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Quince (*Cydonia oblonga* Mill.) Waste By-Product Characterization as a Potential Functional Ingredient

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Abstract: Currently, the production of waste in the food industry is increasing, which is a serious problem. However, most of these residues, especially those derived from fruits and vegetables, have great unknown properties that are not used. The main objective of this article is the analysis and characterization of the waste from quince after its processing to observe its properties and its potential use in different industries as a functional ingredient, thus favoring the circular economy and sustainability. Quince by-product nutritional parameters such as proteins, fibers, sugars, vitamins, and minerals were analyzed. Also, the antioxidant capacity was measured by various methods: 1,1-diphenyl-2-picrylhydrazyl radical scavenging activity (DPPH), antioxidant capacity in Trolox equivalent antioxidant capacity (TEAC/ABTS), and total polyphenol content (TPC). Finally, the antimicrobial capacity against different postharvest-pathogenic fungi was measured in direct sample and extract. The nutritional results showed a nutritional profile rich in soluble and insoluble fiber, potassium, calcium, and magnesium, and low in fat. The antioxidant results from the extract showed significant levels of phenols and higher antioxidant capacity from the extracted sample. No positive results were found in the antimicrobial capacity study. Quince by-products could be a potential ingredient in the industry due to their nutritional composition and antioxidant content.

Keywords: antioxidant capacity; food waste; nutritional composition; circular economy

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1. Introduction

Currently, the population growth is increasing, having a forecast of 8.9 billion people by 2050, which will translate into an increase in demand for food between 56 and 98% for this year [1]. This increase in demand directly causes an increase in the production of waste and by-products that cause serious environmental and socio-economic problems [2]. The fruit and vegetable sector is one of the most affected in terms of waste generation due to the sensitivity and properties of these products. The most common reasons for discarding fruits and vegetables are injuries, bumps, excessive ripening, appearance, and freshness [3]. It is estimated that about 1300 million tons of food are wasted every year, with the fruit and vegetable sector accounting for 60% of these losses [4]. Food waste poses a significant environmental threat, representing a major source of greenhouse gas (GHG) emissions that exacerbate global warming and climate change, potentially contributing to the extinction of numerous species [5].

Highlighting this aspect, the food industry contributes to GHG emissions, generating 26% of global emissions, including methane (CH_4), dioxins, and ammonia (NH_3), which pollute air and water, impacting both environmental and human health [6]. Therefore,

the implementation of effective waste management strategies within the food industry, particularly in the fruit and vegetable sector, is paramount to mitigating these severe consequences [6].

The growing demand for food is also driven by per capita consumption since there is greater access to energy-rich foods, which often require significant resources for their production and consumption [1], causing a change in dietary habits and increasing the interest in fresh and nutritious foods.

The United Nations, through the Sustainable Development Goals (SDGs), has set a target of reducing per capita food waste by 50% by 2030 [7]. There is a total of 17 SDGs and 7 of them, such as the end of poverty, health, and well-being, zero hunger, sustainable production and consumption, clean water and sanitation, underwater life, climate action, and life of terrestrial ecosystems, are directly related to the food supply chain and its sustainability [8].

For the reasons mentioned above, there has been a growing interest in recent years to find ways to utilize this waste to promote the circular economy and sustainability. Research has revealed that food waste by-products from fruits and vegetables, such as seeds, peels, leaves, and stems, are rich in antioxidants, fibers, bioactive compounds, and enzymes, making them valuable resources for the food, pharmaceutical, and cosmetic industries [3]. Likewise, these products possess low toxicity and high efficacy, generating an added value [9]. Studies have also shown antifungal and antimicrobial activity in plant by-products. For instance, several works have described the antioxidant and antimicrobial capacity of pomegranate peel and its results against various food pathogens, which can be applied in the food industry as a natural additive and as a natural antimicrobial [10–13]. Other authors analyzed its cytotoxicity and effect on human health such as Lai et al. (2013) [14] and Rodríguez-Gonzalez et al. (2017) [15] who described the anti-cancer and anti-diabetic properties of citrus and mango residues, respectively. Therefore, these residues can be used as functional foods that are described as foods that have a positive impact on a person's health, physical performance, or mood, in addition to their nutritional value [16].

Among fruits, the quince (*Cydonia oblonga* Mill.) is a great unknown despite its different properties, becoming one of the most prized pitted fruits despite its low interest as a fresh fruit [17]. Quince is part of the Rosaceae family and grows from a deciduous tree. The immature fruit has a green color that becomes more yellowish as the fruit matures. Quince has a shape like a pear or an apple and inside there are numerous brown seeds covered by a whitish mucilage. The fresh fruit is not very appreciated due to its hard and astringent pulp [18]. It is a climacteric fruit; therefore, it is harvested after it reaches physiological maturity, which usually occurs from October to November [18]. The most common way of fruit preservation and storage is refrigeration at temperatures between 0 and 5 °C helping to slow microbial growth and the generation of ethylene, a hormone responsible for fruit ripening, slowing it down [18]. The origin of the quince fruit dates to the Transcaucasian zone (Iran, Armenia, Azerbaijan, etc.), and it is estimated that it began to be cultivated in the year 4000 B.C. As it can tolerate climatic changes, it allowed its extension to China and Europe [18]. The introduction of quince into the Mediterranean is directly linked to the invasion of the Middle East by Alexander the Great, so its scientific name, *Cydonia*, derives from a city in Crete called Cydonea [18]. In ancient Greece, quince was used at wedding banquets or to make wine. This custom was continued until the Middle Ages and was considered a protector against the black death [18].

The worldwide production of quince between 2017 and 2019 was 674,894 tons, of which 77% was grown on the Asian continent while 6.8% of the production was on the European continent [17]. Turkey is the main country producing quince, followed by others such as China, Iran, and Morocco [19]. In 2022, 82,941 ha were dedicated to the cultivation of quince, producing 702,015 tons of fruit [20]. Bayav and Sahin (2023) estimated that Turkey would increase its production to 208,112 tons and export to 18,685 in 2023 [17].

In terms of its composition, quince is a highly nutritious fruit of great interest to various industries. It is one of the best sources of pectin and phytochemicals [18], rich

in carbohydrates, fibers, proteins, vitamins, minerals, and organic acids [21]. Notably, quince contains a high level of phenolic compounds, which contribute to its antioxidant capacity [22].

Pectins, which are an important component in quince, are polysaccharides present in the cell wall and can act as a gel, binding cells together. After ingestion, it has various physiological benefits, such as reducing glucose and cholesterol levels and acting as a prebiotic [23]. Pectins are also used in various industries due to their gelling properties. Quince is a notable source of pectin, the content of which will vary depending on the degree of maturity [18].

Quince also boasts a high content of flavonoids, phenolic acids, and lignin among other active ingredients. The main phenolic compound is 5-O-caffeoylquinic acid, the primary substrate for the enzyme polyphenol oxidase, which makes quince highly susceptible to enzymatic browning [24]. Additionally, quince leaves have various medicinal uses, including antifungal properties, protection of the liver system, antioxidant properties, the treatment of skin lesions, and antitussive, sedative, and antipyretic properties [18,25].

Typically, quince is consumed cooked in the form of jams, marmalades, or jellies [25–27]. However, the industrial manufacturing process of these products generates by-products, around 50,000 kg per year in the quince paste manufacturing process (Figure 1) [20]. This by-product is formed by the central area of the fruit with seeds and mucilage, small parts of skin, and leaves that are not used and discarded. As mentioned above, quince is rich in numerous components and this by-product could have a rich nutritional profile and components that generates a functional ingredient for food that is not used in any way. Therefore, it is important to characterize the by-product to know its properties and possible applications and uses.

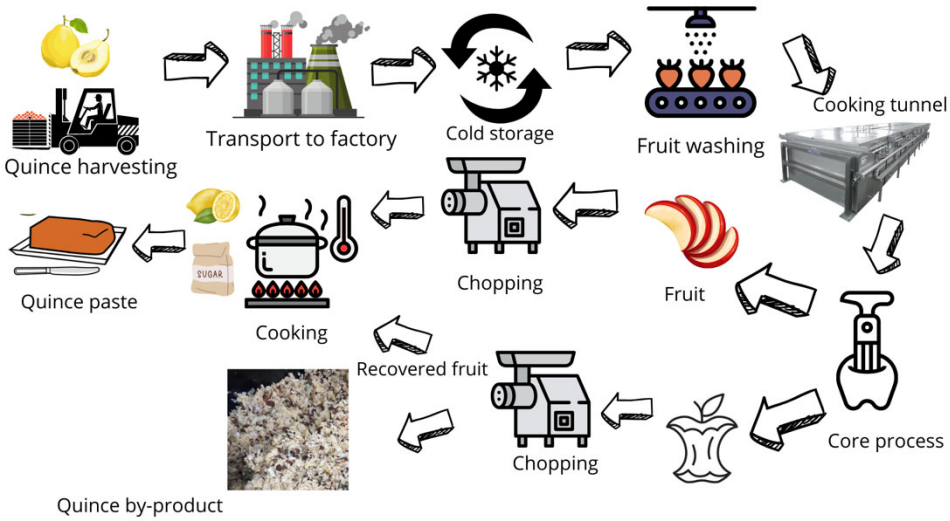

Figure 1. Quince manufacturing process.

Thus, the main objective of this study is to analyze and characterize the waste generated during quince product production, exploring its properties and potential applications as a functional ingredient in the food industry.

2. Materials and Methods

2.1. Raw Material

The quince residue (the central part of the fruit) obtained after the manufacturing process was kindly provided by the company Yemas de Santa Teresa S.L. (Ávila, Spain). To obtain the by-product, the fruit undergoes a specific processing consisting of several processes. First, the fruit is washed with water and subjected to a cooking process. Once cooked, it is cored to separate the central area of the pulp. The pulp obtained will be used for the manufacture of the final product. On the other hand, the quince core is passed

through a chopper equipped with a sieve to recover as much pulp as possible, which will be used in the manufacturing process. The discarded surplus is the generated by-product that is wasted. Once obtained, it was stored in deep-freezing at −80 °C until use.

2.2. Nutritional Parameters

The nutritional parameters, such as moisture, fats, ash, carbohydrates, fibers, vitamins, and minerals, were analyzed in triplicate. The moisture content was determined gravimetrically [28]: a total of 5 g of by-product were prepared to constant weight in a hot air oven at 80 °C for about 24 h.

The fat was analyzed using petroleum ether (40–60 °C) for 4 h by means of a Soxtec System 2055 Tecator extractor (FOSS, Hillerød, Denmark) and subsequently measured gravimetrically [29]. The ash content was also determined by by-product incineration to constant weight in a muffle at 550 °C for 5 h [30]. The result was expressed in g per 100 g of by-product. Carbohydrates were calculated by difference. The method described by Dumas [31] was used to measure the protein content using a CN-2000 Analyzer (Leco Corp., St. Joseph, MO, USA). Based on the results, the protein content was calculated from nitrogen by the conversion factor 6.25.

Soluble and insoluble fibers were analyzed by the method described by the Association of Official Analytical Chemists (AOAC) [32] using the TDF-100 kit (Sigma-Aldrich, St. Louis, MO, USA). The samples were measured together with blank samples.

The total sugar content was analyzed by high-performance liquid chromatography (HPLC) according to the AOAC 1990, method 982.14 [33]. A 50% ethanol dilution was prepared for the extraction of sugars. Once obtained, the extract was passed through a Sep-Pak C18 cartridge and filtered through a 0.45 mm nylon disk. The quantification and separation were performed by means of a column with amino bonds and detection with a refractometer 1260 Infinity II (Agilent Technologies, Waldbronn, Germany). The results were expressed as g per 100 g of sample.

Vitamin C was measured using a standard vitamin C measurement kit Vitafast (R-Biopharm AG, Darmstadt, Germany). High-performance liquid chromatography was used to analyze the sugars [30], and the sample was homogenized with distilled water and filtered. The filtrate was injected into HPLC 1100 VWD (Agilent Technologies, Waldbronn, Germany). Standard sugars were purchased from Sigma-Aldrich. The minerals calcium, magnesium, and potassium were measured by means of ICP-MS Avio, 220 Max (PerkinElme, Waltham, MA, USA) in triplicate based on the method described by Santos et al., 2022 [34]. Proximal composition was expressed in g per 100 g of sample.

2.3. Antioxidant Capacity

2.3.1. Sample Processing

The by-product was subjected to a lyophilization process by a lyophilizer (LYOQUEST-55, Azbil Telstar Technologies S.L.U., Terrassa, Spain) for 24 h and stored at 5 °C until use.

2.3.2. Extraction

After lyophilizing the sample, it was ground by an analysis mill (Tube Mill control) of IKA Works S.L (Barcelona, Spain) until a fine and homogeneous powder was obtained. Once the powder was obtained, 5 g were dissolved in 100 mL of methanol and water (1:1) at pH 2. It was kept under stirring for 24 h at room temperature (20 °C) and covered to avoid solvent evaporation. After resting, the extract was centrifuged for 20 min at 6000 rpm. The supernatant was filtered with qualitative filter paper (Whatman, UK), made up to 100 mL with methanol and water (1:1) pH 2, and stored at −80 °C until use.

2.3.3. Antioxidant Capacity Determination

The total polyphenol content (TPC) was measured by the Folin–Ciocalteu method [35] with the use of a spectrometer at 760 nm. The results were expressed as mg gallic acid

equivalent (GAE)/100 g weight using a gallic acid calibration curve (9.8 µm–70 Mm). The TP was measured only in an exact sample.

The antioxidant capacity in the Trolox equivalents (TEAC) method was used to evaluate the antioxidant capacity both during extraction and directly in the lyophilized sample following the method reported by Re et al., 1999 [36]. The reduction in the absorbance at 730 nm was recorded by a spectrophotometer (Thermo Fisher Scientific, Genesys 150, Madison, WI, USA). Trolox (7.5–240 µM) was used as a standard.

The effect of antioxidant activity on DPPH was analyzed based on the method described by Brand-Williams, Cuvelier, and Berset 1995 [37]. The results were expressed as a percentage of the inhibition of the DPPH radical. The TEAC and DPPH methods were both analyzed in an extract and direct pre-lyophilized sample.

All the antioxidant activity test samples were diluted 1:10 with miliQ water.

2.4. Antimicrobial Capacity

To measure antimicrobial capacity, the by-product extract was previously lyophilized. To evaluate the antimicrobial activity of quince, an assay was conducted against two phytopathogenic fungi, *Botrytis cinerea* (CECT 20973) and *Colletotrichum acutatum* (CECT 21009), obtained from the Spanish Type Culture Collection (CECT) in Valencia, Spain. Fungal disks (approximately 6 mm) were excised from fully grown 7-day-old cultures and placed at the center of a PDA medium. Regarding the quince extract solution, a concentration of [1:1] was prepared using distilled, autoclaved water, and sterilized using 0.22 µm syringe filters. In total, 5 µL of the extract was inoculated alongside four equidistant points surrounding the fungal disks, with each point containing the quince extract residue. The plates were incubated at room temperature for seven days and observed routinely for fungal growth inhibition. The experiment was repeated in triplicate, with a total of five plates per fungal species. The area of inhibition was measured by the ImageJ photographic analyses software 1.53k (NIH, National Institutes of Health, Bethesda, MD, USA).

3. Results and Discussion

3.1. Nutritional Composition

The results of the nutritional analysis of the quince by-product are shown in Figure 2.

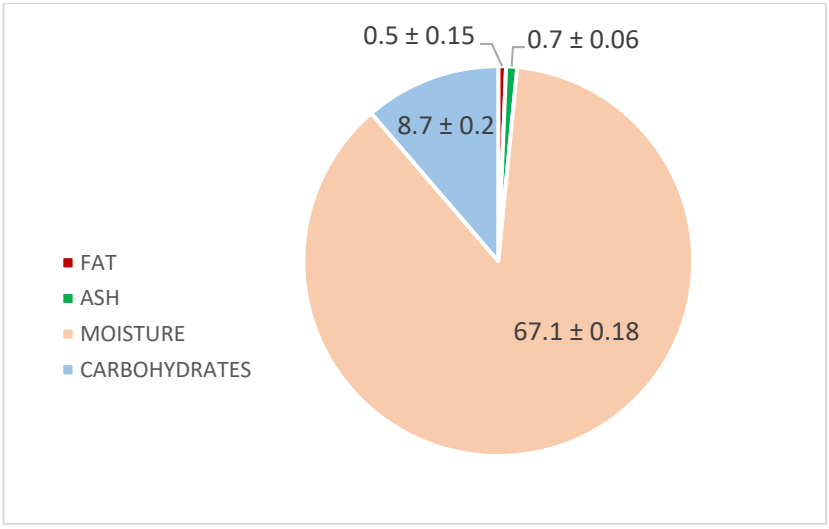

Figure 2. Nutritional profile of quince by-product. Fat, ash, moisture, and carbohydrates. Data expressed in g/100 g (Wet Base) as mean values ± standard deviation (n = 3).

The fat content showed significantly low values. According to the current legislation [38], it can be indicated as a "low-fat" product that does not contain more than 3 g of harrow per 100 g of solid matter, so according to the results obtained, this claim can be

applied to our product. "Low-fat" could also be established with the results obtained in other studies where fat values range from 0.20 g to 0.6 g per 100 g [26,39,40].

Dimitriu et al. (2023) [41] characterized the composition of quince pulp without treatment and with ethanol treatment, where significantly higher values of untreated carbohydrates were obtained (27.53 ± 2.46 mg of glucose/xylose equivalent/100 g of sample) than in the present work (8.7 ± 0.2 g/100 WB sample). On the other hand, other authors reported higher levels (75.80 ± 0.28 g per 100 g sample) [42]. This difference in results may be due to various factors such as part of the fruit as a whole fruit or only the central area as in our test, the origin of cultivation, the ripeness index of the fruit, etc.

Additional results on the nutritional profile of the sample are shown in the following Table 1.

Table 1. Quince by-product nutritional composition.

Soluble Fiber (g/100 g WB)	Insoluble Fiber (g/100 g WB)	Total Sugars (g/100 g WB)	Vitamin C (g/100 g WB)	Calcium (g/100 g WB)	Magnesium (g/100 g WB)	Potassium (g/100 g WB)
2.2 ± 1.23	12.6 ± 0.32	7.4 ± 2.47	<0.02 ± 0.01	0.056 ± 0.01	0.024 ± 0.08	0.21 ± 0.52

Data expressed in g/100 g (Wet Base) as mean values ± standard deviation (n = 3).

The sugar content obtained is low compared to the results previously reported by Coimbra et al. (2023) [40], where they characterized the powder obtained from the peel of the quince and observed that it was a product rich in sugars, especially reducing sugars. Previous studies coinciding with Coimbra et al. (2023) [40] obtained greater reduction than non-reducing sugar, although not with a great difference [43]. The by-product sample consists of the central part of the fruit which includes seeds and mucilage but also skin and small portions of pulp from the central area which can be found in smaller proportions. By working with this by-product, numerous advantages are obtained, such as waste reduction and the optimization of resources rich in various nutritional components.

The most abundant mineral element found was potassium with 210 mg per 100 g, followed by calcium with 56 mg per 100 g followed by calcium. Potassium is one of the main intracellular elements in the body and is indispensable for the normal functioning of cells in processes such as ATP synthesis. Magnesium and calcium are of great importance in bone composition since 99% of the body's calcium is present in bones and teeth. Magnesium is involved in various enzymatic processes and in the maintenance of body levels of potassium and calcium. For its part, potassium is one of the main body elements and is indispensable in the normal functioning of cells in processes, such as ATP synthesis [39,44].

Calcium, magnesium, and potassium were analyzed in the present work and in previous works. The main component obtained was potassium, followed by magnesium and to a lesser extent calcium. In other studies that also analyzed these minerals together, potassium was also the majority element followed by magnesium [39,43,45]. However, in their paper, Rather et al. (2023) [21] described a higher content of calcium than magnesium in the nutritional parameters of quince. The values obtained vs. the previous literature are similar. However, the potassium levels recorded by Krzepiłko and Prażak (2023) [45] were much higher (887.17 mg and 781.02 mg) versus the 210 mg obtained. This difference may be since in our work the residue was composed not only of seeds, but also of mucilage and a very small part of pulp remains that could have been left while Krzepiłko and Prażak (2023) [45] focused their research only on seeds. Another possible cause of this difference could be due to the different species analyzed. *C. oblonga* is the species from which the analyzed residue comes, while the seeds of the revised work [45] belonged to two species, *Chaenomeles japonica* and *C. superba*. However, Byczkiewicz et al. (2021) [43] also analyzed the components in *C. japonica* and obtained a lower amount of potassium, resulting in values relatively more like our work. The relative variations in fiber content, and in mineral content can be altered by cultivation and even by the environmental conditions in which these are developed [46].

Vitamin C or ascorbic acid is an important antioxidant and its amount in fruit ranges from 2.5 to 11.6 mg per 100 g, its reference intake value according to the USDA being 15 mg/100 g [46]. Less than 20 mg/100 g were obtained in the study, being within the range reported in the literature. However, other studies reported higher values, such as 15.46 mg/100 g or 50 to 80 mg/100 g in cultivars from the Czech Republic [46]. It seems that the vitamin content is also affected by the location of the cultivar [46]. Likewise, vitamin C is thermolabile, and in the case of the study, the sample has previously undergone a cooking heat treatment necessary for the manufacturing process and obtaining the studied by-product, which could affect the final vitamin C content. Therefore, optimizing the treatment and process could help to better maintain vitamin C both in the final product and in the derivative product.

The results showed a high level of dietary fiber in the quince by-product, especially soluble fiber followed by carbohydrates and insoluble fiber. On the other hand, the fat content is very low. The quince by-product nutritional profile suggests that the sample may be suitable for diets that require a high intake of fiber with a low fat content. Fiber is defined as plant components that cannot be digested but can be fermented by the intestinal microbiome. The recommended daily intake of fiber is estimated to be 38 g/day in men and 25 g/day in women [47]. Foods rich in fiber can improve insulin sensitivity, metabolic profile, and weight control, as well as reduce blood pressure [47]. The non-soluble fiber consists of non-cellulosic polysaccharides such as pectin, which agrees with the results of the known high pectin content of quince. On the other hand, insoluble fiber constitutes the cell wall [48]. Soluble dietary fiber has a great water retention capacity and viscosity that dilutes nutrients in the intestine and causes a feeling of satiety allowing a lipid reduction mechanism [49,50]. Several studies describe the ability of soluble dietary fiber to absorb and sequester cholesterol, which reduces triglyceride levels. Pectin cannot be degraded by intestinal enzymes but is degraded by bacteria and various studies have described that pectin improves the intestinal population, with bacteria such as Lactobacilli and Bifidobacteria [48].

Other authors carried out an analysis of the nutritional composition of quince, where lower fiber results were obtained than those obtained in our study (1.9 g of fiber per 100 g of fruit) [51]. This difference in fiber can be due to two issues: the first is that the authors performed the analysis on fresh fruit while in the present analysis it was performed on already cooked fruit, which reduces the insoluble fiber. On the other hand, this work focuses on the residue obtained from industrial processing, that is, the heart of the fruit, while Khan and Ahmad (2021) [51] reported results on the complete fruit including pulp and skin.

As far as we know, there are no previous studies that indicate the nutritional content of quince by-product, that is, not only the seeds, although there are others that have described the skin and pulp content [39,52,53]. Quince peel fiber levels (20.2 g/100 g) were reported [39], being more like the present work, while the fiber content in the pulp was less than 1 to 6 g per 100 g [39,52,53].

3.2. Antioxidant Capacity

As mentioned above, except for the total polyphenols, the parameters selected to measure the antioxidant capacity were performed on the extract obtained from the by-product and directly (by-product previously lyophilized).

The TPC of the extract was 22 mg of GAE (Table 2). Polyphenols are compounds that have antioxidant capacity and have hydroxyl groups in the para or ortho position, which facilitates redox-type reactions; this allows them to be oxidized easily since they can transport protons [44].

Table 2. Quince residue total polyphenols and antioxidant capacity.

Sample	TCP (mg of GAE)	DPPH (% of Inhibition)	TEAC (μmol TE 100 g [1])
Direct sample	n.m [1]	47.88 ± 3.57 [2]	31.49 ± 6.12 [2]
Extract	22.62 ± 1.34 [2]	72.39 ± 2.77 [2]	377.10 ± 48.09 [2]

[1] not measured. [2] the results are expressed by media ± standard deviation.

Phenolic compounds are related to the health properties of the fruit and quince is considered a good source of these compounds [26]. Phenols are related to beneficial effects in diseases and are one of the most important antioxidants present in fruits and vegetables. Ibrahim Anber and Asadi-Gharneh (2024) [46] reported a phenolic content of 32.4–143.1 mg/100 g of GAE in the studied genotypes. Lower values were obtained in the previous study by Byczkiewicz et al. (2021) [43] on three varieties of quince which turned out to contain 17.10 mg GAE/g, 18.14 mg GAE/g, and 17.35 mg GAE/g, respectively. A study reported the presence of 16 phenolic compounds in the quince peel and it was determined that the extraction method quantitatively affected the phenolic content [43]. For its part, Silva et al. (2023) [3] analyzed the phenolic content of quince leaves (209.78 ± 14.28 μg/mg), but they saw that the phenol content in the seed extracts were the ones with the lowest phenolic content presented, 12.54 ± 1.09 μg/mg [3]. The results obtained in our trial agree with the previous literature, although, like the nutritional composition, there are variations. It is known that the total content of phenols can be affected by crop conditions since agents such as light, nutrients, and soil temperature [3,54]. Benahmed et al. (2021) [54] reported a phenolic content of 23.3 mg/100 g GAE in the fruit, like the content obtained in the test in the extract (22.62 mg/100 g GAE).

The highest antioxidant capacity is found in the extract with the TEAC method (377.10 ± 48.09 μmoles Trolox/g) followed by the % inhibition of DPPH. The opposite occurs in the direct residue where we find the highest value (Table 2) of the % inhibition of DPPH. However, in both cases, the values obtained are higher in the extract compared to the lyophilized residue. This may be because the extract was made with a methanol–water mixture at pH 2, which facilitates the extraction of components.

Two methods of measuring antioxidant capacity were used to obtain a more reliable assessment by combining both. The antioxidant activity is closely related to the phenolic content since they are responsible for this in large part [55]. Authors such as Silva et al. (2023) [3] corroborated this statement when they saw that quince leaves presented the highest phenolic content, followed by the peel and finally the seeds. The antioxidant activity was equated to being the highest in the part that had the highest phenolic content—the leaves followed by the peel and the seeds. Aguayo-Rojas et al. (2024) [56] analyzed the antioxidant capacity in the methanol extracts of quince (peel and pulp) with the combination of two methods (DPPH and ABTS/TEAC), as did the authors. In the same way, they registered a higher antioxidant capacity in the extracts by the ABTS/TEAC method (11,050 μmol Trolox equivalents/100 g). However, our test has higher values of antioxidant capacity. On the other hand, the opposite is true in the study by Byczkiewicz et al. (2021) [43] where a higher antioxidant capacity was reported in the DPPH method instead of in ABTS analysis in the three varieties of quince analyzed. Other authors also showed a relatively higher value with ABTS in different ethanol extracts and in two varieties of quince [49]. Krzepilko and Prazak. (2023) [45] reported a higher antioxidant capacity in the extracts with ethanol and water in *C. japonica* (3.38 mmol TE 100 g^{-1}), while in the *C. superba*, there were no significant differences in the antioxidant capacity between the different extracts.

3.3. Antimicrobial Capacity

The resistance of microorganisms to drugs is increasing worldwide, assuming a very important problem in human health. For this reason, the research and development of new components and antibiotics are becoming increasingly important [3].

The antimicrobial activity in this assay was measured by the disk diffusion method against two fungi (*B. cinerea* and *C. acutatum*) and was performed in pre-lyophilized extract dilution. There are numerous studies on the antimicrobial activity of quince on human pathogens. However, as far as the authors are aware, there is not much literature on its activity against fungal phytopathogens. For this reason, the two strains selected for the antimicrobial test were important fungal pathogens in post-harvest diseases. The results obtained are shown in Figure 3.

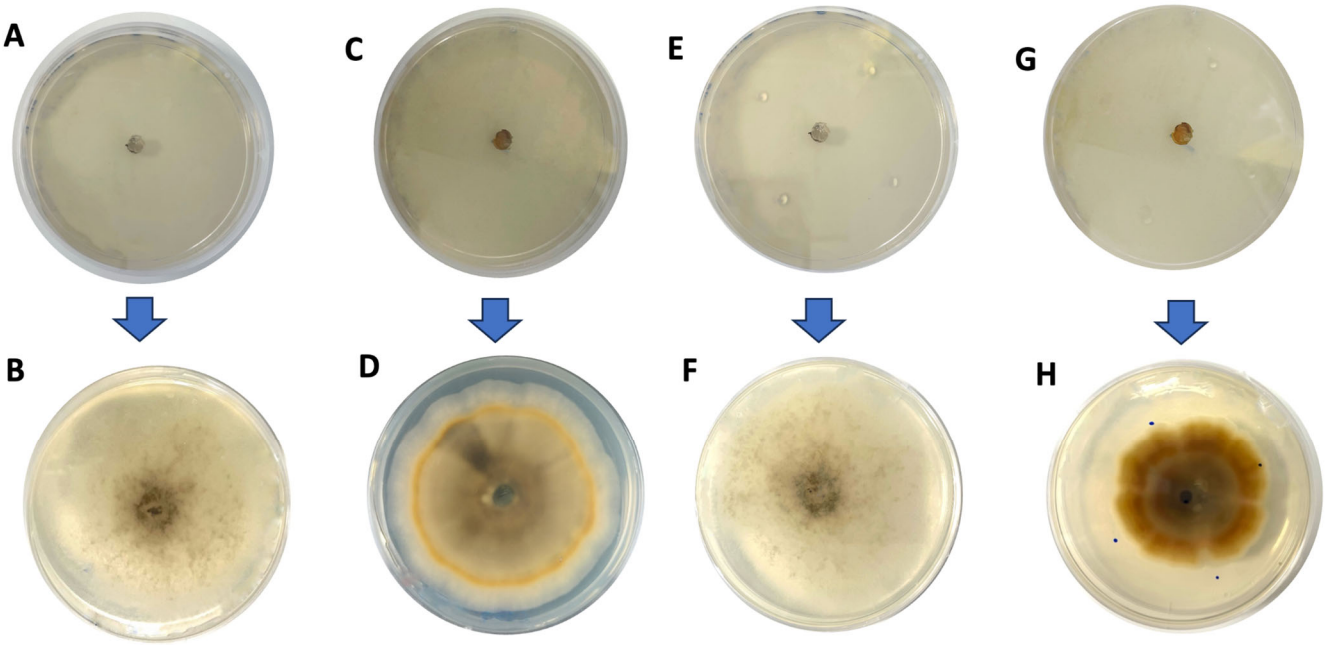

Figure 3. Quince by-product antimicrobial activity assay. (**A**) Control PDA plate with *B. cinerea* disk at time 0. (**B**) Control PDA plate with *B. cinerea* disk at time 7 of incubation at room temperature. (**C**) Control PDA plate with *C. acutatum* disk at time 0. (**D**) Control PDA plate with *C. acutatum* disk at time 7 of incubation at room temperature. (**E**) PDA plate inoculated pre-lyophilized extract dilution (1×) and *B. cinerea* disk at time 0 days. (**F**) PDA plate inoculated pre-lyophilized extract dilution (1×) and *B. cinerea* disk after 7 days of incubation at room temperature. (**G**) PDA plate inoculated pre-lyophilized extract dilution (1×) and *C. acutatum* disk at time 0 days. (**H**) PDA plate inoculated pre-lyophilized extract dilution (1×) and *C. acutatum* disk after 7 days of incubation at room temperature.

The results in the antifungal activity against pathogens were negative (Figure 3) since in none of the cases inhibition halos were observed at the points of application of the extract and the areas measured with the software presented non-existent values (400–650 μm^2). Higher concentration may be required to achieve antifungal activity. Similarly, the content of total phenolic compounds can interfere with the antimicrobial capacity of the extract [3]. Although phenols are generally positively correlated with antimicrobial ability, this was not the case with quince extract, which may be related to the TPC values obtained.

As mentioned above, not much literature has been found to study the antifungal properties of the fruit or by-product of quince against phytopathogens. However, Tarihi and Nejad. (2023) [57] studied the antibacterial capacity of silver nanoparticles obtained from the extract of the petals of the quince flower against *Erwinia amylovora*, responsible for the bacterial fire blight disease that devastates fruit tree crops such as pear trees, obtaining positive results dependent on the size and applied dose. Lykholat et al. (2022) [58] focused their study on knowing the endophytic population of quince (*Chaenomeles speciosa*) and its antifungal properties against various phytopathogens. The endophytic communities were isolated from both the skin and the pulp of the fruit. The species *Penicillium expansum*, *P. viridicatum*, and *P. hirsutum* were identified in the skin, while the species *P. chrysogenum*, *P.*

cyclopium, and *P. purpurogenum* were identified in the pulp [58]. The antifungal capacity was studied against the pathogens of the genus *Fusarium*, specifically *F. culmorummycelium* and *F. oxysporum*, where positive inhibition results were obtained without finding significant differences between the skin and pulp isolates [58].

Altuntas and Korukluoglu (2024) [59] studied the antifungal activity against *Saccharomyces cerevisiae, Candida albicans, Aspergillus flavus*, and *Penicillium roqueforti*. They obtained very positive results in the extracts made with the leaves of quinces. The extract with a concentration of 6.25 mg/mL resulted in 93.8% inhibition against *S. cerevisiae* while a concentration of 25 mg/mL inhibited *C. albicans* by 90%. However, if the concentration of the extract was increased, the inhibition was reduced. No 90% inhibition results were obtained with any concentration of any of the other quince parts used (peel, pulp, seeds, and juice). However, the highest concentration of seeds (100 mg/mL) managed to inhibit *A. flavus* and *P. roqueforti* [59]. It has been found that the number of phenolic compounds is not as important in antioxidant activity as the type of compound. The fungi could use the sugars available in the extract as nutrients, which could have affected the analysis carried out in this trial [59]. Likewise, the phenolic compounds, as indicated above, are closely related to the antimicrobial capacity [60] and there is a possibility that the extraction method of the phenolic compounds has affected the antimicrobial properties [3].

In the quince antimicrobial capacity from human pathogen studies, Anna et al. (2011) [61] studied the effect of plant extracts on *Helicobacter pylori* and described that quince extract had the greatest potential against this pathogen followed by blueberry extract. Other authors reported the activity of quince phenolic components against *Escherichia coli, Candida albicans*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, obtaining positive results with different components, such as chromogenic acid [21]. Silva et al. (2023) [3] also studied the antimicrobial capacity of the extract of the different parts of quince against Gram+ and Gram− bacteria, where a stronger inhibition was observed against Gram+ bacteria since they are more susceptible to phenolic compounds. Gram− bacteria have a higher negative electrical charge that reduces the interactions between the membrane and phenolic compounds [62]. No action against any of the Gram-tested bacteria was observed with the quince extracts [3].

4. Conclusions

Quince by-product presents a very interesting nutritional profile which is high in fiber and low in fat, which makes it a potential ingredient for the formulation of products with specific properties. It also has a high antioxidant capacity, making it a natural antioxidant and a potential functional ingredient. This fact is very important because of the increasing demand for natural antioxidants versus chemical antioxidants by consumers. It does not have antifungal properties for the specific strains selected. The use and revalorization of the by-products also promote sustainability, circular economy, waste reduction, and resource optimization.

However, despite the results obtained in the assay, it is necessary to encourage research on the properties of this fruit since studies are relatively scarce. In future lines of research, it is important to study the behavior of the antioxidant capacity of this by-product in food. These results show that quince by-products could be used in the short future as a functional ingredient in the food industry such as a source of fiber for snacks or fiber bars for athletes. It also could be used as a natural preservative that delays oxidation thanks to its antioxidant properties.

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