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RESEARCH ARTICLE

Characterization of five Chilean agribusiness by-products and their potential use as food supplements

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ABSTRACT

Chilean agribusiness generates large quantities of by-products and they have been little studied. According to the literature they represent important sources of sugar, protein, lipid, micronutrient, fiber, and others that have a broad field of action. In this work, by-products (white and red grape seeds, peach stones, avocado seeds, olive pomace, and corn cob) of Chilean agribusiness are characterized chemically with a view to their functional and nutritional potential. They are analyzed following standardized methodology which revealed that by-products are found to be a suitable source of protein (0.59-10.00 % on DW), fiber (33.85-71.93 % on DW), lipid (0.61-14.4 % on DW)), organic matter (77.34-99.87 % on DW), inulin (8.3-33 mg fructose/g dry sample), and a wide range of essential metals. They are rich in K, Ca, and Mg. Moreover, they have very good antioxidant capacity (FRAP, and DPPH), and total phenolics and flavonoids contents. In conclusion, Chilean agribusiness by-products are attractive potential sources of food products, which could be used for nutritional purposes, and for the development of technologies.

Keywords: Antioxidant activity; By-products; Macro and micronutrients; Total phenolics; Total flavonoids

INTRODUCTION

At present it is known that annually around 1.3 million tons of food (fruits, vegetables, meat, fish, dairy, and bakery products, among others) are wasted/lost, causing the loss of millions of dollars in industrialized and developing countries (Chen et al., 2017; Saqit et al., 2019). This situation triggers a serious environmental, economic, and social impact that translates, for example, in terms of waste of resources (agricultural land, water, energy, among others), unnecessary emissions of CO_2, and other pollutants (Chen et al., 2017; Tlais et al., 2020).

Fruits and vegetables are the most used among all horticultural crops. The food industries generate large volumes of waste, becoming serious nutritional, economic and environmental problems (Sagar et al., 2018). Grains are the crops that generate more harvest residues over the surface of the land and of difficult degradation (Tlais et al., 2020). In Chile, we do not know the volume of food lost and/or wasted in the various food chains. For this reason, information is being collected on the amount of food that is lost and/or wasted and its causes (Eguillor, 2019).

The huge amounts of by-products generated annually from agricultural activities and from the processing of agricultural products are extremely diverse due to the broad range of processes and the multiplicity of the product. However, they represent important sources of sugar, protein, lipid, micronutrient, fiber, and others that have a broad field of action (Chen et al., 2017; Sagar et al., 2018; Torres-León et al., 2018; Tlais et al., 2020). Cerda-Carrasco et al. (2015) reported that grape pomaces (*Vitis vinifera* L.) from five varieties (Sauvignon Blanc, Chardonnay, Cabernet, Sauvignon, and Carménère) have high contents of polyphenols and antioxidant capacities. Yalcin et al. (2016) demonstrated that grape (*Vitis vinifera*) seeds of five varieties (Cabernet, Gamay, Kalecik Karasi, Okuzgozu, and Senso) have high amounts

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of oil, crude protein, and total phenolic compounds. Daiuto et al. (2014) found that the Hass avocado peel can be considered an alternative source of nutrients, suggesting its use in food products, mainly due to its mineral composition. The greater antioxidant activity found in the peel and seed than, the pulp of the Hass avocado, suggests that the use of these two residues (peel and seed) as sources of natural antioxidants for industrial application replacement of synthetic antioxidants. Flores et al. (2019) indicated that avocado (*Persea americana* Mill.) seeds of two varieties (Hass and Negra de la Cruz) are good sources of lipids, proteins, fibers, total phenols, and antioxidant and antibacterial activities. Zagmutt et al. (2016) studied three varieties of olive pomace (Arbequina, Barnea, and Frantoio), and the results indicated that they have a high concentration of phenols and flavonoids and a high antioxidant potential. Pasten et al. (2017) investigated Arbequina olive pomace, and the results showed that it is a promising source of dietary fiber, proteins, fatty acids, tocopherols, total phenolics, total flavonoids, and total flavanols. Moreover, it is rich in minerals, particularly has abundant amount of potassium. Furthermore, there is a positive correlation between antioxidant capacity and total phenolics and total flavonoids. Ashraf et al. (2011) studied the fruit pulp, seed, and shell of indigenous *Prunus persica*. The results showed that they have good nutritional values in fiber, carbohydrates, and fat. Besides, they are the source of essential metals such as K and Na are in higher amounts, while iron (Fe), zinc (Zn) and copper (Cu) are in small quantities. Abubakar et al. (2016) studied corn cob as possible source of nutrients in formulating animal feeds. The results revealed that it has high carbohydrate content and crude fiber.

Nowadays, worldwide there is still little information about the nutritional and functional values from by-products from agribusiness (Uribe et al., 2014; Chen et al., 2017; Saavedra et al., 2017; Sagar et al., 2018; Torres-León et al., 2018; Hernández et al., 2020; Tlais et al., 2020). Therefore, the goal was to obtain a functional and nutritional profile of Chilean agribusiness by-products (peach stones, avocado seeds, olive pomace, white and red grape seeds, and corn cob) as potential food supplements. This investigation included the analysis of the dry matter, ash, crude fiber and lipid, total nitrogen and carbon, organic matter, protein, minerals (Ca, K, Na, Mg, Cu, Fe, Mn, and Zn), total flavonoid and phenol, inulin, and antioxidant capacity using standardized methodologies.

MATERIALS AND METHODS

Material

Peach stones [*Prunus persica* (L.) Batsch var. Andross, and Dr. Davis], avocado seeds (*Persea americana* Mill. var. Hass), olive pomace (*Olea europaea* L. var. Arbequina, Frantoio, and Picual), grape bagasse samples (*Vitis vinifera* L. var. Chardonnay, and Sirah) were purchased from Aconcagua Foods, Valle del Peumo Chile, Olivares de Quepu SA, and MDA Wines SA respectively in 2017 summer. The corn cobs (*Zea mays* L.) were obtained from Maize Producers of San Clemente in 2018 summer. The samples were stored in dark bags and transported to the laboratory and kept in the refrigerator until analysis. Photos from by-products is shown in Figure 1. A map of the location of the sampling site is shown in Figure 2.

Content of dry matter and ash

Grape bagasse samples contained grape pomace, seed, and skin, then seeds were separated into the white grape seed (Chardonnay variety), and red grape seed (Sirah variety). The seeds of the peach stone samples were removed. Olive pomace consists of pieces of skin, pulp, stone, and olive kernel. Dry matter and ash contents were determined according to AOAC method (1998). Procedural details according to Soriano et al. (2021). To obtain the dry matter of olive pomace, the sample was lyophilized in a freeze dryer (Labconco).

Content of crude fiber and lipid

Crude fiber content was determined according to AOAC method (1998). Crude lipid content was determined by alkaline hydrolysis according to AOAC method (2002).

Content of total carbon and nitrogen

Total carbon and nitrogen contents were determined following the Dumas dry combustion method using the autoanalyzer equipment TruSpec micro-CN, LECO (Watson and Galliher, 2006). Crude protein value was calculated by multiplying the percentage of total nitrogen by 6.25, while for organic matter, the percentage of total carbon was multiplied by 1.72. Procedural details according to Soriano et al. (2021).

Fig 1. By-products: RGB – red grape bagasse, WGB – white grape bagasse, PS – peach stone, OP – olive pomace, AS – avocado seed, CC – corn cob

Essential metals

The content of Ca, Na, K, Mg, Fe, Zn, Cu and Mn was spectrophotometrically determined using atomic absorption equipment (Agilent 280FS AA) according to the methodology described by Fernandez-Hernandez et al. (2010). Procedural details according to Soriano et al. (2021).

Content of inulin

Inulin content was determined by spectrophotometry, measuring the total fructose content, based on the Seliwanoff reaction (Apostol et al., 2015). Procedural details according to Soriano et al. (2021).

Content of total flavonoids and phenolics

Total flavonoid content was determined spectrophotometrically by using the method described by Zhishen et al. (1999), meanwhile total phenolics content was determined by the Folin-Ciocalteu method (Singleton and Rossi, 1965).

Antioxidant activity

The FRAP assay was already carried out following Benzie and Strain (1996) methodology. The DPPH method to assess the free radical scavenging activity was carried out according to Fernández-Pachón et al. (2004).

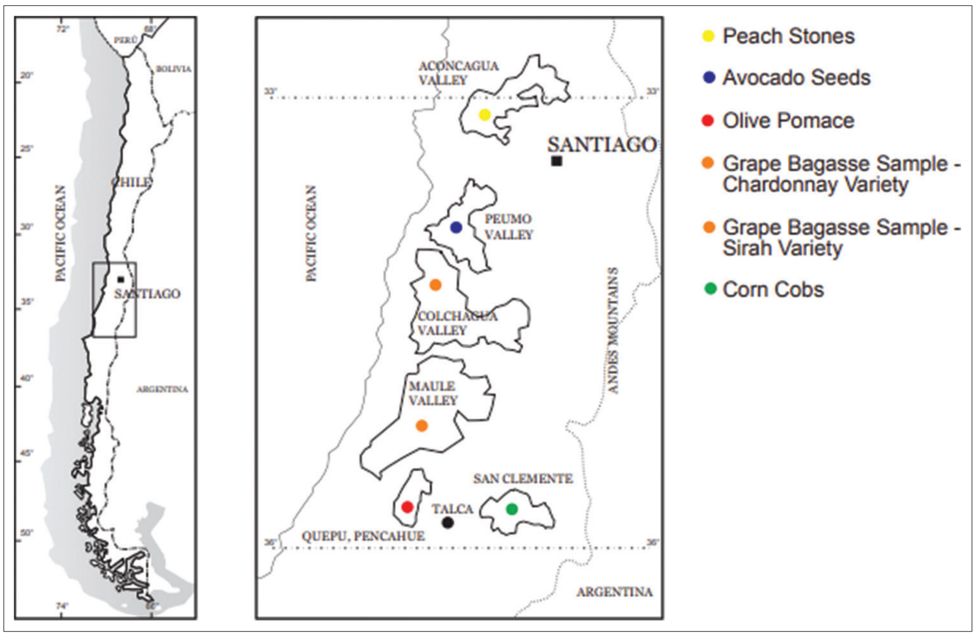

Fig 2. Map of the location of the sampling site from By-products

Table 1: Main physicochemical data related to nutritional characteristics of Chilean Agribusiness By-products

	PS	AS	OP	WGS	RGS	CC
DM	87.17	55.62	34.54	59.02	51.08	96.48
Ash	0.66±0.32	2.58±0.07	3.78±0.38	2.88±0.17	2.25±0.07	2.5±0.01
CF	71.93±1.18	4.14±0.90	46.70±1.13	33.85±1.15	46.7±0.74	-
CL	0.61	1.08	9.62	14.4	10.9	0.62
TN*	0.09	0.50	1.04	1.34	1.60	0.90
CP*	0.59	3.11	6.5	8.38	10.00	5.63
TC*	52.79	44.86	48.23	56.16	57.93	45.10
OM*	91.01	77.34	83.15	96.82	99.87	77.70

*Standard deviations were less than 0.001, DM – dry matter, CF – crude fiber, CL – crude lipid, TN – total nitrogen, CP – crude protein, TC – total carbon, OM – organic matter, PS – peach stone, AS – avocado seed, OP – olive pomace, WGS – white grape seed, RGS – red grape seed, CC – corn cobs

Table 2. Main data related to functional characteristics of Chilean Agribusiness By-products

	PS	AS	OP	WGS	RGS	CC
Inulin	10.5±0.2	10.2±0.1	8.3±0.70	32.2±0.21	33±0.4	-
TP	1226.9±8.4	76.6±2.2	44.8±3.8	371.5±7.7	327±17.7	96.5±32.3
TF	1648.6±8.4	131.4±9.7	138.9±15.5	378.2±1.7	330.3±3.2	130.8±12.0
FRAP	20.8±0.1	3.6±0.0	3.35±0.0	6.4±0.2	6.1±0.1	3.93±0.0
DPPH	3.06±0.0	5.0±0.0	2.0±0.0	0.29±0.1	0.4±0.1	1.0±0.1

Inulin in mg fructose/g dry sample, TP – total phenolic in mg Gallic acid equivalents/g dry extract, TF – total flavonoid in mg Catechin equivalents/g dry extract, FRAP (Fe^{2+}) in mmol Fe^{2+}/g dry extract – ferric reducing antioxidant power, DPPH – 2,2-diphenyl-1- picrylhydrazyl, IC_{50} half concentration of inhibition in mg dry extract/mL solution, PS – peach stone, AS – avocado seed, OP – olive pomace, WGS – white grape seed, RGS – red grape seed, CC – corn cob

Table 3. Macro and Micronutrients (mg/L)* of Chilean Agribusiness By-products

	PS	AS	OP	WGS	RGS	CC
Ca	50.56	8.69	33.58	131.24	73.85	14.68
K	9.32	214.17	282.25	93.52	117.48	121.10
Na	2.34	1.14	1.4	0.35	0.67	0.61
Mg	2.18	10.4	9.65	25.85	23.35	16.69
Cu	0.1	0.1	0.14	0.23	0.31	1.37
Fe	4.35	0.18	0.86	0.82	0.85	4.40
Mn	0.22	0.12	0.15	0.21	0.42	0.46
Zn	0.89	0.23	0.18	0.37	0.35	0.61

*Standard deviations were less than 0.001; PS – peach stone; AS – avocado seed; OP – olive pomace; WGS – white grape seed; RGS – red grape seed; CC – corn cob

Statistical data treatment

The research methodology was based on *in vitro* experiments, through triplicate analysis. The data generated were presented as mean ± standard deviation using Excel 97-2003, and OriginPro 2018 programs.

RESULTS AND DISCUSSION

Physicochemical characteristics

The results obtained in the analysis of physicochemical characteristics from by-products are shown in Table 1. Between by-products analyzed, corn cob and peach stone had higher values of dry matter, while that peach stone, red and white grape seeds presented the higher contents of organic matter. Olive pomace had the lowest dry matter value. The peach stone contains the lowest percentage of ash, and the higher content of crude fiber, suggesting that it is an excellent raw material for food and/or energy purposes. Red and white grape seeds have the highest crude protein and lipid contents, essential nutrients in nutrition. Ash and protein contents in grape seed are in accordance with the earlier report (Yalcin et al., 2016). Dry matter, ash, and crude protein contents in the corn cob were close to those obtained by Abubakar et al. (2016). Ash, crude fiber, and protein contents in olive pomace were like those obtained by Uribe et al. (2014). Crude lipid, and protein contents in avocado seeds were like those obtained by Saavedra et al. (2017). Peach stone had the lowest crude protein and lipid contents compared to literature (Vásquez-Villanueva et al., 2015; Chamli et al., 2017), precisely because the seed was removed.

Functional Characteristics

Peach stone, white and red grape seeds had the highest total phenolic and flavonoid contents (Table 2). White and red grape seeds had the highest antioxidant capacity according to DPPH assay. Already, the FRAP trial confirmed that peach stone, white and red grape seeds showed the highest antioxidant capacity. The results obtained were different than the literature because they used different methodologies in the analysis such as extraction method, solvent, and others (Sagar et al., 2018). However, the results obtained in this research and those of the literature agree that grape seeds are excellent sources of total phenolics, total flavonoids and antioxidant capacity. Red and white grape seeds have the highest contents of inulin, a soluble fiber constituted by a group of naturally occurring polysaccharides produced by many species of plants. Liu et al. (2017) associated the inulin with an improvement of glucose regulation by the modification of satiety hormone response (PYY and GLP-1).

Essential metals

Eight elements were analyzed (Fe, Cu, Zn, Mn, Ca, Mg, K and Na) in by-products (Table 3). Potassium (K) was observed as the main essential metal found in all by-products, followed by calcium (Ca), and magnesium (Mg). Olive pomace and avocado seed had the highest K contents while those white and red grape seeds were the highest in Ca and Mg. The low Na content in red and white grape seeds added to their high K content makes them attractive for consumption, especially for the prevention and treatment of hypertension and cardiovascular diseases, once a potassium deficit increases the blood pressure (Burnier, 2019). Peach stone had a low mineral content, and this result is correlated with its low ash content. Daiuto et al. (2014) revealed essential metals contents in avocado seeds, different from those obtained in this research. They obtained lower values in Ca, Mg, and K, but higher values in Cu, Mn, Fe, and Zn. They did not analyze sodium in the sample.

Not all the results obtained in this research coincide with the literature, since there are multiple factors that affect the content of nutrients in fruits, vegetables, and cereal such as type of soil where the crop has grown, the agronomic management, seasonal changes, weather, altitude, precipitation, age, variety, maturity and ripening stage, and others depend on the process applied and on the operating conditions (Harrigan et al. 2010, Chen et al. 2017, Sagar et al. 2018, Torres-León et al. 2018, Tlais et al. 2020).

CONCLUSIONS

In conclusion, it was obtained functional and nutritional profile of Chilean agribusiness by-products showed that they are attractive sources of nutrients (fiber, lipids, essential metals, proteins, antioxidants compounds, and others) to produce new food and/or technological products.

Conflicts of interest

The authors declare no conflict of interest.

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Authors' contributions

Investigation design, collection of by-products, physicochemical and nutritional analysis, and research supervision, YM-G and MDPCS; Inulin assay, MDPCS; Determination of total phenolics and flavonoids contents, and antioxidant activity, VRO, HYiH, and LGJ. Funding acquisition, and methodology, RDP, AJ, and FL; The manuscript has been prepared by MDPCS and YM-G with the approval of all authors.

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