in the orchard due to its poor conditions, aware that it will be rejected by the marketer, so they do not take it to the packaging center.

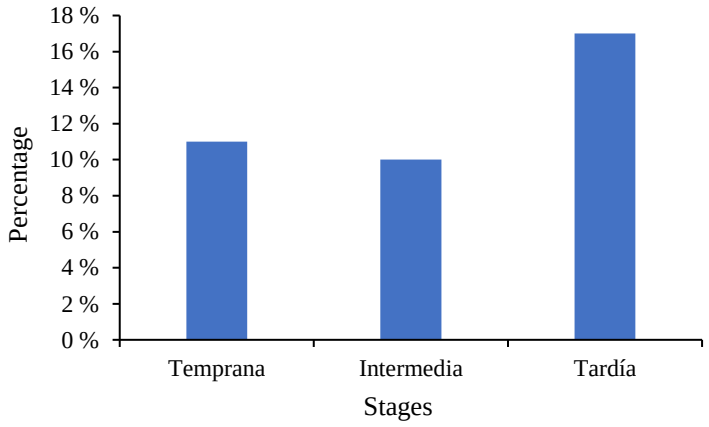

Figure 1. Average percentage of melon losses in the orchard.

A higher percentage of waste (17%) is observed in the late sowings, period in which the production conditions are very unfavorable for the melon plant due to the high temperatures and rains that occur during the months of August and September, which generates a high incidence of pests and diseases that reduce the quality of production. In early and intermediate sowings, the losses were lower with values of 10-11%.

These data are lower than the losses found in the state of Jalisco, Mexico by Sipra (2019) in tomato (24.64%) and losses similar to the avocado crop (15.15%). Without considering the management of the tomato in the orchard, perhaps the highest percentages of losses are due to its greater degree of perishability compared to cantaloupe melon. In the same way, the results in melon in the study region are similar to those found in chayote (13.7%) and mango (10%) crops in the state of Veracruz, Mexico, but lower than manzano pepper (30%) (Del Ángel *et al*., 2019).

The data on melon losses found in this study are less than the 55% found in Latin America for fruits and vegetables by FAO (2017). However, the results are not comparable because the FAO study covers distribution and consumption, while in this work only the stages of production, packaging and transport were studied. In a study, Redlingshöfer *et al*. (2017) found losses of up to 12% in fruits and vegetables, values very similar to this study, although the fruits and vegetables studied are not specified.

The characteristics for which the producers themselves discard the melon are diverse, Table 1, but the inadequate size of the fruit (very small or large) (26%), fruit with cracks (21%), spots (17%) and deformities of the fruit (16%) stand out. The most demanded fruits are the sizes between 23 and 36, so very large or small fruits have little demand. A size 23 melon refers to the fact that 23 melons fit on a 40 kg wooden crate; that is, melons of approximately 1.74 kg per piece, while melons of size 36 refer to 36 melons in a wooden crate of 40 kg; that is, melons of approximately 1.11 kg each.

Table 1. Characteristics of melon for which producers discard it.

Characteristic	(%)
Deformed fruit	16
Spots on fruits due to contact with moisture	17
Fruit with cracks	21
Spots on fruits due to damage from pests and diseases	8
Inadequate size	26
Overripening	9
Smooth (lack of mesh)	3

The melon discarded in the orchard is used as organic fertilizer and as feed for domestic animals, mainly pigs, cattle and goats. The results found by Sipra (2019) in tomato and avocado crops and by Del Ángel *et al*. (2019) in chayote, mango and chili, also refer to physical defects in the fruit caused by climatic factors, pests and diseases as the factors causing fruit losses.

Other authors who have done similar works but in avocado for export found the following as causes of rejection during preharvest and harvest: small sizes, damage to the epidermis by insect pests, thrips, mites, bugs, overripe fruits and sunburn (Ramírez-Gil *et al*., 2020). Some authors such as Delgado *et al*. (2021) have found some micro factors as causes of losses, citing the case of pests and diseases and deficiencies in storage and transport, but at the macro level they mention lack of credit and education as determinants of losses.

Quantification of losses, causes and uses of melon in packaging centers

Figure 2 shows the percentages of melon rejection in the packaging centers by sowing stage. As in the case of losses in the orchard, in the case of packaging centers, it is in late sowings where the greatest rejections are recorded, reaching 19%. These percentages of rejection in the different stages of sowing are averages; however, when the melon goes to chains of self-service stores, the percentages reach up to 30% (Ávila, 2017).

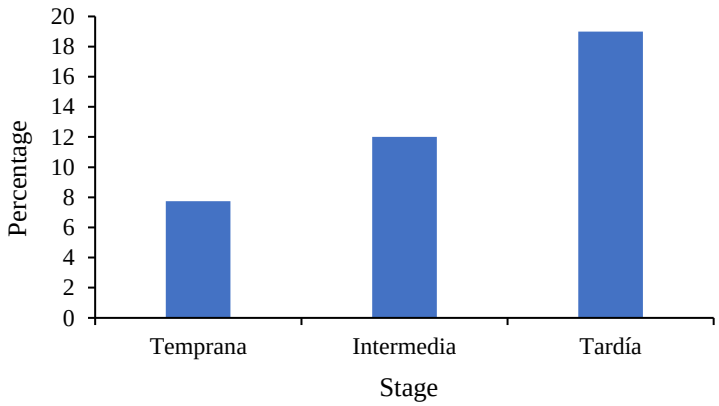

Figure 2. Percentage of melon that packaging centers reject from producers.

This is due to the greater demand in quality by the type of consumer who goes to this type of stores, a case contrary to when the melon is sold in popular markets of popular neighborhoods. In the early sowing stage, the percentage of rejection is lower (8%) due, in large part, to the fact that production, in those months, is low in relation to demand and the levels of demand in terms of quality decrease significantly.

In relation to the characteristics for which the melon is rejected in the packaging centers, Table 2, the inadequate size of the fruit (22%), melon with bites and cracks (21%) and overripening (17%) stand out. The causes of rejection in the packaging center are very similar to those that occur in the orchard; that is, they are physical characteristics of the fruit. Neither on the packaging center nor in the orchard are tests carried out, for example, to evaluate the amount of sugar (degrees Brix).

Table 2. Characteristics of the melon for which the intermediary rejects it.

Characteristic	(%)
Deformed fruit	9
Spots on fruits due to contact with moisture	9
Fruit with bites and cracks	21
Spots on fruits due to damage from pests and diseases	13
Inadequate size	22
Overripening	17
Loose	9
Total	100

The melon rejected in the packaging center, of second or third quality, is sold to other small intermediaries called 'pachangueros' at very low prices and is sold to consumers in plastic bags in the streets of the most important cities in the region, such as Torreón, Gómez Palacio, Lerdo, Francisco I. Madero, Matamoros and San Pedro. It is worth mentioning that much of the melon marketed in the region is still handled in bulk; that is, unpacked. In this regard, Wang *et al*. (2016) mention that handling packaged foods is a good strategy to reduce food waste.

Quantification of losses during transport, causes and uses of melon

The transport of melon to the destination markets is mainly carried out in two types of units: a) truck with thermoking-type refrigeration with a capacity of 20-25 t, where the temperature inside during the trip is maintained at around 7 °C; and b) unrefrigerated Thorton-type truck with a capacity of 12-15 t. In the latter case the melon is regularly transported in bulk; that is, unpacked and covered on top with a layer of ground ice about 20 cm thick.

The ice takes about six hours to melt. In the thorton-type truck, the temperature is irregular since the melons at the top are colder because of their proximity to the ice, unlike those that go in the middle and at the bottom. The journey to the destination markets is an average of 650 km with distances ranging from 400 km, such as the city of Monterrey, to 1 200 km, such as the city of Puebla.

Figure 3 shows the percentage of melon losses in the two types of transport: in the truck with refrigerator the losses were on average 1.75% of the load, while in truck with ice they were 2.2%.

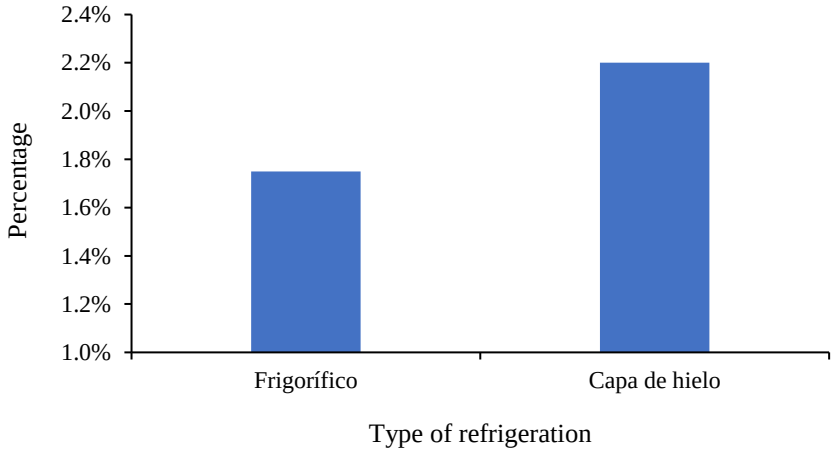

Figure 3. Average melon losses during transport to the destination market.

Lipinska *et al*. (2019), in a study for the case of dairy transport, estimated this percentage at 0.5%. According to Lipinska *et al*. (2019), the main causes of food losses during transport are mechanical, such as the breakdown of the cold chain and accidents, which causes the product not to be delivered in a timely manner or delivered to the buyer in poor condition.

The melon that arrives in poor condition at the Central de Abastos (Supply Centers) is collected by trucks, along with other fruits and vegetables, to be used for animal consumption, for the preparation of compost for agricultural uses and in some cases for donation to food banks. According to Gustavsson *et al*. (2011), to reduce losses and waste, it is necessary to invest in cold chain infrastructure, improve the types of packaging, improve the training of the participants in the different links of the chain and improve the infrastructure of the distribution chain.

Conclusions

The analysis of the results indicates that the main causes of cantaloupe melon losses in the Comarca Lagunera are for reasons of physical appearance of the fruit and they range from spots and cracks to inadequate sizes and overripening. Some of the reasons for these damages have to do with climatic aspects; nevertheless, a better management of the crop, from seed selection, proper pest and disease control, irrigation, fertilization and timely harvesting can substantially reduce losses.

The losses or rejections of the producers' melon that the buyer makes in the packaging centers are greater in late sowings due to the lower quality of the product obtained on those dates. The lowest quality identified in the packaging center comes from the orchard, so it is from there where work should be done to obtain a better quality product. The accumulated losses for producers in the orchard, plus what they lose in the packaging center, for early, intermediate and late sowings totaled 19, 22 and 36% of their harvest, respectively. If an average physical yield in orchard of 45 t ha^{-1} is considered, the losses amounted to 8.55, 9.9 and 16.2 t ha^{-1} in the three sowing dates, respectively.

At an average rural price of \$4 180 t^{-1} in force in the agricultural year of study, these losses, on the three sowing dates, were equivalent to \$35 739, \$41 451 and \$67 845 pesos ha^{-1}, respectively, which significantly impacted the producer's economy because they are equivalent to more than 50% of the cost of production per hectare. This verifies the working hypothesis that melon losses are of economic importance and significantly affect the income of producers.

To improve the quality and productivity of melon, greater training of producers in technological components related to their production is recommended. This training should include from the preparation of the land, the selection of the seed, irrigation, fertilization, pest and disease control and timely harvesting. Before starting the training, a diagnosis should be made to see which technological components should be placed greater emphasis.

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