

Proceeding Paper

Potential of Onion Byproducts as a Sustainable Source of Dietary Fiber and Antioxidant Compounds for Its Application as a Functional Ingredient [†]

Jessica Báez ^{1,2}, Gian Marra ¹, Victoria Olt ^{1,2}, Adriana Maite Fernández-Fernández ¹ and Alejandra Medrano ^{1,*}

¹ Laboratorio de Bioactividad y Nanotecnología de Alimentos, Departamento de Ciencia y Tecnología de Alimentos, Facultad de Química, Universidad de la República, General Flores 2124, Montevideo 11800, Uruguay; jbaez@fq.edu.uy (J.B.); gianfmarra@gmail.com (G.M.); volt@fq.edu.uy (V.O.); afernandez@fq.edu.uy (A.M.F.-F.)

² Graduate Program in Chemistry, Facultad de Química, Universidad de la República, General Flores 2124, Montevideo 11800, Uruguay

* Correspondence: amedrano@fq.edu.uy; Tel.: +598-2924-26-75

[†] Presented at the 4th International Electronic Conference on Foods, 15–30 October 2023; Available online: <https://foods2023.sciforum.net/>.

Abstract: Onion is one of the main crops in the world and there has been an increase in the demand for processed onion in the form of frozen and freeze-dried chopped onion in the last decade, with detrimental impact on the environment. Onion byproducts (tops and bottoms of onion bulbs, onion skins, and undersized, malformed, diseased, or damaged bulbs) are a rich source of dietary fiber and bioactive compounds, representing a sustainable alternative to the use of traditional ingredients in the formulation of food products for the application of circular economy concept. The aim of this work was to study the potential of onion byproducts as a functional ingredient by determining their *in vitro* bioactive properties. Onion byproducts, skin (OS) and pulp with 9% of skin (OP), proximal analysis was performed (AOAC, 1999): moisture, ashes, proteins, fat, total dietary fiber (TDF) and total carbohydrates by difference. Bioactive properties were assessed by determining total phenolic compounds (TPC, Folin-Ciocalteu method), antioxidant capacity (ABTS, ORAC-FL and HORAC methods), and α -glucosidase inhibition capacity. Among the most relevant results of proximate analysis, OS showed 70 \pm 3% of TDF. OS showed the highest TPC (113 \pm 7 mg GAE/g) and antioxidant capacity (699 \pm 94 and 1782 \pm 92 μ molTE/g for ABTS and ORAC-FL methods, respectively, and 46 \pm 2 mg chlorogenic acid/g for HORAC method) ($p < 0.05$), as well as the highest α -glucosidase inhibition capacity (lowest IC₅₀, 447 \pm 40 and 625 \pm 58 μ g/mL for OS and OP, respectively). In conclusion, onion byproducts present potential as a functional ingredient because of the evaluated health-promoting effects, with subsequent positive environmental impact by applying the circular economy concept.

Keywords: antidiabetic; antioxidant; bioactive compounds; circular economy; dietary fiber; functional ingredient; onion byproducts; sustainable ingredient

Citation: Báez, J.; Marra, G.; Olt, V.; Fernández-Fernández, A.M.;

Medrano, A. Potential of Onion Byproducts as a Sustainable Source of Dietary Fiber and Antioxidant Compounds for Its Application as a Functional Ingredient. *Biol. Life Sci. Forum* **2023**, *26*, x.

<https://doi.org/10.3390/xxxxx>

Academic Editor(s): Name

Published: date



Copyright: © 2023 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The food industry shows interest in the development of new high added value products with a strong nutritional impact. The generation of innovative products with bioactive properties is one of the most current lines in terms of innovation. In this sense, onion byproducts are a rich source of dietary fiber and bioactive compounds, which represent a sustainable alternative to the use of traditional ingredients in the formulation of food products for the application of circular economy concept [1].

Much of the problem facing the horticultural sector is the significant volume of production that cannot be marketed. Particularly, in the packaging process of onions, it is visualized which ones are more likely to be marketed. The remaining ones that are of good quality are kept for later commercialization at a lower price or are directly discarded, leaving a significant volume of production that cannot be commercialized. These non-commercialized onions could be used as ingredients in the formulation of foods with bioactive properties [2].

Onion byproducts include the tops and bottoms of onion bulbs, onion skins, and undersized, malformed, diseased, or damaged bulbs [3,4]. In the last decade, there has been an increase in the demand for processed onion in the form of frozen and freeze-dried chopped onion, for ready-to-eat foods, leading to an increase in the generation of waste at the industrial level [5], making the recovery of onion byproducts necessary to reduce the impact on the environment.

Bioactive properties of onions and their byproducts have been reported, in addition to their high nutritional quality due to their composition in dietary fiber and phenolic compounds, mainly flavonoids, that may exert antioxidant effects [1,6]. This increases their potential as a functional ingredient in the development of foods with health-promoting properties [1].

To confirm its potential as a functional ingredient, it is necessary to identify the functional compounds that are to be added to the food product and where they can be obtained from, evaluating their bioactive properties through *in vitro* assays [7].

This work proposes an improvement in the management of waste from agrifood production, both from the economic and environmental point of view, focusing on the search for alternatives for the recovery of byproducts generated in the processing and production of onion.

2. Materials and Methods

2.1. Onion Byproducts Treatment

Brown onion skins (OS) were dried in a conventional oven at 60 °C until a constant weight was achieved (24 h) and milled using a domestic coffee mill (Figure 1a). Additionally, brown onion pulp was combined with 9% OS and processed using an electronic processor to create onion puree (OP) (Figure 1b). To extract the bioactive compounds from both OS and OP, an extraction was performed using DMSO in H₂O (6%, 60 µL DMSO and 940 µL H₂O) [8].



Figure 1. Brown onion skin (a) and onion pulp with 9% of onion skin (b).

2.2. Proximal Analysis

Proximal analysis of both OS and OP was carried out following the method outlined in AOAC [9]. This involved the assessment of fat, protein, moisture, total dietary fiber, ash and total carbohydrates (calculated as the difference using measurements of moisture, protein, fat, and ash content).

2.3. Bioactivity Assays

2.3.1. Total Polyphenol Content (TPC) and Antioxidant Capacity

The Total Polyphenol Content (TPC) was determined using the Folin-Ciocalteu method [8]. Briefly, 10 μL of the sample (OS and OP) or the standard solution (gallic acid), with 200 μL of sodium carbonate solution and 50 μL of Folin-Ciocalteu reagent, were added to each translucent well of a 96-well plate. After the incubation in darkness for 30 min the absorbance was measured at 750 nm using a microplate reader (Thermo Scientific Multiskan FC model, MA, USA). Results were expressed as mg of Gallic Acid Equivalents (GAE)/g of sample.

Antioxidant capacity was determined by ABTS [8], ORAC-FL [10] and HORAC-FL [10] methods. For ABTS assay, 10 μL of either the sample (OS and OP) or the standard solution (Trolox) and 190 μL of the ABTS radical were introduced into each well of a 96-well translucent plate. Following a 10 min incubation period in darkness, the absorbance was measured at 750 nm utilizing a microplate reader (Thermo Scientific Multiskan FC model, Massachusetts, USA) [8]. For ORAC-FL assay, each well of a 96-well black plate contained 25 μL of either the sample (OS and OP) or the standard solution (Trolox), along with 150 μL of the fluorescein working solution and 25 μL of AAPH. Fluorescence measurements ($\lambda_{\text{excitation}} = 485 \text{ nm}$, $\lambda_{\text{emission}} = 535 \text{ nm}$) were measured at 37 °C every minute for a duration of 45 min using a Varioskan™ Lux (SkanIt RE 5.0 software, Thermo Scientific, MA, USA) fluorimeter microplate reader [10]. In both cases (ABTS and ORAC-FL) the results were expressed as μmol of Trolox Equivalents (TE)/g of sample. For the HORAC assay, the reaction took place in a 96-well black plate by mixing in each well 190 μL of fluorescein working solution, 20 μL of sample (OS and OP)/buffer (negative control) or standard solution (chlorogenic acid) with 15 μL of H_2O_2 solution and 75 μL of cobalt chloride solution. Fluorescence measurements ($\lambda_{\text{excitation}} = 485 \text{ nm}$, $\lambda_{\text{emission}} = 535 \text{ nm}$) were measured at 37 °C every minute for a duration of 180 min using a Varioskan™ Lux (SkanIt RE 5.0 software, Thermo Scientific, MA, USA) fluorimeter microplate reader. The results were expressed as mg chlorogenic acid/g of sample [10].

2.3.2. Antidiabetic Capacity

The potential antidiabetic effect of the samples (OS and OP) was evaluated determining the capacity to inhibit α -glucosidase enzyme [11]. This inhibition was determined by the fluorescence ($\lambda_{\text{excitation}} = 360 \text{ nm}$, $\lambda_{\text{emission}} = 460 \text{ nm}$) generated from the hydrolysis of the enzyme substrate (4-MUF- α -D-glucopyranoside) by α -glucosidase over 30 min duration at 37 °C using a Varioskan™ Lux (SkanIt RE 5.0 software, Thermo Scientific, MA, USA) fluorimeter microplate reader. Results were expressed as the concentration of sample causing 50% inhibition (IC_{50} , mg/mL) of α -glucosidase.

2.4. Statistical Analysis

The results were expressed as means \pm standard deviation ($n = 3$). Significant differences were determined by the t-test ($p < 0.05$) using Infostat v. 2015 program (Universidad Nacional de Córdoba, Córdoba, Argentina).

3. Results and Discussion

3.1. Proximal Analysis

Chemical composition of OS and OP (Table 1) was in agreement with the reported by Benítez et al. [2] for Recas and Figueres cultivars (Spain), highlighting the total dietary fiber (TDF) content of OS and OP that could lead to beneficial effects on health [2]. Particularly, Ca content was within the values of Recas and Figueres cultivars, in contrast with Fe content of OP which was lower than onion inner scale of these two cultivars [2]. This feature could add value to developed foods based on this byproduct. Both byproducts presented high nutritional quality so they could be employed in the formulations of food products with high nutritional value.

Table 1. Proximal analysis and mineral composition of onion skin (OS) and onion pulp combined with 9% of OS (OP).

	OS	OP
DM (%)	91.2 ± 0.2b	14.1 ± 0.3a
Proteins (%)	2.38 ± 0.01	-
Lipids (%)	0.53 ± 0.01	-
Dietary fiber (%)	69.9 ± 2.9b	43.9 ± 0.8a
Ashes (%)	9.4 ± 0.6b	5.3 ± 0.2a
Minerals (mg/g)		
Ca	24.5 ± 0.5b	9.7 ± 1.5a
Fe	0.048 ± 0.004b	0.018 ± 0.003a

Values are means ± SD, n = 3. Means within a row with different letters are significantly different at $p < 0.05$ by *t*-test. All the results are expressed in dry matter (DM) basis.

3.2. Bioactivity Assays

OS showed the highest TPC and antioxidant capacity determined by ABTS, ORAC-FL and HORAC, as well as the highest α -glucosidase inhibition capacity (lowest IC_{50}) ($p < 0.05$) (Table 2). OS and OP showed higher TPC values than Korean onion extracts from pulp and skin (aqueous and ethyl alcohol extracts) [12]. Moreover, TPC values of OS were in agreement with extracts of onion skin from fifteen cultivars [13] and were higher than the reported by Benítez et al. [2]. OS showed higher antioxidant capacity by ABTS and ORAC-FL than “Rossa di Tropea” and “Ramata di Montoro” onion skin extracts [14], as well as ABTS values of different onion cultivars [15]. Also, ABTS values of OP were higher than those shown by the internal parts of onions from different cultivars [15]. As to α -glucosidase inhibition capacity, Korean pulp and skin onion extracts presented 20–90% inhibition in a concentration 2 mg/mL of extract showing lower inhibition than OS and OP [12]. The current results are in agreement with the reported onion antidiabetic properties [16]. The different extent of the determined bioactive properties may be due to onion variety and cultivation conditions (different regions) with the subsequent diverse bioactive compound composition [1].

Table 2. Total Polyphenol Content (TPC), antioxidant activity and α -glucosidase inhibition capacity of onion skin (OS) and onion pulp combined with 9% of OS (OP).

Bioactive Properties	OS	OP
TPC (mg GAE/g DM)	112.9 ± 7.4b	19.3 ± 3.8a
<i>Antioxidant capacity</i>		
ABTS (μ mol TE/g DM)	699.0 ± 94.2b	162.5 ± 14.4a
ORAC-FL (μ mol TE/g DM)	1782.0 ± 92.0a	2989.4 ± 70.9b
HORAC (mg chlorogenic acid/g DM)	46.1 ± 2.2b	5.7 ± 0.1a
<i>Antidiabetic capacity (IC_{50}, μg/mL DM)</i>		
α -glucosidase inhibition capacity	447.2 ± 40.5a	625.1 ± 58.0b

Values are means ± SD (n = 3). Means within a row with different letters are significantly different at $p < 0.05$ by *t*-test. DM: dry matter.

Altogether, the results showed OS presented higher bioactive properties than OP showing greater potential as a functional ingredient which may be due to higher phenolic compound content [1]. Moreover, OS is known for having greater quercetin content which could explain the highest bioactive properties [12]. Particularly, brown onion skin such as the one of the present work, has shown high content of quercetin aglycone [2], which may be the responsible for the exerted bioactive properties. Onions are also composed of vitamin C (190 mg/100 g) [17] which may contribute to the exerted antioxidant capacity.

Both byproducts could be used in the formulation of foods of high nutritional quality due to their dietary fiber content and composing natural antioxidants. These components would provide not only potential beneficial health effects [3], but could also provide techno-functional benefits such as increasing the shelf life of the food developed such as bread [18], pasta, noodles and meat [1]. Food processing effects on onion byproducts, such as thermal processing, should be evaluated when developing food products as it may affect phenolic compounds [19]. Also, the development of new foods should be accompanied by consumer sensory studies (at least 100 consumers) to ensure their acceptability because of their chemical composition that may affect the sensory attributes of the food product.

4. Conclusions

In the current work, brown onion skin (OS) and pulp with 9% of skin (OP) were chemically characterized and studied for their bioactive properties to evaluate their potential as functional ingredients. OS and OP presented high total polyphenol content, antioxidant and antidiabetic capacities showing OS higher bioactive properties than OP.

Based on the health-promoting effects demonstrated by both onion byproducts, it can be concluded that they have significant potential to be used as functional ingredients. In addition, their use as ingredients will subsequently include a positive impact on the environment through the application of the circular economy concept. Further studies regarding food products' development and sensory studies should be assessed to ensure their feasibility as ingredients.

Author Contributions: Conceptualization, J.B., A.M.F.-F. and A.M.; methodology, J.B., A.M.F.-F. and A.M.; validation, J.B.; formal analysis, J.B., G.M. and A.M.F.-F.; investigation, J.B., G.M., V.O. and A.M.F.-F.; resources, A.M.; data curation, J.B., G.M., V.O. and A.M.F.-F.; writing—original draft preparation, J.B., V.O. and A.M.F.-F.; writing—review and editing, J.B., G.M., V.O., A.M.F.-F. and A.M.; visualization, J.B., A.M.F.-F. and A.M.; supervision, J.B., A.M.F.-F. and A.M.; project administration, A.M.; funding acquisition, A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Agencia Nacional de Investigación e Innovación (ANII), J.B. scholarship POS_NAC_2021_1_169815 and V.O. scholarship POS_NAC_M_2020_1_164532; J.B. and V.O. student scholarship from Programa de Desarrollo de las Ciencias Básicas (PEDECIBA).

Institutional Review Board Statement:

Informed Consent Statement: Not applicable.

Data Availability Statement: All the data is presented within the Results and Discussion section.

Conflicts 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.

References

1. Kumar, M.; Barbhai, M.D.; Hasan, M.; Dhupal, S.; Singh, S.; Pandiselvam, R.; Rais, N.; Natta, S.; Senapathy, M.; Sinha, N.; et al. Onion (*Allium Cepa* L.) Peel: A Review on the Extraction of Bioactive Compounds, Its Antioxidant Potential, and Its Application as a Functional Food Ingredient. *J. Food Sci.* **2022**, *87*, 4289–4311. <https://doi.org/10.1111/1750-3841.16297>.
2. Benítez, V.; Mollá, E.; Martín-Cabrejas, M.A.; Aguilera, Y.; López-Andréu, F.J.; Cools, K.; Terry, L.A.; Esteban, R.M. Characterization of Industrial Onion Wastes (*Allium Cepa* L.): Dietary Fibre and Bioactive Compounds. *Plant Foods Hum. Nutr.* **2011**, *66*, 48–57. <https://doi.org/10.1007/s11130-011-0212-x>.
3. Bedrníček, J.; Jirotková, D.; Kadlec, J.; Laknerová, I.; Vrchotová, N.; Tríska, J.; Samková, E.; Smetana, P. Thermal Stability and Bioavailability of Bioactive Compounds after Baking of Bread Enriched with Different Onion By-Products. *Food Chem.* **2020**, *319*, 126562. <https://doi.org/10.1016/j.foodchem.2020.126562>.
4. Choi, I.S.; Cho, E.J.; Moon, J.H.; Bae, H.J. Onion Skin Waste as a Valorization Resource for the By-Products Quercetin and Biosugar. *Food Chem.* **2015**, *188*, 537–542. <https://doi.org/10.1016/j.foodchem.2015.05.028>.

5. Benítez, V.; Mollá, E.; Martín-Cabrejas, M.A.; Aguilera, Y.; López-Andréu, F.J.; Terry, L.A.; Esteban, R.M. The Impact of Pasteurisation and Sterilisation on Bioactive Compounds of Onion By-Products. *Food Bioprocess Technol.* **2013**, *6*, 1979–1989. <https://doi.org/10.1007/s11947-012-0866-x>.
6. Benítez, V. *Caracterización de Subproductos de Cebolla Como Fuente de Fibra Alimentaria y Otros Compuestos Bioactivos*; Universidad Autónoma de Madrid, 2011.
7. Fidelis, M.; de Oliveira, S.M.; Sousa Santos, J.; Bragueto Escher, G.; Silva Rocha, R.; Gomes Cruz, A.; Araújo Vieira do Carmo, M.; Azevedo, L.; Kaneshima, T.; Oh, W.Y.; et al. From Byproduct to a Functional Ingredient: Camu-Camu (*Myrciaria Dubia*) Seed Extract as an Antioxidant Agent in a Yogurt Model. *J. Dairy Sci.* **2020**, *103*, 1131–1140. <https://doi.org/10.3168/jds.2019-17173>.
8. Fernández-Fernández, A.M.; Iriondo-DeHond, A.; Dellacassa, E.; Medrano-Fernandez, A.; del Castillo, M.D. Assessment of Antioxidant, Antidiabetic, Antiobesity, and Anti-Inflammatory Properties of a Tannat Winemaking by-Product. *Eur. Food Res. Technol.* **2019**, *245*, 1539–1551. <https://doi.org/10.1007/s00217-019-03252-w>.
9. AOAC. *Official Methods of Analysis*; 16th ed.; Association of Official Analytical Chemists: Washington, DC, USA, 1999.
10. Báez, J.; Fernández-Fernández, A.M.; Tironi, V.; Bollati-Fogolín, M.; Añón, M.C.; Medrano-Fernández, A. Identification and Characterization of Antioxidant Peptides Obtained from the Bioaccessible Fraction of α -Lactalbumin Hydrolysate. *J. Food Sci.* **2021**, *86*, 4479–4490. <https://doi.org/10.1111/1750-3841.15918>.
11. Fernández-Fernández, A.M.; Dumay, E.; Lazennec, F.; Miguez, I.; Heinzen, H.; Lema, P.; López-Pedemonte, T.; Medrano-Fernandez, A. Antioxidant, Antidiabetic, and Antiobesity Properties, TC7-Cell Cytotoxicity and Uptake of Achyrocline Satureioides (Marcela) Conventional and High Pressure-Assisted Extracts. *Foods* **2021**, *10*, 893. <https://doi.org/10.3390/foods10040893>.
12. Kim, M.H.; Jo, S.H.; Jang, H.D.; Lee, M.S.; Kwon, Y.I. Antioxidant Activity and α -Glucosidase Inhibitory Potential of Onion (*Allium Cepa* L.) Extracts. *Food Sci. Biotechnol.* **2010**, *19*, 159–164. <https://doi.org/10.1007/s10068-010-0022-1>.
13. Sagar, N.A.; Pareek, S.; Gonzalez-Aguilar, G.A. Quantification of Flavonoids, Total Phenols and Antioxidant Properties of Onion Skin: A Comparative Study of Fifteen Indian Cultivars. *J. Food Sci. Technol.* **2020**, *57*, 2423–2432. <https://doi.org/10.1007/s13197-020-04277-w>.
14. Celano, R.; Docimo, T.; Piccinelli, A.L.; Gazzerro, P.; Tucci, M.; Di Sanzo, R.; Carabetta, S.; Campone, L.; Russo, M.; Rastrelli, L. Onion Peel: Turning a Food Waste into a Resource. *Antioxidants* **2021**, *10*, 304.
15. Lorenzo León, H.C.; Rodríguez Galdón, B.; Rodríguez Rodríguez, E.M.; Díaz Romero, C. Capacidad Antioxidante de Diferentes Variedades de Cebolla: Antioxidant Capacity of Different Onion Cultivars. *CYTA—J. Food* **2009**, *7*, 53–58. <https://doi.org/10.1080/11358120902850784>.
16. Mohamed, S. Functional Foods against Metabolic Syndrome (Obesity, Diabetes, Hypertension and Dyslipidemia) and Cardiovascular Disease. *Trends Food Sci. Technol.* **2014**, *35*, 114–128. <https://doi.org/10.1016/j.tifs.2013.11.001>.
17. Datta, S.; Sinha, B.K.; Bhattacharjee, S.; Seal, T. Nutritional Composition, Mineral Content, Antioxidant Activity and Quantitative Estimation of Water Soluble Vitamins and Phenolics by RP-HPLC in Some Lesser Used Wild Edible Plants. *Heliyon* **2019**, *5*, 1431. <https://doi.org/10.1016/j.heliyon.2019>.
18. Sagar, N.A.; Pareek, S. Fortification of Multigrain Flour with Onion Skin Powder as a Natural Preservative: Effect on Quality and Shelf Life of the Bread. *Food Biosci.* **2021**, *41*, 100992. <https://doi.org/10.1016/j.fbio.2021.100992>.
19. Shahidi, F.; Yeo, J.D. Insoluble-Bound Phenolics in Food. *Molecules* **2016**, *21*, 1216. <https://doi.org/10.3390/molecules21091216>.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.