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Bioactive Compounds Extracted From Edible Legumes not Suitable for Marketing, A Source of Functional Ingredients †

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Abstract: Agroindustry generates different types of waste every year, among which are food suitable for human consumption, but without commercial value since they do not meet the strict marketing parameters. In this sense, the Food and Agriculture Organization of the United Nations (FAO) estimates that food losses reach 1,300 million tons, 44% corresponding to vegetables and fruits [1]. In addition, inadequate waste management becomes a problem of economic profitability and environmental sustainability. The nutritional characterization of plant matrices, as well as their bioactive properties, allows the design of alternative strategies for the recovery of bioactive waste molecules and their subsequent use, incorporating them back into the food chain and promoting the circular economy. Current literature affirms that legumes are rich in phenolic compounds that are recognized for their antioxidant, anti-inflammatory and antimicrobial capacity, among others, and their potential applications in food preservation and consumer health. In this study, five edible legumes not suitable for marketing, since they do not meet quality standards, were studied form their protein content (25.11-50.96%), total sugars (17.46-57.20%) total phenolic compounds (9.62-32.74 mg GAE/g sample) and minerals composition. Samples came from different geographical areas, namely: Medicago spp. (France), Phaseolus vulgaris (Spain and Argentina), Cicer arietinum (Spain), Lens culinaris (Spain) and Glycine max (United States, France and China). The nutritional characterization and quantification of the bioactive compounds of these not-suitable species reveals the convenience of their valorization in the formulation of nutraceuticals, functional foods, cosmetics, or drugs, due to their potential as oxidative stress controllers, also avoiding the generation of large food waste.

Keywords: Agro-industrial by-products; biomass; legumes; bioactive compounds

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1. Introduction

Legumes is the common name given to the edible seeds of the family Leguminosae. They are the fifth most cultivated vegetable, behind cereals such as rice, wheat or maize and their global production has been estimation in 500 million tons between 2014-2019 [1]. These crops are largely cultivated for their grains, utilized as valuable ingredients of various products for human consumption and used for animal feed. The significant role of grain legumes species on diet has been studied, especially on nitrogen dynamics in peas and fava beans [2]. Legumes are highly nutritious crops since they are essential sources of macronutrients, especially protein and polypeptides or amino acids, but also micronutrients, such as vitamins or carotenoids. Furthermore, they have been described to contain several phenolic compounds, suggesting that these crops may also promote health besides their nutritional properties. In fact, legumes have approximately 3 times more protein than cereal grains and are accounted for being the terrestrial family with highest protein content.

The health benefits of consuming legumes are fundamentally related to the amount of dietary fiber and polyphenols. The dominant phenolic compounds present in leguminous seeds are flavonoids, phenolic acids, and procyanidins, which act as radical scavengers, reducing agents, and chelators of metal ions [3,4]. The bioactive compounds, the antioxidant activity and the radical scavenging capacity of various legumes, together with the effect of processing and germination on these processes have been previously reported [5]. Moreover, a number of epidemiological studies have correlated the consumption of legumes with high phenolic content to the reduced incidence of diseases such as cancer, ageing, diabetes, and cardiovascular disease [6]. Tannins, phytic acid and saponins, among others have been hypothesized to prevent chronic diseases [7].

In the present study, the nutritional composition (moisture, ashes, total protein, sugar, and nitrogen content) together with total phenolic content were evaluated in five edible legumes but not suitable for marketing since they do not meet quality standards. The study of these species reveals the convenience of their revaluation in the formulation of nutraceuticals, functional foods, cosmetics, or drugs, which allow to counteract oxidative stress, also avoiding the generation of large food waste.

2. Materials and Methods

2.1. Sample Preparation

Samples came from different geographical areas, namely: Medicago spp. (France) (1), Phaseolus vulgaris (Spain (3) and Argentina (2)), Cicer arietinum (Spain) (2), Lens culinaris (Spain) (4) and Glycine max (United States (2), France (1) and China (1)). A total of 16 samples of different varieties of these species were evaluated (Table 1).

Table 1. Species, variety, and origin of the studied samples.

Nº	Acronym	Species	Variety	Origin
1	ALF	*Medicago* spp.	Alfalfa	France
2	GB		"*Granja*" beans	Spain
3	BB		Black bean	Argentina
4	PB	*Phaseolus vulgaris*	Pinto beans	Argentina
5	WB		Navy beans or white pea beans	Spain
6	RB		Red beans	Spain
7	CH	*Cicer arietinum*	Chickpea	Spain
8	PCH		"*Pedrosillano*" chickpea	Spain
9	CL		"*Castellana*" lentils	Spain
10	PL	*Lens culinaris*	"*Pardina*" lentils var. *Variabilis*	Spain
11	RL		Red lentils	Spain
12	GL		Green lentils	Spain
13	YS		Yellow soy	US
14	WS	*Glycine max*	White soy	France
15	BS		Black soy	US
16	GS		Green soy	China

2.2. Nutritional Composition

The samples were thoroughly washed with distilled water, air-dried, crushed, and sieved to obtain legumes homogenates, which were stored at -80°C until use. The nutritional characterization was carried out following methodology previously adapted. The moisture content was determined by drying the homogenate in an oven at 105°C until a constant weight was obtained. The ash content was measured by incineration in an oven at 550°C for 24 h. Additional analyses were total nitrogen though the method of Havilah et al. (1977) [8], proteins were determined according to the method of Lowry et al. (1951) [9] and total sugars were carried out by phenol–sulphuric reaction [10], according to the method of Strickland and Parsons (1968) [11], with glucose as a standard. All determinations were carried out by duplicate, and results were expressed in terms of percentage of composition.

2.3. Total Phenolic Content (TPC)

The TPC was determined using the Folin-Ciocalteu reagent, following an adaptation of the method developed by Singleton and Rossi (1965) [12]. Deionized water, Folin-Ciocalteu reagent (diluted 1:50) and the sample were prepared in mixture (3:1:1, v:v:v). Then, incubated in the dark for 6 min and 100 µL of Na2CO3 (75 g/L) were added. After incubated for 90 min, the absorbance was determined at 765 nm. The results were expressed as mg of gallic acid equivalents (GAE)/g of dw.

3. Results and Discussion

The consumption of legumes has increased in recent years, being considered beneficial food ingredients. The protein content in the legumes studied varied between 25.11%, in the case of "Pedrosillano" chickpeas (PCH), and 50.96% corresponding to yellow soy (YS). In general terms, the highest protein content was evidenced in legumes belonging to the Glycine max species (soybeans) followed by Lens culinaris (lentils) (Figure 1). These data agree with Zhao et al. who reported similar amounts of proteins in legumes [13]. Regarding total sugars, the levels oscillated between 17.46% for white soy (WS) and 57.20% for alfalfa (ALF) whereas for total nitrogen content, values ranged between 2.43% for black beans (BB) and 90.45% in the case of red lentils (RL), showing very variable levels between species. The ash and moisture content were general low. The ash content varied from 4.86% of "Pardina" lentils (PL) to 10.99% of "Granja" beans (GB). For moisture, the values ranged between 2.44% for black soy (BS) and 8.90% for chickpea (CH). Therefore, legumes could be considered as a rich source of proteins and to play a significant role on nitrogen dynamics for their elevated content in total nitrogen.

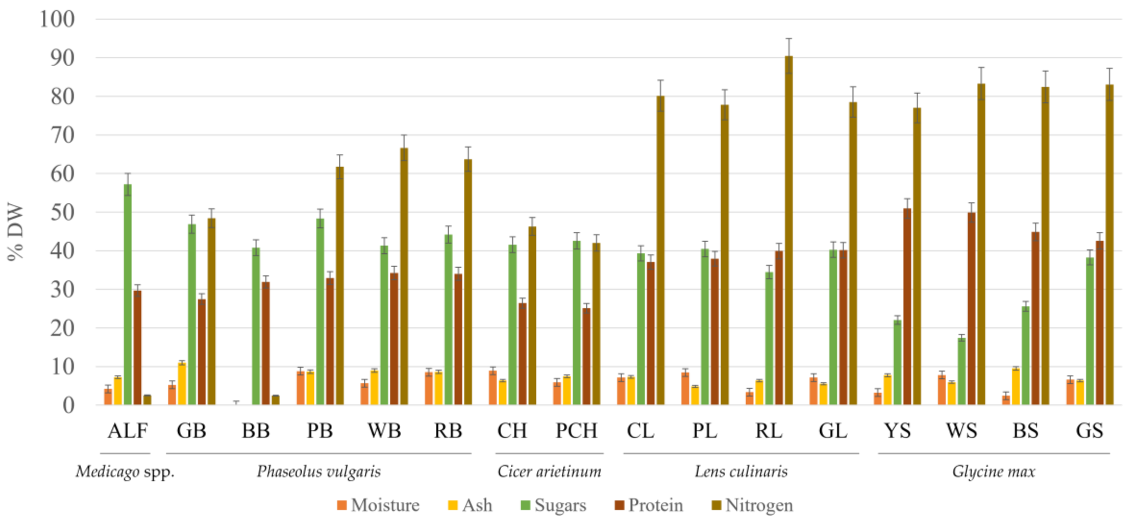

Figure 1. Moisture, ash, total sugar, protein, and nitrogen content in the extract of different legumes.

On the other hand, Figure 2 shows the total phenolic content (TPC), measured by spectrophotometry of the legumes under study, where the wide variability in the phenolic content between species is evidenced. For example, yellow soy (YS) contained 9.62 mg GAE/g sample, whereas alfalfa (ALF) showed 32.74 mg GAE/g sample. In agreement Conti et al., phenolic compounds vary considerably according to the species, the geographical area, the climate, and the situations of environmental stress, among other aspects, so this could be the main reason for this variability [3]. However, the high values of some of these samples could be correlated with potential antioxidant activity which will be further studied.

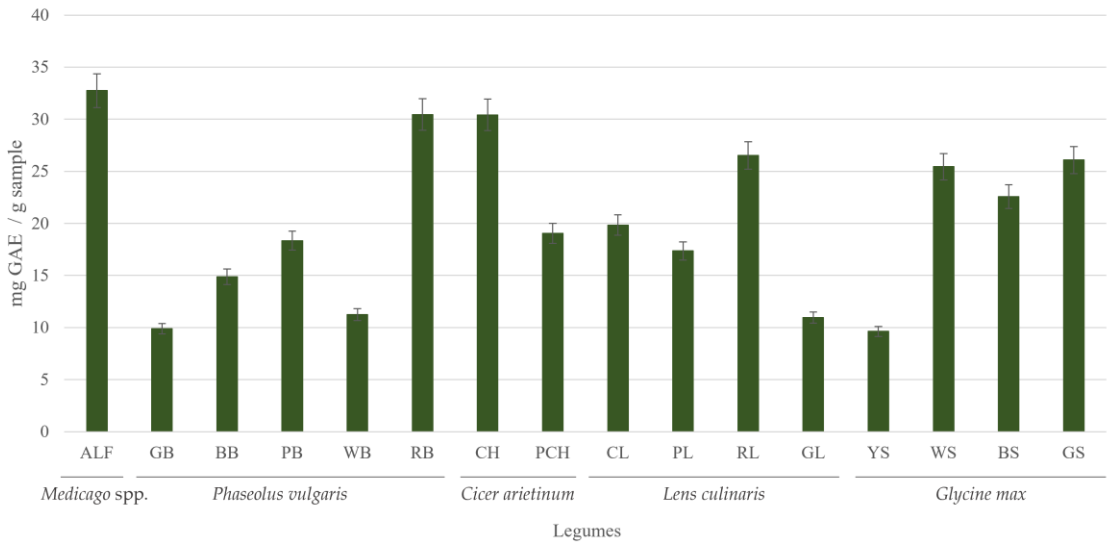

Figure 2. Total phenolic compounds (TPC) of different legumes expressed as mg GAE/g of sample.

4. Conclusions

There is a growing awareness of how legumes represent an important source of bioactive compounds with important benefits for human health, sharing antioxidant properties, essential to prevent or delay oxidative stress and related diseases. In this study, the rich contribution of phenolic compounds contained in legumes by-products that are not suitable for commercialization and their nutritional composition is demonstrated. This alternative contributes to waste management and provides useful information on the effective utilization of legumes in food processing for the formulation of functional products.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "conceptualization, M.C., F.C. and M.A.P.; methodology, M.C., F.C., P.G.-O. and M.B.-M.; validation, M.C., F.C., P.G.-O. and M.B.-M.; formal analysis, M.C., P.G.-P. and L.C.; investigation, M.C., F.C. and M.A.P.; resources, J.S.-G. and M.A.P.; data curation, J.S.-G. and M.A.P.; writing—original draft preparation, M.C. and F.C.; writing—review and editing, M.C., P.G.-P. and L.C.; visualization, M.C., F.C. and M.A.P.; supervision, J.S.-G. and M.A.P.; project administration, J.S.-G. and M.A.P.; funding acquisition, J.S.-G. and M.A.P.".

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Conflicts of Interest: The authors declare no conflict of interest.

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