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Valorization of extracts of Andean roots and tubers and its byproducts: bioactive components and antioxidant activity *in vitro*

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Abstract

Andean roots and tubers are endemic crops and grow in South America, they have high levels of nutrients and bioactive components. This work aimed to determine the polyphenols, flavonoids, and anthocyanins contents in peels and pulps of Andean roots and tubers; to evaluate the antioxidant activity by 2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS), 1,1-diphenyl-2-picrylhydrazyl (DPPH), and ferric reducing antioxidant power (FRAP) and to establish the correlations between the bioactive content, antioxidant methods and the antioxidant potency composite (APC) index. All trials were based on the absorbance measurements using UV-visible spectroscopy and the correlation coefficients were calculated using bivariate statistical methods. The results obtained show that the polyphenol content in pulps varied from 17.46 to 29.65 mg GAE/g, and in peels was from 14.18 to 28.37 mg GAE/g. The methods for testing antioxidant activity were presented in the following order: FRAP > ABTS > DPPH, the highest APC was for mashua peel, and the lowest APC was for ulluco pulp yellow. The correlations for the variables studied were moderate ($0.3 < r < 0.7$). In conclusion, it can be mentioned that the Andean roots and tubers can be used as a functional ingredient and medicinal from their pulps and peels.

1. Introduction

In the countries of the Andean region, several important root and tuber crops are produced that are part of the traditional diet and used in vernacular medicine (Hermann and Heller, 1997). The production of these foods is small-scale, in some cases, they are only produced for home consumption, among these resources are the oca (*Oxalis tuberosa*), olluco (*Ullucus tuberosus*), mashua (*Tropaeolum tuberosum*), yacon (*Smallanthus sonchifolius*), ahipa (*Pachyrhyzus* spp), maca (*Lepidium meyenii*), arracacha (*Arracacia xanthorrhiza*), achira (*Canna edulis*), mauka (*Mirabilis expansa*), and chicash (*Stangea rhizanta*) (Heil *et al*., 2017; Leidi *et al*., 2018; Luziatelli *et al*., 2020; Pacheco *et al*., 2020; Behar *et al*., 2021), and due to the great diversity of species that grow in the Andean region (Venezuela, Argentina, Colombia, Ecuador, Peru, Bolivia, and Chile), it is recognized as one of the most important geographies of origin and diversity of crops in the world.

Roots and tubers are gaining great interest due to their nutritional benefits and a large number of bioactive components (Choquechambi *et al*., 2019). Yacon is an Andean tuberous root that has a great potential prebiotic, especially fructooligosaccharides (FOS) and inulin, these prebiotics have the ability to modulate the intestinal microbiota, due to their bifidogenic benefits (Jiménez *et al*., 2015; Verediano *et al*., 2021). The different bioactive compounds extracted have shown nutrigenomic properties, and antimicrobial and antioxidant effects

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(Cao *et al*., 2018). The olluco is an interesting source to produce folates obtained from fermentative processes through lactic acid bacteria, in addition, it is a source of betalains such as histidine-betaxanthine, arginine-betaxanthine, glutamine-betaxanthine (betaxanthins), betanin and iso-betanin (betacyanins) (Svenson *et al*., 2008), these betalain pigments can be used as natural colourants for derived products in the food industry (Cejudo-Bastante *et al*., 2014). In fact, these pigments are not only used as natural pigments and antioxidants but are also valuable for their health-promoting properties (Slimen *et al*., 2016). Oca is a tuber widely consumed by the Andean peoples, the oca flour can be used to make gluten-free products, it also provides excellent levels of proteins, fibres, minerals, antioxidants, and phenolic compounds (Güemes-Vera *et al*., 2018), these compounds produce effects that contribute to intestinal health (Jiménez *et al*., 2015). Mashua is an Andean tuber, which is used as food and remedy in popular Peruvian medicine for the treatment of various diseases, especially those related to inflammation (Gonzales de la Cruz *et al*., 2014), due to the presence of alkamides (N-oleoldopamine and N-(2-Hydroxyethyl)-7Z,10Z,13Z,16Z-docosatetraenamide) that inhibit the inflammatory response induced by nuclear factor kappa B and tumour necrosis factor-alpha (Apaza *et al*., 2019). Arracacha is an edible root with a high starch content and rich in amylopectin, which can be used as food in the food industry, but it also contains vitamins A, B and C (Hermann and Heller, 1997; Castanha *et al*., 2018).

In the scientific documentation, several types of by-products have been reported for the recovery of proteins, lipids, minerals, carbohydrates, fibre and bioactive compounds, among them, cocoa, banana, mango, pineapple, grape, pomegranate, citrus fruits, tomato, and potato (Akyol *et al*., 2016; Torres-León *et al*., 2018; Cádiz-Gurrea *et al*., 2020; Alam *et al*., 2020). The roots and tubers due to their bioactive components and their healthy properties have been considered as functional foods and nutraceutical ingredients (Chandrasekara and Kumar, 2016; Leidi *et al*., 2018). In this context, the use of by-products to produce food ingredients with high nutraceutical value may be considered economically attractive. However, to our knowledge, there is little scientific information on the content of polyphenols and antioxidant activity of extracts of by-products of Andean roots and tubers. Therefore, the objective of the present study was to evaluate the content of polyphenols, flavonoids and anthocyanins in extracts of peels and pulps of Andean tubers and roots, as well as the evaluation of the antioxidant activity by 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric-reducing antioxidant power (FRAP), overall antioxidant potency composite index (APC) and the degree of correlation among the different variables studied.

2. Materials and methods

2.1 Samples

The samples (yacón, red olluco, mashua, and oca) were acquired from local producers in Huaraz province (3,052 m.a.s.l), Ancash, Peru, while the yellow olluco and arracacha were obtained from Tarma province (3,053 m.a.s.l), Junin, Peru.

2.2 Sample preparation and extraction

The samples were washed to remove traces of dust and other particles adhering to the surface of the roots and tubers, then they were allowed to dry at room temperature. The samples were then cut into thin slices and dehydrated at 50°C for 24 hrs until reaching moisture between 8 and 12%. The dehydrated samples were subjected to particle size reduction using a coffee grinder super junior (Moulinex©, France), with an exposure time of eight seconds, immediately afterwards the samples were homogenized using a mesh with a pore diameter of 600 µm (Ramos-Escudero *et al*., 2010).

2.3 Total polyphenol content

The total polyphenol content was determined using the Folin-Ciocalteu method with some modifications (Alvites-Misajel *et al*., 2019). To 100 µL of extract, 750 µL of the Folin-Ciocalteu reagent (0.2 N) was added, the mixture was vortexed (Vortex-Genie 2, Scientific, Inc., USA), for 15 s, and allowed to react for 5 mins. Then 750 µL of 7.5% sodium carbonate was added. The reaction was developed for 18 hrs at room temperature and in the dark. Absorbances were recorded at 765 nm, using a UV/Vis 2550 spectrophotometer (Shimadzu Co., Columbia, SC). The results were expressed in mg of gallic acid equivalent (GAE) per gram of sample (mg GAE/g).

2.4 Total flavonoid content

The total flavonoid content was determined following the method described by Zhu *et al*. (2010), with some modifications. A 50 µL aliquot was placed in a conical bottom centrifuge tube (15 mL) to then add 60 µL of a sodium nitrite solution (0.5 g/L), then the mixture was vortexed and kept in rest for 5 mins. After this time 60 µL of aluminium chloride hexahydrate (10%) was added, immediately stirred, and then kept at rest for 5 mins. Finally, 440 µL of a sodium hydroxide solution (1 M) was added, the mixture was vortexed and allowed to react for 15 mins. The absorbances were recorded at 510 nm. The results were expressed in mg of

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catechin equivalent (EC) per gram of sample (mg CE/g).

2.5 Total anthocyanin content

The total anthocyanin content was determined using the pH differential method. To 1000 µL of the extract was added with 1000 µL of buffer pH 1 (0.2 M potassium chloride, adjusted with 0.2 M hydrochloric acid) and 1000 µL of buffer pH 4.5 (1.0 M sodium acetate, adjusted with 1.0 M hydrochloric acid). The mixtures were vortexed for 15 seconds and then kept at rest for two hours to equilibrate at room temperature. Absorbances were recorded at 510 nm and 700 nm using a UV/Vis 2550 spectrophotometer (Shimadzu Co., Columbia, SC). The total anthocyanin content was expressed as mg of cyanidin 3-glucoside per gram of sample (mg C3G/g).

2.6 DPPH radical assay

The DPPH radical scavenging activity was measured by the Brand-Williams *et al*. (1995) method. A 50 µL aliquot of the extract was reacted with 950 µL of DPPH (the solution of the DPPH radical was prepared at 100 µM in methanol) the mixture was vortexed and then allowed to react for 30 mins. The absorbances in the spectrophotometer were recorded at 515 nm. The results were expressed in millimole of Trolox equivalent (mmol TE).

2.7 ABTS radical assay

For the ABTS assay, the procedure described by Van Oververl *et al*. (2000) was used. For the preparation of the ABTS-radical, the following procedure was carried out: A mixture of 5.0 mL 2250 mM ABTS, 5.0 mL 20 mM 2,2-azobis(2-amidinopropane)HCl and 40 mL phosphate-buffered saline (pH 7.4) was incubated at 70° C for 20 mins. The resulting compound presented an absorbance between 0.7 to 0.8 at a wavelength of 734 nm. The evaluation of the ABTS radical-scavenging activity was carried out by mixing 10 µL of the sample, followed by 990 µL of the ABTS solution and the absorbance of the reaction was recorded after 30 mins. The results were expressed in millimole of Trolox equivalent (mmol TE).

2.8 FRAP assay

The reducing power was determined according to the method proposed by Cheung *et al*. (2007). The FRAP reagent preparation included a mixture of 25 mL of 0.3 M sodium acetate (pH 3.6), 2.5 mL of 2,4,6-Tripyridyl-s-Triazine (10 mM TPTZ) in 40 mM hydrochloric acid and 2.5 mL of 20 mM ferric chloride hexahydrate. The measurement of the antioxidant capacity was carried out in a cuvette by mixing 30 µL of the extract and 900 µL of the FRAP solution. The absorbance of the reaction was recorded at a wavelength of 593 nm using a UV/Vis 2550 spectrophotometer. The results were expressed in millimole of Trolox equivalent (mmol TE).

2.9 Antioxidant potency composite index determination

The antioxidant potential composite index was adapted from Seeram *et al*. (2008). This index was used to calculate the rank order of extracts of Andean roots and tubers and their by-products. To calculate the antioxidant index score of each method (DPPH, ABTS and FRAP), the extract score and the best score were taken into account "antioxidant index score = [(extract score/best score)×100]".

2.10 Statistical analysis

Statistical analysis was carried out using a completely randomized design with independent replications (n = 3). The significant difference between means was separated using the Duncan test at $p < 0.05$. The content of phenolic compounds was compared with the results of the antioxidant activity through Pearson's correlation, the strength of the positive/negative correlation was considered: low for $\pm 0.1 < r < \pm 0.3$, moderate for $\pm 0.3 < r < \pm 0.7$, strong for $r > \pm 0.7$. The data analysis was developed using the STATISTICA version 8.0 program (StatSoft, Inc., Tulsa, Oklahoma, USA).

3. Results and discussion

The results of the different samples of Andean roots and tubers and their by-products are summarized in Table 1. The polyphenol content in the pulps of Andean roots and tubers varied between 17.46 to 29.65 mg GAE/g of the sample, while in the peels ranged values between 14.18 to 28.37 mg GAE/g. Among the pulps and peels of Andean roots and tubers studied, it is observed that the yacón and arracacha pulps presented higher contents than their respective peels. On the other hand, in the red olluco, yellow olluco, mashua, and oca showed lower polyphenol contents in the pulps than in the peels.

The data obtained on the total polyphenol content of Andean roots and tubers are scarce in the scientific literature, especially that related to the use of their peels. Previous reports indicate that the polyphenol content of thirty-five yacon accessions varied between 7.9 to 30.8 mg (chlorogenic acid equivalent)/g of dry mass (Campos *et al*., 2012), these results are very similar to those reported in this work. In the case of yacon flour, a total polyphenol content of 275 mg (gallic acid equivalent)/100 g of dry weight has been reported, which are associated with the presence of four main phenolic

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Table 1. Content of total polyphenols, flavonoids, anthocyanins and non-flavonoids of Andean roots and tubers and its by-products.

	Total polyphenols (mg GAE/g)	Total flavonoids (mg CE/g)	Total anthocyanins (mg C3G/g)	Non-flavonoids*
Pulps				
yacon	29.65±0.15^{a}	19.93±0.24^{a}		9.72±0.09^{h}
red olluco	21.51±0.19^{g}	7.52±0.84^{d}		13.99±1.03^{f}
yellow olluco	17.46±0.11^{h}	1.30±0.00^{h}		16.16±0.11^{e}
mashua	27.22±0.19^{c}	1.18±0.02^{h}	2.84±0.71^{d}	26.04±0.21^{a}
arracacha	24.77±0.26^{e}	6.79±0.07^{e}		17.98±0.20^{d}
oca	24.53±0.08^{ef}	2.57±0.11^{g}	4.36±0.05^{b}	21.96±0.03^{c}
Peels				
yacon	14.18±0.23^{i}	2.62±0.18^{g}		11.61±0.34^{g}
red olluco	23.91±0.19^{f}	16.57±0.51^{b}	3.59±0.02^{c}	7.39±0.70^{j}
yellow olluco	21.86±0.60^{g}	2.98±0.07^{g}		18.88±0.67^{d}
mashua	28.37±0.30^{b}	5.26±0.11^{f}	8.36±0.01^{a}	23.11±0.41^{b}
arracacha	23.94±0.23^{f}	15.45±0.31^{c}		8.49±0.08^{i}
oca	25.94±0.57^{d}	16.53±0.24^{b}	3.74±0.02^{c}	9.41±0.81^{ih}

Values are presented as mean±SD, n = 3. Values with different superscripts within the same column are statistically significantly different at $p<0.05$ according to Duncan's test.

* Non-flavonoids = total polyphenols - total flavonoids.

acids: chlorogenic acid, caffeic acid, coumaric acid. and protocatechuic acid (Sousa *et al*., 2009). Chirinos *et al*. (2009) reported that the total polyphenol content in oca genotypes ranged from 40.8 to 138.1 mg GAE/100 g of fresh weight. The polyphenol content of *Oxalis tuberosa* varies depending on the colour of the peel, they can be white, cream, yellow, orange, pink, and purple. In the case of olluco it varies between 0.41 to 0.77 mg/g of fresh weight (Campos *et al*., 2018). Some phenolic compounds found in this resource include rutin and kaempferol 3-O-(2',6'-di-O-α-L-rhamnopyranosyl)-β-D-glucopyranoside (Campos *et al*., 2006), olluco presents different colours (white, yellow, pink, orange, magenta or red), so the phenolic content varies according to the genotype. According to our results, the content of polyphenols in mashua; both pulp and peel were 27.22 and 28.37 mg GAE/g of dry weight, respectively. These values agree with the results reported by Chirinos *et al*. (2008) who showed values between 10.9 to 57.4 mg GAE/g of dry weight for crude mashua extracts.

The flavonoid content in pulps and peels of roots and tubers were analyzed and the results show that when the samples are considered as a whole, the pulps and peels present an average of 6.55 and 9.89 mg EC/g of dry weight, respectively. Chirinos *et al*. (2009) reported that the flavonoid content in the oca extract varied from 0.75 to 1.11 mg of quercetin equivalent (QE) per 100 grams of fresh sample, while in four mashua genotypes it varied from 1.8 to 7.8 mg EC/g of dry weight, the most relevant flavonoids were gallocatechin, procyanidin B2, epigallocatechin, quercetin and myricetin derivatives (Chirinos *et al*., 2008). However, in the case of yacón, the pulp has a higher content of flavonoids than in the peels, while the rest of the roots and tubers, the peels have higher contents than the pulps. In the case of some fruits (plums), it is observed that the peels are around 20 times more than the pulp (Cosmulescu *et al*., 2015), while in wild apples the richness of flavonoid compounds such as catechin, chlorogenic acid, epicatechin, quercetin and phloridzin, are greater in the peel than in pulp (Mihailović *et al*., 2018), these variations are dependent on genotype.

The anthocyanin content was detected in pulps and peels of mashua and oca, while in red olluco peel it was also found. In the case of pulps, these contents were 2.84 and 4.36 mg C3G/g, respectively. Regarding the anthocyanin content in the peels, these were: red olluco (3.59 mg C3G/g), mashua (8.36 mg C3G/g) and oca (3.74 mg C3G/g). Dusuki *et al*. (2020) reported that the red and purple variety sweet potato peels presented total anthocyanin contents of 0.43 and 3.08 µg C3G/g respectively. While in different pigmented potato peel total anthocyanin content varied between 59.67 to 293.57 mg C3G /100g fresh weight (Yin *et al*., 2016).

The results of the different antioxidant tests (ABTS, DPPH and FRAP) and the antioxidant potency composite index of the extracts of Andean roots and tubers and their by-products are summarized in Table 2. The comparison of these three antioxidant methods for the studied samples shows the following order: FRAP > ABTS > DPPH. For all the tests, the mashua (peel) showed the highest antioxidant activity that presented values of 570.95, 339.01 and 309.62 µM TE respectively. The sample with the lowest antioxidant activity was the yellow olluco (pulp) whose values were

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Table 2. Antioxidant activity measured by various methods and antioxidant potency composite (APC) index of Andean roots and tubers and its by-products.

	Antioxidant activity (μmol trolox equivalent)			APC
	ABTS	DPPH	FRAP	
Pulps				
yacon	56.09±3.49^{g}	127.45±2.55^{a}	356.21±0.74^{d}	40.03
red olluco	279.75±2.49^{c}	109.08±1.28^{e}	260.95±0.74^{f}	54.48
yellow olluco	87.14±1.50^{f}	38.62±2.98^{g}	138.58±2.61^{j}	18.63
mashua	274.81±6.49^{c}	172.01±3.41^{b}	226.47±0.37^{h}	58.07
arracacha	206.72±3.99^{e}	68.73±2.98^{f}	261.21±1.86^{f}	42.98
oca	261.05±8.98^{d}	145.21±7.24^{c}	238.84±1.49^{g}	55.94
Peels				
yacon	63.85±8.48^{g}	125.04±2.55^{d}	226.47±1.12^{h}	32.96
red olluco	313.26±4.99^{b}	131.06±6.81^{d}	480.68±1.86^{b}	72.97
yellow olluco	206.72±5.99^{e}	36.81±3.81^{g}	187.53±1.12^{i}	34.54
mashua	335.49±9.48^{a}	309.62±0.43^{a}	570.95±4.47^{a}	100
arracacha	307.97±2.49^{b}	35.91±2.55^{g}	298.58±5.58^{e}	51.68
oca	267.75±4.49^{cd}	178.03±11.07^{b}	420.42±1.49^{c}	70.04

Values are presented as mean±SD, n = 3. Values with different superscripts within the same column are statistically significantly different at $p<0.05$ according to Duncan's test.

138.58, 87.14 and 38.62 μM TE respectively. When the samples were analyzed using the antioxidant potency composite index (APC), the order of the samples was as follows (pulps): mashua > oca > red olluco > arracacha > yacón > yellow olluco. In the case of the peels, the order was: mashua > oca > red olluco > arracacha > yellow olluco > yacon. In previous studies, it has been reported that the antioxidant activity of mashua is higher than in olluco, the presence of vanillic acid, caffeic acid, cinnamic acid and malvidin, are probably the compounds that contribute significantly to this activity (Campos *et al*., 2006). On the other hand, the presence of proanthocyanidins found in mashua has been reported as the main contributor to antioxidant activity measured by oxygen radical absorbance capacity (ORAC). In addition, a protective effect on the biological structures of polyunsaturated fatty acids has been reported (Chirinos *et al*., 2008). Other studies showed that the antioxidant activity of yacon (*Smallanthus sonchifolius* Poepp. & Endl) of 35 accessions ranged from 6.4 to 65 g/100 g of dry weight, this activity may be related to the presence of chlorogenic acid and hydroxycinnamic derivatives (Campos *et al*., 2012). These results of antioxidant activity measured by ABTS, DPPH and FRAP demonstrate the ability of roots and tubers extracts to sequester free radicals or chelate metal ions. The differences in response between the three antioxidant methods are related to the dependence of phenolic compounds on the number and position of free hydroxyl groups in the flavonoid structure (Kunar and Pandey, 2013). On the other hand, when the antioxidant activity is measured, it is necessary to take into account the solvent's polarity, the reaction time, the units to express the results.

The square scatters matrix and fit linear between the antioxidant methods (ABTS, DPPH and FRAP), antioxidant potency composite (APC) index, the content of total polyphenols and the content of flavonoids are shown in Figure 1. The antioxidant properties of the polyphenols present in Andean roots and tubers, and their by-products are due to their redox properties, these free flavonoids allow them to interact as reducing agents, hydrogen donors and metal chelators. In all cases, a positive correlation is observed between the assays. In particular, the content of total polyphenols between antioxidant methods such as FRAP ($r = 0.57$), DPPD ($r = 0.48$) and ABTS ($r = 0.43$) show a moderate correlation, while between the content of flavonoids and antioxidant activity measured by ABTS and DPPH show a low correlation ($r < 0.40$). However, the correlation between FRAP ($r = 0.55$) is in the range of $0.3 < r < 0.7$ which indicates moderate correlation.

According to Campos *et al*. (2006), the correlation between the antioxidant capacity by DPPH and the polyphenol content for mashua and oca was high ($r = 0.84$ and 0.75, respectively) while the correlation for olluco was moderate ($r = 0.64$). Some reports showed that the correlation between the antioxidant methods (ABTS and DPPH) and the polyphenol content ($r = 0.94$ and 0.95 respectively) was greater than the correlation between the flavonoid content ($r = 0.39$ and 0.46 respectively) (Piluzza and Bullitta, 2011). Regarding the antioxidant methods and the content of polyphenols and flavonoids in Andean roots and tubers and their by-products, depend on several factors, including the presence of non-flavonoid compounds that can react with the Folin-Ciocalteu reagent and can interfere or not be

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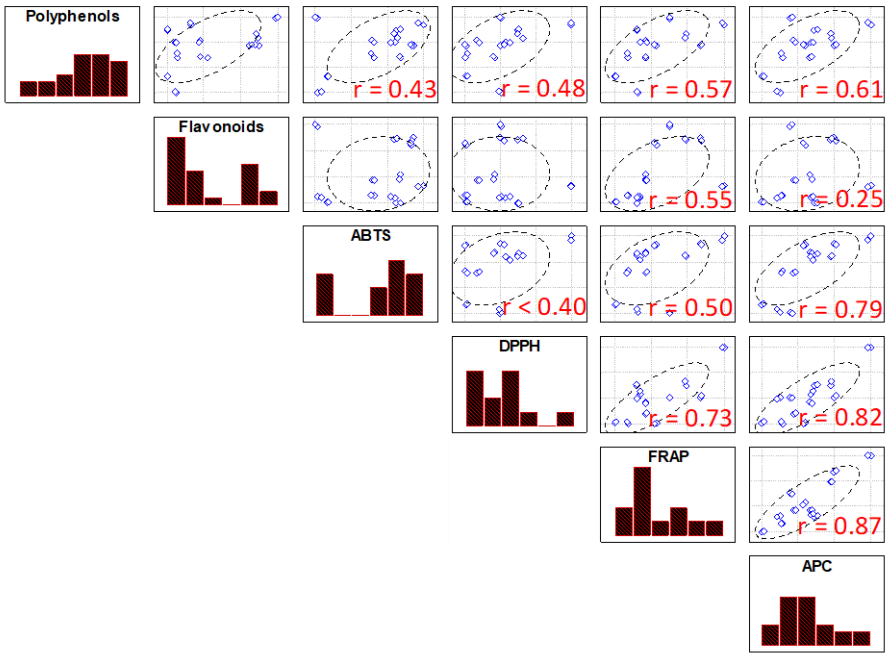

Figure 1. Pearson's correlation scatter plot of between observed values

effective as free radical scavengers. The low correlation between flavonoid content and methods such as ABTS and DPPH could be associated with flavonoid composition of Andean roots and tubers and its by-products, as well as the complexity of kinetic reactions. According to Hossain and Shah (2015) indicated that the antioxidant activity of an extract cannot be explained on the basis of its phenolic content, this is not enough, however, it requires a characterization of the individual phenolic compounds to establish the structure-activity relationship (Granato *et al*., 2018).

A wide variety of antioxidant methods have been used to determine the antioxidant activity of plant extracts (Cömert and Gökmen, 2017), in this case, the ABTS, DPPH and FRAP assays were used for the evaluation of the antioxidant activity in extracts of Andean roots and tubers and its by-products. The correlation of the different methods was as follows: For DPPH vs FRAP, it presented a high correlation ($r > 0.7$), while for ABTS vs FRAP and ABTS vs DPPH it presented a moderate correlation ($0.3 < r < 0.7$). Some reports mention that there is a high correlation between these two methods DPPH vs FRAP; $r \geq 0.82$ (Sricharoen *et al*., 2015), this shows that the correlation obtained in this study was similar. Some authors suggest that there is a high degree of redundancy in the use of both methods to evaluate antioxidant activity (Sricharoen *et al*., 2015). On the other hand, a moderate correlation is observed for the other assays (ABTS vs FRAP; $r = 0.50$; and DPPH vs ABTS; $r = 0.37$). However, other studies report high correlations for these antioxidant methods, evaluated for extracts of varieties of chili peppers (Floegel *et al*., 2011). In other studies, it was mentioned that there is a moderate correlation between the antioxidant capacity measured by the ABTS/DPPH assays and the oxygen radical absorbance capacity (ORAC). On the basis of these results, it is possible to affirm that the correlations between antioxidant methods may vary and, in many cases, have a high dependence on the type of food matrix, and it is likely that vegetables with high pigment content such as mashua, oca and olluco can generate interferences during the analysis. In many cases antioxidant methods such as ABTS, DPPH and FRAP are used to map the antioxidant activity of plant extracts, however, the antioxidant response does not show a direct correlation (Ruslan *et al*., 2018), in this sense a combination of the data would provide a better description of the antioxidant activity than when obtained by a single assay. Presumably, the correlation between APC vs flavonoids has not improved significantly ($r = 0.25$), however, the correlation with the content of total polyphenols has generated a slight increase ($r = 0.61$) (Figure 1).

4. Conclusion

The result of this research contributes to the current knowledge on the nutraceutical value of Andean roots and tubers and their by-products (yacón, red olluco, mashua, and oca). Andean roots and tubers, both pulps and their peels can be processed and used by the food industry for the production of functional foods and nutraceuticals. From these species and their by-products, bioactive components with functional properties can be obtained and used as bioactive ingredients. The results indicate that Andean roots and tubers and their byproducts are a good source of phenols and antioxidant activity. The anthocyanin content in mashua, red olluco and oca pulps, as well as their respective peels, can be

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used as natural colourants in different commercial applications. On the other hand, this research must be understood from the point of view of the interest of these resources, in addition to increasing knowledge about these Andean crops with growth potential.

Conflict of interest

The authors declare no conflict of interest.

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