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Unlocking Value: Transforming Agri-food Surpluses from a Chilean Wholesale Market into Healthy and Sustainable Foods

Aprovechando su potencial: Transformando excedentes agroalimentarios de un Mercado Mayorista Chileno en alimentos saludables y sustentables

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ABSTRACT

Introduction. Food waste is a serious global problem with impacts on the environment, society, and the economy. Around 1.300 million tons of foods produced for human consumption are lost or wasted, with fruits and vegetables having the highest waste rates. Moral and social aspects of food loss and waste are equally essential to consider, since it affects food security, mainly in the most vulnerable populations. The aim of this study was to add value to fruits and vegetables, or part of them, discarded from a main wholesale market in Santiago, Chile.

Methods: 17 prototypes were developed from surplus broccoli, celery, beets, and tomatoes and were performed for subsequent sensory evaluation.

Results: Two prototypes were selected and produced. For this purpose, a pilot plant was designed located inside the wholesale market in order to have immediate access to the raw material. 79.3 kilos of Green concentrate and 63 kilos of Red concentrate were produced. Finally, the products elaborated were distributed free of charge to elderly people through a food bank.

Conclusions: This study represents a unique and innovative social, environmental, and business in Chile based on the valorization of food surpluses through the development of new foods that can be replicated globally.

Keywords: Food waste; food surplus; high-value products; fruit; vegetables

RESUMEN

Introducción. El desperdicio de alimentos es un problema global grave con impactos en el medio ambiente, la sociedad y la economía. Alrededor de 1.300 millones de toneladas de alimentos producidos para el consumo humano se pierden o desperdician, siendo las frutas y verduras las que tienen las tasas más altas de desperdicio. Los aspectos morales y sociales del desperdicio de alimentos son igualmente esenciales de considerar, ya que afectan la seguridad alimentaria, principalmente en las poblaciones más vulnerables. El objetivo de este estudio fue agregar valor a las frutas y verduras, o parte de ellas, descartadas desde el principal mercado mayorista de Santiago, Chile.

Metodología. Se desarrollaron 17 prototipos de concentrados salados a partir de excedentes de brócoli, apio, remolacha y tomates, los cuales fueron sometidos a evaluación sensorial.

Resultados. Se produjeron 79,3 kilos de concentrado verde y 63 kilos de concentrado rojo. Finalmente, se seleccionaron y produjeron dos prototipos. Para ello, se diseñó una planta piloto ubicada al interior del mercado mayorista con fin de poder acceder inmediatamente a la materia prima. Por último, los alimentos generados fueron distribuidos de forma gratuita a adultos mayores a través de un banco de alimentos.

Conclusión. Este estudio representa una iniciativa social, ambiental y empresarial única e innovadora en Chile basada en la valorización de excedentes alimentarios a través del desarrollo de nuevos alimentos que puede ser replicada de manera global.

Palabras clave. Desperdicio de alimentos; excedentes agroalimentarios; productos de valor agregado; frutas; vegetales

KEY MESSAGES

- Food waste is a major global issue, due to the unsustainable use of natural resources, putting the entire environmental balance at risk.
- Surplus fruits and vegetables were processed to create different nutrient-dense foods.
- The development of healthy and sustainable foods was driven by an innovative approach to the valorization of food waste.
- Social, environmental and business benefits, thus contributing to the circular economy and food security.

INTRODUCTION

Agricultural production as well as agro-industrial processing generate a high amount of waste and food losses. Particularly fruits and vegetables represent 45% of waste and food losses worldwide (where 100% = 1.3 billion tons)[1]. In the agri-food business, one of the major problems affecting all the activities and their sustainability is food loss and waste across the food supply chain (FSC) which is not only determined by both biological and climate factors. Probably, the most important one is urbanization, which has resulted in the gradual extension of the FSC, increasing the remoteness between the place of production and the final consumption. This remoteness requires the transport of food products over greater distances and, consequently, the improvement of transport and storage to avoid additional losses[2]. Also, socio-economic factors related to strategic and operational decisions, such as incorrect application of inventory turnover, improper conditions of storage during transportation[3,4]. These factors not only culminate in the extravagant depletion of invaluable resources, notably water, arable land, and energy but also contribute substantially to the exacerbation of greenhouse gas emissions, thereby aggravating climate concerns. They result in the inefficient use of natural resources like water and energy, contribute to deforestation and habitat destruction, and increase greenhouse gas emissions due to the energy expended in producing and transporting lost food[5]. Addressing food losses is essential to reduce these environmental consequences and promote a more sustainable food system. Many of these biomaterials end up in municipal landfills where they create serious environmental problems due to microbial decomposition and leachate production[6].

Fruits and vegetables are cornerstones of a healthy diet, playing a pivotal role in human nutrition and well-being. They are rich sources of essential vitamins, minerals, dietary fiber, and antioxidants, all of which are vital for maintaining optimal health[7]. Regular consumption of fruits and vegetables has been associated with a reduced risk of chronic diseases, including heart disease, diabetes, and certain types of cancer[8,9]. Additionally, their low-calorie density and high nutrient content make them valuable components of weight management and overall health[10]. Moreover, the diverse array of fruits and vegetables available provides an opportunity for individuals to enjoy a varied and satisfying diet while reaping the numerous health benefits they offer. Thus, the incorporation of ample fruits and vegetables into one's daily nutrition is a fundamental aspect of fostering and maintaining a balanced and healthful dietary regimen[11]. In this sense, healthy and sustainable eating is of great importance in the elderly population due to specific diseases and functional losses associated with old age, such as musculoskeletal diseases and non-communicable diseases (NCDs) and cardiovascular diseases[12].

The recovery of nutrients from discarded fruits and vegetables is a crucial aspect of sustainable food systems and resource conservation. Considering the social impact attributed to an ethical and moral dimension within the general concept of global food security since 805 million people across the globe suffer from hunger. Byproducts from fruit processing, including pomace, peels, trimmings, stems, leaves, skins, bran, and seeds, Byproducts from fruit processing, including pomace, peels, trimmings, stems, leaves, skins, bran, and seeds,

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constitute an important proportion of the total fresh fruit and vegetables harvested. These byproducts can be transformed into a variety of products, such as biofuels, organic fertilizers, food and feed additives, thus contributing to sustainable waste management and resources[13]. For example, in Nigeria and Kenya the use of mango by products has been suggested as the main ingredient in the diet of infants and adults since it increases the content of protein and antioxidants[14,15].

In Chile, a microcosm reflecting broader global trends, food waste also commands attention. Scientific research estimates significant losses throughout the food supply chain[16], commencing at the production stage and extending to retail and consumption levels. These losses encompass fruits and vegetables, which represent valuable nutritional resources lost to inefficiencies and suboptimal practices. As the empirical documentation of food waste accumulates, it underscores the compelling necessity for scientific rigor in devising strategies and interventions to curtail this wasteful phenomenon, both globally and within the Chilean context, ultimately harmonizing ecological imperatives with food security concerns.

The aim of this pilot study was to transform agri-food surpluses from a Chilean wholesale market into nutritional foods. This raw material was processed to create nutrient-rich prototypes, which were then delivered free of charge to beneficiaries of a food bank in Santiago, Chile.

METHODS

Material selection

The raw materials used in this study were discarded fruits and vegetables collected from a wholesale market in Santiago, Chile. Specifically, these included broccoli leaves and stems, beet leaves and stems, celery leaves and stems, and tomatoes. The raw materials were procured from 'vins' located in the trucks of intermediaries and farmers who routinely enter the market to sell their produce. Given that the raw materials arrived intact without differentiation between stems and leaves, a process of coarse cutting and classification was initiated. This process incorporated visual inspection to minimize the presence of damaged stems, wilted leaves, and visible fungi. Following the cutting and classification of the raw materials into fruits, vegetables, stems and leaves. All raw material obtained was weighted.

Cleaning and sanitization of raw material

The procedure was carried out according to Rodríguez Palleres et al[17]. Briefly, the raw materials were cleaned in a washing machine with water. The sanitization procedure was carried out with a 200 ppm solution of benzalkonium chloride. Finally, the raw material was rinsed again with water to eliminate excess sanitizing solution.

Prototype elaboration

A total of 17 prototypes were elaborated. The 17 prototypes encompassed different ingredient proportions of raw materials described above and were carried out with the objective of formulating products that would be sensorially acceptable. The prototypes included the following ranges of ingredients: broccoli leaves (0-15.6%), broccoli stems (0-26.9%), beet leaves (0-37%), beet stems (0-23%), celery leaves (0-20.4%), celery stems (0-30.6%), and tomatoes (0-60%). Additionally, the prototypes may have contained black pepper (0-0.2%), onion, garlic (0-5%), garlic powder (0-1%), salt (0-1.2%), vegetal oil (9-10.1%), cornstarch (1-3%), and water (0-54%) as needed to complete the formulation.

Prototype sensory evaluation

The 17 prototypes were analyzed through an internal sensory evaluation by a panel of evaluators, who evaluated flavor, texture and smell. After this sensory evaluation, a sensory analysis of the selected products was carried out with a panel of evaluators, involving an open and qualitative discussion, evaluating flavor, texture and smell. A subjective sensory analysis was conducted using a 5-point hedonic scale to evaluate the product's acceptance across four different sensory parameters: aroma, acidity, bitterness, astringency, and salty taste. The coded samples were individually presented to the panel participants. Prior to the evaluation, an induction session was conducted to explain the procedure and how to fill out the form. Subsequently, each sample was presented one by one, and the scores assigned to each attribute were recorded on the form by the nutritionist in charge of the panel. Finally, the two prototypes selected were evaluated in 48 older adults and 28 schoolchildren. The elderly participants were aged between 65 and 75 years and had no diagnosed cognitive impairments. The schoolchildren group consisted of participants aged 12 to 15 years. The sensory evaluation was based on 5 criteria: Scent with a scale from 0 to 7, where 0 indicated “Dislike” and 7 indicated “I like it a lot”; Acidity with a scale from 0 to 7, where 0 indicated “Nothing acidic” and 7 indicated “Extremely acidic”; Bitterness with a scale from 0 to 7, where 0 indicated “Nothing bitter” and 7 indicated “Extremely bitter”; Astringency with a scale from

0 to 7, where 0 indicated “Nothing astringent” and 7 indicated “Extremely astringent”; Salty taste with a scale from 0 to 7, where 0 indicated “Nothing salty” and 7 indicated “Extremely salty”. Following this sensory evaluation, further modifications were made to the formulations and obtained, 2 final prototypes, one called as the “Green concentrate”, comprising broccoli stems and leaves, celery stems and leaves, and beet leaves; and another termed the “Red concentrate”, featuring tomatoes and broccoli stems.

Scalable production

The final formulations of the two prototypes were prepared in a food pilot plant, located in the Wholesale Market. Initially, a fine cutting process was carried out, beginning with manual cutting to facilitate milling. This was followed by an automated cutting process, which involved the use of a fruit and vegetable cutter to reduce the size of the raw materials. Milling of the raw materials was conducted using a colloid mill, resulting in the formation of a concentrated product in paste form. This concentrate was subsequently subjected to pasteurization in a cooking vessel for 25 min at 96°C to eliminate pathogenic agents and prevent food spoilage. The final products were packaged in pre-sterilized glass containers and labeled prior to storage in refrigeration chambers, where temperatures were maintained between 0 and 3°C. At beginning, intermediate, and final steps, the raw material, intermediate or final product, were weighted to obtain the percentage of conversion of raw material into a final product. This involved comparing the initial weight of the raw materials with the combined weight of intermediates and the final packaged product. The calculation for the percentage of conversion was determined using the following formula:

$$\text{Equation 1 (eq1). Percentage of Conversion} = (\text{Weight of Final Product or Raw material cleaning and cutting} / \text{Weight of Raw Material}) \times 100$$

This formula allowed for a quantitative assessment of the efficiency of the production process, providing valuable insights into the yield and effectiveness of the transformation from raw materials to the final packaged product. The weighing process was repeated independently for each of the three production batches to ensure reliability and consistency in the results.

Chemical analysis

To assess the safety of raw materials, patulin and ochratoxin a mycotoxin produced by various fungi, were measured. Patulin was quantified using the HPLC-MS/MS method described by Silva et al. (2022)[18]. Ochratoxin was quantified using ELISA Microtiter Plate method, described by Zheng et al. (2005)[19]. In addition, copper, lead, selenium, and zinc were measured according to the AOAC methodology[20].

Microbiological analysis

In final products, microbiological analyses were performed. Counting of aerobic mesophilic bacteria (NCh 2659. Of. 2002), coliforms (Petrifilm method), *Staphylococcus aureus* (NCh 2671 Of. 2002), *Escherichia coli* (ISO 16649-2: 2001) and *Salmonella spp* (NCh 2675, Of. 2002) were quantified using the serial dilution and plate count method. These analyses were conducted in accordance with prevailing national regulatory standards[21]. In addition, a conventional PCR was developed to determine the presence or absence of *Salmonella spp., E. coli, Staphylococcus aureus, and Listeria monocytogenes*. Briefly, DNA extraction was performed with DNeasy PowerSoil ProKit (QIAGEN) following the manufacturer instructions. DNA quantification was performed with Qubit 4 Fluorometer (Thermo Fisher Scientific). The PCR profile used was: 10 min for initial denaturation at 94ºC; 35 cycles of 60 s at 94ºC, 60 s at 55ºC and 120 s at 72ºC; and a final extension of 7 min at 72ºC. Each reaction mixes of 25 µL contained 0.125 U de GoTaq Flexi DNA Polymerase (Promega, USA), 1.5 mM $MgCl_2$, 0.2 mM of each deoxynucleotide triphosphate (dNTP), 0.1 µM of each primer, Buffer 1X and 20 ng of DNA. The PCR products were visualized by electrophoresis in an 1.5% Tris-acetate-EDTA (TAE) agarose gel using standard 100 bp and staining with gel red at 1X.

Nutritional analysis

Nutritional characterization was conducted through proximate analysis. The nutritional analysis of final products was performed by “Unidad de Análisis de Aguas y Alimentos del Laboratorio DICTUC”. The samples analyzed correspond to a mix of different packaged products from the same batch. The parameters measured included energy, protein, carbohydrates, fat and dietary fiber. The procedure followed the methods described by Rodríguez-Palleres and Rojas (2022)[22]

Statistical Analysis

Numerical variables were presented as mean ± standard deviation. The p-value was calculated using the student t test to evaluate significant statistical differences. The level of significance was established at 5% (p<0.05). The values obtained were analyzed with the SPSS® statistical program, version 25.0

RESULTS

Prototypes formulation and evaluation

We developed a range of formulations based on palatability and availability of discarded raw materials. Once the desired parameters for taste and color of the products were achieved, an internal sensory acceptability assessment was conducted, involving a panel of evaluators. Based on the results of this assessment, adjustments were made to the ingredients and proportions of the raw materials, resulting in the creation of 13 prototypes. From these prototypes, a sensory analysis of the products was undertaken with a panel of evaluators, involving an open and qualitative discussion. Consequently, 2 prototypes were selected: one referred to as the green concentrate, comprising broccoli stems and leaves, celery stems and leaves, and beet leaves; and another termed the red concentrate, featuring tomatoes and beet stems (table 1). Table 2 presents the results of the sensory evaluation of the 2 prototypes. In older adults, the red concentrate presented higher scores in scent (5.21 ± 1.97), acidity (2.5 ± 2.27) with significant differences compared to the green concentrate (0.027) and greater saltiness. The green concentrate presented a higher value in bitterness (1.79 ± 2.42) and astringency (1.97 ± 2.47). In the schoolchildren population, the green concentrate was superior in scent (3.89 ± 2.76) and astringency (5.14 ± 2.46) with significant differences compared to the red concentrate (P<0.05).

Table 1. Proportions of the ingredients of the two prototypes.

Ingredients	"Green concentrate"	"Red concentrate"
Broccoli-stem	12.5%	0%
Broccoli-leaf	4.5%	0%
Celery-stem	3.4%	0%
Celery-leaf	3.1%	0%
Beet-stem	0%	10.35%
Beet-leaf	9.5%	0%
Tomato	0.5%	52.0%
Cornstarch	1%	1%
Onion	0%	12.0%

Garlic	0%	1%
Garlic powder	0.8%	0%
Oil	10.2%	1%
Salt	0.3%	0.65%
Oregano	0%	1%
Pepper	0.2%	1%
Water	54.0%	20.0%
Total	100%	100%

Table 2. Sensory evaluation of the two prototypes by older adults and schoolchildren population

		OLDER PEOPLE			
Food prototypes	**Scent**	**Acidity**	**Bitterness**	**Astringency**	**Salty taste**
Green concentrate	4.47 ± 2.71	1.45 ± 2.03	1.79 ± 2.42	1.97 ± 2.47	1.39 ± 1.94
Red concentrate	5.21 ± 1.97	2.5 ± 2.27	1.28 ± 2.03	1.51 ± 2.04	1.67 ± 2.00
p-value	0.166	0.027	0.298	0.358	0.517
		SCHOOLCHILDREN POPULATION			
Food prototypes	**Scent**	**Acidity**	**Bitterness**	**Astringency**	**Salty taste**
Green concentrate	3.89 ± 2.76	0.96 ± 1.99	3.62± 3.11	5.14 ± 2.46	3.00 ± 2.43
Red concentrate	3.85 ± 3.20	1.22 ± 2.02	3.70 ± 2.75	2.22 ± 2.73	3.03 ± 2.76
p-value	0.959	0.637	0.926	0.000	0.959
		p-value between both groups			
Green concentrate	0.369	0.310	0.005	0.001	0.003
Red concentrate	0.038	0.022	0.000	0.240	0.025

Scalable production

In order to access and select the starting raw material, a pilot plant was developed into Wholesale Market. The pilot plant was developed by the School of Nutrition and Dietetics of Bernardo O'Higgins University and this facility is used for research and development and production of innovative food. The pilot plant was designed following all Chilean requirements for manipulation and food production

The prototypes selected above were produced in the pilot plant (figure 1A). A performance of 62.2% is observed for the green concentrate, while the red concentrate demonstrates a performance of 55.5%, as detailed in table 3.

Table 3. Percentage of raw material from recovered fruit waste for the production of prototypes.

	Raw material from fruit waste (kg)	Raw material cleaning and cutting (kg)	Final product (kg)*
Green concentrate			
Celery	61.4	44.7	
Beet	21.3	13.5	
Broccoli	44.9	32	
Total	127.6	93.2	79.3
Performance		73%	62.2%[1]-85.1%[2]
Red concentrate			
Tomato	96.7	61.6	
Beet	16.8	7.9	
Total	113.5	69.5	63
Performance		61.2%	55.5%[1]-90.6%[2]

*After the raw materials are minced, they are mixed together. Therefore, the total product is reported only at the overall total level.
[1]Percentage of Conversion considered the ratio of the conversion between final product and raw material (eq 1).
[2]Percentage of Conversion the ratio of the conversion between final product and raw material cleaning and cutting (eq 1).

Chemical, Microbiological and Nutritional Analysis

Analysis of the raw materials revealed that patulin and ochratoxin were undetectable in all samples, indicating minimal risk of mycotoxin contamination. Furthermore, lead and selenium were found to be below the detection limit of the technique, suggesting low levels of these metals in the samples.

To assess the safety of final products, microbiological analysis to detect aerobic mesophilic bacteria (AMB), coliforms and relevant pathogens, including *Salmonella* spp, *E. coli* and *S. aureus*, was conducted following the national requirements[21]. The microbial load in the final products showed to be within the permissible limits[21] set by regulatory authority, demonstrating compliance with industry standards. In addition, using conventional PCR, amplification of main pathogens associated with food contamination were not detected (table 4).

Table 4: Microbiological analysis of final products

Prototypes	***AMB***		***Coliforms***		***Salmonella***		***E. coli***		***Listeria***		***S. aureus***	
	Agar	**PCR**	**Agar**	**PCR**	**Agar**	**PCR**	**Agar**	**PCR**	**Agar**	**PCR**	**Agar**	**PCR**
Green concentrate	<10	-	<10	-	0	ND	<10	ND	-	ND	<10	ND
Red concentrate	<10	-	<10	-	0	ND	<10	ND	-	ND	<10	ND

-, Not Determine

ND, Not Detected

The nutritional analysis reveals differences in their caloric and macronutrient contents (table 5). The green concentrate had the most calories containing 266 calories/100 g. The red concentrate had slightly fewer calories (200 cal). This analysis highlights the variability in nutritional profiles among different vegetables concentrates, which can inform dietary choices based on specific nutritional needs and preferences. In this sense, the products were donated through the "Lo Valledor Food Bank Foundation (FBALV)" at "Long Stay Establishments for the Elderly (ELEAM)". At least 100 elderly individuals experiencing food insecurity received the products developed in this study (figure 1b).

Table 5. Nutritional composition for prototypes.

	Calories	**Protein (g)**	**Carbohydrates (g)**	**Total fat (g)**	**Dietary fiber (g)**
Green concentrate	266	1.41	22.1	19.1	9.13
Red concentrate	200	1.40	21.7	12.0	8.0

All contents are expressed in grams per 100 grams.

DISCUSSIONS

Due to the development of modern civilization and industrialization, agriculture has increasingly intensified on a larger scale, which has resulted in the generation of large amounts of agri-food losses and waste[23]. The generation of these agri-food waste could be due to the inefficiencies of food systems through the unsustainable use of natural resources, putting the entire environmental balance at risk[23]. This problem added to the exponential growth of the human population, putting pressure on the availability of food, management, and elimination of these, also creating a gap between the demand and supply of food[24]. The moral and social aspects of food loss and waste are equally essential to consider, as it affects the food security of the world's population by reducing the amount of food suitable and available for human consumption in the final stages of the food chain. Indeed, globally along the supply chain could feed almost 2 billion people on a diet of 2,000 calories per day[25]. It has been estimated that by reducing and reallocating food waste by 15%, in the United States alone, approximately 25 million people could be fed and $161 billion saved.

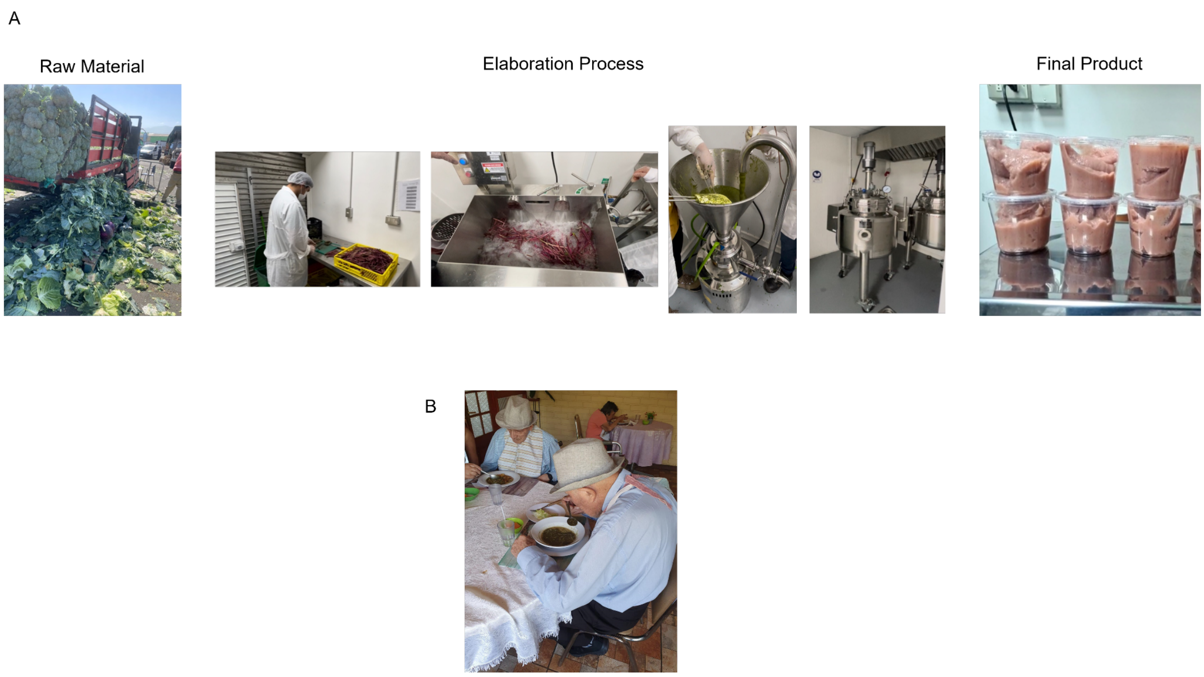

Figure 1. A. Scalable prototype production. Example of raw material, pilot plant and final product. B. Donation of green concentrate and red concentrate products to elderly residents of Long Stay Establishments for the Elderly

Wholesale Market in Santiago is the main wholesale market for fruit and vegetable products in Chile, and tons of organic waste are sent to landfills daily. In recent studies we have evaluated the nutritional value and antioxidant capacity of fruit and vegetable waste from this wholesale market [17,22]. With this in consideration and due to nutritional, nutraceutical, and functional properties of the food waste, it can be argued that vegetables and fruits are excellent as raw material for significant potential and numerous applications in food formulations based on their different content of biomolecules as protein, lipids, starch, vitamins, minerals, fibers, and antioxidants, present in the food wastes and byproduct.

On the other hand, beet was selected in both formulations because biologically active phytochemicals as betalains, flavonoids, polyphenols, saponins and a diversity of minerals as potassium, sodium, phosphorous, calcium, magnesium, copper, zinc and manganese. Probably the most controversial mineral is inorganic nitrate (NO_3^-) which has been attributed to hypotensive and ergogenic properties[26]. Broccoli is a source of glucosinolates, essential minerals, phenolics compounds and other antioxidants like vitamin C and vitamin K1[27]. Celery comprises different health promoting constituents such as, dietary fiber, vitamins, minerals, and amino acid tryptophan[28]. Tomato was selected as a good source of bioactive molecules, especially carotenoids, such as β-carotene and lycopene, which confers not only high nutritional value but also beneficial health properties, due to their high antioxidant content. They also contain proteins, sugars, waxes and seed oil[29].

In supply chains, postharvest losses and waste of fruits and vegetables are mainly due to operational causes such as inadequate harvesting, classification, storage, handling and transportation, but are also intentionally thrown away in markets, supermarkets and homes[30]. The vegetable and fruit industry produces the largest volumes of waste of around 1,400 million tons produced, representing approximately 46%, and the waste from peels, seeds, pulp and pomace of these foods ranges between 25% to 30%. In households in the European Union (EU), waste from fresh fruits and vegetables exceeds 17,000 million kg per year, which corresponds to 35.3 kg per person, of which 14.2 kg could be avoidable[31]. Data from 2,000 Americans indicated that on average per week they waste 10 dollars' worth of fruits by throwing them in the trash, which is equivalent to the amount of 520 dollars per year[32]. This situation of loss and waste of fruits makes up the main 'blue water hotspot', while vegetable waste constitutes a significantly larger "carbon footprint"[6].

The circular economy model is based on keeping resources in the economy for as long as possible, which involves reusing, repairing, renewing and recycling existing materials and products as much as possible, thus extending the life cycle of the products and maintaining the resources in the economy for as long as possible[33]. According to the circular economy, a prioritization model is proposed in the management of food waste, ranging from the most preferable option to the least favorable, providing a guide for selecting the most efficient treatment from an environmental point of view[34]. The prevention of waste generation is the first instance, the purpose of which is to avoid the generation of food losses and waste throughout the entire food production, supply and consumption chain, however there will always be an amount of food waste that will not be possible to avoid and that corresponds to the inedible parts of food[35].

Among the intermediate actions of the hierarchy model, the reuse of surplus food that is suitable for human consumption is established, for example through food banks, however one of the most common problems of these organizations is the provision of insufficient micronutrients since fruits and vegetables are the most wasted food group[36]. Unfortunately, there is an inevitable amount of fruit and vegetable waste, but whose waste has enormous power in providing nutrients and bioactive compounds of great value, so reintroducing them into the value chain is a circular economy strategy[37]. It is important to point out the limiting factors in the valorization of surplus fruits and vegetables. One of them is the logistical issues that relate to the time necessary to collect a sufficient amount of food waste for treatment[34]. Another logistical factor to consider is that fruit and vegetable waste can deteriorate very quickly, generating restrictions on their use to produce value-added products. The transportation costs associated with food recovery and its management is another point to consider when valuing fruit and vegetable surpluses[33]. In this sense, since the pilot food processing plant is located inside the Wholesale Market, it avoids the costs of transporting organic matter from fruit and vegetable waste and their deterioration. Furthermore, the Market's goal is to be zero waste in organic matter from fruit and vegetable waste by 2030, therefore, there is availability of raw material for the production of salty concentrates and other products. On the other hand, the losses in raw materials after cleaning and cutting were primarily due to the disposal of fruits deemed unsuitable for processing. For instance, fruits displaying signs of fungal decay were discarded. With an abundance of bioactive components in fruits and vegetables, including those that are discarded in our process, there is an opportunity for extraction and utilization in the development of functional foods[38]. The primary objective is to achieve production without losses. Moreover, the sustainability of food production is inherently linked to the safety of the food produced. Microbial spoilage can compromise food quality, leading to deterioration and posing health risks. Therefore, microbiological criteria are essential in evaluating the safety and quality of food products, requiring adherence to national and international regulations[39]. The results for the red and green concentrate prototypes were within the permissible limits established by regulatory authorities[21].

The importance of having this type of food is given because in recent decades the prevalence of overweight and obesity has increased rapidly, becoming one of the biggest health problems worldwide[40]. According to data from the 2016-2017 National Health Survey (ENS) in Chile, 31.2% of adults are in a nutritional state of obesity and 3.2% are classified as morbidly obese, while 39.8% are classified as overweight[41] and according to the latest report by the Organization for Economic Cooperation and Development (OECD) "Health at a Glance: Latin America and the Caribbean 2023", the prevalence of obesity in Chile is 26.4% in the population over 15 years (OECD 2023). In the case of the Chilean child population, the prevalence of malnutrition due to excess that includes overweight and obesity for the year 2022 was 53% in schoolchildren between 4 and 14 years old[42].

The causes that explain the increase in obesity are given by the change in the eating pattern towards a Western-type diet, which is associated with a greater consumption of processed foods that are characterized by their high content of sodium, saturated fats and sugars, but at the same time with a lower intake of vegetables, fruits and legumes[43]. In Chile, the consumption of fruits and vegetables (F&V) is below the minimum recommended daily intake, with only 15% of the population meeting the daily intake of 400 grams[44], despite its bioactive compounds that explain the inverse association between high F&V consumption and the risk of coronary and cardiovascular diseases[45]. This low consumption of fruits and vegetables also affects older people, which is reflected in the low intake of dietary fiber and vitamin C, a situation that is even worse in older adults who do not have the economic resources, therefore delivery of these healthy and sustainable foods promotes food security[38]. Understanding the reasons behind this low consumption and exploring innovative ways to make fruits and vegetables more appealing is vital for improving dietary habits by introducing alternative formats that align with individual preferences and needs.

Children and adults show significant differences in the perception of most parameters analyzed, reaffirming the potential to create nutrient-rich foods from agri-food surpluses tailored to the specific tastes and needs of these populations. Red concentrate was evaluated with higher acidity in older adults and children, because its predominant component is tomato, a fruit characterized by its content of citric acid (9%) and malic acid (4%)[46], giving it that acidic flavor. The salty taste of green[47] concentrate and red concentrate was rated lower by the older adult group, which could be explained by a reduction in the taste threshold for salty flavors, implying that older people require a greater amount of sodium in food to perceive this flavor.

This study did not evaluate the preference regarding[48] consistency and temperature, but in a qualitative study of 8 older adults diagnosed with presbyphagia, the preferred temperature when consuming food was hot, explained by the decrease in thermal sensitivity and regarding consistency, they preferred semi-solid foods due to physiological changes in the mouth. These results are interesting to consider, since the red concentrate and green concentrate have a semi-solid consistency and are consumed at a hot temperature.

In 2019, FBALV was established, whose objective is to rescue those fruits and vegetables not sold by the merchants of the Wholesale Market for different reasons, but that continue to maintain their nutritional value and are suitable for human consumption. Once these foods are received, the Foundation delivers them free of charge to different previously registered vulnerable organizations, such as ELEAM, children's homes that house and feed girls and boys whose rights have been violated, shelter homes, solidarity kitchens, among others. All these social organizations are located in the Metropolitan Region of Chile and have a scheduled withdrawal calendar as well as the number of kilos of fruit and vegetables that they can withdraw per month. The number of kilos that social organizations can withdraw depends on the number of people they benefit. In the case of the beneficiaries of the FBALV, receiving our products prevents the food insecurity suffered by these people, understanding food insecurity as an inability of people to access nutritious, sufficient and safe food to satisfy nutritional needs and food preferences for an active and healthy life, due to lack of financial resources and transportation problems[49].

In Chile, the Complementary Food Program for the Elderly (PACAM acronym in Spanish). was created in 1999 as a strategy for implementing food security policies[50]. This program provides a precooked soup called "Golden Years Cream" made with legume and cereal flour and a mixture of vitamins and minerals. However, "Crema Años Dorados" is not very well accepted, due to the organoleptic characteristics of the product, such as the flavor, added to the fact that it is considered a processed and not a natural product[51]. Therefore, the current trend is the creation of natural products derived from leaves and stems and fruit waste, being an alternative for people to ingesting compounds with health benefits[31]. This is why the valuation of fruit and vegetable waste is of great interest for its reincorporation into the marketing chains and therefore, it can be consumed by the population, thus contributing to the circular economy and food security[49]. And it will also promote job creation and new business opportunities that will directly benefit the most vulnerable communities[40].

CONCLUSIONS

In conclusion, this study developed and evaluated products from discarded raw materials, resulting in two final products: a green concentrate (broccoli, celery, beet leaves) and a red concentrate (tomatoes, beet stems). The products were produced in pilot plant enabled safe production and met regulatory standards. These final products enhanced the intake of essential nutrients, including vitamins, minerals, antioxidants, and dietary fiber, thus were successfully distributed to elderly individuals facing food insecurity, demonstrating an effective approach to valorizing food waste. However, it is important to recognize the multiple challenges for effective valorization of fruit and vegetable waste. One of them is to know the nutritional and antioxidant composition of the leaves and stems of vegetables and fruits waste to give them correct use in the formulation of new food products. Another point to consider is that these raw materials are often not consumed, mainly due to lack of knowledge in their use and for cultural and tradition reasons of each country, which could cause rejection among consumers; that is the importance of sensory panels and continuous improvements of prototypes.

Given that fruit and vegetable waste is mainly used for composting and landfills, having a protocol for cleaning and sanitizing raw materials is vital, as well as microbiological analysis once they have been prepared. Finally, collaborative work between industry and universities to improve the environmental and economic sustainability of food waste should be seen as an opportunity to reduce the impact on the environment caused by food waste and promote food security for the most vulnerable populations in developing countries.

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CONFLICT OF INTEREST
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

AUTHOR CONTRIBUTION
X. Rodríguez: Methodology, Research, Funding acquisition, Writing – original draft. S.A Correa: Research, results analysis, Writing – review & editing. M. Castillo-Ruiz. Research, results analysis, Writing – review & editing. F. Rojas: Methodology, Project administration & Resources. JM. Castagnini: Methodology, writing – review & editing.

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DATA AVAILABILITY STATEMENT
The data presented in this study are available upon request from the corresponding author.

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