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Scientific Paper

The environmental and microbiological efficiency of vegetable cleaning

A eficiência ambiental e microbiológica da limpeza de vegetais

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ABSTRACT

Faced with the increase in water scarcity periods, the optimization of the use of this resource is increasingly necessary. This study aimed to evaluate the cleaning stage of *Lactuca sativa* for the preparation of meals outside the home with the participation of 9 restaurants using the Life Cycle Assessment tool, being later also extended to homes, with the participation of 8 households. The agricultural stage represented an average of 39.8% of all the impacts, the lettuce polypropylene wrap 14.4% and the transport stages 26.1%. The use of "blue" water ranged from 38 to 71 liters per kg of raw lettuce only in the cleaning stage, which represents 76% (households) and 77% (restaurants) of all the water used in the whole life cycle. In evaluations carried out, cleaning was considered efficient from the sanitary point of view, with 100% of the samples with *Escherichia coli* counts below the maximum allowed. The variability of the data obtained and the measured efficiency of sanitization, together, support the possibility of reducing the water consumption, mainly through training and awareness of the operators.

Keywords: water use; microbiological contamination; restaurants; households.

RESUMO

Diante do aumento dos períodos de escassez de água, a otimização do uso desse recurso se faz cada vez mais necessária. Este estudo teve como objetivo principal avaliar a etapa de limpeza de alface (*Lactuca sativa*) para o preparo de refeições fora do lar, com a participação de 9 restaurantes, utilizando-se princípios da ferramenta de Avaliação do Ciclo de Vida, sendo posteriormente também estendido para lares, com a participação de 8 domicílios. A etapa agrícola representou em média 39,8% de todos os impactos, o envoltório de polipropileno de alface 14,4% e as etapas de transporte 26,1%. O uso de água "azul" variou de 38 a 71 litros por kg de alface crua apenas na etapa de limpeza, o que representa 76% (domicílios) e 77% (restaurantes) da água utilizada em todo o ciclo de vida. Em todas as avaliações realizadas, a limpeza foi considerada eficiente do ponto de vista sanitário, com 100% das amostras com contagens de *Escherichia coli* abaixo do máximo permitido. A variabilidade dos dados obtidos e a eficiência do saneamento medida, em conjunto, sustentam a possibilidade de redução do consumo de água, principalmente por meio de treinamento e conscientização dos operadores.

Palavras-chave: uso da água; contaminação microbiológica; restaurantes; residências.

INTRODUCTION

Water scarcity is a problem that affects the whole world and worries the authorities and the population in general. Renewable fresh water in the world corresponds to a small fraction of the global water reservoir: although the planet has three quarters of its surface covered by water, its total amount on earth is fixed and its allocation in space and time is governed by the hydrological cycle (JACKSON *et al.*, 2001). To meet population growth, urbanization, rising standard of living, high consumption of food and industrialized products, in the last 100 years, the global use of water has increased almost six times and continues to grow (PFISTER *et al.*, 2011; WADA *et al.*, 2016). The recent and frequent water crises have signaled the urgency and the need to optimize the use of this natural resource and better planning of its supply and demand. In addition to being necessary for many aspects of daily life, water is also critical to the functioning of the food preparation sector, such as restaurants, for the generation of safe and properly produced food services.

Food services outside the home or foodservice have been one of the main options for Brazilians to have their meals. According to a survey carried out by the Serviço Brasileiro de Apoio às Micro e Pequenas Empresas (SEBRAE, 2017), of the 20 service sector segments with the highest concentration of small and medium enterprises (SME), restaurants and snack bars occupy 36.6%, of

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which 47% are self-service and 30%, *à la carte* service. The food sector in Brazil represents the fifth largest in the world and, in 2019, this market recorded an approximate growth of 3.5% (MELO, 2021).

Dining out is no longer a leisure option and has become a matter of necessity. Of the total expenses of Brazilian families with food, almost a third (32.8%) is destined for meals away from home, according the data from the sixth survey carried out by the Instituto Brasileiro de Geografia e Estatística (IBGE) on family budgets (Pesquisa de Orçamentos Familiares – POF 2017-2018 — IBGE, 2018). The participation of vegetables was 2.4% in household expenses with food, with lettuce occupying the eighth position among the most consumed ones (IBGE, 2018).

Vegetables are important dietary components because they provide essential nutrients, such as vitamins, minerals and fiber, and many health benefits (MAFFEI; SILVEIRA; CATANOZI, 2013). The diverse and daily consumption of these foods is recommended at all stages of life, which plays a fundamental role in promoting and maintaining health and quality of life (BRASIL, 2014).

According to Maffei, Silveira and Catanozi (2013), despite the health benefits, the risk of microbiological contamination in green leaves is worrying. Therefore, many consumers question the quality and safety of these foods. Pathogens can be inserted in primary production or in any other stage of distribution chain and can multiply if hygiene and temperature control actions are not carried out correctly (ANTUNES, 2020).

The quality of the vegetable cleaning process depends on the sanitizing agent, concentration, solubility, and quantity of microorganisms present in the raw material. Disinfection is understood as the operation, by physical and/or chemical method, of partial reduction of the number of pathogenic microorganisms or not, without the obligation to also eliminate the spores (SÃO PAULO, 2013; SÃO JOSÉ, 2017). Resolução da Diretoria Colegiada (RDC) No. 331, of December 23, 2019, which establishes microbiological standards for food, limits the maximum values allowed for fecal coliforms and salmonella (BRASIL, 2019b).

Escherichia coli is included both in the group of total and thermotolerant coliforms; their natural habitat is the intestinal tract of warm-blooded animals. *E. coli* is an important microorganism indicating the hygienic conditions of manufacturing processes; it is easily inactivated by sanitizers and capable of colonizing several processing sites when sanitization fails (SILVA *et al.*, 2017). The common clinical picture after consuming food contaminated with the microorganism *E. coli* is diarrhea, vomiting, fever, colic, malaise, and chills (SILVA, 2020). According to the Instrução Normativa (IN) No. 60, the standard required for a safe food is a count of less than 1 x 10^1 colony-forming unit (CFU)·g^{-1} (BRASIL, 2019a).

Salmonella spp. is an enteric bacterium responsible for serious food poisoning; its main habitat is the intestinal tract of humans and animals, being one of the main agents involved in outbreaks recorded in several countries (SILVA *et al.*, 2017). Brazilian legislation (BRASIL, 2019a) establishes the standard for the absence of salmonella in 25 g of product.

In a study carried out by Nascimento and colleagues (2005), 42 samples of lettuce (*Lactuca sativa*) sold in street markets in the municipal market of São Luiz (MA) were submitted to microbiological analysis and the results verified the absence of *Salmonella spp.* and the presence of *Escherichia coli* in 29 of them.

For Gonçalves and co-workers (2018), in 80 samples of traditional cultivation and 80 samples of organic lettuce sold at local fairs in the city of Pelotas (RS), there was no *Salmonella spp*. in the samples of traditional cultivation and the presence in 5% of the samples of organic cultivation.

Ferreira and research team (2011) carried out the collection of lettuce samples in two supermarkets in Campo Grande (MS), in order to compare the effectiveness of sanitization. Research was carried out on thermotolerant coliforms, *Salmonella sp*. and coagulase-positive *Staphylococcus*. No sample showed the presence of *Salmonella spp*. All samples before sanitization showed contamination by thermotolerant coliforms and *Staphylococcus*. At the end of the process, the samples showed no contamination by thermotolerant coliforms or coagulase-positive *Staphylococcus*, demonstrating that vegetable sanitization is effective in reducing at least 97% of the initial microbial load by thermotolerant coliforms and *Staphylococcus*.

Silva and Medeiros (2015) carried out research to evaluate the efficiency of chlorine in the sanitization of leafy vegetables used in raw salads. Twenty-four samples of different species were used, 12 of which were collected after being washed in running water and 12 after being sanitized with chlorine solution at a concentration of 200 parts per million (ppm) by immersion for 15 minutes. As a result, it was concluded that the sanitization process has satisfactory effectiveness, the consumption of vegetables washed and sanitized with chlorine is considered safe in terms of hygienic-sanitary aspects.

The main objective of the present study Is to identify and quantify the main environmental interfaces of the practices adopted in restaurants and households in the process of cleaning "smooth hydroponic lettuce" (*Lactuca sativa*), while evaluating its effectiveness in microbiological decontamination. In addition to the sanitation process itself, it also aims to understand the main environmental impacts of this production chain and identify opportunities to improve the environmental performance of this process.

METHOD

This study was developed and modeled for restaurants. A first gate-to-gate approach was carried out for the collection of lettuce cleaning data, the main focus of this work, with subsequent extension to a cradle-to-grave approach, according to ISO 14040:2006 (International Organization for Standardization — ISO, 2006). As the project was developed during the pandemic period, when most restaurants were closed, the authors included data collection in some households.

The inclusion of households in the project generated important comparative assessments regarding the scale of preparation. However, the main focus of the project was maintained in the survey carried out with the restaurants, given their greater representativeness.

First gate-to-gate approach

Scope and data collection

As the main objective of this work is to improve the environmental performance of the process of cleaning vegetables, data collection was focused on this stage through personal interviews and visits to restaurants and households.

Data collection was carried out in two stages. In a first stage, a questionnaire was prepared, called a previous survey (PS), with the aim of classifying the sites according to their capacity, volume, type of production, and average monthly consumption of resources as well as water and electricity, which also made it possible to collect information about the quantities of lettuce needed for the second stage of the research.

In this project, it was decided to provide the vegetable to participants, to reduce the effects of their variability, so that the results could primarily reflect the existing differences in handling operations, food preparation structure and specific conditions of the sampled locations. After acquiring them, the measurements were scheduled *in loco*, in each restaurant or household. Lettuce produced by a single supplier was used in each restaurant and household participating in the research.

In order to encourage the provision of data and collaboration in the process, the cleaned vegetables were given to the establishment at the end of data collection.

Product surveyed

The vegetable used was the cultivar "smooth hydroponic lettuce" (*Lactuca sativa*), which has large, smooth leaves in a conical shape. All lettuce samples were obtained from the same supplier to reduce the variability of the initial conditions of the samples. The quantities of lettuce normally consumed by each project participant were previously separated and taken to the measurement sites.

Functional unit

The study was carried out taking as a functional unit 1 kg of sanitized lettuce, ready for consumption.

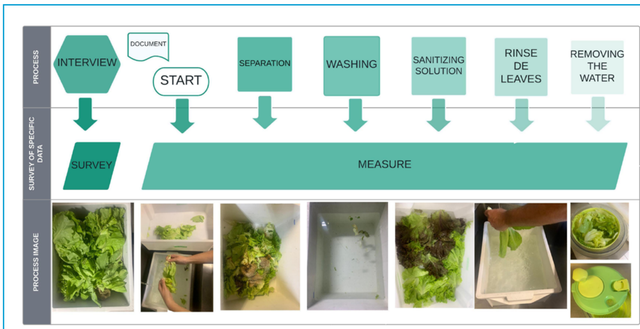
Cleaning process

At the state level, the hygiene of fruit and vegetables must be carried out in an appropriate place, with drinking water and disinfectant products, regulated by the Agência Nacional de Vigilância Sanitária (ANVISA), and must comply with the instructions recommended by the manufacturer (SÃO PAULO, 2013).

According to a São Paulo municipal decree (SÃO PAULO, 2011), the process of cleaning fruits and vegetables must include the following steps:

I. selection for removal of deteriorated parts and units;
II. selection for removal of sprouted units, dirt, pests and vectors;
III. careful washing carried out in running and potable water: leaf by leaf, vegetable by vegetable, bunch by bunch, fruit by fruit;
IV. disinfection carried out according to the recommendation of the manufacturer of the sanitizing product used;
V. rinsing carried out carefully in running and potable water or according to the manufacture's recommendation.

Figure 1 illustrates the sequence of steps followed during the cleaning process. The initial amount of lettuce used by each participant is initially weighed. After this step, the handler performs the separation of the leaves and washes in running water to remove solid residues. In the sink where the cleaning is carried out, a plastic collection box is placed, so that the input is later weighed and accounted for during the process. After this step, the leaves are transferred to plastic boxes containing water and the sanitizer used for a period that varies, according to the manufacture's instructions, between 10 and 15 minutes. As soon as the leaves are removed from this solution, this water is weighed and accounted for in the process. The leaves are then washed again to remove chemical residues and any other vectors that are still present.



Note: weight measurements: lettuce (starter, residue and sanitized) and water (prewash, sanitizing solution and post-sanitization).
Source: elaborated by the authors.

Figure 1 – Flowchart of cleaning process.

After completing the cleaning process, three 60 g samples were collected and sent to the laboratory for microbiological analysis.

Microbiological analysis

The *Escherichia coli* analysis was performed by the method of colony forming units counting (SILVA *et al.*, 2017): 10 g sample is diluted, buffered, and homogenized. Aliquot (1 mL) was incubated in Violet Red Bile (VRB) agar culture medium for 24 hours at 35°C. For counting, two methods were used with incubation for 48 hours: bright green (35°C) and medium *E. coli* (45°C). In the occurrence of gases, eosin methylene blue (EMB) agar was added to count the pathogenic colonies (SILVA *et al.*, 2017).

The method for determining the presence or absence of *Salmonella spp.* started with a 25 g sample, which was added to a buffered aqueous solution, homogenized, and incubated at 35°C for 24 hours. Aliquot (1 mL) was placed in *selenite cystine broth* culture medium and incubated at 35°C for 24 hours. After cooling, it was placed in two different media — bright green and *ectoine enriching agar* — and incubated at 35°C for another 24 hours.

These analyzes were performed according to the Compendium of Methods for Microbiological Analysis of Food (American Public Health Association — APHA, 2017); all analyses were performed in triplicate. The results were compared to the interpretative bases described in IN No. 60 (BRASIL, 2019a), of December 23, 2019, and in Resolution RDC No. 331, of December 23, 2019 (BRASIL, 2019b).

Statistical treatment

Anderson-Darling and Shapiro-Wilk normality tests were performed to verify if the data follow a normal probability distribution, with the exception of the water (prewash — kg) and lettuce (kg) characteristics, in which the Box-Cox transformations were performed, which resulted in normality. To assess variability, Fisher and Bartlett tests were performed. As all data sets follow a normal probability distribution, the T-Student test for independent samples at a 95% confidence level was used to compare the means. The analysis was carried out with Addinsoft Software — XLSTAT —Version 2015.6.01.24494.

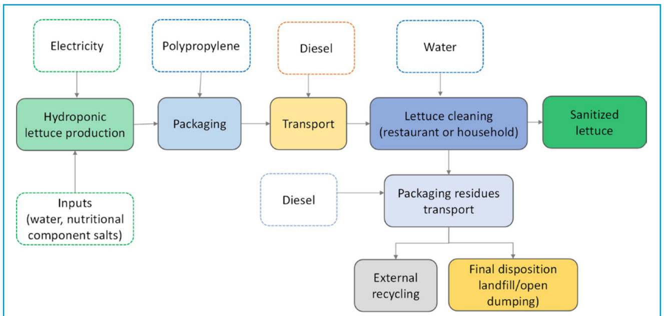
Complete cradle-to-grave approach — System evaluated

In order to understand the environment impact of the cleaning stage in the whole chain, the study was extended to include downstream and upstream stages (Figure 2). This extension included the agricultural stage of hydroponic lettuce production, its transport to the cleaning site and the sanitization process itself. Agricultural stage data related to hydroponic lettuce production were obtained from the available scientific literature. The seeds are initially placed in a foam that provides support for the growth of the seedlings and later transplanted into polyethylene channels. Plants are fed by the roots by circulating solution containing the nutrients necessary for their growth.

For the construction of the inventory, the following data were used, from the published study Graf and Figueiredo (1999), calculated per kg of lettuce: electric energy (1.5 kWh in irrigation), water (12.86 L of water) and the composition of the nutrient solution cited by these authors. The components of the nutrient solution and/or their agronomic equivalents, considering the macronutrients N, P and K and micronutrient Ca, as well as the available inventories in Gabi professional software used to model the hydroponic plantation (per 1000 kg of lettuce produced) were: 7.58 kg of potassium chloride (agrarian, 60% K_2O), 4.78 kg of urea (agrarian), 2.86 kg of magnesium sulphate, 1.61 kg of lime, and 1.57 kg of monoammonium phosphate (MAP, agrarian).

The inventories of the other components were selected from the Gabi professional software databases: polypropylene (2013) and sodium hypochlorite (2011), both from PlasticsEurope. A transport distance of 10 km between agricultural/sanitary and sanitization/recycling stages or final disposal were considered, according to data reported by Graf and Figueiredo (1999).

For post-consumer waste from the polypropylene bag, the following data were used: 91.2% of solid waste is collected in the country, 17% of the plastic waste collected is recycled, 82.5% goes to controlled or sanitary landfills, and 17.55% goes to dumps (ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS — ABRELPE, 2019).



Source: elaborated by the authors.

Figure 2 – Flowchart of the stages included in life cycle assesment of lettuce.

RESULTS AND DISCUSSION

Participants characterization

The restaurants were characterized by *à la carte* or self-service. In addition to the type of restaurant, the average amounts of daily meals and consumption of inputs such as energy and water were surveyed. These parameters are variable due to the structure of each location, depending directly on the amount and types of refrigeration equipment, air conditioners, electric or gas machinery, and dishwashing equipment.

Among the nine participants, six had self-service and three had the *à la carte* service. The restaurants are located in the city of São Paulo, with eight in the south region, Itaim Bibi, Jardins, Vila Mariana and Saúde; and one in the west region, in Vila Leopoldina.

The number of meals a day ranged from 80 to 400. In the *à la carte* service, service capacity is lower, due to the complexity of assembling individual meals. The self-service service allows for a greater number of daily meals.

The study included eight household participants. The number of residents ranged from 1 to 3 people, between 32 and 65 years old, being a household with two children, respectively, 5 and 12 years old. Most reported having a daily meal at home, giving preference to dinner. Among those interviewed, 19% eat all their meals at home.

Average monthly water consumption was surveyed based on bills paid by participants and ranged from 2.460 to 6.120 liters.

Lettuce cleaning characterization processes

The main results of the survey carried out with industrial restaurants is presented in Table 1. All the participants prepare together around 1.610 meals daily, considering the nine units which are located in the city of São Paulo.

The results show that water consumption in commercial establishments evaluated in lettuce sanitization ranged from 75 kg of water to 38 kg per kilogram of sanitized vegetables, as shown in Table 1. It is observed that this variation is not related to the efficiency of the sanitizer, but rather the specific practice of each location. The method used in cleaning vegetables is common to all locations, the variation identified was the type of sanitizer and the individual practice of each employee. When questioned, no place showed training or training

Table 1 – Main parameters of the process of cleaning vegetables in restaurants.

Parameter	R1	R2	R3	R4	R5	R6	R7	R8	R9	Average	CV (%)
Input											
Water – prewash (kg)	44.4	20.10	23.50	20.60	20.10	24.70	13.00	25.70	18.40	24.00	36.4
Water – sanitizing (kg)	3.90	8.20	7.10	10.70	9.20	6.60	8.00	6.80	4.00	7.60	29.4
Water – final washing (kg)	23.2	13.10	13.10	14.60	12.80	19.60	19.20	15.50	15.50	16.00	23.6
Sanitizer – actives (g)	0.33	1.18	0.80	0.95	1.82	0.66	1.17	0.97	0.37	1.00	46.3
Lettuce (kg)	1.12	1.21	1.26	1.58	1.47	1.65	1.33	1.38	1.38	1.37	12.5
Output											
Sanitized lettuce (kg)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0
Waste (kg)	ND	0,68	0,33	0,75	0,49	0,74	0,41	0,50	0,51	0,55	28,4
Effluent (kg)	71.50	41.40	13.8	45.80	42.10	50.90	40.20	45.30	37.80	47.61	21.2

Note: functional unit (parameter per kg of sanitized lettuce); R: restaurant; CV: coefficient of variation; ND: not determined.
Source: elaborated by the authors.

in hygiene regarding the reduction of water consumption, only the effectiveness of the process, with an emphasis on ensuring that the vegetables do not present vectors after cleaning.

The high variability in water consumption denotes little environmental awareness in the use of this resource, as also found in the work of Carvalho and Pereira Filho (2004): in their research, carried out with students from the 5th to the 7th year of the municipality of Santa Maria (RS), it was found that the total daily consumption varied from 98.1 to 182.8 L per person, which, compared to the volume of water considered necessary by the United Nations (UN) of 80 L per day per capita, leads to the conclusion that a large part of the target audience is using water unnecessarily.

According to the Healthy Eating Food Guide prepared by the Brazilian Ministry of Health (BRASIL, 2014), the recommended portion per person is the consumption of 3 daily servings of vegetables. A serving of lettuce is equivalent to 15 leaves (120 g), so, when consuming 120 g of lettuce in a restaurant, according to the results obtained, there is a consumption associated with the cleaning process of 5.7 kg of water on average.

All restaurants follow the hygiene protocols established by Portaria 2619 (SÃO PAULO, 2011), that is, they clean in three stages: pre-wash, soak, and sanitizer removal. Pre-washing is the most water-demanding step, with an average consumption of 24 kg of water per kg of sanitized lettuce (50%), which is understandable, since it is necessary to remove the dirt visually adhering to the leaves, mostly from the planting stage, even though they are plain lettuce, of hydroponic origin. Considering that the lettuce used is of the same type and supplier, it is observed that this step has the greatest variability (36%) and, therefore, should be one of the steps to be worked on among the necessary actions to make the process more efficient. There is a participant that uses only 13.8 kg of water in this stage (R7 restaurant).

In restaurants, it is not possible to compare the effectiveness of the sanitizing effect according to the quantities used, as establishments use different active principles: sodium dichloroisocyanurate (R1, R3, R8), trichloroisocyanuric acid (R2), sodium hypochlorite (R4, R5, R6, R7), and dichloro-s-triazinetrione (R9).

The amounts of lettuce losses identified as residues varied between 21 and 45% of the input weight. In food services, the generation of organic waste is inevitable in the different stages that encompass this process, such as pre-preparation, preparation, distribution, and consumption (RIBEIRO, 2020). To reduce losses, it is important to reduce the period of time between harvesting and consumption of vegetables, keeping vegetables under adequate humidity and temperature conditions while stored, and performing good management to balance the quantities prepared and consumed.

The variability of the amounts of waste generated among the participants highlights the possibility of improving efficiency and reducing the number of residues generated. The main results of the survey carried out with households is presented in Table 2. The average value of water consumption in households is 48.9 kg of water per kg of lettuce.

Statistical analysis comparing data obtained in restaurants and households, for each of the measured flows — lettuce, water (pre-washing, sanitizing and final washing), actives of sanitizer and waste —, did not identify a significant difference for any of these evaluated parameters, at 95% of confidence level.

The great variability in the amount of water, measured by the coefficient of variation, which is 17.5% in households and 21.2% in restaurants (21.2%), occurs mainly due to differences in the opening of the faucet while the handler performs individual cleaning activities on the leaves, which may vary in the prewash and/or rinse stages.

Great variability was observed in the amounts of sanitizers (actives) in restaurants (46.3%) and households (54.4%). However, nothing can be concluded regarding differences in sanitization efficiencies as different active ingredients are used. In industrial restaurants, actives such as sodium dichloroisocyanurate and trichloroisocyanuric acid are used, in addition to sodium hypochlorite, used in all households.

In all samples of sanitized lettuce collected, both in restaurants and in households, the sanitization processes were efficient, with count results below 1.00×10^1 CFU·g^{-1} for *Escherichia coli*. The control samples, which were not subjected to cleaning, showed contamination, ranging from $3.4–4.5 \times 10^3$ CFU·g^{-1}.

It is not possible to conclude that the cleaning process is efficient for the elimination of *Salmonella spp.*, since the presence of salmonella was not detected in the original control samples.

The data obtained allow us to state that the sanitization method and amounts used were efficient in eliminating pathogenic microorganisms. Among the

Table 2 – Main parameters of the process of cleaning vegetables in home.

Parameter	H1	H2	H3	H4	H5	H6	H7	H8	Average	CV (%)
Input										
Water – prewash (kg)	26.1	25.0	22.5	15.6	25.6	31.4	23.7	33.0	25.6	21.2
Water – sanitizing (kg)	6.9	7.9	4.7	6.9	3.8	6.3	4.0	5.0	5.7	26.4
Water – final washing (kg)	18.0	8.7	10.8	18.9	16.8	22.4	32.5	12.5	17.6	43.0
Sanitizer – actives (g)	0.93	0.57	0.98	1.27	1.58	2.65	0.68	1.09	1.22	54.4
Lettuce (kg)	1.31	1.34	1.35	1.34	1.41	1.86	2.01	1.55	1.52	17.6
Output										
Sanitized lettuce (kg)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0
Waste (kg)	0.41	0.47	0.42	0.45	0.48	0.91	0.77	0.73	0.58	33.2
Effluent (kg)	53.0	41.6	38.0	41.4	46.3	60.1	60.3	50.5	48.9	17.5

Note: functional unit (parameter per kg of sanitized lettuce); H: Home; CV: coefficient of variation.
Source: elaborated by the authors.

sanitizers used by the restaurants and households evaluated, it was observed that the recommended immersion time, that is, the time of action in the food, varied from 10 to 15 minutes, with the exception of two options that suggest a time of five minutes. This variation is due to the active principle of each sanitizer and its concentration both in the formulation and after its dilution in water, respecting the recommendation of each manufacturer.

In the samples acquired for the study — called control samples 1, 2 and 3 —, the presence of *E. coli* was detected, at levels higher than those allowed for ingestion. Contamination of raw materials may be related to the absence of good practices in planting, in the post-harvest process, transport to markets and exposure time.

As Berbari, Paschoalino and Silveira (2001) demonstrated in their research, the analyzed lettuces showed a high initial microbial contamination load, especially by bacteria of the total coliform group, but the presence of salmonella was not detected in the sample. In this same work, immersion of vegetables in solutions containing 70, 100 and 130 mg·L^{-1} of chlorine, conferred shelf life at 2°C, of 6, 9 and 9 days, respectively.

Ramiro (2019) argues that water waste in food services is high. The biggest waste of water occurs in the washing of utensils, due to lack of training and qualification on the conscious use of water. In his study, Ramiro (2019) shows that the use of water for washing vegetables per meal is 5.05 L, representing 15.5% of total water consumption. When comparing the results of the present survey, with an average consumption of 47.6 kg of water per kg of lettuce, considering that a meal consists of an average of 120 g of vegetables, the consumption of water would be 5.7 L of water, a value 13% higher than of the one found in the study by Ramiro, and therefore very close to its result. These amounts vary depending on the type of food and the condition of the product in its initial state, as well as the hygiene protocol of each establishment and, mainly, of the handlers involved in the operation.

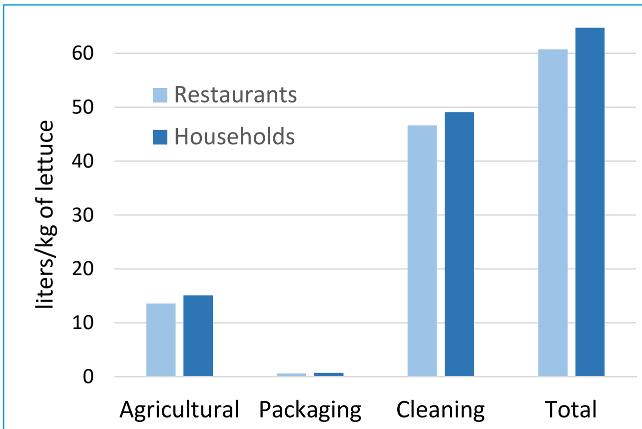
An important question that is analyzed with these results is: where does microbiological contamination come from? Probably from irrigation water that is not sanitized. This fact makes a huge amount of water necessary in the washing step by consumers, whether in restaurants or households, mainly due to the sauce source and the subsequent washing step to eliminate the sanitizer flavor. Thus, what is proposed in this work is that the water used in cultivation has its microbiological contamination controlled, so that this contamination does not demand so much water in the subsequent washing step.

Extension of the study to include the chains before and after cleaning

Blue water use evaluation

Since water consumption is the main natural resource related to the cleaning stage, blue water use was calculated in the different stages of the lettuce life cycle, as shown in Figure 3.

The water classified as blue is fresh water from the surface, such as rivers and groundwaters. "Blue water use" measures only water use but not the status of water returned to the ecosystem, if it has changed from its original quality (THYLMANN; KUPFER; HORLACHER, 2021). What can be observed is that, regardless of the location of sanitization, this is a highly water-demanding stage, compared to the others, that is, 76–77% of all water consumed in the lettuce production cycle, considering from the agricultural stage, transport and final disposal is intended for its sanitization. In this evaluation, it must be considered that the lettuce used is hydroponic, which consumes much less water than that produced in the soil, in conventional planting. As already seen in previous assessments, domestic use has a slighter greater use of water (65 L·kg^{-1} of lettuce), about 6% higher than the consumption observed in restaurants.



Source: elaborated by the authors.

Figure 3 – Blue water use contribution analysis in life cycle assessment of lettuce.

A study carried out in Italy (FUSI *et al*., 2016) for fresh cut lamb's lettuce has boundaries very similar to this study, as it is sanitized lettuce packed in polypropylene bags, grown in an agricultural greenhouse. Water consumption in the agricultural stage from the Italian study was 14 times higher (186 L·kg^{-1} of lettuce) than the present study (14 L·kg^{-1} of lettuce). In the cleaning stage of the present study, the average value measured in restaurants (47 L·kg^{-1} of lettuce) was about 20% higher than the found one by the Fusion and colleagues (2016) study: 39 L·kg^{-1} of lettuce. These data show, as expected, that the water consumption for lettuce cultivation in a conventional system is much higher than in the hydroponic system used in the present study.

Main environmental impacts and contribution analysis

The main environmental impact categories of production and consumption of lettuce are shown in Table 3. A small difference of 10–34% in all impact categories was found between restaurants and households, basically due to the lower restaurant yield during lettuce cleaning, as household consumers seem more rigorous in cleaning vegetables at their homes.

Considering the contribution analysis of stages at restaurants, it is important to note that, besides the use of water, the cleaning has significant impact related to depletion of abiotic elements, ozone layer depletion and terrestric ecotoxicity due to the sanitizing agent. The agricultural stage represents, on average, 39.8% of the impacts measured by the Centrum voor Milieukunde Leiden (CML) 2001 methodology of August 2016. Considering only the polypropylene wrapping as packaging, it is observed that it represents 14.4% on average of the impact, and transport also has a significant portion of 26.1%. Thus, to improve this profile, it can be proposed to remove the wrapping when possible and encourage the purchase of vegetables from local producers. In this case, distances of 10 km were considered both between the consumer and transport to final destinations.

Table 3 – Main environmental impact categories and contribution analysis.

Impact category (CML 2001, Aug. 2016)	Restaurants	Households	Contribution analysis at restaurants (%)			
			AGR	PACK	TR	CLE
ADP elements [kg Sb eq.]	3.9E-05	5.1E-05	50.1	3.7	0.0	46.3
ADP fossil [MJ]	2410	2680	41.5	57.3	0.5	0.8
AP [kg SO_2 eq.]	10.40	11.60	30.8	2.5	66.7	0.0
EP [kg phosphate eq.]	2.40	2.67	24.2	0.8	75.0	0.0
FAETP inf. [kg DCB eq.]	0.937	1.050	94.7	1.3	2.4	1.6
GWP 100 years [kg CO_2 eq.]	487	542	84.0	10.9	5.0	0.3
HTP inf. [kg DCB eq.]	355	395	26.4	1.9	71.4	0.5
MAETP inf. [kg DCB eq.]	23.4	26.1	18.9	74.3	0.0	6.9
ODP (steady state) [kg R11 eq.]	5180	5900.0	0.0	0.0	0.0	100.0
POCP [kg Ethene eq.]	4.7E-10	7.1E-10	30.8	3.4	65.9	0.0
TETP inf. [kg DCB eq.]	0.754	0.838	36.7	2.1	0.0	61.2
Average	-	-	**39.8**	**14.4**	**26.1**	**19.8**

Note: Functional unit: (quantity per 1000kg of lettuce); ADP: abiotic depletion; AP: acidification; EP: euthophication; FAETP: freshwater aquatic ecotoxicity; GWP: global warming potential; HTP: human toxicity; MAETP: marine aquatic ecotoxicity; ODP: ozone layer depletion; POCP: photochemical ozone creation; TETP: terrestric ecotoxicity. Stages: AGR: agricultural; PACK: polypropylene wrap packaging; TR: transport; CLE: cleaning.
Source: elaborated by the authors.

CONCLUSIONS

The number of restaurants associated with the constant growth of the largest metropolis in the country explains the need to assess and quantify water consumption related to food production. The water consumption per kg of washed vegetables was between 38 and 71 L only in the sanitization stage. The results suggest that the training of teams in relation to environmental awareness and the implementation of systematized and monitored processes can significantly reduce the water consumption indicator.

Lettuce is, however, a vegetable that requires to be well washed so that it is not a vehicle for the transmission of pathogenic microorganisms and the minimization of water use requires careful evaluation of the efficiency of sanitization. There are few studies related to water consumption in the cleaning and sanitization of vegetables. It is recommended that further studies be carried out with other cultivars, such as curly lettuce, using different washing procedures and initial contamination. The cleaning processes of vegetables used by the restaurants and households in this research proved to be efficient from the sanitary point of view, in which, in 100% of the samples, the *E. coli* count was lower than 1.00×10^1 $CFU \cdot g^{-1}$.

The variability of the data obtained and the efficiency of the sanitization measured, together, support the possibility of reducing this precious natural resource that is water.

Importance should be given to environmental awareness programs for the population, since water crises have been more frequent in recent years and washing vegetables is a daily practice.

It is extremely important to control microbiological contamination of water consumed at the agricultural stage, which is the real source of entrance of microorganisms into this chain.

In the extension of the study including the steps before and after the sanitization, it is observed that the sanitization step is responsible for about 76–77% of all the "blue" water used in the lettuce production cycle.

Agricultural stage, packaging and transport have also significant environmental impacts and they are responsible for all other impacts measured by CML methodology. Removal of wrapping when possible and acquisition of lettuce of local farmers could also be prioritized in order to minimize impacts.

AUTHORS' CONTRIBUTIONS

Di Santillo, C.P.R.S.: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft. Mourad, A.L.: Conceptualization, Funding acquisition, Methodology, Software, Supervision, Validation, Writing – review & editing.

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