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Proceeding Paper

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

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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 a 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 the 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. For the onion byproducts—skin (OS) and pulp with 9% of skin (OP)—proximal analysis was performed (AOAC, 1999): moisture, ash, proteins, fat, total dietary fiber (TDF) and total carbohydrates by difference. Bioactive properties were assessed by determining the 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 the proximate analysis, OS showed 70 ± 3% of TDF. OS showed the highest TPC (113 ± 7 mg GAE/g) and antioxidant capacity (699 ± 94 and 1782 ± 92 µmolTE/g for the ABTS and ORAC-FL methods, respectively, and 46 ± 2 mg chlorogenic acid/g for the HORAC method; $p < 0.05$), as well as the highest α-glucosidase inhibition capacity (lowest IC_{50}, 447 ± 40 and 625 ± 58 µg/mL for OS and OP, respectively). In conclusion, onion byproducts present potential as a functional ingredient because of the evaluated health-promoting effects, with a 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

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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 recent trends 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 the 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 economic and environmental points 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 H_2O (6%, 60 µL of DMSO and 940 µL of H_2O) [8].

(**a**) (**b**)

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 contents).

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–Ciocalteau reagent, were added to each translucent well of a 96-well plate. After incubation in darkness for 30 min, the absorbance was measured at 750 nm using a microplate reader (Thermo Scientific Multiskan FC model, Waltham, MA, USA). Results were expressed as mg of gallic acid equivalents (GAE)/g of sample.

Antioxidant capacity was determined by the ABTS [8], ORAC-FL [10], and HORAC-FL [10] methods. For the 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 using a microplate reader (Thermo Scientific Multiskan FC model, Waltham, MA, USA) [8]. For the 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 (λexcitation = 485 nm, λemission = 535 nm) were measured at 37 °C every minute for a duration of 45 min using a Varioskan^{TM} Lux (SkanIt RE 5.0 software, Thermo Scientific, Waltham, 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 190 µL of fluorescein working solution and 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 in each well. Fluorescence measurements (λexcitation = 485 nm, λemission = 535 nm) were measured at 37 °C every minute for a duration of 180 min using a Varioskan^{TM} Lux (SkanIt RE 5.0 software, Thermo Scientific, Waltham, 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 (λexcitation = 360 nm, λemission = 460 nm) generated from the hydrolysis of the enzyme substrate (4-MUF-α-D-glucopyranoside) by α-glucosidase over a 30 min duration at 37 °C using a Varioskan^{TM} Lux (SkanIt RE 5.0 software, Thermo Scientific, Waltham, 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 ± standard deviation (n = 3). Significant differences were determined by the *t*-test ($p < 0.05$) using the Infostat v. 2015 program (Universidad Nacional de Córdoba, Córdoba, Argentina).

3. Results and Discussion

3.1. Proximal Analysis

The chemical composition of OS and OP (Table 1) was in agreement with that 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, calcium (Ca) content was found within the values of Recas and Figueres cultivars, in contrast with iron (Fe) content of OP, which was lower than the 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 ± 0.2 b	14.1 ± 0.3 a
Proteins (%)	2.38 ± 0.01	-
Lipids (%)	0.53 ± 0.01	-
Dietary fiber (%)	69.9 ± 2.9 b	43.9 ± 0.8 a
Ash (%)	9.4 ± 0.6 b	5.3 ± 0.2 a
Minerals (mg/g)		
Ca	24.5 ± 0.5 b	9.7 ± 1.5 a
Fe	0.048 ± 0.004 b	0.018 ± 0.003 a

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

3.2. Bioactivity Assays

OS showed the highest TPC and antioxidant capacity, as 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 those 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]. Additionally, ABTS values of OP were higher than those shown by the internal parts of onions from different cultivars [15]. As for the α-glucosidase inhibition capacity, Korean pulp and skin onion extracts presented 20–90% inhibition in a concentration of 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 extents of the determined bioactive properties may be due to the 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 ± 7.4 b	19.3 ± 3.8 a
Antioxidant capacity		
ABTS (μmol TE/g DM)	699.0 ± 94.2 b	162.5 ±14.4 a
ORAC-FL (μmol TE/g DM)	1782.0 ± 92.0 a	2989.4 ± 70.9 b
HORAC (mg chlorogenic acid/g DM)	46.1 ± 2.2 b	5.7 ± 0.1 a
Antidiabetic capacity (IC_{50}, μg/mL DM)		
α-glucosidase inhibition capacity	447.2 ± 40.5 a	625.1 ± 58.0 b

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

Altogether, the results showed that OS presented higher bioactive properties than OP, showing greater potential as a functional ingredient, which may be due to the higher phenolic compound content [1]. Moreover, OS is known for having a greater quercetin content, which could explain the highest bioactive properties [12]. Particularly, brown onion skin, such as that used in the present work, has shown a high content of quercetin aglycone [2], which may be 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 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 the phenolic compounds [19]. Additionally, the development of new foods should be accompanied by consumer sensory studies (at least 100 consumers) to ensure their acceptability because their chemical composition may affect the sensory attributes of the food products.

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 and antioxidant and antidiabetic capacities, with OS showing 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.

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