Food losses from farm to retail operations: agricultural produces supply chain of Baja Peninsula, México

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ABSTRACT

Objective: To evaluate food losses (FL) volumes generated by farms in Baja California Peninsula, México, of five agricultural commodities.

Design/methodology/approach: Baja California Sur (BCS) state was the study area. Information was gathered from a total of 380 sampled chain actors in asparagus, mango, strawberry, orange and tomato by survey and personal interviews. Tobit technique was applied to identify factors that influence FL percentage.

Results: Data shows about 11.8% of asparagus is lost during harvesting and distribution, as well as 8.5% of strawberry, 26% of mango, 17.8% of oranges and 3.5% of tomatoes, representing 29.9% loss rate of marketed yield.

Limitations on study/implications: This study did not classify commodities in the last steps of the supply chain. The five commodities used in the current study correspond to the more important agricultural produces in BCS, but given changing market, harvesting time and produce availability did not consider the waste of the supply chain.

Findings/conclusions: Commodity, type of transportation and distribution, education, and human resources has been identified as influence factors in the volume of FL. This exploratory study fills the void in information in terms of its geographic scope and food group number, and farm owners willing to manage food losses for the purpose of obtaining bioactive compound.

Keywords: Food loss, agrifood, desert agriculture, food security, retail.

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INTRODUCTION

Food losses and waste (FLW) has been recognized as a major global, environmental and societal challenge. The United Nations (UN) through their Sustainable Development Goals in 2030 Agenda has been clear about it setting two specific goals, "2 Zero hunger" and "12

responsible consumption and production" (ONU, 2015). Besides, FLW has a significant impact in food related companies decreasing economic growth and viability. One-third of all food produced globally is lost or wasted, which means that annually 1.3 billion tons of probably perfect human consume food is discarded along food supply (FAO, 2013). FLW implies that in addition to throwing away food, greenhouse gases are released in food production, nutrient soil is wasted, but also when wasted food is sent to landfill (Qin and Horvarth, 2022). The issue of FLW is one of the greatest challenges of the new century. It is important to document that food loss does not mean only a boost in food production, if not; it is something even more complex. FLW reduction/disappear includes the adaptation of production habits and the implementation of new technologies and strategies that allow food production system to be sustainable and environmentally friendly even in pandemic times (Saboori *et al.*, 2022).

Although the terms 'food loss' and 'food waste' are often used interchangeably, there is an important difference between these two concepts (Affognon *et al.*, 2015). Food loss describes the situations whereby edible food leaves the food supply chain because of unintentional events, such as bad growing, size, shape, no special color or flavor, no temperature control in distribution or packing, among others. Quantification of FLW may go beyond the FLW definition scope and accounting for production-level factors during FLW measurement may be important to FLW management strategies. Using post-harvest losses implies that the timing of when FLW is considered occurs after harvest has been completed. However, post-harvest loss may in fact account for losses that occur during harvest (Affognon *et al.*, 2015). Different supply chain stages where loss occurs, and associated reasons for loss, respond differently to distinct types of policy incentives and measurements (HLPE, 2017).

The Causes and feedback process of FLW along supply chain may be different that the stage where FLW occurs even in different countries or different territories (HLPE, 2014). For example, although the amount of FLW is similar in developed and developing countries, 670 and 630 million tons (Mts), they are different on per capita factor (HLPE, 2017). More than 160kg/capita of food is thrown away annually from agricultural production to retail, while the actual amount changes from region to region (Amicarelli and Box, 2020). The highest loss occurs in Latin America with 200kg/capita, while the lowest loss occurs in South and Southeast Asia (100 kg/capita) (Amicarelli and Box, 2020). Several recent studies have used self-report or direct measurement methods to quantify region —and supply chain— specific FLW of perishable foods, finding losses concentrated at the producer level (Benites-Zapata *et al.*, 2021; Pereira and Filimonau, 2022; Ronen, 2023).

Our study assesses the extent, stages, and determinants of FLW along five perishable vegetable species (commodities) supply chains in Baja California Sur, México, from farm to retail. Unique to this study, we use data collected at the harvest and distribution levels to compare FLW. Using detailed data on production, harvest, and postharvest context, we examine the associated determinant of FLW at the farmer stages.

MATERIALS AND METHODS

This study was conducted in Baja California Sur State, in five municipalities (Figure 1). Food losses of every commodity were assessed in Los Cabos, La Paz, Comondú, Loreto

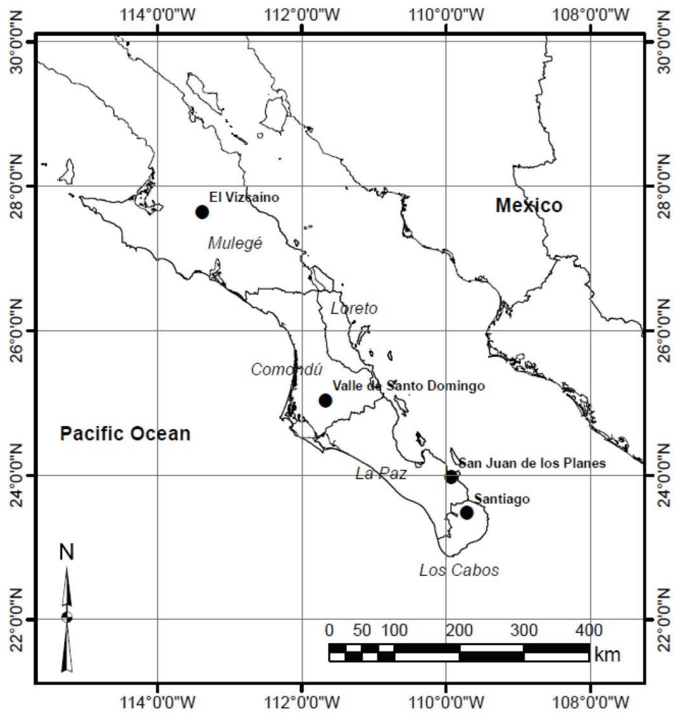

Figure 1. Map of Baja California Sur indicating the municipalities and localities included in the study.

and Mulege, across supply chains from farm to retail stages. Data were collected using surveys and pile-sort group discussions from August 2021 to February 2022.

Descriptive statistics and study variables

Participants in the survey were the owners of the farms used in the study. Direct variables included location, crop, cropland size, season, production quantity (ton), losses due to diseases, technical difficulties, packing method, packing location, type of distribution and channel, and quantities of losses due to distribution (Table 1).

Food losses (FL) were calculated as percentage of total production (TP) in each farm minus marketed production delivered (DP) to a distributor, as described below:

$$MY = \left(\left(TP - DP \right) \right) / TP * 100 \quad (1)$$

Selection of the estimation method

Food losses data in percentage causes that independent variable food loss volume was truncated. Data truncation nature requires the selection of a suitable estimation approach. Data were submitted to Tobit modeling technique providing three equations linking location, season, and commodity with the percentage of food loss. Therefore, each equation modeling the percentage of food loss in a given category is independently estimated. This approach is further supported by the variability of technical difficulties across season and commodity characteristics of different farmlands and often unpredictability of specific solutions that solve these problems. The Tobit equation is represented by three algebraic

Table 1. Descriptive statistic of demographic and socioeconomic characteristics.

Variable name	Units	Mean[a]	Standard deviation	Min	Max
Farm size[b]	Size category	2.86	0.34	1	4
Number of employees[c]	Employee category	3.84	0.35	1	5
Farm location[d]	Municipality category	4.27	0.15	1	5
Farm owner education	1=university degree; 0=otherwise	0.62	0.11	0	1
Employee technical training	1=Basically training or more; 0=no training	0.43	0.17	0	1
Gender	1=man; 0=woman	0.71	0.50	0	1

[a] In case of binary variables the reported figure is share.
[b] Size categories are: 1=100 ha or less; 2=101-300 ha; 3=301-500 ha; 4=500 ha or more.
[c] Employee categories are: 1=100 or less; 2=101-300; 3=301-500; 4=501-800; 5=801 or more.
[d] Municipality categories are: 1=La Paz; 2=Los Cabos; 3=Loreto; 4=Comondú; 5=Mulegé.

sentences where N is the number of observations; Y_i is the observed dependent variable and Y_i^* is the unobserved variable; β is parameters vector, and ε_i is the error for equation; this error must be normally distributed with the mean in cero and variance σ^2. Tobit equation is represented as:

$$\begin{aligned} &Y*im = X_i' \ \beta_m + \varepsilon_i, i = 1,2,...,N \text{ and} \\ &Y_i = Y_i^* \text{ if } Y_i^* > 0 \\ &Y_i = 0 \text{ if } Y_I^* \leq 0 \end{aligned} \tag{2}$$

Independently, a binary dependent variable equation was specified to model the decision to agree to use food losses for the regional obtaining of bioactive compounds. The yes/no nature of the decision suggested the use of the probit technique to identify the factors that encourage or impede such a choice. The variables used in the specified empirical model are commonly used in consumer studies and surveys such as including socio-economic and demographic characteristics of the respondent and their farmland. In this case the variables are, among others, crop, season, production (ton), income by commodity production, farmland size, number of employees, farmer education and harvest technique. These variables capture factors identified in earlier studies as associated in other desert regions as well as agricultural farmlands to food losses. Crop and season are associated with water scarcity and land fertility as well as culture region (Gao *et al.*, 2022). Farmer education is negatively correlates with loss food, the better educated owner and farmer would be expected to lose less food if that is their concern. Smaller farmland tends to consume more water, having more technical difficulties and lose more food. The current study adds a square measure of the farmland implying that the empirically tested effect on the volume of food loss can change as farmland size diminish. Similarly, number of employees squared of a respondent can capture changes in food losses.

RESULTS AND DISCUSSION

Factors influencing food losses in commodities

The identified factors influencing the amount of food losses vary across commodities. Consequently, it appears that reduction of food losses requires a different approach if the goal is to alter harvesting and distribution behavior. Food losses are remarkably different within the five commodities, *i.e.*, asparagus, strawberry, mango, orange, and tomato (Table 2). It appears that asparagus food losses are positively associated with packing conditions after harvest and harvest time from farm to the primary packing location. These factors were affected by the non-controlled transportation temperature (Table 3). Strawberry and tomato food losses were affected by 8 out of 16 explanatory variables (Table 3). The high quantity of tomato losses reported here and in earlier studies is possibly associated with the packing and distribution (Abera *et al.*, 2020; Chaboud and Moustier, 2021). Strawberry and tomato seasons are directly affected by hot weather in the farm, which causes technical difficulties for transportation (Sasaki *et al.*, 2021b). Moreover, tomato trade characteristics have a limited window especially if it must be transported long distances. Packing is affected by the fruit characteristics like color, size, shape, and optimal conditions to distribution, as strawberry and tomato trade has very rigorously policies associated to national and international markets. Packaging systems play an essential role in the logistic chain for protecting, labelling, and stacking of valuable or fragile perishable commodities (Sasaki *et al.*, 2021a). Our results were positively affected by this variable showing high food losses in packaging step. Farm owner education has significant impact to mitigate food losses all along harvest and distribution stages (Table 3).

Oranges and mangos had the highest food losses estimates, related to different variables (Table 3). One of them is hot weather in the farm (Table 4) causing high food losses (Tang *et al.*, 2020; Liu *et al.*, 2022). Refrigerated distribution of perishable food is required, but almost no cooling practices are done at any stage of the chain in the studied municipalities. Some producers transport their produce to the local market covered with available materials to reduce exposure to the sun. The lack of optimum temperature management positively influences the food losses volume in the distribution stage in all the commodities assessed. There was a significative difference among the level of transportation and its influence on food losses. In 2007 clarified that during transportation the commodities should be

Table 2. Food losses estimation of commodities at harvest and distribution step.

Commodity	Supply chain step losses		Food losses Ton (%)
	Harvesting Ton (%)	Distribution Ton (%)	
Asparagus	2,638 (9.5%)**	659 (2.3%)	3,297 (11.8%)
Strawberry	378 (5.6%)*	201 (3%)	579 (8.5%)
Mango	1,540 (18%)**	673 (8%)	2,213 (26%)
Orange	6451 (12.8%)**	2,481 (5%)	8,932 (17.8%)
Tomato	2,223 (2.5%)**	794 (1%)	3,017 (3.5%)

Results are the mean in the municipalities. *, ** indicate significant differences ($p<0.05$) and highly significative difference ($p<0.01$), respectively, according to ANOVA, followed by a Tukey post hoc test ($p<0.05$) between supply chain step losses by commodity.

Table 3. Tobit model estimation results of the percentage of losses from asparagus, strawberry, orange, mango and tomato by farmland sector BCS, México.

Variable name / Parameter	Asparagus	Strawberry	Mango	Orange	Tomato
	t-value				
Intercept	−0.65	−1.12	−0.72	3.40***	−1.7
Farm size	1.53*	0.9	1.53**	0.53**	0.7
Farm size squared	−0.56	−0.56	−0.61	−0.03	−0.33
Number of employees	20.34	9.8123	12.34	11.09*	6.5612
Number of e. squared	−0.65	−0.35	−0.12	−0.08	−0.15
Packing in farm	1.32**	1.28*	0.35**	−1.12**	1.17*
Packing outfarm	1.91*	0.81***	0.73**	1.05**	0.91***
Farm location	0.23	0.03***	1.4***	0.5***	0.01***
Local distribution	−0.04	−0.12	−0.17	−0.07	−0.14
National distribution	1.17	2.34***	2.01	1.17	1.34***
International distribution	0.61	3.71***	1.63	0.8	4.56***
Farm owner education	1.32*	0.31	0.13	0.04	0.43
Gender	1.78*	0.72*	0.23	1.62*	0.61**
Employee technical training	0.11	0.23	1.4**	0.3**	0.15
Transportation temperature control	−1.77*	−5.89**	−2.55*	−3.77*	−7.89**
No transportation temperature control	1.95*	1.37*	3.47**	3.8**	2.15*
Sorting for bioactive compounds	0.16	0.27	0.4567	0.23	0.78

*Significant at 0.10; ** Significant at 0.05; *** Significant at 0.01.

packaged and stacked to avoid excessive movement (Rehman *et al.*, 2007). A commonly explanatory variables is the kind of cultivation, harvesting method, according to collected data analysis these commodities have harvesting time associated to farm size, collecting type and employee technical training (Table 3), among other factors that increase food losses in the farm. It was reported that food losses volume was significantly influenced by farmland size, use of water and these factors influence the emissions (Karthikeyan *et al.*, 2020; Qin and Horvarth, 2022). However, the latter also found a negative correlation between the crop size and food losses is that is using a high level of sensor technology to irrigate.

The ordered probit results suggested that farm owners are interested in sorting food losses to produce bioactive compounds and this decision was positively influenced by socio-economic and demographic factors (Table 4). Those that are more likely to sort food losses for the obtaining bioactive compounds have a technical training in agriculture or university degree. The results are consistent with expectations that education favors higher environmental awareness and encourages behavior consistent with environmentalism (Arslan, 2012). Respondents participating in the survey recognized they can convert food losses into a useful resource. The positive effect on farm owner's decision to separate food

Table 4. Ordered probit estimation results of the willingness to separate food loss for the purpose to obtain bioactive compounds.

Variable name /Parameter	Estimated coefficient	Standard error	t-value
Intercept	−0.6789	1.1302	−0.65
Farm size	0.7892	0.0067	2.31**
Farm size squared	−0.0023	0.0567	2.09*
Number of employees	0.3781	0.0124	1.20*
Number of e. squared	−0.7821	0.2301	−1.18*
Packing in farm	−0.6283	0.3201	−3.45***
Packing outfarm	−0.5674	0.1569	−0.62**
Farm location	0.1173	0.2583	0.34
Local distribution	−0.0105	0.1123	−0.63
National distribution	−0.6573	0.5743	−1.11*
International distribution	−0.2006	0.1893	−0.98**
Farm owner education	1.6743	0.1673	6.43***
Employee technical training	−0.5042	0.0981	−0.28*
Gender	−0.7823	0.0011	−4.85***

*Significant at 0.10; ** Significant at 0.05; *** Significant at 0.01.

losses seems to capture the attitudes of individuals who have human resources available in the farm and therefore have more flexibility of schedule.

Food loss estimation

There was a significant difference between losses during harvesting and distribution, accounting for 2.5%-18% and 1-8%, respectively (Table 2). This represents food loss between 3.5% and 26% in the commodities across the supply chain. The crops with the lowest losses were tomato and strawberry with losses of 2.5% and 5.6% during harvesting, respectively. Mango presented an interesting case. More than 3.5% of the total mango produced was left in the field, with an estimated loss of 3,017 ton over the whole season of mango produced in total. During harvesting, ripe mango fruit fall off the tree, crashed on the ground, becoming inedible (Zhang *et al.*, 2019). Losses of mangos pointed out the important need for proper food loss definition. In the actual loss definition ripe mango not intended to be harvested and therefore not intended for human consumption is considered a loss (FAO, 2019).

Results showed that losses vary significatively ($p<0.05$) between crops during the harvesting and distribution stages. The loss volume of asparagus during distribution was highly significatively different ($p<0.01$) with respect to the losses in the distribution with the differences between 2,638 ton to 659 ton approximately. The same case has been shown for strawberry, mango, orange, and tomato (Table 2).

In Baja California Sur desert, geographical location plays an import role in the commodities distribution, associated with weather and the conditions of storage, both in marketability and in food loss (Widener, 2018). Recent studies show that geographical proximity is beneficial for food supply chains, especially with regard to transport time, due to the short farm-to-market transport time, decreasing the probability of losses (Widener, 2018; FAO, 2019; Zhang *et al.*, 2019).

In México there are no geographical limited studies about food losses. Our study pointed up causes of small and large farm food losses generation in a desert region with critical weather conditions. Commodities assessed showed a different losses behavior which has crucial impact to future treatments and facilities to use all nutrients and compounds of food losses.

CONCLUSIONS

Characteristics of agricultural desert system in BCS state peninsula achieved to estimation the amount of food losses of five commodities. Food losses share in both categories decrease as the farm size increased, strongly suggesting that the smaller farms may be a primary source of food losses. Rural farm owners of desert in BCS peninsula with asparagus, strawberry, mango, orange and tomato commodities, with large farms and a high employee number are likely to sort their food losses for the purpose of obtaining bioactive compound. The willingness to undertake sorting is essential in using food losses in BCS state peninsula.

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