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Visual quality and waste of leafy vegetables in the retail market

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ABSTRACT

Food waste at retail and consumer level is estimated by the United Nations to be around 17% of total global food production. From that, 2% is believed to happen in retail. However, this estimate has a great degree of uncertainty due to the very small data set on which it was built, coming almost exclusively from high income countries. The present research contributes to fill this gap, presenting primary data on waste of leafy vegetables at two supermarket chains in Federal District, Brazil. Both studies evaluated: 1) number of produce items delivered and discarded; 2) visual quality of produce at reception and 3) cause of discard. The majority of the produce, 37 out of 47, had more than 80% of the units with good visual quality, but this frequency varied from 62.0 to 88.4% among stores and from 56.0 to 97.1% among suppliers. Within a global waste equal to 20.0%, the amount observed for individual produce ranged from 1.0 to 83.0% and varied considerably across stores and suppliers. The presence of wilt- rotten and yellow- wilt- rotten leaves were the first and second main causes of discard. Vegetable waste at retail level in an upper middle-income country such as Brazil can be substantial, supporting the recent change in narrative that now considers food waste to be relevant in all countries, regardless of its income.

Keywords: food wastage, supermarket, postharvest handling.

RESUMO

Qualidade visual e desperdício de hortaliças folhosas no varejo

As Nações Unidas estimam que o desperdício de alimentos, no varejo e no consumo, atinge 17% da produção mundial de alimentos. Deste total, 2% ocorrem no varejo. Entretanto, estas estimativas embutem um grande grau de incerteza devido à estreita base de dados usada nesta estimativa, agravada pelo fato da quase totalidade dos dados ser proveniente de países de alta renda. O presente estudo contribui para aumentar o conhecimento nesta área, apresentando dados primários de desperdício de hortaliças folhosas em duas cadeias de supermercado no Distrito Federal, Brasil. Os dois estudos avaliaram: 1) número de unidades de hortaliças entregues e descartadas; 2) qualidade visual da hortaliça entregue na loja; 3) causas do descarte. A maioria dos produtos, 37 de um total de 47, apresentou mais de 80% das unidades com boa qualidade visual, mas esta frequência variou de 62,0% a 88,4% entre lojas e de 56,0 a 97,1% entre fornecedores. Obteve-se a estimativa para o índice médio de desperdício global de 20,0% das unidades de hortaliças folhosas compradas, sendo que a amplitude do desperdício foi de 1,0 a 83,0% a depender da hortaliça e estes valores variaram consideravelmente entre lojas e fornecedores. As principais causas de descarte foram a presença de folhas murchas e podres, seguida pela presença de folhas amarelas-murchas e podres. O desperdício de hortaliças no varejo, em um país de renda média alta como o Brasil, pode ser elevado, o que corrobora as recentes mudanças de narrativa, que afirmam ser o desperdício de alimentos importante em países de todas as faixas de renda.

Palavras-chave: Perda e desperdício de alimentos; supermercado; manuseio pós-colheita.

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Food loss and waste (FLW) have negative impacts on both food security and the environment. Its reduction is one of the targets of the Sustainable Development Goal (twelve) responsible consumption and production. FLW reduction is also directly and indirectly related to a number of other Sustainable Development Goals concerning food security, poverty reduction, nutrition and environmental sustainability (FAO, 2019).

The United Nations calls for a coherent set of policies, investments and legislation, from production to consumption, with the aim of achieving efficiency gains and reduction of FLW, and hence, increasing the availability and the affordability of healthy diets (The State…, 2021). For that, a great effort has been made to estimate FLW, identify its causes and propose solutions to prevent and reduce it.

Globally, around 14% of the food produced is lost from the post-harvest stage up to, but excluding, the retail stage (FAO, 2019). Food waste at the retail and consumer levels (households and food service) is estimated to be around 17% of the total global food production (United Nations Environment Programme, 2021).

Global estimates for FLW are important to identify the regions and commodity groups in which the issue is relevant, as much as to raise awareness of and promote advocacy around this issue (FAO, 2019). However, effective

public policies at national, regional and local levels need data collected at the same level of aggregation, due to the large variation in volume and causes of FLW in specific food supply chains. Besides that, global estimates have high degree of uncertainty, due to the very small data set upon which they are built (United Nations Environment Programme, 2021). The most recent estimates for food waste, for example, are based on a majority of studies from high-income countries, especially on food service and retail. Because of that, it is important to obtain primary data for specific value chains to identify effective solutions, capable of guiding the actions on regulatory framework, public policies and strategies of communication as much as to improve the global estimate models (Intersectoral…, 2018; United Nations Environment Programme, 2021).

Vegetables are both an essential food group in a healthy diet and one of the food groups with higher levels of FLW, due to its perishability. A previous study reported waste of leafy vegetables in a Brazilian supermarket chain, varying from 8,7 to 97,0% of the number of units delivered, depending on the store, supplier and vegetable species considered (Lana & Moita, 2019). The study indicates that, in an upper middle-income country like Brazil, food discard at the retail level can be very high. Losses in quality, which can influence consumer preference and result in food waste in the household, were also discussed.

Due to the scope of the study, a case study involving four stores, the question was raised whether the observed results were a particular condition of the chain evaluated, or whether they were representative of the region where the research was conducted. Data on food waste are intrinsically very variable, and repeated studies, using a consistent methodology, are necessary to obtain robust estimations (Eriksson *et al.*, 2012; United Nations Environment Programme, 2021). To increase the robustness of the vegetable discard estimates, new research data were collected in another supermarket chain, including two types of stores, namely "atacarejo" (a store that sells both at wholesale and retail level), usually located far from the city centers and small supermarkets, located in residential areas.

Different from what happens in more developed countries, where vegetable waste at retail is mainly related with consumer behavior and management (WRAP, 2012; Porat *et al.*, 2018; Teller *et al.*, 2018), in Brazil the poor quality of the vegetable received at the store also figures as a relevant driver of food waste (Lana & Banci, 2020).

The production of vegetables is concentrated in small farms where harvest and post-harvest handling involve a number of operations that result in intense manipulation and damages the produce. Leafy vegetables, mainly produced near urban centers, are transported to the market soon after harvest and most of the damage caused during harvest, early handling and transport will be visible only in the later stages of the supply chain, namely retail and consumption. Inadequate practices during reception, display and restock, the lack of cold chain, together with rough handling by consumers, are factors expected to further damage the produce and result in its discard. This implies that reduction of food waste at retail demands simultaneous actions at both farm and retail levels.

The present research addresses the following questions: 1) what is the visual quality of leafy vegetables delivered at the retail market? 2) What is the volume of discard of leafy vegetables in the retail market? 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.

MATERIAL AND METHODS

Study site and plant material

The study was conducted in two regional supermarket chains in Distrito Federal, Brazil. In each chain, four stores were chosen from a group of 15 and 18 stores, respectively, to include those that differed in size, volume of sales and customer profile. In the second group, two of the stores were a hybrid model of distribution which integrates wholesale and retail in the same store ("atacarejo" in Portuguese).

All leafy vegetables and fresh herbs sold in the stores, excluding cabbage, were included in the research (Table 1). Each store sold a different variety of vegetables and herbs which was dependent on supplier and time of the year.

Data collection

The first study (Chain 1) extended from January to July 2017 and the second one (Chain 2) from July 2018 to March 2019. Data from the first study and a preliminary report of both studies were previously published (Lana & Moita, 2019; 2020), being the last one aimed to promote discussion among rural extension officers and public managers. In the present paper, data from both studies were grouped for a more robust analysis.

Data of both studies consist of four replicates for each store. A replicate was obtained by grouping the observations from five different weekdays allocated at random at each store. This data collection plan allowed that, for every replication, each store had observations for the five different days of the week from Monday to Friday. This data collection plan was conducted because previous interviews with the supermarket staff indicated that the quantity of waste is dependent on day of the week. No store personnel knew in advance the day their store would be visited.

At each evaluation day the following data were collected:

1- **Number of produce items received**: upon reception at the store, all produce received were counted and expressed as the number of units of each vegetable species per supplier, store and day of the week. For data analysis, the amount delivered was calculated per week, adding the values from Monday to Friday, within each replicate.

2- **Visual quality of produce**: it was assessed using a 1 to 5 visual scale, developed by the authors, where 5 = absence of decay, bruises, wilting or

yellowing; no trimming necessary; 4 = presence of decay, bruises, wilting, or yellowing, combined or isolated, in the outer or lower leaves, which could be easily trimmed while replenishing the shelves, making it a grade 5 quality; 3 = 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; 2 = presence of decay, bruises, wilting or yellowing, combined or isolated, in such scale that after trimming not enough vegetable was left to sell; 1 = deteriorated. The number of units sampled per vegetable for visual quality was 1, 2, 3 or 4 units, when the number of units delivered was respectively less than 5 units; 5 to 10 units; 10 to 30 units; more than 30 units. Samples were taken at random, immediately after reception and before display. One single grade was given per vegetable species. When the appearance was not similar among the units sampled, additional units were inspected to allow the establishment of a grade that best represented the batch. All the units sampled were inspected, photographed and later reunited with the remaining vegetables and put on sale.

3 - **Number of produce items discarded**: discard of vegetables no longer marketable was made by the supermarket staff, without interference of the researcher. The vegetables discarded at the store at each sampling day were counted and expressed as the number of units of each vegetable species per supplier, store and day of the week. The discard proportion from the total delivered was calculated on a weekly basis by adding the values from Monday to Friday within each replicate.

4 – **Cause of discard**: after counting, all discarded vegetables were classified into 1 of 7 mutually exclusive categories, 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 were associated with the bruises, nor if decay, when present, was preceded by bruises. Counting and analysis of the discarded vegetables were performed immediately after the culling operation done by the store staff. For each category, the number of units of each vegetable species per supplier, store and day of the week was obtained.

Data analysis

The effects of stores and suppliers on the proportion of discarded produce were analyzed through analysis of variance. Further pairwise comparisons between the distinct stores and suppliers were made using Tukey tests. Interactions among stores and suppliers were not studied because not all suppliers were present in all stores. The frequencies of produce in each class of visual quality and the relative importance of each cause of discard were calculated. Chi-Square tests were conducted to assess the relationship among factors such as stores, suppliers, and type of product to the frequencies of the different causes of discard and the visual quality of the products. All the statistical analyses were carried out using the R programming language and environment (R Core Team, 2021).

RESULTS AND DISCUSSION

The quality of the leafy vegetables at delivery and the amount and causes of discard were very similar in both supermarket chains. The results and discussion that follows are based on the joint analysis of the 2 data sets generated by the study, as highlighted previously.

Visual quality at reception

The appearance, or visual quality, of the leafy vegetables, at the reception stage at the store, was judged by the presence of wilted, yellowed, rotten and/or damaged leaves.

The majority of the produce, 37 out of 47, had more than 80% of the units with visual quality grades 4 or 5 (Table 2). At this stage, the main defects presented by the produce were physical damage and darkening of the damaged tissues. Wilted and yellowed leaves were very rare, and when present, restricted to a few leaves which should have been removed during preparation of the produce to the market (external leaves in lettuce and lower leaves in watercress, for example).

The vegetables with better visual quality were hydroponic lettuces green frizlly, red frizlly, lollo sanguine and romaine, Ceylon spinach, Chinese cabbage, parsley, sage and rosemary. The remaining hydroponic produce also presented more than 90% of the units with grade 4 or 5, except hydroponic mixed-spring onion-coriander with about 80% and rocket baby with 89,5% of the units within these grades (Table 2).

Vegetables such as watercress, butterhead lettuce, wild chicory and rocket, presented a frequency of grades 1 and 2 higher than 10%. For common sow thistle and mustard greens, this frequency was around 45% (Table 2).

The relative frequency of vegetables in each class of visual quality was not homogenous across stores and suppliers (Pearson's Chi-squared test p-value 0.0001, for both cases). The frequency of produce with grades 4 and 5 varied from 62.0 to 88.4% among stores and from 56.0 to 97.1% among suppliers (Table 2).

Differences among stores were most likely due to differences among suppliers, rather than differences in quality from the same supplier in different stores. To test this hypothesis, Pearson's Chi-squared tests were performed individually for suppliers' number 1, 5 and 11, which were present in more than two stores. The results of the test showed that the proportion of produce with grades 1 to 3 and 4 to 5 was homogenous across all stores (p-value = 0.5184, 0.0732 and 0.2500, respectively for suppliers' number 1, 5 and 11).

Stores number 2, 3, 5 and 7 were the ones which received a higher proportion of vegetables with grades 1 and 2. Their main suppliers were, respectively, suppliers' number 3, 5, 5 and 2, the same ones with a higher proportion of vegetables with inferior quality (Table 2).

The variety of vegetables received by each store indirectly influenced the proportion of vegetables in each class of quality. The presence of hydroponic

Table 1. List of leafy vegetables analyzed. Brasília, Embrapa Hortaliças, 2021.

Common name in English	Scientific name	Common name in Portuguese
basil	*Ocimum basilicum*	manjericão
celery	*Apium graveolens*	aipo ou salsão
Ceylon spinach	*Basella alba*	bertalha
Chinese cabbage	*Brassica pekinensis*	couve-chinesa
common sow thistle	*Sonchus oleraceus*	serralha
coriander	*Coriandrum sativum*	coentro
coriander, hydro	*Coriandrum sativum*	coentro, hidropônico
endive, broad-leaved	*Cichorium endivia* var. *latifolia*	chicória lisa
kale	*Brassica oleracea* var. *acephala*	couve
kale, hydroponic	*Brassica oleracea* var. *acephala*	couve, hidropônica
leek	*Allium porrum*	alho-porró
lettuce, butterhead	*Lactuca sativa*	alface lisa
lettuce, gem	*Lactuca sativa*	alface mini-romana
lettuce, green leaf	*Lactuca sativa*	alface crespa
lettuce, green leaf, hydroponic	*Lactuca sativa*	alface crespa, hidropônica
lettuce, green-frizzly, hydroponic	*Lactuca sativa*	alface green-frizzly, hidropônica
lettuce, iceberg	*Lactuca sativa*	alface americana
lettuce, lollo-sanguine, hydroponic	*Lactuca sativa*	alface lollo-sanguine, hidropônica
lettuce, oakleaf	*Lactuca sativa*	alface mimosa
lettuce, purple	*Lactuca sativa*	alface roxa
lettuce, purple, hydroponic	*Lactuca sativa*	alface roxa, hidropônica
lettuce, red-frizzly, hydroponic	*Lactuca sativa*	alface red-frizzly, hidropônica
lettuce, romaine, hydroponic	*Lactuca sativa*	alface romana, hidropônica
lettuce, salanova	*Lactuca sativa*	alface salanova
marjoram	*Origanum majorana*	manjerona
mixed spring onion and coriander	*Allium fistulosum* + *Coriandrum sativum*	cheiro verde com coentro
mixed spring onion and coriander, hydroponic	*Allium fistulosum* + *Coriandrum sativum*	cheiro verde com coentro, hidropônico
mixed spring onion and parsley	*Allium fistulosum* + *Petroselinum crispum*	cheiro verde com salsa
mixed spring onion and parsley, hydroponic	*Allium fistulosum* + *Petroselinum crispum*	cheiro verde com salsa, hidropônico
mustard greens	*Brassica juncea*	mostarda de folha
oregano	*Origanum vulgare*	orégano
parsley	*Petroselinum crispum*	salsa
parsley, hydroponic	*Petroselinum crispum*	salsa, hidropônica
rocket	*Eruca sativa*	rúcula
rocket, baby, hydroponic	*Eruca sativa*	mini-rúcula, hidropônica
rocket, hydroponic	*Eruca sativa*	rúcula, hidropônica
rosemarin	*Rosmarinus officinalis*	alecrim
sage	*Salvia officinalis*	sálvia
spearmint	*Mentha spicata*	hortelã
spinach, New Zealand	*Tetragonia tetragonioides*, syn. *Tetragonia expansa*	espinafre da Nova Zelândia
spring onion	*Allium fistulosum*	cebolinha
spring onion, hydroponic	*Allium fistulosum*	cebolinha, hidropônica
thyme	*Thymus vulgaris*	tomilho
trio, hydroponic	*Lactuca sativa* + *Lepidium sativum* + *Eruca sativa*	trio
Watercress, soil cultivated	*Nasturtium officinale* sp.	agrião, cultivo em solo
watercress, hydroponic	*Lepidium sativum*	agrião, hidropônico
wild chicory	*Cichorium intybus*	almeirão

Table 2. Proportion of produce units in classes of visual quality, delivered to the store. Values for produce include data of all suppliers and stores. Values for store include data of all produce and suppliers in each store. Values for supplier include data of all produce and stores for each supplier. Brasília, Embrapa Hortaliças, 2021.

Produce	Grades 1 and 2	Grade 3	Grades 4 and 5
basil	1.3	10.3	88.4
celery	4.8	47.6	47.6
Ceylon spinach	0.0	4.8	95.2
Chinese cabbage	0.7	4.6	94.8
common sow thistle	44.4	0.0	55.6
coriander	4.3	12.8	83.0
coriander, hydro	2.5	5.0	92.5
endive, broad-leaved	2.9	14.3	82.9
kale	3.4	10.3	86.3
kale, hydroponic	0.0	7.1	92.9
leek	0.9	9.5	89.7
lettuce, butterhead	10.8	33.8	55.4
lettuce, gem	0.0	0.0	100.0
lettuce, green leaf	1.6	20.6	77.9
lettuce, green leaf, hydroponic	1.5	7.7	90.8
lettuce, green-frizzly, hydroponic	0.0	0.0	100.0
lettuce, iceberg	5.7	12.4	81.9
lettuce, lollo-sanguine, hydroponic	8.3	0.0	91.7
lettuce, oakleaf	2.5	10.1	87.3
lettuce, purple	3.5	9.1	87.4
lettuce, purple, hydroponic	0.0	0.0	100.0
lettuce, red-frizzly, hydroponic	0.0	0.0	100.0
lettuce, romaine, hydroponic	0.0	0.0	100.0
lettuce, salanova	0.0	4.2	95.8
marjoran	0.0	14.3	85.7
spring onion and coriander	7.5	23.7	68.8
spring onion and coriander, hydroponic	4.2	15.3	80.6
spring onion and parsley	3.5	4.4	92.0
spring onion and parsley, hydroponic	0.0	0.0	100.0
mustard greens	46.7	38.3	15.0
oregano	0.0	10.0	90.0
parsley	0.6	3.8	95.6
parsley, hydroponic	0.0	0.0	100.0
rocket	23.6	34.1	42.3
rocket, baby, hydroponic	5.3	5.3	89.5
rocket, hydroponic	0.0	5.4	94.7
rosemarin	2.4	2.4	95.2
sage	0.0	0.0	100.0
spearmint	5.4	35.9	58.7
spinach, New Zealand	2.4	14.4	83.2
spring onion	0.5	7.0	92.5
spring onion, hydroponic	2.2	6.5	91.3
thyme	2.8	11.1	86.1
trio, hydroponic	5.6	5.6	88.9
watercress	10.3	25.5	64.1

and organic vegetables contributed to a higher proportion of grades 4 and 5.

Amount of discard

The global proportion of vegetables discarded at all the stores, expressed as a percentage of the amount delivered per week, varied considerably across individual produce, stores and suppliers. Within a global proportion of discard equal to 20.0% (all produce included), the amount observed for individual produce ranged from 1.0 to 83.0% (column Total on Table 3). A proportion of discard equal or higher than 50% was observed for marjoram, wild chicory, broad-leaved endive, mustard green, Ceylon spinach, celery and sage. Values lower than 10% were observed for hydroponic parsley, hydroponic rocket, leek, hydroponic mini-rocket and hydroponic kale. Intermediary values were observed for the remaining produce.

Comparisons with data obtained in other studies are quite limited due to large differences in methodology and scope as much as in the index used to calculate waste. The most recent estimates published by UN Environment are that global food waste at retail is 15 kg/capita/year, amounting to 118 million tons in 2019 (United Nations Environment Programme, 2021). This data includes all food groups discarded at retail level and comparisons with particular food groups are not possible. Besides that, the confidence in this estimate is very low because they were based on a very small set of data, corresponding mainly to high-income countries.

The estimates reported by Buzby *et al.* (2016), were derived from data obtained from retailers and defined as shrink which includes food loss plus product removed from stores by theft, accounting and others. The estimated average shrink for vegetables in 2011-12 was 11.6%. The lowest average shrink was 2.2% for sweet corn, followed by 4.4% for sweet potato and the highest was 62.9% for turnip greens followed by 61.1% for mustard greens. Overall, greens showed the highest shrink of four vegetable groups, namely greens, cooking vegetables, salad/snacking

Table 2 continuation

watercress, hydroponic	0.0	3.3	96.7
wild chicory	14.3	47.6	38.1
Chain-Store	**Grades 1 and 2**	**Grade 3**	**Grades 4 and 5**
Chain 1, store 1	1.1	10.6	88.4
Chain 1 store 2	6.2	18.6	75.2
Chain 1 store 3	6.4	15.6	78.1
Chain 1 store 4	4.8	15.4	79.8
Chain 2 store 5	5.2	15.2	79.6
Chain 2 store 6	2.6	9.0	88.5
Chain 2 store 7	13.0	25.1	62.0
Chain 2 store 8	4.1	12.5	83.5
Supplier	**Grades 1 and 2**	**Grade 3**	**Grades 4 and 5**
Supplier 1	1.0	7.8	91.2
Supplier 2	7.5	15.9	76.6
Supplier 3	15.0	29.0	56.0
Supplier 4	4.5	13.7	81.9
Supplier 5	8.8	22.2	69.0
Supplier 6	1.3	14.4	84.4
Supplier 7	3.7	10.5	85.9
Supplier 8	0.0	3.5	96.6
Supplier 9	2.4	15.0	82.7
Supplier 10	2.6	5.1	92.3
Supplier 11	0.0	2.9	97.1
All	5.08	14.56	80.36

Grade 5= absence of decay, bruises, wilting or yellowing; no trimming necessary; Grade 4= presence of decay, bruises, wilting, or yellowing, combined or isolated, in the outer or lower leaves; light trimming make it a grade 5 quality; Grade 3= presence of decay, bruises, wilting or yellowing, combined or isolated, in the outer and inner leaves; extensive trimming make it a grade 5 quality; Grade 2= presence of decay, bruises, wilting or yellowing, combined or isolated, in such scale that after trimming not enough vegetable was left to sell; Grade 1= deteriorated.

vegetables, and hard/winter vegetables. Despite the differences in methodology, the range of values reported is similar to the range reported here.

In Sweden, the average waste for all fruit and vegetables from six stores was 4.3% by mass in relation to quantity delivered, much lower than the one reported here. The two most wasted products among fruits and vegetables were potatoes and lettuce (Erickson *et al.*, 2012). Different from what was reported by Erickson (2012; 2017), in both Brazilian chains reported here, rejection at delivery was a very rare event and negligible compared with store waste.

Waste volumes reported for lettuce (8.8%), parsley (0.9%), chives (0.5%), spinach (0.4%) and leek (0.4%) in a Polish supermarket (Bilska *et al.*, 2018) are not comparable to the present study. In the Polish study, waste was calculated as the percentage of the total mass discarded, which included 15 food groups, while here, waste was calculated as the percentage of the amount delivered of each item. Besides that, the authors acknowledge the limitation of their study that lasted for 2 weeks, and for that, did not account for potential seasonal variations on food mass.

Analysis of variance revealed significant differences in the amount of discard among stores (p-value <0.0001) and among suppliers (p-value =0.0061). Confirmatory non-parametric analyses were carried out to assess the robustness of the observed results under possible departures of normality and homoscedasticity. Kruskal-Wallis rank sum tests confirmed the significance of store (p-value <0.0001) and supplier (p-value =0.0066) to the proportion of discard.

Individual analysis of variance was calculated for stores and suppliers due to the imbalanced distribution of suppliers among the stores. While suppliers' number 1, 5, 11 and 9 were present in, respectively, 6, 3, 3 and 2 stores, the remaining ones were present in one single store each. In the second group, effects of store and supplier are confounded in the joint analysis making it more difficult to detect differences among the factors studied.

The total discard per store (including all produce and suppliers) varied from 9.5% in store 4 to 27.8% in store 1. The significant differences among stores (Figure 1A) include differences within the same chain and between chains. Part of the difference among stores can be related to the quality of the produce received, but the management in the shop is also important, as discussed later in this article. Comparisons of global discard per supplier (Figure 1B) indicate that most of the differences observed were not significant. Suppliers differ not only in the visual quality and potential shelf-life of their produce but also in the variety of vegetables they offer and stores they supply. Suppliers with a lower variety concentrate their offer on vegetables with a higher turnover, which can contribute reducing waste even when their produce has low quality. To better estimate differences among suppliers, it would be necessary to estimate the interaction between supplier and store, which was not possible here, as already discussed.

The presence of outliers (Figure 1) is most probably related to promotions, especially of iceberg lettuce, when the supermarket buys a large amount of this vegetable at a lower price, but does not succeed in promoting its sale.

Cause of discard

When data from all produce, including all stores and suppliers, were

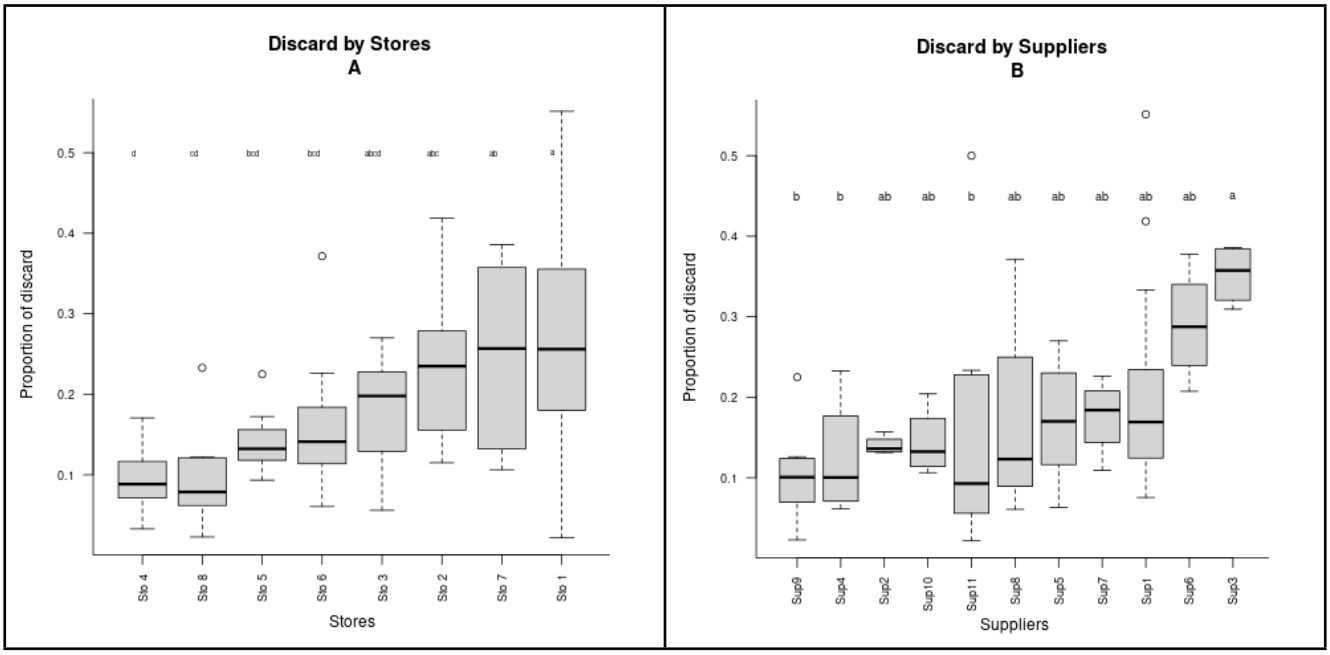

Figure 1. Proportion of discard (number of units discarded per week/number of units delivered per week) of leafy vegetables by stores (A) and suppliers (B). Values for store include data of all produce and suppliers in each store. Values for supplier include data of all produce and stores for each supplier. Values followed by the same letters have mean values not significantly different from each other by Tukey test ($p \leq 0.05$). Brasília, Embrapa Hortaliças, 2021.

combined, the global amount of discard was equal to 20.0% of the amount delivered per week (Table 3). From that amount, 7.0% was discarded when wilt-rotten and 5.0% was discarded when yellow-wilt-rotten. The other causes were responsible for 0.0 to 2.0% of the volume of discard, each.

The presence of wilt and rotten leaves was the main cause of discard for 23 out of 47 produce and the second main cause for 13 out of 47 produce. Rotten, in this case, encompassed a large array of symptoms including wounded tissue, darkening of damaged tissues, soft rot, dry rot, with and without microorganism structures such as bacterial pus, spores, mycelium and others. Whatever the case, the association of these symptoms with physical damage was clear.

Wilting was the main cause of discard for 15 out of 47 produce and the second main cause for 9 out of 47 produce. The produce more likely to be discarded due to wilting were hydroponic vegetables, fresh herbs and Ceylon spinach, the same produce with less physical damage and better visual quality at delivery (Table 2).

When pooling the data from individual produce to compare stores and suppliers, wilt-rotten and yellow-wilt-rotten were, again, the most frequent first and second main causes of discard (Table 3). In just 2 stores, the main cause of discard was yellow-wilt-rotten leaves, followed by wilt-rotten. In store 4, an increase in the amount of yellowing was observed when the vegetables display was moved to a warmer and less ventilated corner of the store. In store 1, yellowing was ever an important cause of discard due to the heat radiated by the lamps placed above the non-refrigerated display.

For suppliers 8 and 10, wilt was as important as wilt-rotten. Both were suppliers of hydroponic produce which presented a low level of physical damage and consequently less rotten tissue.

It is important to consider that the scale used here did not take into account the severity of the symptoms, so that a light wilt and a severe wilt vegetable would be classified as wilt. This is a matter of concern when estimating how much waste can be donated to food charity. Although there was no separation of waste in edible and inedible fractions, it is possible to affirm, from observations, that most of the waste was not proper for donation, due to its advanced state of deterioration. This would happen because the vegetables deteriorated very fast and/or because the vegetables with low quality would be left on display intentionally.

It was observed that partially damaged produce was sold, when produce of higher quality was not available. It is expected that part of these vegetables will be wasted at household and food service, due to the discard of damaged leaves, independently of how aware and willing is the consumer to avoid food waste.

Relation between amount delivered and discarded

There was no direct correlation between the amount delivered and discarded per week, when discard was calculated as a proportion of the amount delivered (p-value =0.2144, cor =0.1385, Pearson's test). This result confirms what was registered in the first report (Lana & Moita, 2019) and the rate of turnover is likely to be one of the main predictors of waste. Although the stores demand a large variety of leafy vegetables from the suppliers, sales are concentrated in leaf lettuce, kale and mixed spring onion with

Table 3. Proportion of discard (number of units discarded per week/number of units delivered/week*100) in classes of cause of discard. Values for produce include data of all suppliers and all stores. Values for store include data of all produce and suppliers in each store. Values for supplier include data of all produce and stores for each supplier. Brasília. Embrapa Hortaliças. 2021.

Produce	Yellow	Wilt	Rotten	Yellow wilt	Yellow rotten	Wilt rotten	Yellow wilt rotten	Other	Total
basil	0.0	16.0	1.0	2.0	0.0	6.0	0.0	1.0	26.0
celery	0.0	27.0	2.0	0.0	0.0	19.0	3.0	0.0	52.0
Ceylon spinach	0.0	25.0	4.0	1.0	0.0	24.0	5.0	1.0	60.0
Chinese cabbage	0.0	3.0	3.0	1.0	0.0	2.0	2.0	5.0	17.0
common sow thistle	0.0	31.0	0.0	0.0	0.0	12.0	0.0	0.0	44.0
coriander	0.0	1.0	1.0	0.0	0.0	12.0	4.0	0.0	18.0
coriander, hydro	0.0	1.0	5.0	0.0	0.0	6.0	0.0	0.0	13.0
endive, broad-leaved	0.0	8.0	5.0	2.0	5.0	17.0	27.0	0.0	64.0
kale	1.0	1.0	0.0	2.0	3.0	1.0	4.0	1.0	13.0
kale, hydroponic	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0
leek	0.0	0.0	3.0	0.0	1.0	0.0	1.0	1.0	7.0
lettuce, butterhead	0.0	0.0	8.0	0.0	5.0	8.0	22.0	0.0	45.0
lettuce, gem	0.0	1.0	7.0	0.0	0.0	10.0	1.0	0.0	21.0
lettuce, green leaf	0.0	1.0	4.0	0.0	3.0	8.0	7.0	0.0	24.0
lettuce, green leaf, hydroponic	0.0	3.0	1.0	0.0	0.0	5.0	3.0	0.0	12.0
lettuce, green-frizzly	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0
lettuce, iceberg	0.0	1.0	7.0	0.0	0.0	8.0	1.0	0.0	17.0
lettuce, lollo-sanguine, hydroponic	0.0	26.0	0.0	0.0	0.0	0.0	0.0	0.0	26.0
lettuce, oakleaf	0.0	2.0	8.0	0.0	4.0	17.0	11.0	0.0	43.0
lettuce, purple	0.0	2.0	4.0	0.0	0.0	18.0	0.0	0.0	24.0
lettuce, purple, hydroponic	0.0	8.0	0.0	0.0	0.0	9.0	0.0	0.0	18.0
lettuce, red-frizzly, hydroponic	0.0	5.0	0.0	0.0	0.0	5.0	0.0	0.0	11.0
lettuce, romaine, hydroponic	0.0	0.0	1.0	0.0	1.0	28.0	5.0	0.0	34.0
lettuce, salanova	0.0	3.0	0.0	0.0	0.0	14.0	0.0	1.0	17.0
marjoran	0.0	17.0	0.0	0.0	0.0	57.0	0.0	9.0	83.0
spring onion and coriander	0.0	0.0	1.0	1.0	0.0	3.0	7.0	1.0	13.0
spring onion and coriander, hydroponic	0.0	1.0	1.0	4.0	0.0	5.0	4.0	0.0	16.0
spring onion and parsley	1.0	2.0	0.0	3.0	1.0	1.0	5.0	0.0	13.0
spring onion and parsley, hydroponic	0.0	7.0	0.0	1.0	0.0	2.0	3.0	0.0	13.0
mustard greens	0.0	14.0	3.0	4.0	2.0	26.0	15.0	0.0	64.0
oregano	0.0	14.0	14.0	0.0	0.0	19.0	0.0	0.0	46.0
parsley	0.0	5.0	1.0	2.0	0.0	2.0	3.0	1.0	13.0
parsley, hydroponic	0.0	4.0	0.0	0.0	0.0	3.0	1.0	0.0	9.0
rocket	0.0	3.0	2.0	1.0	0.0	14.0	18.0	0.0	38.0
rocket, baby, hydroponic	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	6.0
rocket, hydroponic	0.0	3.0	0.0	1.0	0.0	2.0	2.0	0.0	8.0
rosemarin	0.0	12.0	0.0	0.0	0.0	1.0	0.0	1.0	15.0
sage	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0
spearmint	0.0	1.0	2.0	0.0	1.0	16.0	0.0	0.0	21.0
spinach, New Zealand	0.0	5.0	1.0	0.0	0.0	24.0	1.0	0.0	30.0
spring onion	2.0	1.0	0.0	4.0	1.0	1.0	5.0	0.0	14.0
spring onion, hydroponic	1.0	2.0	2.0	3.0	0.0	7.0	7.0	0.0	23.0
thyme	0.0	42.0	0.0	0.0	0.0	3.0	0.0	0.0	46.0
trio, hydroponic	0.0	3.0	0.0	0.0	0.0	19.0	1.0	0.0	24.0
watercress	0.0	5.0	1.0	3.0	0.0	4.0	26.0	0.0	39.0

Table 3 continuation

watercress, hydroponic	0.0	7.0	1.0	2.0	0.0	3.0	3.0	1.0	17.0
wild chicory	0.0	5.0	8.0	1.0	5.0	38.0	9.0	1.0	67.0
Chain - store	**Yellow**	**Wilt**	**Rotten**	**Yellow wilt**	**Yellow rotten**	**Wilt rotten**	**Yellow wilt rotten**	**Other**	**Total**
Chain 1 store 1	0.00	0.02	0.03	0.01	0.01	0.07	0.13	0.00	0.27
Chain 1 store 2	0.00	0.02	0.01	0.01	0.01	0.10	0.07	0.00	0.22
Chain 1 store 3	0.00	0.02	0.04	0.01	0.01	0.06	0.05	0.00	0.20
Chain 1 store 4	0.00	0.02	0.02	0.00	0.01	0.04	0.02	0.00	0.11
Chain 2 store 5	0.00	0.01	0.02	0.01	0.00	0.05	0.06	0.00	0.14
Chain 2 store 6	0.00	0.03	0.02	0.01	0.01	0.06	0.03	0.00	0.17
Chain 2 store 7	0.00	0.03	0.03	0.03	0.02	0.11	0.08	0.01	0.31
Chain 2 store 8	0.00	0.02	0.01	0.01	0.01	0.05	0.02	0.00	0.12
Supplier	**Yellow**	**Wilt**	**Rotten**	**Yellow wilt**	**Yellow rotten**	**Wilt rotten**	**Yellow wilt rotten**	**Other**	**Total**
Supplier 1	0.00	0.02	0.02	0.01	0.00	0.06	0.06	0.00	0.18
Supplier 2	0.00	0.01	0.02	0.00	0.00	0.04	0.06	0.00	0.14
Supplier 3	0.00	0.03	0.03	0.03	0.03	0.13	0.09	0.02	0.35
Supplier 4	0.00	0.02	0.02	0.01	0.01	0.06	0.02	0.00	0.13
Supplier 5	0.00	0.02	0.03	0.00	0.01	0.07	0.04	0.00	0.17
Supplier 6	0.00	0.03	0.03	0.01	0.01	0.06	0.14	0.00	0.28
Supplier 7	0.00	0.03	0.02	0.00	0.01	0.07	0.03	0.00	0.17
Supplier 8	0.00	0.04	0.01	0.02	0.00	0.04	0.03	0.00	0.14
Supplier 9	0.00	0.02	0.00	0.00	0.00	0.04	0.05	0.00	0.11
Supplier 10	0.00	0.04	0.01	0.03	0.00	0.04	0.03	0.00	0.15
Supplier 11	0.00	0.02	0.03	0.01	0.00	0.05	0.02	0.00	0.14
All	0.0	2.0	2.0	1.0	1.0	7.0	5.0	0.0	20.0

coriander. There is no merchandising in the stores to promote less consumed vegetables (spinach, watercress, oakleaf lettuce and others) and vegetables that are unknown by a large part of the population (Ceylon spinach, broad-leaved endive, wild chicory, mustard greens). Frequently, these vegetables are hidden in the display, without any labeling and the supermarket staff can rarely inform customers about their preparation. Likewise, Buzby *et al.* (2016) considered that a general lack of consumer knowledge about some vegetables and their preparation may have contributed to their high shrinkage in USA supermarkets.

Relation between visual quality and amount of discard

The relation between the amount discarded per week and the quality of the produce, represented by the proportion of produce with a grade higher than 3, was analyzed grouping the data per produce, store, and supplier to answer the following questions: are the produce with higher grades the ones less wasted? Are stores that receive a higher proportion of produce graded 4 and 5 the ones with less waste? Are suppliers with a higher proportion of produce graded 4 and 5 the ones with less waste?

A significant and negative correlation between quality and waste was observed for produce (cor =-0.5093; p-value =0.0002) and supplier (cor =-0.6121; p-value =0.0453) but not for stores (cor =0.0887; p-value =0.8345) (Figure 2). Although significant, the correlation between waste and produce quality and waste and supplier was only moderate. These relations are likely affected by the turnover rate of the vegetable considered and the evolution of the visual quality in the market, which in turn depends on how the product is handled in the store.

In the first case, it is hypothesized that the purchase of vegetables such as green leaf lettuce and spring onion-coriander mix are less influenced by visual quality because customers will buy it regularly, even when they are not of premium quality. On the other extreme, vegetables such as Ceylon spinach and mustard greens have a low turnover even when of premium quality.

In the second case, it is proposed that some of the effects of careless handling during harvest and transport are not visible at the time of reception, but will progress rapidly in the store during commercialization. A produce from one supplier, handled with care, protected from high temperature, low humidity and microbial contamination but with few bruises, will look similar to a produce from another supplier, which also shows few bruises but had been submitted to conditions of high temperature, low humidity and lack of hygiene. The shelf-life of the second will be much shorter compared to the

first, since later in the day the effects of careless handling will be visible through wilting, yellowing, darkening and rotting of the damaged tissues.

The evolution of visual quality also depends on the way the produce is handled in the store. Improper handling, deficient inventory control and poor merchandising at the store can result in high discard, even when produce has good quality at delivery. Store 1 had a discard 18% higher than store 4 (same chain) and store 8 (another chain). The conventional vegetables supplier from store 1 (supplier 6), had a proportion of 84.4% of vegetables with grades higher than 3, compared with 69.0% from the supplier of store 4 (supplier 5). Both stores had the same hydroponic and organic suppliers. The quality of vegetables by conventional suppliers of store 1 and 8 was similar (84.4% and 81.9% of vegetable with grades higher than 3, respectively) while for hydroponic vegetables this difference was larger (97.1 and 82.7% of vegetables with grades higher than 3, respectively). In other words, store 1 received produce of equal or better quality compared with store 4 and 8, but its waste was 18% higher, due to errors in handling the produce in the shop. Among these errors, not fully investigated here, there are the lack of refrigerated display, display with lamps above the vegetables that induced yellowing, culling and display of new produce late in the morning and permanence of partially deteriorated vegetables on display, in the hope they could be sold. Customers, arriving early in the day at store 1, would have to rummage through the boxes or give up buying, when checking the quality of the vegetables on display. Store 4, on the other hand, was an example of how proper management reduces waste since vegetables are sold rapidly, before they deteriorate. At this store the lower quality of the vegetables was compensated by culling and displaying new produce very early in the morning together with careful handling, good inventory control and refrigerated display.

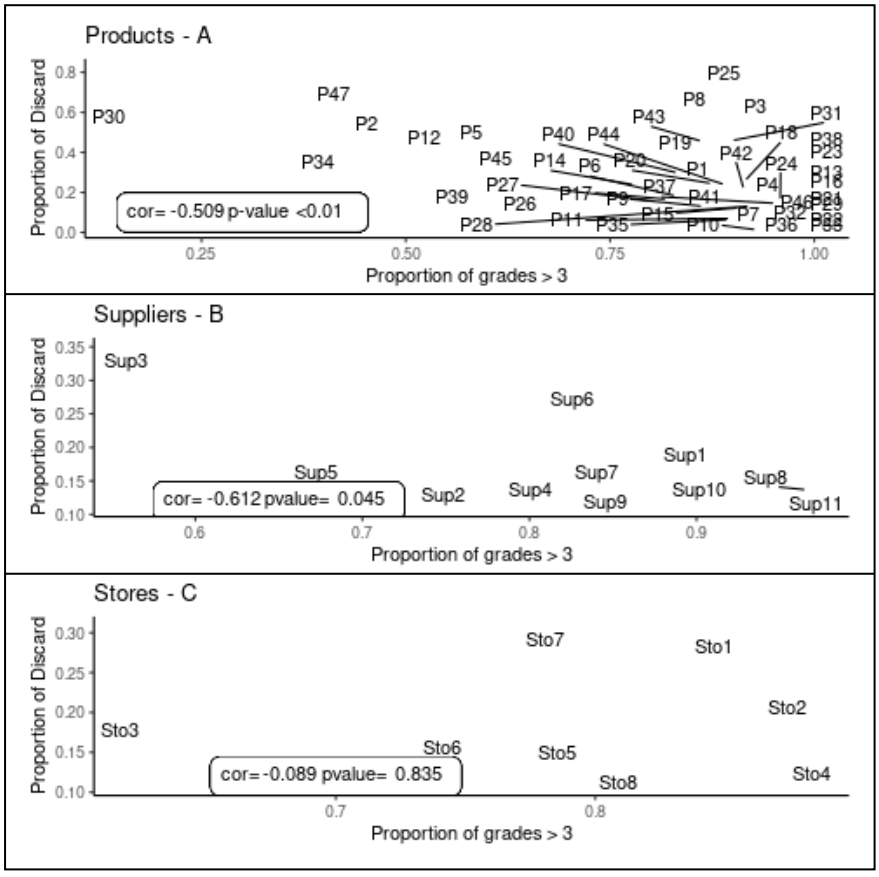

Figure 2. Correlation between the proportion of produce with grade 4 + 5 and the amount of produce discarded when data was pooled by produce (A) by store (B) and by supplier (C). Produce are identified by ID number as referred in Table 1. Brasília, Embrapa Hortaliças. 2021.

Final considerations

Vegetable waste at the retail level in an upper middle-income country such as Brazil can be high, and it is due to both inadequate post-harvest handling in the supply chain and bad management practices at the supermarket. A global waste of 20% encompass a broad range of values depending on the vegetable species, which highlights the importance of disaggregation of data by produce. Differences in the visual quality of the vegetables delivered by suppliers who share similar socio-economic conditions, in the same region in the country, indicate that there is room for improvement in the adoption of good practices in harvest and post-harvest handling. This should be taken into consideration by the technical assistance and the rural extension service, to achieve a more sustainable vegetable supply chain. Differences in the amount of discard among stores go in the same direction, indicating that even within a supermarket chain much can be learned from the stores with a better-quality management of vegetables. The road towards sustainability also asks for more cooperation between farmers and retailers, to assure that the good practices that keep the produce sound, extend shelf life and reduce food loss and waste are adopted at all stages of the supply chain.

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