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Guidelines on the measurement of harvest and post-harvest losses

Findings from the field test on estimating harvest and post-harvest losses of fruits and vegetables in Mexico

FIELD TEST REPORT



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Abstract

This technical report provides findings of field test conducted in identified states/districts/municipalities/study area in Mexico on the basis of sampling methodology for estimation of post-harvest losses of horticultural crops (fruits and vegetables) developed by the team led by Dr. Tauqueer Ahmad, Head, Division of Sample Surveys, Indian Agricultural Statistics Research Institute, Institute of Indian Council of Agricultural Research (ICAR-IASRI), New Delhi, India. The Technical Report entitled “Findings from the field test conducted on estimating post-harvest losses of fruits and vegetables in Mexico” contains details of findings of the developed methodology implemented in Mexico, including challenges encountered and lessons learnt. It is expected that this report will help the users from different countries in designing surveys for measurement of post-harvest losses of horticultural crops (fruits and vegetables).

In collaboration with:

Global Strategy to Improve Agricultural and Rural

Division of Sample Surveys Indian Council of Agricultural Research (ICAR)-Indian Agricultural Statistics Research Institute (IASRI)

Instituto Nacional de Estadística y Geografía, México

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1. Introduction

1.1 Background and genesis

Over the last two decades, the quantity and quality of agricultural statistics have undergone a serious decline. Many countries, especially the developing world, lack the capacity to produce and report even the minimum set of agricultural statistics required to monitor national trends.

The Global Strategy to Improve Agricultural and Rural Statistics (GSARS) provides the framework essential to meet the current and emerging data requirements and the demands of policy makers and other data users so that they can fill these urgent needs. The Statistics Division of Food and Agriculture Organization of the United Nations (FAO), Rome has established a global office to lead and coordinate the implementation of Global Strategy to Improve Agriculture and Rural Statistics adopted by United Nations Statistical Commission 2010.

One of the key programmatic areas of FAO is the measurement of country's progress towards achieving Sustainable Development Goals (SDG). SDG 12.3 has set the target that "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses." The target is two-fold and requires different approaches and thus separate indicators to focus first on the 'reduction of losses along the food production and supply chains' (supply oriented) and second on measuring 'halving per capita global food waste at the retail and consumer level' (demand oriented). The target and indicator belonged to Tier III, i.e. those indicators for which an internationally agreed methodology is not yet developed, and data are largely unavailable. FAO adopted a two-pronged approach for addressing the lack of data i) by improving data collection ii) and by using estimation methods for data gaps.

The FAO organized an Expert Consultation on SDG 12.3 – Measurement and action to meet the target on reducing food losses and food waste held at FAO headquarters, Rome, Italy during 28–29 September 2017 in which the Indian Agricultural Statistics Research Institute, institute of Indian Council of Agricultural Research (ICAR-IASRI) was invited as an expert in view of his experience of developing a sampling methodology for estimation of post-harvest losses for 45 crops and commodities that include grains, fruits, vegetables, milk, meat and fish for India. The advantage of this methodology is that though it is developed for India, but it is applicable world-wide.

In 2018, FAO, has developed a sampling methodology for estimating harvest and post-harvest losses of cereals and pulses using a double sampling approach, which was published in the Guidelines for countries to implement cost-effective data collection and improved methods for estimating losses of grains (FAO, 2018). In 2017, FAO initiated a collaboration with ICAR-IASRI to meet the growing demand from countries for methodological orientation and technical assistance in form of three guidelines on (i) fruits and vegetables, (ii) milk & meat, and (iii) fish and fish products.

Each guideline captures the differences in the measurement methods, economic actors, value chains, sampling design, sample size and estimation procedure which are different across commodity group and sub-sectors. The primary objective is to identify, test and recommend cost-effective and statistically sound methods to measure post-harvest losses on and off the farm, i.e. among the value chain entities such as commercial producers, farmers, traders, transporters, processors, and others, to determine the extent of various types of losses at critical times. The ICAR-IASRI has developed sampling methodologies for the different commodity groups and corresponding three guidelines for estimation of post-harvest losses of fruits and vegetables, livestock (meat and milk) and fish products, that are published as annexes to the Guidelines on the measurement of harvest and post-harvest losses in cereals and pulses. The collaboration included field testing of the developed methodology in two to three countries.

1.2 Objectives

Main objectives of the field testes on fruits and vegetables in Mexico:

- To test whether operational definitions are relevant and applicable
- To test the proposed approach of sampling design and questionnaire design
- To test primary data collection based on the guidelines for a limited number of commodities, critical loss points and sample size

1.3 Approach

The focus of the suggested measurement approach for harvest and post-harvest food losses is on combining inquiry and actual measurement methods for statistical pooling and using a sample survey approach. The developed methodology was tested for fruit and vegetables in Mexico, keeping in view the country's existing agricultural statistics system. The primary data collection was carried out through Computer Assisted Personal Interviewing (CAPI).

The developed guidelines were tested in Mexico with the technical and financial collaboration with the National Institute of Statistics and Geography (*Instituto Nacional de Estadística y Geografía*, INEGI). The fruits and vegetable guidelines were developed based on ICAR-IASRI experience in designing and applying surveys (face-to-face interviews) and direct measurements (taking samples of the product in the field) of food losses in India.

1.4 Study area and crops covered

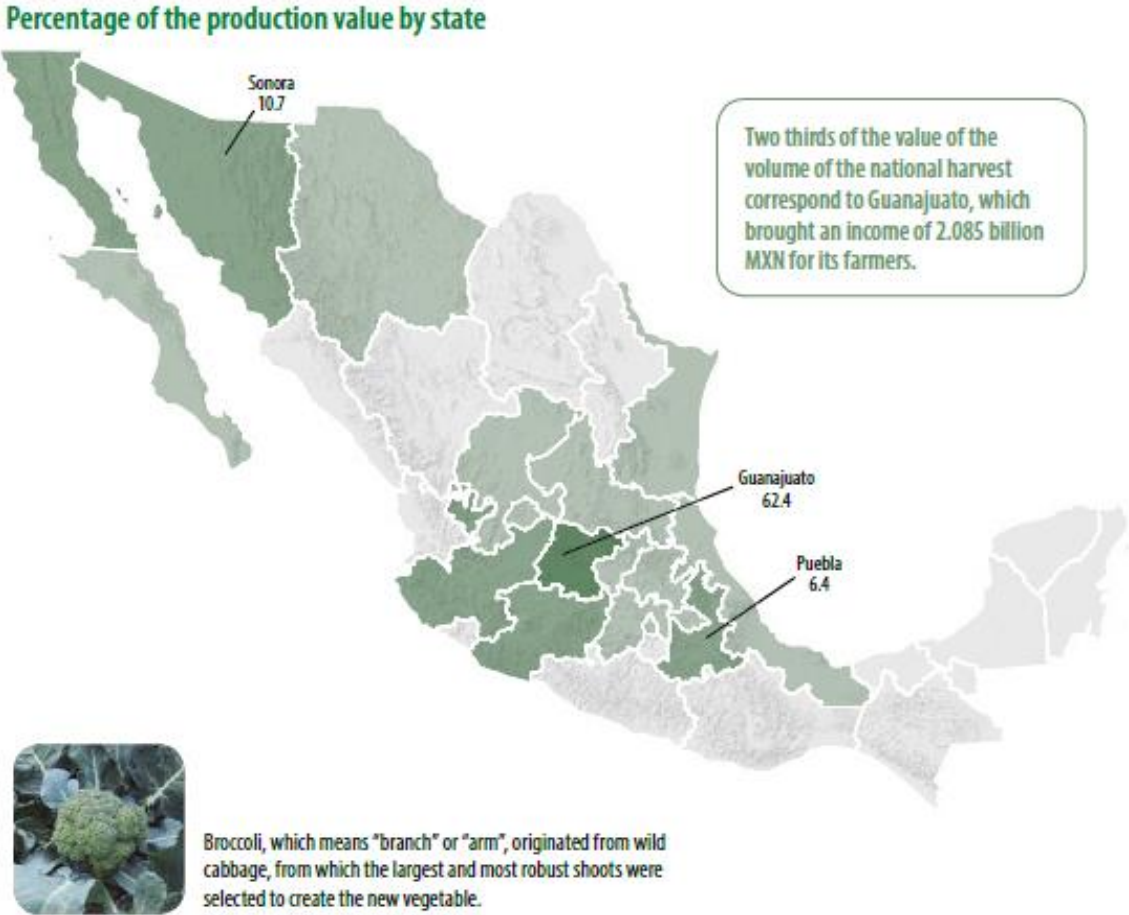
According to the latest data from 2018, Mexico is the sixth largest producer of fruits and vegetables in the world with a total of 38 million tonnes per year (FAOSTAT, Fruits and vegetables, 2018). Climate advantages and an increasing demand for export are the main factors for a growing fruit and vegetable sector in Mexico during the last decade. For the vegetable production, Mexico cultivates over 95 000 hectares, mainly dedicated to green chili, tomatillo, and tomato. In the production of fruits, over 150 000 hectares are cultivated mainly for mango, orange, avocado, lime, strawberry, and watermelon (SIAP, Food and Agriculture Atlas (2012–2018)).

To some extent, the producers' profit from favorable climate, which allows them in some parts of the country to produce fruits and vegetables all year round. The country is divided into temperate and tropical zones. Land north of the twenty-fourth parallel experiences cooler temperatures during the winter months whereas South of the twenty-fourth parallel, temperatures are fairly constant year-round and vary solely as a function of elevation. Mexico has pronounced wet and dry seasons. Most of the country experiences a rainy season from June to mid-October and significantly less rain during the remaining year. February and July generally are the driest and wettest months, respectively.

The agricultural sector in Mexico, including fruits and vegetable production, is characterized by the coexistence of large-scale producers on the one hand, and medium and small-scale producers on the other hand, with important differences in their production systems. In the present study, two states namely Jalisco and Guanajuato were identified for data collection. Jalisco is divided into 125 municipalities and Guanajuato into 46 municipalities. In Jalisco State, Cihuatlán municipality was identified for data collection on post-harvest losses of banana crop whereas in the State of Guanajuato, three municipalities viz. Dolores Hidalgo, San Miguel de Allende and Valle de Santiago were identified for data collection on post-harvest losses in case of broccoli.

Mexico is the sixth producer of broccoli worldwide with 575 000 tonnes per year, of which Guanajuato produces 62.4 percent.

Map 1 : Percentage of the production value by state (Sonora, Guanajuato, Puebla)



Source: Servicio de Información Agroalimentaria y Pesquera (SIAP), Food and Agriculture Atlas (2012–2018), Mexico.

In terms of banana production, Mexico produces around 2.1 million tonnes per year, being the 12th producer worldwide. The country’s main producer states are Chiapas and Tabasco, while Jalisco with 173,000 tonnes is the fifth producer behind Colima and Veracruz. Jalisco was chosen for the pilot testing due to operational reasons of the data collection and proximity to Guanajuato.

Map 2 : Percentage of the production value by state (Chiapas, Colima and Tabasco)

Percentage of the production value by state



Source: SIAP, Food and Agriculture Atlas (2012–2018), Mexico.

2. Field Survey

This chapter provides the details of the preparation work for the field survey undertaken in Mexico, including the definitional framework used, the preparation of the questionnaires, listing, as well as the sampling details relating to field testing in the context of estimation of post-harvest losses of fruits and vegetables.

2.1 Definitional framework

For the field test on fruits and vegetables food loss measurement, the operational definition presented in the grain guidelines was used as an orientation to harmonize and facilitate data collection across commodity groups.

Food loss definition: The definitional framework measures any quantity of food that is withdrawn from the supply chain in any point from harvest up to retail level, independently of its intentionality. Pre-harvest losses occur from the mature produce prior to harvesting and are mostly related to diseases, insects, pests and biological or climatic reasons (not included in the food loss framework). Harvest losses are the quantities removed during the harvest operations. Post-harvest losses relate to any operation conducted after the produce was harvested and include grading, cleaning, packaging, transportation, storage, and processing.

It was noted throughout the field test that, compared to cereals and pulses, fruits and vegetables require additional specifications on how to set the boundary between pre-harvest, harvest and post-harvest losses. On the one hand, fruits and vegetables that are affected by pre-harvest causes are still harvested and brought to post-harvest, where they are either used for secondary quality markets or eventually sorted out due to damages. On the other hand, it is more common in fruits and vegetables that produce fit for human consumption is left on the field for different reasons (market quality, market prices, harvesting practice, etc.). Some of these definitional details had to be adjusted during the field test implementation.

Another aspect of food loss in fruits and vegetables is how to treat produce that is sorted out and sold as secondary quality to the food industry, to animal feed or other non-food uses. In general terms, food that is fed to animals is not included as a loss, nor is any other utilization (e.g. fruits going to processing for juice or other value-added products). It was observed in fruits and vegetable supply chains that actors apply sophisticated strategies to allocate the produce to diverse economic destinations, from different fresh markets (exportation, wholesale markets, local markets), to different processed produce (frozen, juice processing), and as animal feed. In some cases, very mature produce was still sent to the juice industry, wherefore it should not be included in food losses beside of its advanced over-mature state. In other cases, packaging firms applied several steps to reuse the produce, starting with cutting and packaging of the produce not fit for fresh markets, and selling the chopped parts to the industry. Some of these complex reutilization strategies were difficult to capture during the field test and require more precise definitions and adjusted questionnaires.

Supply chain definition: The field test covered data collection from on-farm (harvest and on-farm post-harvest operations), rural collection centers and packaging firms, food industry, up to wholesalers and retailers. It became paramount to conduct supply chain analysis prior to the data collection to better define stages and economic entities covered by each stage, as well as to prepare complete listings (especially on retailers, wholesalers, packaging industry, logistic firms and cold storage). It can be complex to distinguish the entities in the fruits and vegetable supply chains, since companies are integrated or fulfill similar roles in the supply chain (for instance to distinguish wholesalers from retailers, rural collection centers from packaging firms and cold storage providers). Supply chain analysis are also helpful to identify what operations are conducted by which stage and actor. In the field test, processing operations were not considered for most supply chain stages but resulted relevant in rural collection centers and packaging firms.

2.2 Questionnaires used in the study

Questionnaires were developed for data collection and pre-tested in the identified study area of the country to examine the suitability. The computer-assisted personal interviewing (CAPI) version of these questionnaires were developed and translated from English into Spanish. Questionnaires were developed as stand-alone instruments for i) listing, ii) on-farm food losses, and iii) off-farm food losses.

Questionnaire 1: Listing of sampling units

Questionnaire 1 was prepared for listing of fruits and vegetables growers, processors, cold storage, wholesalers, and retailers in each of the selected enumeration area/village/municipality. In the case of Mexico, listing at producer level was updated by INEGI in 2016 in preparation of the agricultural census (INEGI, 2016), wherefore no further listing was needed at producer level. A sample of fruits and vegetables plots was selected randomly for data collection by inquiry and actual measurement.

For listing of cold storages and processing units dealing in the fruits and vegetables in the selected district/state, these can usually be obtained from secondary sources or prepared if not available. For the field test, INEGI's business registers were used for listing storage and processing units. It is important to mention that small and medium scale units were underrepresented, as informality is common in rural areas. Agricultural census does not cover these economic units, while the economic census only covers large scale industries in rural areas. Achieve a better listing might be an important step to be analyzed in preparation of off-farm data collection on post-harvest losses, as data gaps in business registers on these stages of the value chain are a common problem.

Similarly, listing of fruits and vegetables wholesalers and retailers might be obtained from economic offices of each selected fruits and vegetables markets or prepared if not available. As wholesalers and most retailers are concentrated in semi-urban or urban areas in Mexico, more updated registers and economic census data was available (although retailers in rural areas are probably underrepresented). A sample of cold storages, processing units, wholesalers and retailers was selected randomly for data collection by inquiry and actual measurement.

During this field test in Mexico, this first questionnaire on listing of economic units was only used to identify all wholesalers within a certain wholesale market that trade broccoli, as administrative data from the wholesale markets was aggregated for either fruits or vegetable wholesalers.

Questionnaire 2 On-farm: Information of loss during different operations of harvest and post-harvest of fruits and vegetables (applicable for both) at producer level (on-farm) by inquiry and actual measurement

In this questionnaire, loss during different operations i.e. plucking/harvesting, collection/grading/packaging, transportation and storage of fruits and vegetables crops grown by selected fruits and vegetables growers were collected by inquiry and actual measurement during the field test in Mexico. The questionnaire separates for inquiry, applied to the whole sample, and actual measurement, applied on a sub-sample only.

To be able to analyze food loss data collected, additional indicators were recorded with the questionnaire:

- a) Harvest: Total area operated, crops grown, methods of operation, weight (kg) of fruits/vegetables plucked / harvested
- b) Post-harvest: Quantity handled (kg) in the different post-harvest operations on-farm mode of transport, transported as loose/boxes, type of storage, quantity transported/ handled/stored

- c) Moisture and temperature
- d) Quantity loss (kg), weight (kg) of damaged fruits during operations, left over fruits/vegetables under selected trees/ Crop Cutting Experiments (CCE) plot, cause of loss is to be recorded

The field test provided useful insights for further developments of harvest and post-harvest on-farm questionnaires. The most relevant conclusion is the additional specifications required to better separate pre-harvest from harvest losses. These include precise formulations of the questions and detailed instructions for the enumerators to identify possible errors in the farmer's declarations, since it was noted that farmers tend to refer to pre-harvest losses when asked for harvest losses. Additionally, the destination markets of the produce can contribute considerably to understand differences in the harvest practices, grading criteria and resulting food losses.

Questionnaire 3 Off-farm: Data on loss by inquiry and actual observation during transportation, storage and other processes of fruits and vegetables at wholesaler/ retailer/ cold storage/ processing unit level in the selected fruits and vegetables market/district

Losses of fruits and vegetables at cold storages, processing units, wholesale and retail level are to be collected in this questionnaire by inquiry and by actual measurement. These economic units realize several different processes to the fruits and vegetables which need to be captured, as grading, handling, processing, storage and transportation. These processes were integrated in the questionnaire by modules and asked for separately.

To be able to analyze food loss data collected, additional indicators were recorded with the questionnaire:

- a) Data on mode of transportation (rail/ road/ air), transported as loose/ packed/both, quantity (kg) transported,
- b) Mode of storage (loose or packed or both), type of storage, quantity (kg) stored/handled, humidity, temperature and causes of loss are to be collected.
- c) Loss (kg) out of total quantity handled in each process, food loss causes

Also for off-farm questionnaires, market destinations are relevant to understand differences in grading and food losses. In off-farm stages, several markets are supplied depending on the quality of the produce, resulting in a hierarchical reutilization strategy. Questionnaires should therefore cover these different destinations to single out quantitative food losses, at the same time it helps to understand qualitative losses¹. Additionally, it was observed that most entities conduct processing operations, which can be highly relevant for food losses and should be considered in the questionnaire design. One generic off-farm questionnaire was designed and applied to each of the off-farm stages, although it was concluded that stage specific modules could allow to capture some of the complexities of the operations and services the entities are specialized on (for instance hierarchical grading structure in packaging firms, different levels and sequences of transportation conducted by wholesalers, different processing operations in the food industry).

2.3 Training imparted

The training for data collection was imparted to the enumerators, supervisors, and officials of INEGI, at INEGI office, Aguascalientes, Mexico by ICAR-IASRI. It was designed for five days, which included two days' classroom training, two days' field training and one day for final feedback. The classroom

¹ Qualitative food losses occur when produce meant for a certain market (fresh markets, export markets) is rejected from this market and sent to a secondary quality market (processing, animal feed). Qualitative food losses often result in economic losses due to lower prices paid for the lower quality of the produce.

training focused on concepts and definitions, sampling methodology and operations/channels of post-harvest losses of fruits and vegetables. The method of data collection from all the selected entities i.e. producers, wholesalers, retailers, cold storage, and processing units, as well as the related Crop Cutting Experiments (CCE) for fruits and vegetables were explained in detail. The data was to be collected using CAPI, a Survey Solution Software, therefore, the CAPI version of the questionnaires and hands-on using Tablets were explained. The training was realized with the help of a translation service to facilitate communication.

The field exercise for measuring post-harvest losses by inquiry and actual measurement was realized in Pabellón de Arteaga and in Calvillo, both close to the city of Aguascalientes. To train the vegetable questionnaire and crop cutting experiments, strawberry had to be used, as broccoli was out of season when the training was imparted. The fruit instruments were trained on guava orchards, as banana is not produced in and near Aguascalientes.

The pre-testing of questionnaires with strawberry growers were done in the field. Afterwards, the method of CCE in the field was demonstrated. Demarcation of CCE plot was practiced by the enumerators in the field. Harvesting was done in the demarcated plot, followed by sorting and grading. The damaged and undamaged produce were weighed by the digital weighing balance being carried by the enumerators. Pre-testing of on-farm questionnaires of fruits was done in guava orchard. The method of CCE for guava in the identified orchard was demonstrated. Selection of trees and marking of selected trees was practiced by the enumerators in the field. Harvesting of Guava was done from the selected trees. Then, sorting and grading were performed, and the damaged and undamaged produce were weighed.

Harvest and post-harvest losses at producer level were recorded by inquiry as well as actual measurement methods by the enumerators using Tablets. The enumerator's doubts arising during the process of testing were clarified.

After fruit on-farm testing of questionnaires, pre-testing of off-farm fruit questionnaire was done at a packaging center. Data on quantity handled and loss along with other information were recorded from the owner and operator of the packaging center, both by inquiry as well as by actual measurement. Additionally, pre-testing of off-site questionnaire was done at the wholesale market in Aguascalientes. Data on quantity handled and loss along with other information was recorded from one banana wholesaler in a wholesale market and data was collected both by inquiry as well as by actual measurement.

A classroom feedback session was organized to clarify the doubts and queries of the enumerators after pre-testing of questionnaire in the field. Main doubts needed to be clarified on the concrete boundaries between pre-harvest, harvest and post-harvest losses to consider, as for instance in Guava all fruits are harvested and grading is done afterwards, while the grading in strawberry already is partly done during harvesting. Several comments were done on the questionnaire to adapt to local context. For the Crop Cutting Experiments, method of selection needed to be clarified after the field test. To solve doubts on the functionalities of the CAPI, an online demonstration was done. Enumerators practiced the CAPI version of questionnaires based on field training.

The required sample size was decided for each operation/channel for both fruits and vegetables. The listing of producers already done by the INEGI office for both fruits and vegetables were discussed in detail. The need of updating listing or questionnaires was explained to the officers and enumerators. After discussion, the future plan of data collection in two identified states were finalized. Adjustments to the questionnaires were done based on the pre-testing results, of which most related to adjusting the questions to the national context, adjusting some functionalities as autocomplete controls, and simplifying some sections. The final CAPI version of questionnaires was generated and provided to the INEGI officers and enumerators.



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2.4 Control of non-sampling errors

Data quality aspect is an important consideration in all surveys including agricultural surveys. For data quality in food losses, providing extensive training to the enumerators/supervisors is key, as shown by the doubts raised regarding the definition and boundaries of food losses to be applied in inquiry and actual measurement. Further, supervision of field work was carried out by INEGI officials to keep the data quality intact. The data was captured electronically to monitor the progress of data collection, and data quality. Furthermore, the use of CAPI software saved the data entry errors as well as minimized the data collection errors. The actual measurement was adopted to measure the losses on a sub-sample of the selected sample to improve data quality by statistical pooling of both food losses declares and directly measured.

2.5 Sampling and data collection

Sampling frame

The study was carried out in one municipality of Jalisco for banana and three municipalities of Guanajuato for Broccoli in Mexico. As mentioned above, listing of producers for on-farm operations/channels was already done by INEGI for all four municipalities which could be used for selection of sample of producers. However, listing of off-farm operations/channels was carried out during the course of main/detailed on-farm survey.

Sampling design

In view of the administrative structure of the country, sampling design used for selection of sample for all operations during field testing in Mexico was uni-stage sampling i.e. Simple Random Sampling Without Replacement (SRSWOR). For the feasibility of the study, municipalities were already pre-selected to assure harvest is in process. However, in the case of adoption of the methodology to national level, the sampling design may be designed as presented in the Guidelines on harvest and post-harvest food loss measurement.² In the case of Mexico, sampling design on-farm at national level could be a stratified two stage sampling design treating the states as strata, municipalities as first stage units, and the plots in the selected municipalities as second stage or ultimate stage units. At off-farm level, sample design could be a stratified two stage sampling design treating the states as strata, municipalities as first stage units and wholesalers, retailers, cold storage, processing units etc. in the selected districts as second stage or ultimate stage units. This sampling design might be complemented in some cases with a list frame of off-stage large-scale entities that are included in the surveys with certainty given their relevance. This sampling design might vary depending product-specific context.

It is important to highlight, that in the sampling design actual measurement implies an additional sampling stage, whereby a sub-sample is selected out of the sampling units identified for inquiry. Actual measurement on-farm need harvest processes to be realized the moment the growers are visited. For this reason, the coordination for data collection resulted to be complex and replacements needed to be sampled for direct measurement, as various producers were not harvesting during the period the field test was conducted. In most cases, actual measurement at harvest and post-harvest grading and handling could be realized together, while on-farm transportation and storage proceeded at the end of the day, implying a second visit for the enumerators.

² To be published on FAO's SDG-indicators Portal (under Guidelines): <http://www.fao.org/sustainable-development-goals/indicators/1231/en/>

Estimation procedure

The detailed estimation procedures are given in the FAO Guidelines on estimating harvest and post-harvest food losses for the countries to adopt in general³. In the case of the field test, the estimation procedures were realized as per the used uni-stage sampling design mentioned in section 2.4.2. In this regard, estimates are provided at municipality level. As part of the estimation procedure, sample results need to be extrapolated to represent municipality food losses. Following the proposed sampling design, the extrapolation factors, or sampling weights, correspond to the inverse of the share of the selected plots/units in the total population of units in the corresponding municipality. In the case of actual measurements, the procedure is similar to loss estimates by inquiry. The only difference lies in the additional sampling step (selection of a sample of fruit-bearing trees among the sample of orchards), which must be reflected in the estimation equations by adding the corresponding extrapolation factor. When food loss estimates are obtained from inquiry and actual measurement, statistical pooling is realized as a method to combine estimates from declarations and physical measurements into a single estimate. This method is intuitive: it consists in taking a weighted average of the two estimates, giving higher importance to the estimate in which more confidence can be placed. In statistical terms, this means attributing weights to each variable that are inversely proportional to their respective share in the total variance. Further details are given in the guideline

Description of data collection

The data collection work was done with the help of 12 interviewers/enumerators, three supervisors and three support people. It was divided in two groups namely on-farm i.e. producer level and off-farm i.e. market level. At on-farm, the data was collected on harvest and post-harvest losses during harvesting/picking, cleaning/sorting/grading/packing, transportation to household/farm-level collection center and farm-level storage. While at off-farm level, the data was collected at transportation, storage, processing, wholesale, and retail. The photographs below show the data collection and losses captured in banana and broccoli at various channels both on-farm and off-farm.

Methods IT used for data collection

The questionnaires were designed with Computer-Assisted Personal Interviewing (CAPI). The operational manual was prepared for data collection for the benefit of field enumerators.

Period of data collection

The field test survey was implemented from 17.09.2018 to 30.09.2018.

Capturing food losses on-farm



All photos: ©INEGI

³ To be published on FAO's SDG-indicators Portal (under Guidelines): <http://www.fao.org/sustainable-development-goals/indicators/1231/en/>

Capturing food losses off-farm



All photos: ©INEGI

3. Results of the field test in Mexico

This chapter provides the results of food losses at harvest, post-harvest, up to retail level obtained in the field test. Sample sizes and representativeness of the results are limited, wherefore the results are to be taken with cautious and only as a general orientation.

3.1. On-farm results banana

Step 1: Results by inquiry (municipality of Cihuatlán)

Table 1 provides estimates of food loss percentage (%loss) by inquiry under different on-farm operations viz. plucking/harvesting, collection/grading/packaging and transportation from farm to storage at producer level in case of Banana in Cihuatlán municipality of Jalisco State along with available sample sizes, standard error (SE of food loss percentage) and percentage covariance (%CV) of estimates of percentage loss under each operation.

Table 1: Estimates of percentage loss under different on-farm operations in case of Banana for Cihuatlán municipality of Jalisco State by inquiry

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level
Sample size	54	21	27
% loss estimates	1.54	1.44	0.19
SE of %loss	0.47	0.48	0.15
%CV of %loss	30.39	33.60	76.37

Out of 54 sampled Banana orchard owners for inquiry, plucking/ harvesting, collection/ grading/ packaging and transportation operations are performed by 54, 21 and 27 orchard owners respectively. Based on these sample sizes, estimates of % loss during these operations are 1.54 percent, 1.44 percent and 0.19 percent respectively with 30.39 percent, 33.60 percent and 76.37 percent CV. The lower the estimated values, covariance levels tend to be higher.

Step 2: Results by actual measurement (municipality of Cihuatlán):

Table 2 provides estimates of percentage loss (%loss) by actual measurement under different on-farm operations viz. plucking/harvesting, collection/ grading/ packaging and transportation from farm to storage at producer level in case of Banana under Cihuatlán municipality of Jalisco State. Out of 28 sampled Banana orchard owners for actual measurement, plucking/harvesting and collection/ grading/ packaging operations are performed by 28 and 13 orchard owners, respectively. None of these sampled 28 Banana orchard owners perform transportation at producer level operation. Based on these sample sizes, estimates of %loss during plucking/harvesting and collection/grading/packaging operations are 3.69 percent and 1.71 percent respectively with 24.80 percent and 55.62 percent CV. It can be observed that food loss percentages are slightly higher for actual measurement compared to results obtained from inquiry.

Table 2: Estimates of percentage loss under different on-farm operations in case of banana for Cihuatlán municipality of Jalisco State by actual measurement

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level
Sample size	28	13	0
% loss estimates	3.69	1.71	-
SE of %loss	0.92	0.95	-
%CV of %loss	24.80	55.62	-

Step 3: Results from statistical pooling (municipality of Cihuatlán):

Table 3 provides optimum pooled estimates of percentage loss (%loss) using inquiry and actual measurement estimates under different on-farm operations. For transportation at producer level inquiry-based estimates are given. Using these estimates, overall on-farm food loss percentage is also computed. It can be seen that pooled estimates of food loss percentage during these operations are

1.98 percent, 1.50 percent and 0.19 percent respectively with 20.99 percent, 28.83 percent and 76.37 percent CV. Overall on-farm food loss percentage estimate for banana is 3.67 percent with 16.81 percent CV, which is reasonably good at municipality level.

Table 3: Pooled estimates of percentage loss under different on-farm operations in case of banana for Cihuatlán municipality of Jalisco State

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level [§]	Overall
% loss estimates	1.98	1.50	0.19	3.67
SE of %loss	0.42	0.43	0.15	0.62
%CV of %loss	20.99	28.83	76.37	16.81

Note: §-Based on inquiry estimates only.

3.2 On-farm results broccoli

3.2.1 Municipality of Dolores Hidalgo

Step 1: Results by inquiry

Table 4 provides estimates of percentage loss (%loss) by inquiry under different on-farm operations in the case of Broccoli for Dolores Hidalgo municipality of Guanajuato state. Out of 25 sampled Broccoli plots for inquiry, these operations are performed by 25, 15 and 6 growers, respectively. Based on these sample sizes, estimates of %loss during these operations are 11.02 percent, 6.18 percent and 2.43 percent respectively with 25.12 percent, 41.60 percent and 83.23 percent CV. High percentage covariance is due to less sample size.

Table 4: Estimates of percentage loss under different on-farm operations in case of broccoli for Dolores Hidalgo municipality of Guanajuato State by inquiry

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level
Sample size	25	15	6
% loss estimates	11.02	6.18	2.43
SE of %loss	2.77	2.57	2.02
%CV of %loss	25.12	41.60	83.23

Step 2: Results by direct measurement

Table 5 provides estimates of percentage loss (%loss) by actual measurement under different on-farm operations viz. plucking/harvesting, collection/grading/packaging and transportation from farm to storage at producer level in case of Broccoli for Dolores Hidalgo municipality of Guanajuato State. Out of 7 sampled Broccoli plots for actual measurement, plucking/harvesting and collection/ grading/

packaging operations are performed by 7 and 2 orchard owners. None of these sampled 7 Broccoli growers perform transportation at producer level. Based on these sample sizes, estimates of food loss percentages during plucking/harvesting and collection/grading/packaging operations are 9.16 percent and 4.3 percent respectively with 46.90 percent and 48.39 percent CV. Here also, high CV is due to less sample size.

Table 5: Estimates of percentage loss under different on-farm operations in case of broccoli for Dolores Hidalgo municipality of Guanajuato State by direct measurement

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level
Sample size	7	2	0
% loss estimates	9.16	43.75	-
SE of %loss	4.30	21.17	-
%CV of %loss	46.90	48.39	-

Step 3: Results by statistical pooling

Table 6 provides optimum pooled estimates of percentage loss (%loss) using inquiry and actual measurement estimates under different on-farm operations in the case of Broccoli for Dolores Hidalgo municipality of Guanajuato State. For transportation at producer level inquiry-based estimates are given. Using these estimates overall on-farm food loss percentages estimate is also computed. Pooled estimates of food loss percentages during these operations are 10.47 percent, 6.73 percent and 2.43 percent respectively with 22.21 percent, 37.94 percent and 83.23 percent CV. Overall on-farm percentage loss estimate for broccoli is 19.63 percent with 20.38 percent CV.

Table 6: Pooled estimates of percentage loss under different on-farm operations in case of broccoli for Dolores Hidalgo municipality of Guanajuato State

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level [§]	Overall
% loss estimates	10.47	6.73	2.43	19.63
SE of %loss	2.33	2.55	2.02	4.00
%CV of %loss	22.21	37.94	83.23	20.38

Note: §- Based on inquiry estimates only.

3.2.2 Municipality of Valle Santiago

Step 1: Results by inquiry

Table 7 provides estimates of percentage loss (%loss) by inquiry under different on-farm operations in the case of Broccoli for Valle de Santiago municipality of Guanajuato State. Out of 80 sampled Broccoli growers for inquiry, these operations are performed by 80, 54 and 12 growers, respectively. Based on these sample sizes, estimates of food loss percentages during these operations are 6.12 percent, 11.62 percent and 1.10 percent respectively with 33.24 percent, 43.40 percent and 88.22 percent CV.

Table 7: Estimates of percentage loss under different on-farm operations in case of broccoli for Valle de Santiago municipality of Guanajuato State by inquiry

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level
Sample size	80	54	12
% loss estimates	6.12	11.62	1.10
SE of %loss	2.04	5.05	0.97
%CV of %loss	33.24	43.40	88.22

Step 2: Results by direct measurement

Table 8 provides estimates of percentage loss (%loss) by actual measurement under different on-farm operations in the case of Broccoli for Valle de Santiago municipality of Guanajuato State. Out of 32 sampled Broccoli growers for actual measurement, plucking/ harvesting and collection/ grading/ packaging operations are performed by 32 and 18 orchard owners. None of these sampled 32 sampled Broccoli growers perform transportation at producer level operation. Based on these sample sizes, estimates of food loss percentages during plucking/harvesting and collection/grading/packaging operations are 34.69 percent and 39.80 percent respectively with 16.73 percent and 12.79 percent CV. These relatively high levels of losses can be explained, to some extent, by the very rainy climate which has affected this area in the period of the survey. The difference between actual measurements and inquiry-based estimates (the former being significantly higher than the latter) is partly due to the difficulty to establish clear boundaries between pre-harvest losses and harvest losses: the rainy climate prior to the survey led to a degradation in the condition of the produce, a high proportion of which was rejected at the time of harvest and accounted as harvest losses when in fact part of these losses are attributable to pre-harvest factors.

Table 8: Estimates of percentage loss under different on-farm operations in case of broccoli for Valle de Santiago municipality of Guanajuato State by actual measurement

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level
Sample size	32	18	0
% loss estimates	34.69	39.80	-
SE of %loss	5.80	5.09	-
%CV of %loss	16.73	12.79	-

Step 3: Results by statistical pooling

Table 9 provides optimum pooled estimates of percentage loss (%loss) using inquiry and actual measurement estimates under different on-farm operations in the case of Broccoli for Valle de Santiago municipality of Guanajuato State. For transportation at producer level, inquiry-based estimates are given. Using these estimates overall on-farm %loss estimate is also computed. It can be seen that pooled estimates of food loss percentage during these operations are 9.25 percent, 25.58 percent and 1.10 percent respectively with 20.76 percent, 14.01 percent and 88.22 percent CV. Overall

on-farm loss estimates for broccoli is 35.93 percent (with 11.63 percent CV) which is quite higher than Dolores Hidalgo municipality of Guanajuato State i.e. 19.63 percent (with 20.38 percent CV).

Table 9: Pooled estimates of percentage loss under different on-farm operations in case of broccoli for Valle de Santiago municipality of Guanajuato State

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level [§]	Overall
% loss estimates	9.25	25.58	1.10	35.93
SE of %loss	1.92	3.58	0.97	4.18
%CV of %loss	20.76	14.01	88.22	11.63

Note: §- Based on inquiry estimates only.

3.2.3 Weighted estimates of Dolores Hidalgo and Valle de Santiago

Table 10 provides weighted estimates of pooled estimates of percentage loss (%loss) of Dolores Hidalgo and Valle de Santiago municipality of Guanajuato State along with standard error and %CV of estimates of %loss in case of Broccoli under different on-farm operations viz. plucking/harvesting, collection/grading/packaging and transportation from farm to storage at producer level. For transportation at producer level inquiry-based estimates are utilized. Using these estimates overall on-farm %loss estimate is also computed.

Table 10: Weighted estimates of pooled estimates of percentage loss of Dolores Hidalgo and Valle de Santiago municipality of Guanajuato State under different on-farm operations in case of broccoli

Statistics	Plucking / Harvesting	Collection / Grading / Packaging	Transportation from farm to storage at producer level [§]	Overall
% loss estimates	9.78	17.41	1.67	28.86
SE of %loss	1.48	2.31	1.03	2.93
%CV of %loss	15.17	13.28	61.74	10.17

It can be seen that weighted estimates of %loss during these operations are 9.78 percent, 17.41 percent and 1.67 percent respectively with 15.17 percent, 13.28 percent and 61.74 percent CV. Overall on-farm %loss estimate for banana is 28.86 percent with 10.17 percent CV which is a reliable estimate at municipality level.

3.3 Off-farm results banana

3.3.1 Wholesalers in Jalisco State by inquiry

Table 11 provides estimates of percentage loss (%loss) by inquiry under different off-farm operations by wholesalers in case of Banana for Jalisco State. Out of 4 sampled Banana wholesalers for inquiry, these operations are performed by 4, 1 and 1 wholesalers, respectively. Estimates of food loss percentages during sorting/ grading/ re-packaging operation is 5.91 percent with 40.88 percent CV. Since there were single observation in the case of transportation and storage, food loss estimates were computed without covariance in these operations. Observed loss percentage in these operations is 4.71 percent and 0.00 percent based on single observation.

Table 11: Estimates of percentage loss under different off-farm operations by wholesalers in case of banana for Jalisco State by inquiry

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	4	1	1
% loss estimates	5.91	4.71	0.00
SE of %loss	2.42	-	-
%CV of %loss	40.88	-	-

Due to unavailability of actual measurement in the wholesaler channel in case of Banana in Jalisco State, pooling estimates of percentage loss are not obtained.

3.3.2 Retailers in Cihuatlán

Step 1: Results by inquiry

Table 12 provides estimates of percentage loss (%loss) by inquiry under different off-farm operations in the case of Banana under Cihuatlán municipality of Jalisco State. It can be seen that out of 3 sampled Banana retailers for inquiry, sorting/ grading/ re-packaging and storage operations are performed by 2 and 3 retailers respectively. None of these 3 sampled Banana retailers perform transportation operation. Estimates of percentage loss during sorting/ grading/ re-packaging and storage operations are 6.03 percent and 6.06 percent respectively with 2.01 percent and 1.71 percent CV.

Table 12: Estimates of percentage loss under different off-farm operations by retailers in case of banana for Cihuatlán municipality of Jalisco State by inquiry

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	2	0	3
% loss estimates	6.03	-	6.06
SE of %loss	0.12	-	0.10
%CV of %loss	2.01	-	1.71

Step 2: Results by actual measurement

Table 13 provides estimates of percentage loss (%loss) by actual measurement under different off-farm operations realized by retailers in case of Banana under Cihuatlán municipality of Jalisco State. It can be seen that out of 3 sampled Banana retailers for actual measurement, sorting/ grading/ re-packaging and storage operations are performed by 2 and 3 retailers respectively. None of these 3 sampled Banana retailers perform transportation operation. Estimates of %loss during sorting/ grading/ re-packaging and storage operations are 8.42 percent and 5.99 percent respectively with 92.76 percent and 43.91 percent CV.

Table 13: Estimates of percentage loss under different off-farm operations by retailers in case of banana for Cihuatlán municipality of Jalisco State by actual measurement

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	2	0	3
% loss estimates	8.42	-	5.99
SE of %loss	7.81	-	2.63
%CV of %loss	92.76	-	43.91

Step 3: Results by statistical pooling:

Table 14 provides optimum estimates of percentage loss (%loss) using inquiry and actual measurement-based estimates under different off-farm operations by retailers in case of Banana under Cihuatlán municipality of Jalisco State. Based on these pooled estimates at different operations, overall food loss estimates by retailers are calculated. None of the sampled Banana retailers perform transportation operation. Pooled estimates of food loss percentages during sorting/ grading/ re-packaging and storage operations are 6.03 percent and 6.06 percent respectively with 2.01 percent and 1.71 percent CV. Overall estimates of %loss during these operations are 12.09 percent with 1.32 percent CV which is a reliable estimate at municipality level.

Table 14: Pooled estimates of percentage loss under different off-farm operations by retailers in case of banana for Cihuatlán municipality of Jalisco State

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage	Overall
% loss estimates	6.03	-	6.06	12.09
SE of %loss	0.12	-	0.10	0.16
%CV of %loss	2.01	-	1.71	1.32

3.3.3 Cold storage in Jalisco State

Step 1: Results by inquiry

Table 15 provides estimates of percentage loss (%loss) by inquiry under different off-farm operations by cold storages in case of Banana under Jalisco State. Out of 3 sampled cold storages for inquiry,

sorting/ grading/ re-packaging, transportation, and storage operations are performed by 3, 2 and 3 cold storages, respectively. In case transportation loss percentage estimate is found to be 0 percent. Estimates of food loss percentages during sorting/ grading/ re-packaging and storage operations are 0.19 percent and 1.67 percent respectively with 83.73 percent and 88.30 percent CV.

Table 15: Estimates of percentage loss under different off-farm operations by cold storages in case of banana for Jalisco State by inquiry

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	3	2	3
% loss estimates	0.19	0.00	1.67
SE of %loss	0.16	-	1.47
%CV of %loss	83.73	-	88.30

Step 2: Results by actual measurement

Table 16 provides estimates of percentage loss (%loss) by actual measurement under different off-farm operations in the case of Banana under Jalisco State. Out of 3 sampled cold storages for actual measurement, sorting/ grading/ re-packaging, transportation and storage operations are performed by 3, 2 and 3 cold storages respectively. In storage, percentage loss estimate is found to be 0.00 percent. Estimates of percentage loss during sorting/ grading/ re-packaging and transportation operations are 2.00 percent, and 5.00 percent respectively with 76.38 percent and 100.00 percent CV.

Table 16: Estimates of percentage loss under different off-farm operations by cold storages in case of banana for Jalisco State by actual measurement

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	3	2	3
% loss estimates	2.00	5.00	0.00
SE of %loss	1.53	5.00	-
%CV of %loss	76.38	100.00	-

Step 3: Results by statistical pooling

Table 17 provides optimum pooled estimates of percentage loss (%loss) using inquiry and actual measurement-based estimates under different off-farm operations by cold storages in the case of Banana under Jalisco State. Based on these pooled estimates at different operations, overall percentage loss estimates by cold storages are calculated. Actual measurement-based estimates and inquiry-based estimates are utilized in case of transportation and storage operations. Pooled estimates of percentage loss during sorting/ grading/ re-packaging, transportation and storage operations are 0.21 percent, 5.00 percent and 1.67 percent respectively with 75.53 percent, 100.00 percent and 88.30 percent CV. Overall estimates of percentage loss during these operations are 6.88 percent with 75.83 percent CV.

Table 17: Pooled estimates of percentage loss under different off-farm operations by cold storages in case of banana for Jalisco State

Statistics	Sorting / Grading / Re-packaging	Transportation [@]	Storage ^{\$}	Overall
% loss estimates	0.21	5.00	1.67	6.88
SE of %loss	0.16	5.00	1.47	5.21
%CV of %loss	75.53	100.00	88.30	75.83

Note: @- Based on actual measurement estimates only, \$- Based on inquiry estimates only.

3.4. Off-farm results broccoli

3.4.1 Wholesalers in Valle de Santiago

Step 1: Results by enquiry

Table 18 provides estimates of percentage loss (%loss) by inquiry under different off-farm operations by wholesalers in the case of Broccoli under Valle de Santiago municipality of Guanajuato State. Out of 3 sampled wholesalers for inquiry, these operations are performed by 3, 3 and 1 wholesalers, respectively. Estimates of percentage loss during sorting/ grading/ re-packaging and transportation operations are 51.44 percent and 11.65 percent respectively with 20.11 percent and 96.11 percent CV. Since single observation was found in case of storage operation, the percentage loss observation was found 10.00 percent without any %CV.

Table 18: Estimates of percentage loss under different off-farm operations by wholesalers in case of broccoli for Valle de Santiago municipality of Guanajuato State by inquiry

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	3	3	1
% loss estimates	51.44	11.65	10.00
SE of %loss	10.35	11.19	-
%CV of %loss	20.11	96.11	-

Step 2: Results by direct measurement

Table 22 provides estimates of percentage loss (%loss) by actual measurement under different off-farm operations by wholesalers in case of Broccoli under Valle de Santiago municipality of Guanajuato State. Out of 3 sampled wholesalers for actual measurement, sorting/ grading/ re-packaging and transportation operations are performed by 3 and 1 wholesalers, respectively. None of these 3 sampled wholesalers perform storage operation. Estimates of percentage loss during sorting/ grading/ re-packaging operation is 31.83 percent with 28.31 percent CV. Since single observation was found in case of transportation operation, the percentage loss observed was found 0.00 percent without any %CV.

Table 19: Estimates of percentage loss under different off-farm operations by wholesalers in case of broccoli for Valle de Santiago municipality of Guanajuato State by actual measurement

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	3	1	0
% loss estimates	31.83	0.00	-
SE of %loss	9.01	-	-
%CV of %loss	28.31	-	-

Step 3: Results from statistical pooling:

Table 20 provides optimum pooled estimates of percentage loss (%loss) using inquiry actual measurement based estimates under different off-farm operations viz. sorting / grading / re-packaging, transportation and storage by wholesalers in case of Broccoli under Valle de Santiago municipality of Guanajuato State along with standard error and %CV of estimates of %loss under each operation. Based on these pooled estimates at different operations, overall %loss estimates by wholesalers are calculated. Inquiry based %loss estimates is utilized in case of transportation operation. Estimate %loss is not found in case of storage operation. Pooled estimates of %loss during sorting / grading / re-packaging and transportation operations are 40.29 percent and 11.65 percent respectively with 16.87 percent and 96.11 percent CV. Overall estimates of %loss during these operations are 51.94 percent with 25.21 percent CV.

Table 20: Pooled estimates of percentage loss under different off-farm operations by wholesalers in case of broccoli for Valle de Santiago municipality of Guanajuato State

Statistics	Sorting / Grading / Re-packaging	Transportation [§]	Storage	Overall
% loss estimates	40.29	11.65	-	51.94
SE of %loss	6.80	11.19	-	13.10
%CV of %loss	16.87	96.11	-	25.21

Note: §- Based on inquiry estimates only.

3.4.2 Retailers in Valle de Santiago

Step 1: Results by inquiry

Table 21 provides estimates of percentage loss (%loss) by inquiry under different off-farm operations viz. sorting / grading / re-packaging, transportation and storage by retailers in case of Broccoli under Guanajuato State along with available sample sizes, standard error and %CV of estimates of %loss under each operation. Out of 7 sampled retailers for inquiry, these operations are performed by 7, 3 and 1 retailers, respectively. Estimates of %loss during sorting / grading / re-packaging and transportation operations are 22.48 percent and 14.67 percent respectively with 37.28 percent and 19.00 percent CV. Since single observation was found in case of storage operation, the %loss estimate was found 20.00 percent without any %CV.

Table 21: Estimates of percentage loss under different off-farm operations by retailers in case of broccoli for Guanajuato State by inquiry

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	7	3	1
% loss estimates	22.48	14.67	20.00
SE of %loss	8.38	2.79	-
%CV of %loss	37.28	19.00	-

Step 2: Results by actual measurement

Table 22 provides estimates of percentage loss (%loss) by actual measurement under different off-farm operations by retailers in the case of Broccoli under Guanajuato State. It can be seen that out of 4 sampled retailers for actual measurement, sorting/ grading/ re-packaging and transportation operations are performed by 4 and 1 retailers respectively. None of these 4 sampled retailers perform storage operation. Estimates of percentage loss during sorting/ grading/ re-packaging operation is 15.19 percent with 64.29 percent CV. Since single observation was found in the case of transportation operation, the observed percentage loss was found 28.00 percent without any %CV.

Table 22: Estimates of percentage loss under different off-farm operations by retailers in case of broccoli for Guanajuato state by actual measurement

Statistics	Sorting / Grading / Re-packaging	Transportation	Storage
Sample size	4	1	0
% loss estimates	15.19	28.00	-
SE of %loss	9.76	-	-
%CV of %loss	64.29	-	-

Step 3: Results by statistical pooling

Table 23 provides optimum pooled estimates of percentage loss (%loss) using inquiry actual measurement-based estimates under different off-farm operations by retailers in case of Broccoli under Guanajuato State. Based on these pooled estimates at different operations, overall percentage loss estimates by retailers are calculated. Inquiry based percentage loss estimates are utilized in case of transportation operation. No food loss data was found in the case of storage operation, which indicates that it is not an operation retailers do in generally. Pooled estimates of percentage loss during sorting/ grading/ re-packaging and transportation operations are 19.39 percent and 14.67 percent respectively with 32.80 percent and 19.00 percent CV. Overall estimates of %loss during these operations are 34.06 percent with 20.39 percent CV.

Table 23: Pooled estimates of percentage loss under different off-farm operations by retailers in case of broccoli for Guanajuato State

Statistics	Sorting / Grading / Re-packaging	Transportation [§]	Storage	Overall
% loss estimates	19.39	14.67	-	34.06
SE of %loss	6.36	2.79	-	6.94
%CV of %loss	32.80	19.00	-	20.39

Note: §- Based on inquiry estimates only.

3.5. Summary

The results presented on food losses, although with limited representativeness and statistical robustness, provide some insights on how to improve data collection on food losses in fruits and vegetables based on sample surveys and combining declarations with actual measurement.

On-farm food loss of banana, with 3.67 percent, show relatively low levels of losses which can relate to the banana being harvested in bunches in a pre-mature state and less affected by harvest damages or low quality. Only some minor parts of the bunch are selected out before the banana is transported directly to collection centers or packaging firms. Data collection by enquiry and by actual measurement didn't face mayor difficulties during the field test and on-farm food loss estimates are relatively consistent between both methods, although with elevated coefficient of variation due to low percentage levels. Actual measurement is slightly higher than the estimates obtained by enquiry, which is commonly observed and is often related to producers underestimating actual food losses. Throughout the field test, bananas were less affected by pest, diseases, and climate, wherefore food losses do not vary, pre-harvest losses were low and harvest losses could be better observed.

Data collection of **on-farm food losses of broccoli**, on the contrary, accounts for most of the difficulties during the field test. Food loss estimates by enquiry show similar results for both municipalities of about 6 to 11 percent in harvesting and grading, but results by actual measurement diverge considerably and range from 10 to 43 percent. While the sample size of actual measurement was relatively low in Dolores Hidalgo, in Valle Santiago the field test achieved actual measures for almost 40 percent of the sample size by enquiry. Actual measurement in Valle Santiago estimates 35 percent of losses in harvesting and 40 percent of losses in grading. The elevated food loss results by actual measurement could be explained by the following factors: i) actual measurement took place during the harvest period that falls into the rain season, which is related to lower yields and quality of the produce, while the main harvest season of broccoli is in March/April. Producers declared average losses of both seasons, while actual measurement could only capture losses occurring during the rainy season, ii) during the field operation, rain affected the harvest operations and it became difficult to set the boundaries between pre-harvest and harvest losses under the high impact of climate. Therefore, higher loss estimates in actual measurement are most probably influenced by partly including pre-harvest losses, iii) to some extent, harvest and grading losses were difficult to separate, as grading is often conducted while harvesting (produce is left on the field), or next to the field. It should be analyzed whether to treat harvest and grading as one operation instead of a sequence of two operations (which means that food loss data of both will be averaged and not added).

Off-farm food loss estimates of banana at the wholesale and retail level show about 10-12 percent of losses (including grading, storage, and transportation) by enquiry. Actual measurement was difficult to implement, since the operations are conducted at different timings, wherefore sample sizes of some operations are low. The results obtained are relatively consistent with what was declared by the

wholesalers and retailers. As to be expected, losses in cold storage with about 2 percent are comparably low.

On the other hand, **off-farm food loss estimates of broccoli** resulted in about 50 percent at wholesaler and 34 percent at retailer level. These elevated food loss percentages can be related to climate-driven quality problems of the produce already identified on-farm. In general terms, sample sizes are lower and variability is known to be high in fruits and vegetable markets, which makes it more complex to obtain robust results for off-farm food losses. For actual measurement, difficulties arose to measure food losses for all operations conducted by wholesalers and retailers, especially on transportation and storage sample sizes are low. Adjusted strategies might need to be identified to facilitate actual measurement of these operations, as only small sample sizes could be obtained.

4. Lessons learnt

Previous supply chain analysis is key to design the questionnaire and sample design

As food losses are captured for the various operations on-site and off-site, it is key to have a general understanding of the different stages and their actors to adapt and adjust questionnaires and methods for data collection. In some stages, discarded food is reused in different ways (to elaborate frozen produce, for the fruit industry, or food processors) wherefore food losses are not identified straightforward, and questionnaires need to be adapted.

Special attention needs to be paid to define the boundaries between pre-harvest and harvest losses in fruits and vegetables, as it was shown that the commonly used definition based on cereals and pulses is not sufficient. To some extent, these boundaries are product and country specific and it is recommended to analyze these before designing the data collection.

In addition, stage boundaries might also be a relevant to review in detail. For instance, in broccoli, some producers do not harvest themselves. It is the buyer, generally a large-scale packaging or export company, who prefers controlling quality standards and harvest practices of their produce. In this case, although the farmer produced the broccoli, harvest and post-harvest food losses couldn't be collected.

Another example from the field test was a broccoli packaging industry, which receives the discarded fresh broccoli back that they have sold to the retailer. The packaging industry selects the produce which still fits for processing (frozen broccoli) but discards about 70 percent of the returned quantity. Especially for actual measurement, but also for data collection by enquiry, these types of operations and dynamics need to be identified previously to prepare enumerators and adjust questionnaires and methods, as needed.

A supply chain analysis can provide relevant information on these highlighted aspects relevant for food loss data collection and contribute to improve the questionnaire and sampling design. Field visits to dialogue with the actors along the various stages might also help to identify what is understood by food losses, as definitional differences are common and can affect data collection (especially by inquiry). For the questionnaires, it was seen that formulations should be chosen carefully.

Actual measurement requires adequate timing for data collection to be operational

To adequately capture harvest and post-harvest losses by actual measurement, timing of data collection needed to coincide with harvesting moments. However, in this study, data collection was restricted to only 15 days, wherefore harvesting could not be timed appropriately and several plots needed to be replaced in the sample. In addition, operations at each stage are distributed throughout the day or along various days (i.e. harvest, grading, storage, transportation). For this reason, data collection by actual measurement implies more than one visit by the enumerator to capture all operations. Due to this problem, it was not possible to collect sufficient data for all operations. As a result, the sample size for the estimation of harvest and post-harvest losses needed to be reduced, especially on actual measurement of post-harvest operations like on-farm transportation or storage.

Coherence between data collection by enquiry and actual measurement is key

Due to the highlighted complexity of multiple operations realized at each stage, actual measurement needs to be designed carefully. As actual measurement is a one-shot picture, it might be important to contextualize the data collection adequately to assure better coherence with the data collected by inquiry. For instance, in broccoli, enquiry referred to food loss during the last year. In the production area the field survey was conducted, several broccoli harvests are possible in a year, while the one selected for actual measurement was realized during the rainy season, a period known for higher losses. Data on the context the physical measurement is being implemented can help to understand difference to food loss results obtained by enquiry.

The coherence might also be affected, when actual measurement modifies the actual operations done at each stage for operational purposes. For instance, in some situations actual measurement captured grading and sorting directly after harvesting, although the actors do not sort at this point but at the collection center. Food losses might be double counted, if actual measurement is done additionally in the collection center and will diverge from data collected by inquiry.

Statistical pooling can help to improve food loss estimates

Both methods, food loss data collection by enquiry and by actual measurement face advantages and limitations for food loss measurement. In general terms, food losses collected by enquiry depend on how well the farmer or operator can declare their losses and apply the required definition (which might differ from what they would interpret as food losses). While food losses collected by actual measurement face the limitation to be exposed to circumstantial factors, as only a one-shot picture of food losses is provided. Nevertheless, the results obtained in the field test, although with a limited sample size, show that combining both methods through statistical pooling can help to improve food loss estimates, lowering standard errors (SE) and coefficients of variation (CV). Larger sample sizes could identify possible patterns between data collection by enquiry and actual measurement, as for instance a tendency to underestimate by enquiry and overestimate food losses by actual measurement.

Sufficient training is paramount to data collection

As food loss measurement is a relatively new concept to be included in sample surveys, and due to its complexity in terms of boundaries, reutilizations, destinations, detailed training is required at all levels i.e. headquarter, supervisors and enumerators. In this regard, the duration of classroom and field training may be increased compared to the 5 days training of the field survey. Special emphasis should be placed in the operational food loss definition for measurement and boundaries between pre-harvest, harvest, and post-harvest losses, as well as a detailed training of direct measurement methods for the various operations realized at each stage.

References

FAO. 2018. *Guidelines on the measurement of harvest and post-harvest losses in cereals and pulses.* (Available at: <http://www.fao.org/3/ca6396en/ca6396en.pdf>).

FAOSTAT. Fruits and vegetable production in 2018 (Available at: <http://www.fao.org/faostat/en/#data/QC>)

Instituto Nacional de Estadística y Geografía (INEGI). 2016. *Actualización del Marco Censal Agropecuario 2016.* (Available at: <https://www.inegi.org.mx/programas/amca/2016/>)

Servicio de Información Agroalimentaria y Pesquera (SIAP), Food and Agriculture Atlas (2012–2018) (Available at: https://nube.siap.gob.mx/gobmx_publicaciones_siap/pag/2018/Agricultural-Atlas-2018).

Guidelines on the measurement of harvest and post-harvest losses

Findings from the field test on estimating harvest and post-harvest losses of fruits and vegetables in Mexico

FIELD TEST REPORT

This technical report provides findings of field test conducted in identified states/districts/ municipalities/study area in Mexico on the basis of sampling methodology for estimation of post-harvest losses of horticultural crops (fruits and vegetables) developed by the team led by Dr. Tauqueer Ahmad, Head, Division of Sample Surveys, Indian Agricultural Statistics Research Institute, Institute of Indian Council of Agricultural Research (ICAR-IASRI) ICAR-IASRI, New Delhi, India. The Technical Report entitled “Findings from the field test conducted on estimating post-harvest losses of fruits and vegetables in Mexico” contains details of findings of the developed methodology implemented in Mexico, including challenges encountered and lessons learnt. It is expected that this report will help the users from different countries in designing surveys for measurement of post-harvest losses of horticultural crops (fruits and vegetables).