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Transformation of fruit and vegetable waste into healthy and sustainable foods and its impact on the health of older people

Transformación de residuos de frutas y verduras en alimentos saludables y sostenibles y su impacto en la salud de las personas mayores

Ximena RODRÍGUEZ PALLERES[1,2], Fancy ROJAS GONZÁLEZ[3], Álvaro TOLEDO SAN MARTÍN[4], Juan Manuel CASTAGNINI[1]

1 Department of Preventive Medicine and Public Health, Food Sciences, Toxicology and Forensic Medicine. Research Group on Innovative Technologies for Sustainable Food (ALISOST). Faculty of Pharmacy, University of Valencia, Burjassot, Valencia, Spain.
2 School of Nutrition and Dietetics. Faculty of Health Sciences, Bernardo O'Higgins University, General Gana, Santiago, Chile.
3 Department of Transfer, Entrepreneurship and Innovation, Bernardo O'Higgins University, Fábrica, Santiago, Chile.
4 Department of Mathematics and Engineering Sciences, Faculty of Engineering, Science and Technology, Bernardo O'Higgins University, Santiago, Chile.

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RESUMEN

Introducción: El desperdicio de frutas y verduras tiene un impacto ambiental, nutricional y social que afecta la seguridad alimentaria de la población, principalmente de las personas mayores.

Objetivo: Analizar el efecto de la ingesta de alimentos saludables y sustentables provenientes de excedentes agroalimentarios sobre la salud de personas mayores en Chile a través de parámetros nutricionales y bioquímicos.

Métodos: Estudio de intervención nutricional. Participaron 45 adultos mayores, divididos en un grupo control y un grupo de intervención. En el grupo de intervención se incorporaron prototipos de alimentos elaborados a partir de residuos de frutas y verduras a la dieta diaria durante 60 días. Se realizaron evaluaciones de ingesta dietética, mediciones antropométricas y análisis de sangre antes y después de la intervención a ambos grupos.

Resultados: La prevalencia de obesidad y sobrepeso post intervención fue de 40,9% en el grupo intervenido y de 30.4%, en el grupo control. En el grupo de intervención, la ingesta de frutas aumentó a 137.50 gramos (p=1.824e-06*) y verduras aumentó a 229.55 (p=1.019e-07*) después de la intervención, con diferencias significativas. Las vitaminas A (0.74 mg/L, p=0.707) y C (5.39 mg/L, p=0.647) aumentaron en el grupo de intervención después de la intervención, pero sin diferencias significativas. El colesterol total (168.5 mg/L, p=0.734) y el colesterol LDL (96.34 p=0.769) disminuyeron en el grupo de intervención después de la intervención, pero sin diferencias significativas.

Conclusión: Primer estudio que muestra la ingesta de alimentos saludables y sostenibles elaborados a partir de residuos de frutas y verduras y su impacto en el estado de salud de las personas mayores.

PALABRAS CLAVES

Desperdicio alimentario, personas mayores, economía circular, sostenibilidad, nutrición.

ABSTRACT

Introduction: Fruits and vegetables waste have an environmental, nutritional and social impact that affects the food security of the population, mainly among older people.

Objective: To analyze the effect of the intake of healthy and sustainable foods from agri-food surpluses on the health of elderly people in Chile through nutritional and biochemical parameters.

Correspondencia:
Ximena Rodríguez Palleres
rximena@docente.ubo.cl

Methods: Nutritional intervention study. 45 older adults participated, divided into a control group and an intervention group. In the intervention group, food prototypes made from fruit and vegetable waste were incorporated into the daily diet for 60 days. Dietary intake assessments, anthropometric measurements, and blood tests were performed before and after the intervention for both groups.

Results: The prevalence of obesity and overweight post-intervention was 40.9% in the intervention group and 30.4% in the control group. In the intervention group, fruit intake increased to 137.50 grams (p=1.824e-06*) and vegetables increased to 229.55 grams (p=1.019e-07*) after the intervention, with significant differences. Vitamins A (0.74 mg/L, p=0.707) and C (5.39 mg/L, p=0.647) increased in the intervention group after the intervention, but without significant differences. Total cholesterol (168.5 mg/L, p=0.734) and LDL cholesterol (96.34 p=0.769) decreased in the intervention group after the intervention, but without significant differences.

Conclusion: First study that shows the intake of healthy and sustainable foods made from fruit and vegetable waste and its impact on the health status of older people.

KEYWORDS

Food waste; Older people; Circular economy; Sustainability; Nutrition.

INTRODUCTION

The intensification of agriculture has resulted in the generation of large amounts of agri-food losses and waste[1]. The generation of agri-food waste could be caused by the inefficiencies of food systems through the unsustainable use of natural resources, putting the entire environmental balance at risk[2]. This problem, added to population growth, which is projected to increase from 7.7 billion to 9.7 billion people by 2050, will put pressure on food availability and disposal[3].

1.3 billion tons of food a year is lost or wasted[4]. In Latin America, it is estimated that food and loss waste (FLW) represent 15% of total food production[5]. In the primary production of fruits and vegetables (F&V), it has been shown that losses vary from 10 to 30% of the production volume[6]. Food dumped in landfills decomposes, releasing methane, 21 times more powerful than carbon dioxide[7].

FLW have a social impact since they affect the food security of the population by reducing the amount of food available for consumption[8]. FLW could feed nearly 2 billion people on a 2,000-calorie-a-day diet. In the United States by reducing and valuing food waste by 15%, 25 million people could be fed and $161 billion saved[9].

Around 12% of the world's population was affected by severe food insecurity in 2020, equivalent to 928 million people, 148 million more than in 2019[10]. Food insecurity is related to lower intake of vitamins A and B6, calcium, zinc and magnesium as a result of low consumption of fruits and vegetables and dairy products[11]. A group at greater risk of suffering from food insecurity is the elderly population due to specific diseases and functional losses associated with old age.

It is necessary to mention the nutritional losses associated with the waste of those foods that have a more complete nutritional profile such as fruits and vegetables, rich in various nutrients. World Health Organization (WHO) guidelines recommend a daily intake of at least 400 grams of fruits and vegetables to improve the health of the population[12]. However, globally approximately 78% of people do not meet the 5 daily servings of F&V[13]. According to the Ministry of Health, in Chile only 15% of the population meets this recommendation[14].

To promote the circular economy and increase the intake of fruits and vegetables, in addition to the limited evidence of the potential for people's health of consuming healthy and sustainable foods from fruit and vegetable waste, the present study aims to analyze the effect of the intake of healthy and sustainable foods from agri-food surpluses on the health of elderly people in Chile through nutritional and biochemical parameters.

MATERIALS AND METHODS

Type of study and sample

Experimental pre-test and post-test nutritional intervention study with two study groups, a control group and an intervention group, carried out between January and August 2023.

Participants were selected through non-probabilistic convenience sampling. The sample was made up of 45 volunteer residents of two long-term care centers for older adults (ELEAM, by this acronym in Spanish), of both sexes, aged between 65 and 80 years, without deterioration in their cognitive abilities, self-sufficient with adequate physical and mental capacity, which was previously evaluated by a doctor. Exclusion criteria included modification of the participants' dietary habits a month ago or doing so during the study, physical impossibility to perform anthropometric measurements, individuals with food allergies or intolerances or any other condition that the research group considered unsuitable for the study. 53 subjects were recruited and included in the study; however, 3 subjects were excluded from the study because they did not meet the inclusion criteria. The sample (50 subjects) was divided into two groups: Control group (25 participants, of which 18 were women and 7 men) and Intervention group (25 participants, of which 23 were women and 2 men) (Figure 1). Finally, out of 50 participants, 5 withdrew from the study. The participants signed the informed consents. The Institutional Ethics Committee of the Bernardo O'Higgins University approved the study.

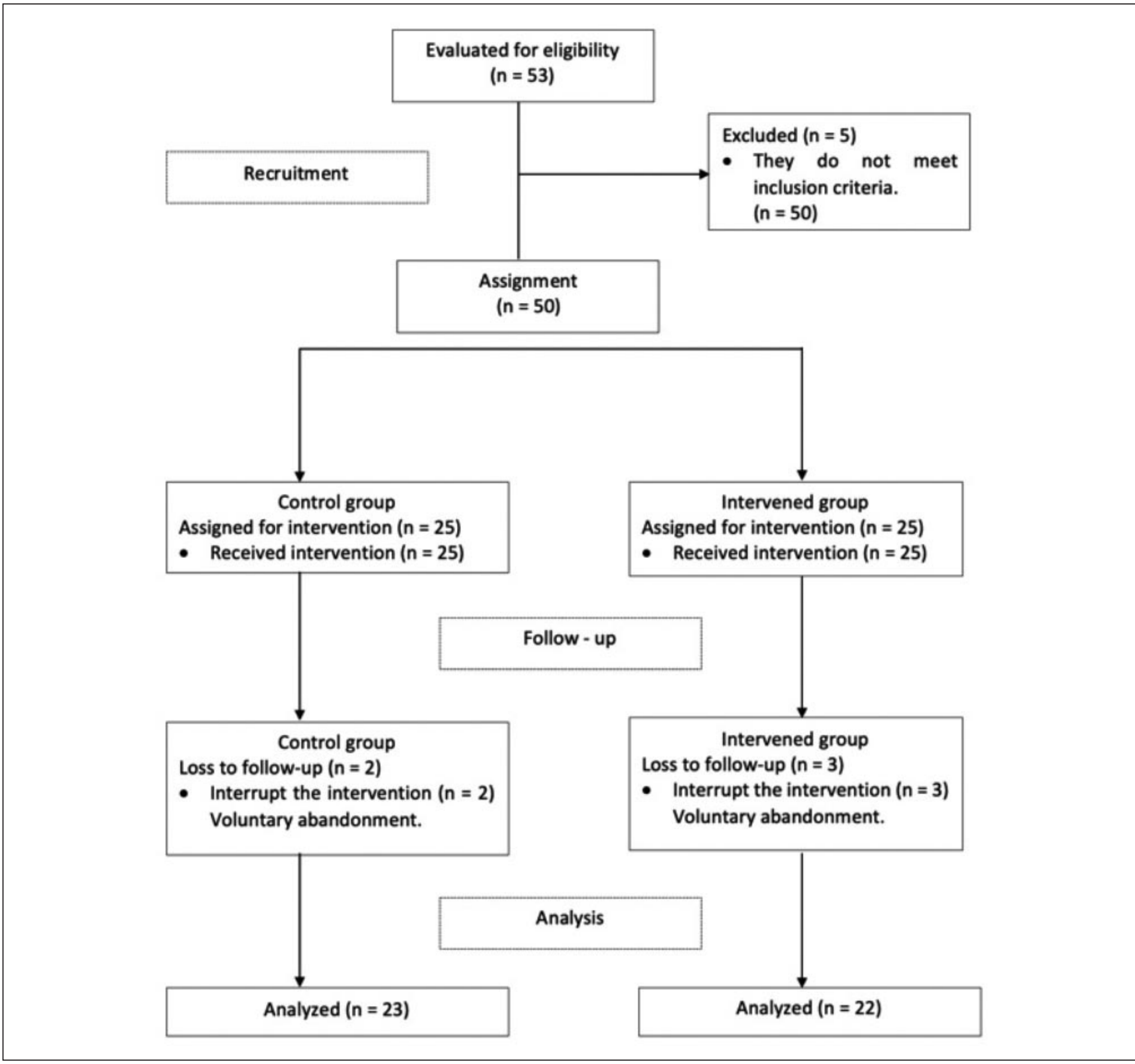

Figure 1. Diagram of the selection of older people participating in the nutritional intervention

Data collection

All nutritional status measurements were performed on day 1 (pre-intervention) and once the nutritional intervention of the study was completed, which was on day 62 (post-intervention). Nutritional status was evaluated using the Body Mass Index (kg/m^2) using the cut-off points of the Chilean Ministry of Health: Underweight (BMI<23 Kg/m2), normal or eutrophic (23-27.9 Kg/m), overweight (28-31.9 Kg/m) and obesity (≥ 32 Kg/m).

Muscle mass was assessed by calf circumference, with the participant standing with their weight evenly distributed on both feet, with the calf exposed, identifying the maximum circumference; the measurement was then taken on the lateral side of the calf. The cut-off points for classifying low muscle mass were <31 cm for both sexes[15]. Muscle strength was assessed using a JAMAR® hydraulic hand dynamometer.

The evaluation of fruit and vegetable intake was through the administration of the 24-hour dietary recall.

A 10 mL venous blood sample was taken from each participant after an 8-hour fast before sample collection. Glycemia, lipid profile and antioxidant vitamins (A, C and E) were analyzed.

Development of food prototypes

17 experimental tests of vegetable concentrates from vegetable waste (stems and leaves of broccoli, celery, beetroot and tomato) and 9 experimental tests of fruit concentrates from fruit waste were developed, and a sensory evaluation was carried out to obtain the 2 prototypes of vegetable concentrate and the prototype of fruit concentrate. The nutritional composition of the three food prototypes does not have warning front labeling (Table 1). To evaluate the safety of food prototypes, a series of microbiological analyses were carried out to detect aerobic mesophilic bacteria, coliforms, Staphylococcus aureus, Escherichia coli, Salmonella spp and Listeria monocytogenes in compliance with national standards.

Nutritional intervention

Day 1 (T1) was the "pre-intervention" stage where the medical and nutritional status evaluation of the 50 participants was carried out.

From day 2 to day 61 was the nutritional intervention stage where healthy and sustainable food prototypes were incorporated into the daily diet of the 22 participants in the intervention group for 60 days. The food prototypes delivered were two vegetable concentrates in soup form, a red concentrated food prototype (RCFP) and a green concentrated food prototype (GCFP).

The intervention group was given 100 grams of one of the two vegetable concentrates at lunchtime. In addition, 80 grams of a fruit compote with a plum-banana flavor was added as a snack. These food prototypes were not additional to the participants' diet, but were given instead of the standard diet. The delivery of the food prototypes to the older adults during lunch and snack time was carried out by ELEAM health personnel and controlled by a nutritionist.

The control group did not receive any of these food prototypes, continuing with their standard diet.

Day 62 was the "post-intervention" stage, in which the nutritional status of 45 participants was assessed again.

Statistical analysis

Shapiro-Wilk normality tests were performed (n < 50). In all cases, the hypothesis of normality of the data distribution is rejected for each variable separated by group and type of treatment (95% confidence). Non-parametric Wilcoxon-Mann-Withney (U Mann-Withney) mean difference tests were applied for independent samples. Significant values were obtained for a p value less than 0.05 (p<0.05). RStudio version 1.0.136 was used for statistical analyses.

RESULTS

The anthropometric characteristics of the older people evaluated are presented in Table 2. In the intervention group, calf circumference decreased to 31.89 ± 3.94 cm in the post-intervention (p=0.385). In the control group, the calf circumference decreased to 31.95 ± 3.89 cm in the post-intervention stage (p=0.553). The grip strength reported in the intervention group decreased to 11.63 ± 5.75 kg in the post-intervention stage (p=0.549). For the control group, grip strength decreased to 11.46 ± 5.51 in the post-intervention stage (p=0.965). About nutritional status, the intervention group presented higher prevalence of obesity and overweight pre-intervention (45.5%, n=10) and post-intervention (40.9%, n=9) compared to the control group (pre-intervention=26.1%, n=6; post-intervention=30.4%, n=7) (data not shown).

Table 3 details that fruit consumption in the intervention group increased significantly post-intervention to 137.50 ± 67.57 grams/day (p=1.824e-06*). In the control group, fruit consumption increased in the post-intervention stage to 47.83 ± 10.43 grams/day (1,954e-09*). In the intervention group, vegetable intake increased in the post-intervention stage to 229.55 ± 53.76 grams/day with significant differences (p=1.019e-07).

Table 1. Nutritional composition of the three food prototypes from fruit and vegetable waste

100 grams of food	Green concentrated food prototype	Red concentrated food prototype	Plum-banana fruit concentrate
Energy (kcal)	266	200	71
Proteins (g)	1.4	1.4	1.3
Total Fat (g)	19.1	12.0	1.0
Carbohydrates (g)	22.1	21.7	14.2
Total Dietary Fiber (g)	9.1	8.0	2.6
Sodium (mg)	373	210	21

Table 2. Anthropometric characteristics of the elderly population of Santiago, Chile pre and post intervention

Variable	Group	Control (n=23)		Intervenid (n=22)		Total		a	b
		Mean	SD	Mean	SD	Mean	SD	c	d
Weight (kg)	pre	60.26	10.33	62.84	12.64	61.52	11.46	0.796	0.809
	post	60.11	11.48	61.92	13.37	61	12.33	0.461	0.323
Height (cm)	pre	152.43	7.61	151.41	8.3	151.93	7.88	1.000	1.000
	post	152.43	7.61	151.41	8.3	151.93	7.88	0.494	0.495
Body Mass Index	pre	25.98	4.33	27.38	4.99	26.66	4.67	0.805	1.000
	post	25.89	4.73	26.94	5.19	26.4	4.93	0.352	0.323
Calf Circumference (cm)	pre	32.51	4.43	33.24	3.46	32.87	3.96	0.385	0.553
	post	31.95	3.89	31.89	3.94	31.92	3.87	0.811	0.525
Brachial Perimeter (cm)	pre	26.2	2.42	26.96	3.11	26.57	2.77	0.217	0.567
	post	25.8	2.55	26.14	3.23	25.97	2.87	0.617	0.345
Handgrip Strength (kg)	pre	11.92	6.71	12.41	5.14	12.16	5.93	0.549	0.965
	post	11.46	5.51	11.63	5.75	11.54	5.56	0.751	0.674

a P-value for the intervention group test in the pre- and post-intervention stage (significant for $p < 0.05$).
b P-value for control group test in pre- and post-intervention stage (significant for $p < 0.05$).
c P-value for test intervention group and control group in pre-intervention stage (significant for $p < 0.05$).
d P-value for the intervention group test and control group in the post-intervention stage (significant for $p < 0.05$).
In (*) significant values at 95% confidence level.

Table 3. Fruit and vegetable consumption of the elderly population of Santiago de Chile pre and post intervention

Variable	Group	Control (n=23)		Intervenid (n=22)		Total		a	b
		Mean	SD	Mean	SD	Mean	SD	c	d
Fruit (grams/day)	pre	40.17	8.76	34.18	40.75	37.24	28.99	1.824e-06*	1.954e-09*
a, b, d.	post	47.83	10.43	137.50	67.57	91.67	65.49	0.113	9.217e-07*
Vegetable (grams/day)	pre	104.78	22.94	97.27	58.97	101.11	44.02	1.019e-07*	2.112e-09*
a, b,, d.	post	122.61	12.51	229.55	53.76	174.89	66.18	0.259	7.074e-06*

a P-value for the intervention group test in the pre- and post-intervention stage (significant for $p < 0.05$).
b P-value for control group test in pre- and post-intervention stage (significant for $p < 0.05$).
c P-value for test intervention group and control group in pre-intervention stage (significant for $p < 0.05$).
d P-value for the intervention group test and control group in the post-intervention stage (significant for $p < 0.05$).
In (*) significant values at 95% confidence level.

Table 4. Biochemical characteristics of the elderly population of Santiago de Chile pre and post intervention

Variable	Group	Control (n=23)		Intervenid (n=22)		Total		a	b
		Mean	SD	Mean	SD	Mean	SD	c	d
Total colesterol (mg/dL)	Pre	177.26	52.55	172.95	47.56	175.16	49.65	0.734	0.583
	Post	170.09	50.98	168.5	51.07	169.31	50.45	0.785	0.991
HDL cholesterol (mg/dL)	Pre	48.48	11.47	43.25	12.49	45.92	12.13	0.796	0.692
	Post	46.52	9.72	44.59	11.76	45.58	10.69	0.212	0.474
LDL cholesterol (mg/dL)	Pre	95.08	40.52	99.03	39.05	97.01	39.4	0.769	0.948
	Post	93.9	37.26	96.34	41.2	95.09	38.8	0.796	1.000
VLDL (mg/dL)	Pre	30.69	11.14	30.85	14.65	30.77	12.86	0.245	0.633
	Post	29.67	12.5	27.57	14.46	28.64	13.38	0.647	0.247
Triglycerides (mg/dL)	Pre	155.52	55.3	152.29	74.49	153.98	64.41	0.245	0.339
	Post	142.78	58.61	137.86	72.31	140.38	64.96	0.532	0.286
Vitamin A (mg/L) [c.]	Pre	0.84	0.18	0.72	0.23	0.78	0.21	0.707	0.090
	Post	1.04	1.5	0.74	0.27	0.9	1.09	0.022*	0.708
Vitamin C (mg/L) [d.]	Pre	3.41	3.43	5.36	4.21	4.36	3.91	0.647	0.701
	Post	2.86	3.01	5.39	2.96	4.09	3.21	0.102	0.0008*
Vitamin E (mg/L) [b, d.]	Pre	15.51	4.44	15.85	4.61	15.68	4.48	0.689	0.029*
	Post	12.83	4.29	15.68	5.46	14.22	5.05	0.642	0.039*

a P-value for the intervention group test in the pre- and post-intervention stage (significant for $p < 0.05$).
b P-value for control group test in pre- and post-intervention stage (significant for $p < 0.05$).
c P-value for test intervention group and control group in pre-intervention stage (significant for $p < 0.05$).
d P-value for the intervention group test and control group in the post-intervention stage (significant for $p < 0.05$).
In (*) significant values at 95% confidence level.

In the control group, in the post-intervention stage, intake increased to 122.61 ± 12.51 grams/day (2.112e-09*).

The lipid profile of the older adults is presented in Table 4. Total cholesterol for the intervention group decreased to 168.5 ± 51.07 mg/dL in the post-intervention stage. For the control group, in the post-intervention stage it was 170.09 ± 50.98 mg/dL. In the post-intervention stage, LDL levels in the intervention group decreased to 96.34 ± 41.2 mg/dL and for the control group, it was 93.9 ± 37.26 mg/dL. For HDL in the intervention group, the value after intervention increased to 44.59 ± 11.76 mg/dL and in the control group, the value was 46.52 ± 9.72 mg/dL.

Regarding plasma levels of vitamin A, the intervention group presented values of 0.74 ± 0.27 mg/L in the post-intervention stage. In the control group, vitamin A in the post-intervention stage was 1.04 ± 1.5 mg/L. The vitamin C values in the intervention group in the post-intervention stage were 5.39 ± 2.96 mg/L. In the post-intervention control group, it was 2.86 ± 3.01 mg/L, with significant differences observed between the intervention group and the control group in the post-intervention stage. (p=0.0008). In the post-intervention stage in vitamin E, in the intervention group it was 15.68 ± 5.46 mg/L and in the control group it was 12.83 ± 4.29 mg/L.

DISCUSSION

According to the literature, this is the first study in Chile that examines the health impact of consuming healthy and sustainable foods made from fruit and vegetable waste in older people. The high prevalence of overweight and obesity reported in this research is comparable to the study carried out in Santiago, Chile, where the prevalence of obesity and overweight was 54.5%[16]. Another study with similar results indicated that the prevalence of overweight and obesity in older people was 30.4% and 22.3% respectively[17]. Data from the Chilean Ministry of Health indicate that the prevalence of overweight is 29.49% and obesity is 24.44%[18].

Calf circumference is a good marker of muscle mass in older people, correlating positively with appendicular skeletal muscle mass (ASM) and appendicular skeletal muscle mass index (ASM/m^2)[19]. The results obtained for calf circumference are lower than those described in other studies in older people, such as in the study carried out in southern Chile where the calf circumference reported was 34.6 ± 2.9 cm[20]. In another study carried out in 377 Chilean older people, higher calf circumference values were also reported compared to the sample analyzed in this study, where in men the calf circumference was 35.3 ± 3.7 cm and in women it was 33.3 ± 3.6cm[21]. Finally, in the study by Pino et al., older female adults had a calf circumference of 35.89 ± 2.33 cm and men of 37.03 ± 3.18 cm[22].

The dynamometry results are lower than those described in 80 older adults from southern Chile where the handgrip strength value was 23.1 ± 7.7 kg[23]. Higher values than those in this study were also reported in 500 older people from different regions of Chile, where in men the handgrip strength was 22.2 ± 11.7 kg and in women it was 16.6 ± 6.4 kg[24]. Low values of low grip strength are associated with a higher risk of cardiovascular events such as stroke and heart failure, cancer mortality, being a predictor of mortality[25].

The aging process is associated with a series of biological changes and deterioration of cognitive abilities accompanied by a series of comorbidities that affect the quality of life of older people. This is why nutrition plays a fundamental role since a healthy eating pattern, characterized by greater consumption of vegetables and fruits, prevents various diseases[26]. A high intake of F&V reduces the risk of chronic diseases such as type 2 diabetes and obesity, cancer, and cardiovascular accidents, because they provide a variety of nutrients and components, such as dietary fiber, flavonoids, carotenoids, vitamins and minerals[27]. Due to the physiological changes in older adults, such as tooth loss and sensory changes, providing soft and easy-to-digest preparations such as purees and soups makes them an attractive and innovative alternative to consuming F&V, complementing the current ways of consuming these foods. Thanks to the inclusion of the portion of fruit compote and the vegetable soup concentrate from fruit and vegetable waste in the intervention group, an intake of fruits and vegetables of 367 grams per day was achieved, close to the national recommendations according to the Chilean Food Guides which promotes the daily consumption of at least 3 servings of vegetables and 2 fruits. Although the daily intake of F&V in the intervention group was double compared to the post-intervention control group (170 grams), the low consumption of these foods is striking, considering that Chile is the sixth largest exporter of fruits in the world, so reducing costs, improving access and seeking the valorization of fruit and vegetable waste seem to be the path to implementing healthy lifestyles and improving the nutritional status of older people[28]. Furthermore, these types of actions promote the circular economy model by reusing food waste, without an associated economic cost as raw material, which allows the development of new healthy and sustainable foods at a low cost.

The aging process generates a progressive loss of several biological functions, at the cellular level, one of them being oxidative stress. To protect itself a non-enzymatic defense where exogenous antioxidants are obtained from the diet vitamin C, vitamin E and carotenoids. In this research, vitamins C, E and A were analyzed due to their action in the body as non-enzymatic antioxidants[29]. There are few studies in the Chilean elderly population that analyze plasma levels of antioxidant vitamins. In the study carried out on 182 elderly individuals between 60 and 80 years old from Chile, vitamin A values between 0.47 mg/L and 0.853 mg/L were reported[30]. When reviewing literature regarding other results on lipid profile parameters, the information is scarce. In 20 older adults evaluated in northern Chile, similar values of HLD cholesterol of 45.5±8.4 mg/dl and total cholesterol of 150.4± 23.2 mg/dl were observed, but not with respect to triglycerides and cholesterol LDL[31].

One of the strengths of this study is that it is the first to provide information on the impact on nutritional and biochemical parameters on the health of older people when consuming healthy and sustainable foods made from fruit and vegetable waste, in which no there is evidence of this. Furthermore, the richness of the data collected provides us with information on serum markers of antioxidant status such as vitamins A, C, and E rather than the dietary intake of these vitamins. Secondly, the number of people evaluated who wanted to voluntarily participate in the study, and who expressed great interest and commitment, which contributed to the high participation rate. Also noteworthy is that the anthropometric evaluations and 24-hour dietary recall were applied by the same nutritionist throughout the nutritional intervention, who was trained, thus reducing the risk of error inherent to this type of evaluations. Finally, the researchers made various visits during all stages of this project, promptly detecting any problems that may arise.

Although the results found in this research are of great value, the existing limitations must be recognized. The present study was limited to a group of older people from Santiago, Chile, so the findings may not be generalizable to other older people; however, the methodology addressed is replicable for the development of a nutritional intervention. In relation to sample selection, it should be noted that we used a convenience sample, which justifies a cautious interpretation of the results. Finally, the lack of scientific evidence on the intake of healthy and sustainable foods made from fruit and vegetable waste and its impact on health demonstrates the need to carry out this type of research for better decision making when consuming this food.

CONCLUSIONS

In conclusion, the preparation of healthy and sustainable foods from F&V waste is a food option for older people, favoring the intake of F&V with positive nutritional consequences such as an increase in antioxidant vitamins and a decrease in cholesterol, triglycerides and glucose at the plasma level.

The generation of agro-food waste also has a negative impact on the environment due to the inefficient use of natural resources, which is why the valorization of fruit and vegetable waste in marketing chains contributes to the circular economy of food systems.

The findings of this study provide valuable information for the design of future studies on the intake of this type of food, but more studies are needed to establish these findings in more diverse populations.

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