DOCUMENTOS
183

ISSN 1415-2312
Dezembro, 2020

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OBJETIVOS DE DESENVOLVIMENTO SUSTENTÁVEL
2 FOME ZERO E AGRICULTURA SUSTENTÁVEL

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Embrapa

ISSN 1415-2312
Dezembro, 2020

Empresa Brasileira de Pesquisa Agropecuária
Embrapa Hortaliças
Ministério da Agricultura, Pecuária e Abastecimento

DOCUMENTOS 183

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Embrapa Hortaliças
Brasília, DF
2020

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Dados internacionais de Catalogação na Publicação (CIP)
Embrapa Hortaliças

Lana, Milza Moreira.
Quantification of vegetable loss at retail market: methodology proposed for leafy vegetables / Milza Moreira Lana, Antonio Williams Moita. - Brasília, DF: Embrapa Hortaliças, 2020.
38 p. : il. color. ; 21 cm x 27 cm. (Documentos / Embrapa Hortaliças, ISSN 1415-2312 ; 183).

1. Green leafy vegetables. 2. Fresh market. I. Moita, Antonio Williams. II. Título. III. Embrapa Hortaliças. IV. Série.

CDD 635.046

Antonia Veras de Souza (CRB 1/2023)

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Acknowledgement

Editing of this work was funded by Fundação de Apoio à Pesquisa do Distrito Federal – project ‘Quantificação e Proposta de Ação para a Redução das Perdas de Hortaliças do Campo à Mesa no Distrito Federal e Entorno’ (Process number 00193-00001681/2019-95).

Foreword

Quantitative and qualitative food losses impact the sustainability of food systems and food security and nutrition. Three dimensions of the sustainability of food systems – economic, social and environmental are affected.

An effort to reduce food loss has been made by many governments and international institutions and it is part of the 2030 Agenda for Sustainable Development adopted by all UN Member States in 2015. To accomplish **Goal 12: Ensure sustainable consumption and production patterns** it was set the **target 12.3**: by 2030, to 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. Decreasing both quantitative and qualitative food loss is also essential to achive **Goal 2: End hunger**, in particular **target 2.1**: by 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.

In Brazil, the Interministerial Chamber for Food and Nutrition Security (Caisan) approved on 2017 the **Inter-Sectoral Strategy for the Reduction of Food Loss and Waste in Brazil.** This document is in consonance with the international commitments on this theme and considers the reduction of food loss as part of the national food policy to assure the population's access to adequate and healthy diets.

The present document aims to contribute with the two following lines of action proposed in Caisan's documents:

1) To focus on elaborating a food loss and waste (FLW) quantification methodology in major food chains (in terms of economic importance and contribution to food nutrition and security), contributing to the elaboration of a FLW diagnosis more reliable to the Brazilian reality and to monitoring the objectives and commitments of PLANSAN CELAC 2025 and 2030 Agenda related to FLW.

2) To promote studies for measuring FLW in Brazil.

The authors

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Introduction

The retail market is an important stage of the productive chain to study postharvest losses of vegetables. Due to their perishability, vegetables are rapidly transported to the market after harvest and most of the damage they suffer from harvest to transport will show up and cause losses only during marketing. On the other hand, the amount of discard depends greatly on consumer's behaviour, including how they handle the vegetables and their preference. In its turn, handling of the vegetable by the market agents and the marketing strategies affect, respectively, the shelf life and the rate of turnover of the produce, and consequently, the volume of loss. In other words, at retail level there are a number of factors, at different levels of complexity, operating as causes of postharvest losses of vegetables.

There is not a single way to measure postharvest loss; it depends on the target issue that is at stake (Chaboud; Daviron, 2017; Møller et al., 2014). The study should be designed differently whether the aim is to evaluate its impact on the environment, the economic cost for the suppliers, the impact on food security or other.

The methodology reported in this text aims to quantify the discard of leafy vegetables at the retail market and to study how the postharvest handling of vegetables affects the causes and extension of discard. It is also interested in determining the quantity and quality of this food group available for the population. It is based in on-site quantification and analysis of the visual quality to addresses the following questions: (1) what is the visual quality of leafy vegetables and fresh herbs purchased by the retail market; (2) what is the volume of discard of leafy vegetables in the retail market and (3) what are the main causes of discard. The study also addresses how these variables are influenced by the vegetable species, the suppliers and the stores evaluated.

Scope

The proposed methodology aims to quantify the post-harvest loss of leafy vegetables at retail stores and to determine its cause. It evaluates how discard

is related with the visual quality of the vegetables received in the market as much as with the conditions in the store which favour the decrease in quality that in turn results in vegetable discard.

The vegetable loss related processes start with the act of delivering the produce at the store by the suppliers followed by the display at the market and ends with the act of purchase by the final consumer. Short-time storage of leafy vegetables at the store is rare in Brazil and, when it happens, it is typically shorter than 36 hours. Leaf vegetables are purchased directly from farmers, although some of them also act as wholesalers buying and selling vegetables from other farmers.

The research includes the evaluation of visual quality. The decision to evaluate visual quality (appearance) of the vegetables at reception in the store is due to a number of reasons, as follows. The appearance is expected to be an indicator of potential loss since damaged vegetables have a shorter shelf life and are more prone to be rejected by consumers. However, whether a damaged vegetable is sold or discarded depends on the extent of the damage, the availability of vegetables with superior quality and on how demanding is the customer. On the other hand, when a customer buys a partially damaged vegetable, for example a head of lettuce with wilted external leaves, part of the discard is transferred to the household. The more advanced is the discard in the productive chain the higher is its environmental cost (FAO, 2014).

The appearance also is an indicator of good handling practices being used (or not) during harvest, preparation for the market and transport. The presence of damaged vegetables at this stage, indicates the need to improve handling at primary production and transport. The presence of blemishes has other implications besides decreasing visual quality. The same conditions of high temperatures that cause yellowing and wilting of the leaves cause vitamin C degradation (Lee; Kader, 2000) and consequently impact the nutritional quality of the food. Mechanical injuries to plant tissues can create openings to internal surfaces that are conducive to microbial contamination and growth (FAO/WHO, 2008), besides causing darkening and rotting. The kind of blemish present in higher frequency can be an indicator to where improvements should be addressed to. Yellowing indicates temperature abuse and/or

exposition to ethylene; wilting indicates low humidity and/or high temperature; physical damage indicates poor handling, and so on. The visual quality of the vegetable impacts consumer preferences and consequently affects the quality of the diet if people choose less nutritious food when the vegetables are damaged. And last but not least, a high proportion of damaged vegetables at reception impacts business. The produce sector worldwide has the power to drive increase sales and customer loyalty and produce appearance and quality are very important to consumers when making purchasing decisions (Steinbach, 2018).

In order to estimated vegetable loss, the amount purchased and the amount discarded by the store staff, are quantified. This is done on-site, and the loss is expressed as a proportion of the purchase.

The visual examination of the discarded vegetables aims to determine the causes of discard. It gives indications as to whether the causes for discard are more related to the environment condition in terms of temperature and humidity (wilting and yellowing of the leaves), to handling (physical damage) or a combination of both. It also gives indication as to whether the food discarded has enough quality left and therefore can be donate to those in need.

Methodology

The study is performed in 4 steps:

I. Quantification of vegetable units received
II. Evaluation of visual quality of leafy vegetables at reception in the store
III. Quantification of vegetable units discarded
IV. Determination of the cause of discard

Quantification of produce units received

Upon reception at the store, all produce received are counted and expressed as number of units of each vegetable species per supplier per store per day of the week.

3.2. Evaluation of visual quality of leafy vegetables at reception in the store

The visual quality of produce received at the store at each sampling day is assessed using a 1 to 5 visual scale (Figure 1), where:

GRADE 5 indicates absence of decay, bruises, wilting or yellowing; no trimming necessary.

GRADE 4 indicates the presence of decay, bruises, wilting, or yellowing, combined or isolated, in the outer or lower leaves, which can be easily trimmed while replenishing the shelves, making it a GRADE 5 quality.

GRADE 3 indicates the presence of decay, bruises, wilting or yellowing, combined or isolated, in the outer and inner leaves, requiring extensive trimming to make it into GRADE 5.

GRADE 2 indicates the presence of decay, bruises, wilting or yellowing, combined or isolated, in such scale that after trimming not enough produce is left to sell.

GRADE 1 indicates the produce is deteriorated and inedible.

Samples should be taken at random, immediately after reception and before display. The number of units sampled per produce for visual quality should be 1, 2, 3 or 4 units, when the number of units received is respectively less than 5 units; 5 to 10 units; 10-30 units; more than 30 units. One single grade is given per produce species sampled. When the appearance is not similar among the units sampled, extra samples are taken until it is possible to establish a grade that best represents the consignment. All the units sampled are inspected, photographed and later reunited with the remaining ones and put on sale. Visual quality is expressed as percentage of samples of each produce species in each class per supplier per store per day of the week.

Quantification of vegetable units discarded

The produce discarded at the store at each sampling day is counted and expressed as number of units of each produce species per supplier per store per day of the week. Discard of produce no long marketable is made by the supermarket staff, with no interference of the researcher.

Figure 1. Grade of visual quality of produce received at the store. Grades vary from 1 to 5 as described in the text.

Determination of the cause of discard

After counting, all discarded produce are classified into 1 of 7 mutually exclusive categories (Figures 2 and 3), namely (1) wilt, (2) yellow, (3) decay and/or bruises, (4) wilt and yellow, (5) wilt and decay and/or bruises, (6) yellow and decay and/or bruises, (7) wilt and yellow and decay and/or bruises. Decay and/or bruises were combined in the same category because at this stage it was not possible to determine whether pathogens are associated with the

Figure 2. Causes of discard of leafy vegetables in the store as described in the text.

Fotos: Milza Moreira Lana

Figure 3. Causes of discard of leafy vegetables in the store as described in the text.

bruises, neither if decay, when present, was preceded by bruises or the result of primary infection.

The number of produce discarded in each category is expressed as percentage of the total number of discarded produce per species per supplier per store per day of the week. Counting and analysis of the discarded produce should be performed immediately after the culling operation by the store staff.

Sampling plan

In this research, the store is the sampling unit. The number of stores to be included in the research is mainly limited by the labour available and the location of the stores. Leafy vegetables are delivered very early in the morning imposing the need to be in the store upon delivery of produce, besides during culling and discard. In addition, the detailed evaluation is time consuming and demanding, being not feasible to visit more than one store per person and day.

When a single researcher is involved, it is feasible to insert 4 stores in the research. Which stores to choose depends on the research question. In an exploratory research, when no previous information is available, it is preferable to choose stores that differ in size, localization and customer profile in order to identify differences that can be further explored.

Day of the week, considering business days only, should be used as a local control unless there is previous information that the quantity of waste is independent from this factor. In the first case, the days of the week should be allocated at random to each store, in a way that in a week (or another defined period of time) the total of the assigned stores are visited, each one in a different day of the week. This scheme is repeated, until all stores had been visited one time each day from Monday to Friday. The 5 evaluations, one in each day of the week in each store, were considered one replicate and, in our case, it was repeated 4 times. The research should be extended for some months in order to include differences in season. In the case of Brasília-Federal District, for example, where differences between hot rainy summer and cold dry winter have a substantial impact in the overall quality and shelf life of vegetables, the research was extended in order to include both seasons. It is advisable to avoid dates when shopping of vegetables is non representative (Christmas, New Year, carnival and Holly Friday)

No store personnel should know in advance the day their store would be visited, in order to prevent changes in the flow of work that could interfere with the results.

Data analysis

The primary objective of the research is to determine the effect of store, supplier and day of the week on the number of items discarded per day. For that, the amount of waste should be corrected for the amount purchased by means of a co-variance analysis so that the effect of store and supplier is not influenced by the amount of purchase in each case. Interactions among store, supplier and day of the week can be studied when all suppliers are present in all stores. Depending on previous knowledge, or interest, other factors might be included in the model.

Descriptive measures of central tendency (mean) and variability (coefficient of variation) are computed for the number of produce units purchased and discarded.

The frequency of produce in each class of visual quality and the relative importance of each cause of discard compared to the other causes is calculated via the Chi_Square test associated with the corresponding contingency table. The results are expressed as the percentage of units discarded in each class in relation to the total number of vegetables discarded.

Difficulties and limitations

This methodology was validated in two studies conducted in two supermarket chains in Brasília-Federal District, Brazil between 2017 and 2019. The discussion in this section is based on the difficulties faced on those studies, each including 4 stores.

Difficulties and limitations to evaluate visual quality at reception

The evaluation of quality at reception should be based on appearance, to be simple and fast to perform, mimicking a commercial quality inspection.

The main difficulty encountered at this stage is to establish the cutting line above which a vegetable is considered damaged, due to the following reasons.

– Classes are used to categorize an attribute that is continuous and in the present case there is no scale of intensity. Because of that, the researcher is faced with questions such as: if only the tips of few external leaves are wilt, should the vegetable be considered wilt (Figure 4)? If the vegetable has a small number of small cuts, which are not dark nor rotten, should it be considered damaged (Figure 5)? If the vegetable has a large number of small cuts, which are not dark nor rotten, should it be considered damaged (Figure 5)?

– In commercial inspection the tolerance for decay is always lower than the tolerance of other defects, due to its capacity to spread and contaminate the whole batch. The question here is whether to grade 2 any vegetable with symptoms of fungal or bacterial infection, no matter its size, in a sort of zero tolerance policy or whether to consider if the damaged leaves can or not be removed by trimming and grade it accordingly (Figure 6).

– In a similar line of reasoning, there is the question on how to grade vegetables with a severe damage that is present in external leaves that can be easily removed by trimming, compared to vegetables with a light damage that is spread in external and internal leaves and cannot be removed by trimming (Figure 7).

To answer these questions the approach used was, respectively, to:

– Define the classes as good as possible. To differentiate 2 from 3 for example it was used a cutoff equal to 50 % of the leaves damaged; when less than 50% of the leaves are damaged, the vegetables is graded 3 and, when more than 50% of the leaves are damaged, it is graded 2.

– Take into consideration the research question. Because we were interested in studying the effect of visual quality on vegetable discard, we considered the “trimming factor” that is, whether the damage can be easily removed by trimming and the impact of trimming on mass loss. When the damaged leaves can be easily removed and trimming has a negligible impact on mass loss, the vegetable is graded 4; when trimming is time consuming and has a significant impact on mass loss, eventually demanding that two trimmed units

are packaged together, the vegetable is graded 3; if the damage cannot be removed by trimming, the vegetable is graded 2.

– Resemble a real market inspection in which damage should be easily perceived. If one needs a magnifying glass, there is no damage. A slight lack of freshness and turgidity (Figure 4) and slight damages and cracks without darkening of the surrounding tissues (Figure 5A to 5F) were not considered.

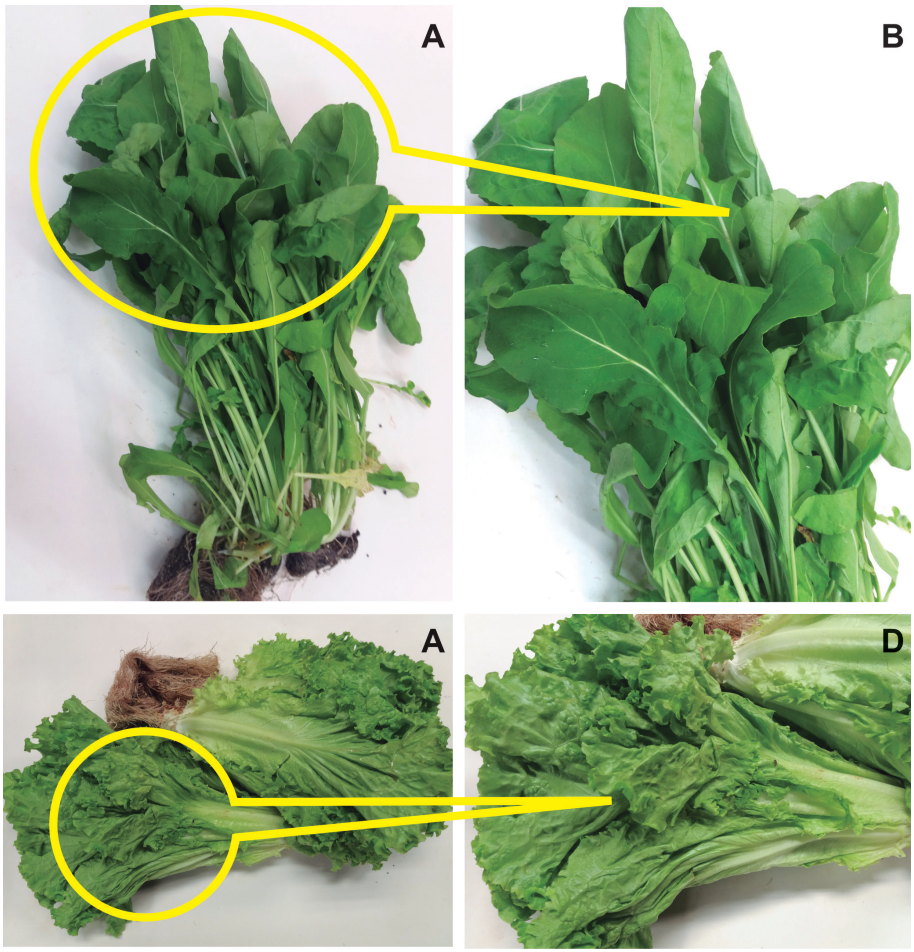

Figure 4. Examples of vegetables considered not wilt. In the arugula bunch, only the tips of some of leaves are lightly wilt (A,B).The few external moderately wilt leaves of leafy green lettuce (C,D) can be easily removed by trimming during replenishment.

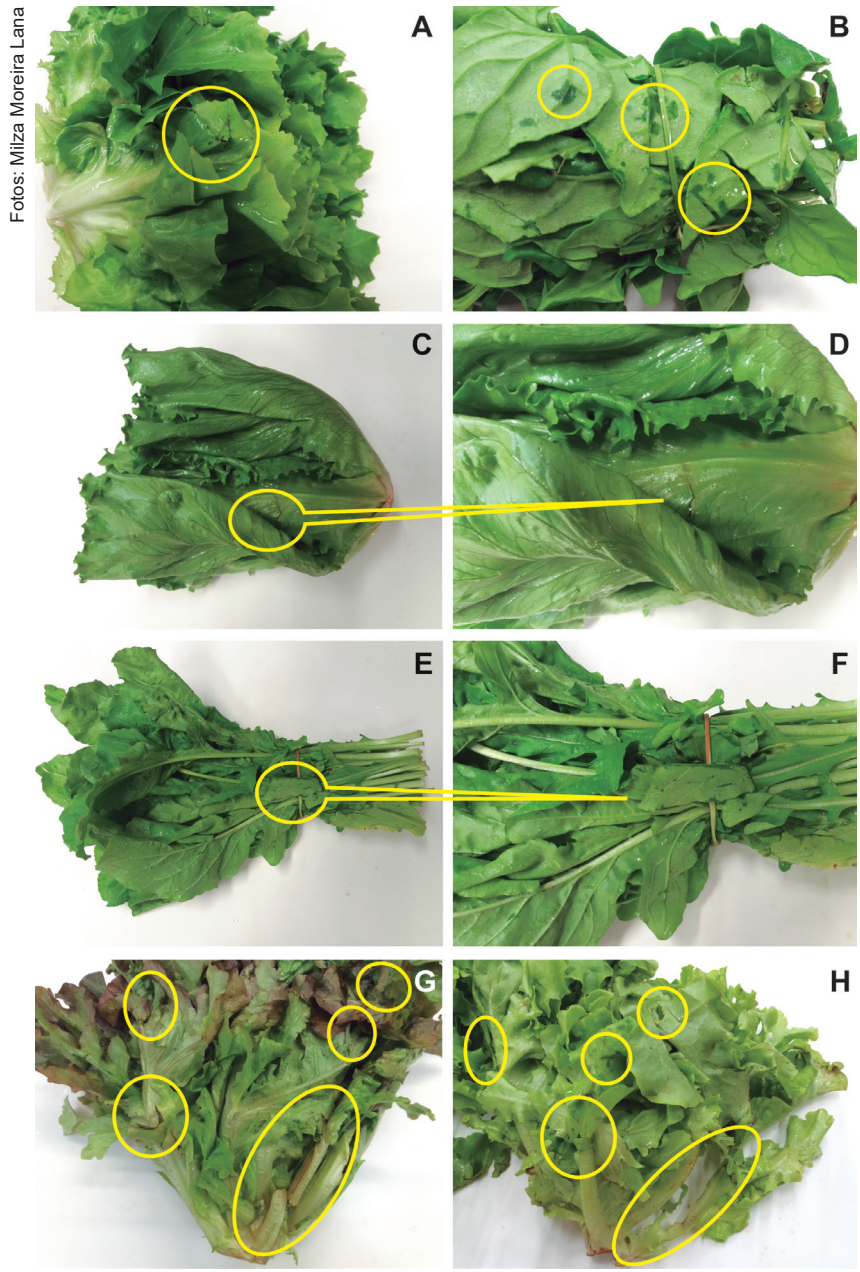

Figure 5. Examples of small physical injuries that are not considered in the evaluation and not affect the grade of visual quality (A to F) compared to extensive damage that decrease the grade of visual quality (G,H).

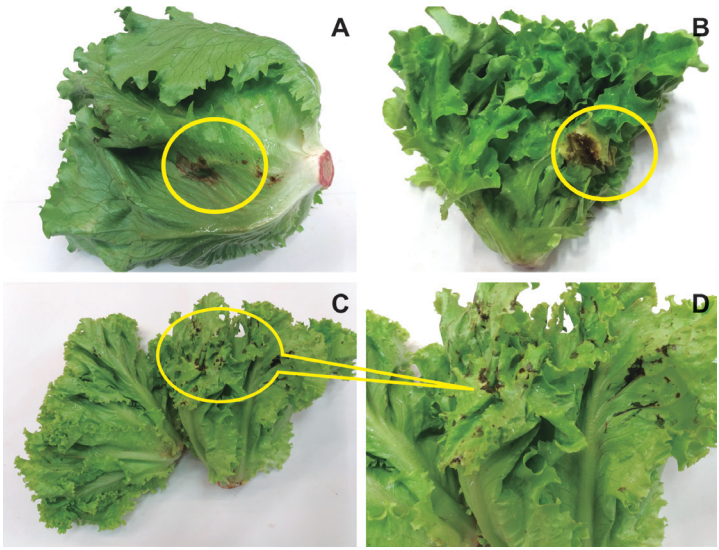

Figure 6. Vegetables graded 4 in the scale of visual quality (A,B) because the rotten tissue is restricted to external leaves which can be easily trimmed during replenishment, compared to vegetables graded 3 (C,D) because the rotten tissue is widespread in more leaves, which demands more extensive trimming.

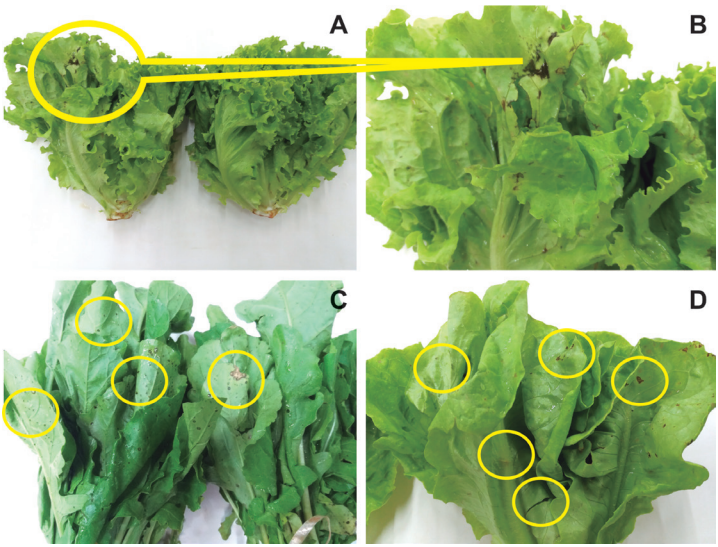

Figure 7. Leafy lettuce graded 4 (A,B) in the scale of visual quality because the severely damaged area is restricted to external leaves which can be easily trimmed during replenishment, compared to arugula (C) and butterhead lettuce (D) graded 3 because the small blemishes are spread in inner and outer leaves.

Difficulties and limitations to evaluate cause of discard

When evaluating the cause of discard, it is necessary to make clear if what is being evaluated is the damage present in the discarded vegetable or the cause considered by the store staff. They are expected to be equal, and most of the time they are, but this is not always the case.

In stores where the selection and culling are less rigorous, the cause for discard of a vegetable with moderate wilting and physical damage can be the presence of decay and/or bruises, while in a store where the selection and culling is more rigorous, the same vegetable is discarded because it is wilt and decayed and/or bruised. This happens because in the first store that leafy vegetable would not be discarded if bruises/decay where not present, since moderately wilt vegetables remain in the produce area. In the second store, that vegetable would be discarded even if it were not bruised and decayed because a moderate wilting is considered sufficient to decrease its commercial value.

The cutoff criterion differ among stores due to differences in the staff system of work. Asking the staff why did he (she) discarded each vegetable would introduce an uncontrollable variation besides being quite difficult to perform since it would require interrupting their work. Because in our research we are interested in the relationship between postharvest handling, shelf life and postharvest loss, we choose to identify the damage present in the discarded vegetable and to consider it to be the cause of discard.

When identifying the cause of discard the researcher is faced with similar difficulties reported for the evaluation of visual quality at reception, that is how severe should a damage or blemish be for it to be taken into account. At this stage, it was used the same criteria described for the evaluation of visual quality at reception. Even using these criteria, one must have in mind that there is a degree of uncertainty in any classification in which a leafy vegetable very wilt, with few yellow leaves, can be classified as ‘wilt and yellow’ or ‘wilt only’ after successive measurements performed by the same or by different evaluators.

Difficulties and limitations to quantify the amount of discard

There are two side flows that were not previously known, and because of that were not considered during the planning of the research. One is the amount

of vegetables used in the supermarket kitchen to prepare meals for the staff and the other one is the amount discarded during trimming.

Quantification and composition of the produce used in the kitchen was variable among stores and among staff from the same store. Most of the time the leafy vegetables taken to the kitchen were from the discarded fraction, but they could be taken from the commercial fraction as well. When taken from the discarded fraction this could be done before or after the staff registered the discard. In the beginning of the research these data were collected and registered as “kitchen fraction”. With time, it proved unfeasible because it depended on the collaboration of the kitchen staff to register the data or that the vegetables were taken when the researcher was present. Kale, lettuce, parsley, spring onion and coriander were the vegetables collected in higher frequency and very few units were collected.

The second one is the “scraps from trimming” that were not quantified when one unit could be sold as one unit after trimming. When trimming resulted in two units packaged together to make one, it was considered that one unit was discarded. In practice, it was counted the amount of empty plastic bags.

Difficulties and limitations to separate food loss and food waste

The concepts of food loss and food waste are still on debate. Chaboud; Daviron (2017) discussed extensively the inconsistencies in these concepts when different authors were considered. FAO’s ‘Global Initiative on Food Loss and Waste Reduction’ has taken a coordinating role to agree on a common definition of food loss and waste (FLW) but inconsistencies are still present. Gustavsson et al. (2011) and Gustavsson et al. (2013) defined food loss as discard of food in the early stages of the food supply chain often related with post-harvest activities with lacking system or infrastructural capacities, while food waste was defined as discard of food mostly at retail and consumer households and often related to human behaviour. Afterwards, in HIGH LEVEL PANEL OF EXPERTS ON FOOD SECURITY AND NUTRITION (2014) food waste was considered as being “an important part of food loss”, “not sharply defined”, “recognized as a distinct part of food loss “ and defined as the removal of food which is fit for consumption, or which has spoiled or expired, mainly caused by economic behaviour, poor stock management or neglect, without mentioning the stage of the supply chain where it happens.

The definition of food loss as not intentional food discard at production, postharvest and processing stages in opposition to food waste as intentional food discard at retail and consumption stages (Gustavsson et al., 2013) is unsuitable do describe what happens in the Brazilian vegetable supply chain. The conception of food waste occurrence as the result of behaviour in opposition to food loss occurrence because of technological constraints is a derivation of that concept and equally unsuitable. This work sustains that leafy vegetables discard at the retail market is the result of both technological, managerial and behavioural factors acting simultaneously along the productive chain, being unfeasible to separate those causes to decide what it is food loss and food waste.

In order to understand the causes of the vegetable discard and to propose solutions to decrease this discard, the concepts of micro, macro and meso causes and solutions (HIGH LEVEL PANEL OF EXPERTS ON FOOD SECURITY AND NUTRITION, 2014) are much more useful. By applying these concepts, it is possible to identify causes/solutions that are located in stages of the productive chain different from the one where the food discard is observed. As detailed in FAO's report, there are "immediate" causes of FLW, linked to how individual actors deal with various "primary" effects that affect food along the chain (micro-level), but these causes may in fact result from other, secondary, reasons (macro-level) or more systemic causes (meso-level). The solutions to deal with these causes are equality at the same levels of complexity.

Take for example the discard of Ceylon spinach when the leaves are wilt and physically damaged with darken and rotten areas (Figures 8A to 8C), when they have no blemishes (Figures 8D and 8E) and when they are lightly wilt (Figure 8F), all happening in the same store. Its discard can be the result of one or a combination of more than one of the following:

– technological deficiencies in primary production such as mechanical damage during harvesting and preparation to the market, abuse of temperature after harvest, inadequate packaging (Figures 8A to 8C, 8F);

– technological deficiencies and inadequate handling during marketing by staff and customers and lack of refrigeration display (Figures 8A to 8C, 8F);

– operational errors and discard of units with good quality before sell by date (Figures 8D and 8E);

– reaching sell by date before deteriorating due to low turnover (Figures 8D and 8E);

– low turnover due to failures in marketing strategy to promote sales and rejection by consumers who don not know how to use this vegetable (Figures 8A to 8E).

A single term (either vegetable loss, vegetable waste, vegetable wastage, vegetable postharvest loss) should be used to refer to all discard happening after harvest and attention should be directed to the interaction of micro, meso and macro causes in this process.

Figure 8. Examples of discarded Ceylon spinach due to physical injurie and rot (A-C) wilting (A,B,F), sell by date (D), no apparent reason (E).

Weight versus number of units

The most common and recommended way to quantify food loss is to measure the mass of food discarded (Møller et al 2014). When measuring the discard of leafy vegetables, however, this can result in underestimation of the discard for two reasons. Leafy vegetables loose water rapidly by transpiration and are sold by unit, not by weight. In a hypothetical situation where all 10 units of watercress bought by the supermarket are discarded after losing 15% of their water content, food discard would be 100% when expressed as units and 85 % when expressed as mass. Because the store buys and sells units, its accounting will be 100% discard, the same amount obtained by the researcher when counting the units instead of weighting them.

Using mass, without considering water loss, would result in underestimation of discard in stores were vegetables were discarded only when very wilt compared with the stores where vegetables are discarded lightly wilt. It is not worthy, neither reliable, to use mathematical models to estimate water loss because the vegetables are discarded at different levels of water loss.

One possible approach to be used in future research is to obtain the average fresh mass of each produce upon reception and use this value to calculate the loss. In this case, loss would be calculated in terms of fresh weight as if no water loss had taken place.

For example:

Average weight of a leafy lettuce = 117 g.

Purchase = 100 units of leafy lettuce = 100 * 117 g = 11.700 g

Discard = 14 units of leafy lettuce = 14 * 117g = 1.638 g

Waste in mass = (1.638/11.700) * 100 = 14 %

In this case, the discard of 14 units represented the discard of 1.638 g from the 11.700 g of mass of lettuce received in the shop. Part of this loss was due to water loss due to transpiration.

Initial quality as a predictor of vegetable loss

It is expected that the visual quality of the vegetable at reception is a good predictor of volume of postharvest loss because damaged vegetables have a shorter shelf life and are rejected by consumers. Inversely, vegetables without visible blemishes will have a longer shelf life and a higher turnover. When the visual quality of the leafy vegetable is not correlated with the amount of produce's discard the following possible reasons must be examined:

1. The quality evaluation may be inaccurate because it takes into account only visible damage. Damage due to the abuse of temperature, for example, which will impact shelf life and consequently the amount of discard, may not be visible at this stage. In this case, the vegetable has a good appearance but it deteriorates rapidly.

2. The quality evaluation is accurate but it is not a good predictor of shelf life when:

a. the quality deteriorates very fast during commercialization when handling and/or environmental conditions in the store are deleterious;

b. consumers buy damaged vegetables when they don't find better alternatives;

c. consumers don't buy unblemished vegetables if they do not perceive them or they don't know how to use and/or prepare them at home.

Strengths and weakness of the proposed methodology

Strength

The main strength of this methodology is to be a quantitative approach were the vegetables discarded are counted and measured direct and effectively. Interviews are not a robust approach to quantify vegetable postharvest loss. In the group of leafy vegetables it was observed that the supermarket

staff frequently overestimate the discard of vegetables such as leafy lettuce and kale (high number of discarded units which represent a low proportion of purchase) and underestimate the discard of vegetables such as Ceylon spinach, watercress and mustard greens (small number of discarded units which represent a high proportion of purchase).

The quality evaluation at reception gives important information about the needs to improve postharvest handling in primary production and transport. This is particularly relevant in countries where inadequate postharvest handling and logistics are still an important drive of vegetable loss. Being a case study, it gives detailed information for the situation studied. Most of the recommendations for postharvest handling in the Brazilian literature on the subject of good agricultural practices are not specific. Because information is available for each individual product, it is possible to have a customized recommendation per vegetable and a list of demands to guide the work of the rural extension service and the relation between the supermarket chain and its suppliers.

In situ research is a unique opportunity to interact with the supermarket staff that actually handles fresh produce, to observe all the steps in the work-flow and identify drivers of vegetable discard. Without decreasing the importance of general recommendations (improve postharvest handling, use better packages) the sector needs more practical and specific recommendations for each produce. Under the conditions of Distrito Federal-Brasília, where this methodology was validated, the discard of vegetables due to expiration date was an important cause of discard for Chinese cabbage and Ceylon spinach but not for lettuce and watercress because they are packaged in different ways. The trimming of old leaves in primary production to improve the visual quality and inhibit the spread of pathogen contamination was necessary for chicory and spinach, but not for spring onion and parsley. Yellowing was an important deterioration process in kale and watercress, but not in spinach and Chinese cabbage.

It is also possible to identify gaps on the knowledge of postharvest handling, which in turn, should be with dealt with in capacity building processes. To cite just a few observed during the validation of this methodology: to downplay the importance of the air relative humidity on the vegetables' shelf-life; to restock

and to stack produce in a way that induces excessive handling; a very modest, if any, use of produce aisle merchandising to promote sales as used in other section of the store.

Weakness

In depth measurements provides very detailed information but are time consuming and expensive. In this case, the high cost comes from the need of specialized labour force to identify the causes of discard and to evaluate the quality of the vegetables.

The amount of discard expressed as the proportion of the amount purchased is the more intuitive way of understating food loss. The more accurate way to measure it is to start from a batch and follow it to the end, what requires a strenuous work and intervention in the way the vegetables are marketed, such as waiting all the old vegetables to be sold before displaying the new ones. In our case, the choice was made to identify the causes for discard in real sale conditions, even if that would imply in a reduction of accuracy in the estimation of the quantity of waste as a ratio of the quantity of purchase. This happens because the vegetables discarded on a given day are not from the same batch purchased in that specific day but from batches purchased in one or more days before the day of sampling. Because of that, it is not possible to calculate the daily ratio of vegetable discard (Equation 1).

Equation 1

$$\text{vegetable discard}_{\text{day n}} = \frac{\text{vegetable purchased}_{\text{day n}}}{\text{vegetable discarded}_{\text{day n}}}$$

This is especially problematic for those vegetables purchased in smaller amount and/or not every day, in a store where the discard only happens when the vegetables are deteriorated. In this case, days of zero discard will be followed by: (1) a day where the number of units discarded is higher than the number of units purchased and consequently if calculated by Eq.1, the discard would be higher than 100%; (2) a day when there is no purchase and consequently if calculated by Eq.1, the discard would be a negative value.

In view of that, instead of calculating the proportion of food loss daily and from that calculating the average daily loss, option was made to calculate an average value obtained from the sum of all purchased and discarded units in the days of sampling.

Equation 2

$$\sum \text{vegetable discard}_{\text{day 1 - n}} = \frac{\sum \text{vegetable purchased}_{\text{day 1 - n}}}{\sum \text{vegetable discarded}_{\text{day 1 - n}}}$$

When measuring the postharvest loss of a group of leafy vegetables one must have in mind that there is a huge variation in the frequency and amount purchased of each produce. In view of that, it is expected that the quantification is more robust for vegetables supplied by all farmers in all stores (leafy lettuce, kale, spring onion and coriander, for example) compared to vegetables supplied by some farmers in some stores and /or not every day of the week (mustard greens, Ceylon spinach, watercress, for example).

Suggestions for improvement

The suggestions for improvement listed here aim to increase the robustness of the quantitative estimates of vegetable loss and to increase the accuracy in the identification of causes and drivers of such loss.

Cooperation with the market to quantify discard

As discussed previously, to quantify vegetable loss at the retail market is a very strenuous and expensive work and because of that, most of the research in the area is composed of case studies. The huge variation in the volume of discard demands the research to be extended on time and the number of stores that can be included in the research is very limited.

A closer cooperation between the retail sector and the research institutes would allow to broaden the scope of the research, including data from many years, stores and produce. Such an approach was reported by Buzby et al. (2016) who reported data from a sample including 1 large national and 4

regional supermarket retailers (roughly 2,900 stores) in 45 States and the District of Columbia in USA.

For that, two major obstacles must be overcome:

1. Confidentiality agreements between the research institutes and the retail chains to establish specific requirements for the proper handling of data that are both very sensitive and of public interest.

2. Adjustments in the way that the data on produce inventory are collected in the store, allowing the segregation of shrinkage due to food loss from that due to donation, theft, take-back agreements, accounting error, and other factors.

Business process mapping

During the validation of the present methodology, the flow of work in each store, from reception to exposition and culling, was described based on observations and discussion with the store staff directly involved with produce marketing. The identification of management related causes of vegetable discard was made empirically and it was not part of the experimental design described in section 3. Despite its limitations, it evidenced the importance of management decisions in the food loss process and the need to further investigate this theme together with the quantification of food loss.

The identification of causes described in section 3.4 is a time-consuming methodology, requires specialized labour force and is very limited to identify causes and drivers of food loss without a corresponding business process mapping and modelling. Such an approach is described in Lana et al. (2010) where process mapping and current reality tree were used to identify failures during grading and packaging of vegetables in a local famer's cooperative which result in decrease in quality and postharvest loss.

On the other hand, to approach food loss using only the business process mapping tools fails to identify specific requirements and deterioration processes of each produce.

The best-case scenario is then a close cooperation between researchers with agronomic and management backgrounds, so that the postharvest physical and biological deterioration of vegetables are understood and contextualized in a management and marketing context.

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