Optimized aqueous extracts of maqui (*Aristotelia chilensis*) suitable for powder production

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Abstract The aim of this work was to obtain powders rich in bioactive compounds from maqui berry aqueous extracts by spray drying. First, the process parameters of the maqui aqueous extraction were optimized. The optimal operating conditions were found using an experimental Box–Behnken design with three factors: solvent/fruit ratio (2:1, 3.5:1 and 5:1), extraction temperature (25, 50 and 75 °C) and extraction time (30, 75 and 120 min). Soluble solids content, monomeric anthocyanin content (ACY), total polyphenol content (TPC) and antioxidant capacity in the liquid extracts were analyzed as key responses to find the optimal extraction conditions. Secondly, the best aqueous extract (solvent/fruit ratio = 2:1; extraction temperature = 75 °C and extraction time = 75 min) was subjected to spray drying. The effects of different drying adjuvants (maltodextrin, colloidal silicon dioxide, arabic gum, and microcrystalline cellulose) on the powders flow properties, the process yield (PY), the bioactive compounds content and the superficial color were studied. The product based

on colloidal silicon dioxide presented the best powder properties: excellent flowability (α : $30.4 \pm 0.7^\circ$, CI: $8.0 \pm 1.7\%$), adequate moisture content ($4.9 \pm 0.3\%$), very good PY ($70 \pm 1\%$), high ACY (1528 ± 41 mg cy-3glu/100 g of powder) and TPC (3936 ± 132 mg GAE/100 g of powder), and a purple hue. This maqui powder offers valuable properties that allow its use, among other applications, as a functional ingredient, natural colorant and nutraceutical product.

Keywords Maqui berry · Spray drying · Antioxidant bioactive compounds · Powder · Flowability

Introduction

In recent years, there has been an increasing demand for products with health-promoting properties. In this sense, the consumption of berries has experienced a significant growth through a great variety of products marketed either fresh or processed. The presence of constitutive nutrients and natural antioxidants, among others, vitamin C, anthocyanins, phenolic acids and tannins, determines the increasing berries demand (Sun-Waterhouse 2011). Particularly, maqui (*Aristotelia chilensis*), a fruit of dark purple color growing in southern Chile and Argentinian Patagonia (González et al. 2015), stands out among the berries because of its high concentration of phenolic and anthocyanin compounds (Fredes et al. 2014a). Although this species has been investigated for bioactive compounds and some medicinal properties such as cardi-protective, anti-carcinogenic, and anti-diabetic activity (Rojo et al. 2012), the effect of maqui processing on bioactive compounds and physical properties of the products has not yet been studied.

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Maqui is a little juicy fruit in comparison to other berries. Hence, the extraction is a required process for obtaining juices or extracts rich in bioactive compounds. The best extraction method is dependent on the berry species; therefore, the maqui extraction conditions (such as solid–liquid ratio, solvent type, extraction temperature and time) have to be optimized to maximize the bioactive compounds and to preserve their stability (Cacace and Mazza 2003). Regarding extraction solvents, organic compounds have been the most commonly used solvents. For instance, Quispe-Fuentes et al. (2017) studied the optimization of maqui extraction process using methanol, ethanol and acetone, being mainly concerned about the composition of the solid residues after solvent evaporation. When organic solvents are used, they have to be removed from the product and disposed/recycled properly. For these reasons, the extraction by means of non-polluting techniques with “green solvents” like water is preferred to obtain extracts rich in bioactive compounds (Castro-Puyana et al. 2017).

Dried extracts offer several advantages over the liquid ones; in fact, they have high stability and are easier to handle, transport and store. Spray drying is a suitable process for commercial production of fruit powders and preservation of heat sensitive components such as phenolic compounds (Sagar and Suresh Kumar 2010).

The addition of carriers to fruit juices is often required to be processed by spray drying. These solid matrices allow the increase of glass transition temperature, limiting the product sticking on the spray-dryer chamber. Besides improving the process yield, the carriers protect active compounds against degradation during processing and storage by reducing their reactivity to environmental factors such as heat, moisture, air, and light (Shishir and Chen 2017). The most conventional carriers used for spray drying of fruit juices are maltodextrin and arabic gum, mainly due to their high solubility and low viscosity (Bhusari et al. 2014; Caliskan and Dirim 2016). Additionally, microcrystalline cellulose combined with maltodextrin or arabic gum (Fazaeli et al. 2012), and colloidal silicon dioxide are common excipients for phytopharmaceuticals production (Gallo et al. 2015). The best carrier and the most suitable composition will depend on the fruit juice; therefore, the selection of the drying adjuvant is a critical factor for the production of fruit powders with adequate physico-chemical properties, antioxidant potential as well as colorant capacity.

The studies about maqui powders are very scarce. Recently, Fredes et al. (2018) used a concentrated commercial juice that was highly diluted and mixed with high concentrations of inulin and sodium alginate as carriers before spray drying. The relatively low bioactive content of the spray-dried products was evidently an effect of the use

of high amounts of carriers and diluted maqui juice. In this context, the present article is focused on an integral study of the maqui aqueous extraction together with the production of powders by spray drying using the lowest possible amount of carrier to maximize the content of bioactives and color in the resulting products. Accordingly, the objectives of this work were: (1) optimization of the aqueous extraction process of maqui berries to maximize the bioactive compounds concentration and the antioxidant capacity, being the set of optimal extraction conditions valuable information for the production of liquid extracts, and (2) study of the influence of different types and concentrations of drying adjuvants on flow properties, process yield, antioxidant bioactive compounds content and superficial color of maqui powder obtained by spray drying.

Materials and methods

Materials

Maqui berry (*A. chilensis*) grown in El Bolson (Río Negro, Argentinian Patagonia) was used. After harvest, fruits were immediately quickly frozen individually (IQF process) and then stored at $-22\text{ }^{\circ}\text{C}$ until use. The excipients used as drying adjuvants were: maltodextrin DE12, arabic gum, microcrystalline cellulose (Parafarm, Buenos Aires, Argentina), and colloidal silicon dioxide (Aerosil 200®, Evonik Degussa Argentina S.A, Buenos Aires, Argentina). Analytical-grade reagents were used in all cases.

Fruit characterization

Maqui fruit was characterized according to AOAC methods (AOAC, 2000): moisture (925.09), soluble solids (932.12), acidity (945.26), and pH (945.27). Water activity was determined using an electronic dew-point water activity meter (Aqualab Series 3TE).

Obtention of maqui extracts

Sample preparation

Fruits were processed as follows: thawing at room temperature for 10 min, fruit weighing (between 60 and 150 g according to the selected solvent/fruit ratio), milling with a mixer for 60 s, addition of 300 ml distilled water, shaking in a thermostated bath and a final centrifugation (6000 rpm-15 min.). Then, the supernatants (extracts) were separated and filtered.

Experimental design for the optimization of the bioactive extraction method

The response surface methodology was used to optimize the aqueous extraction process, and a Box–Behnken design was adopted. The design was formulated with the factors of major effects on the system selected through previous screening studies: X_1 = solvent/fruit ratio (2:1, 3.5:1 and 5:1); X_2 = extraction temperature (25, 50 and 75 °C); and X_3 = extraction time (30, 75 and 120 min). A second-order polynomial as a function of these three variables was used to model the studied response variables: soluble solids content (SS), monomeric anthocyanin content (ACY), total polyphenol content (TPC) and antioxidant capacity (AC). The set of optimal operating conditions was established by simultaneous maximization of the responses related to bioactives contents.

Production of maqui powders by spray drying

Formulations of liquid feeds

The optimal maqui extract with SS of 9.9 ± 0.1 °Brix was mixed with colloidal silicon dioxide (SD), arabic gum (AG), maltodextrin (M) and microcrystalline cellulose (MCC). The spray drying liquid feeds were prepared using the following carrier:SS mass proportions: SD:SS = 0.5:1; AG:SS = 1:1; M:SS = 1:1; M:MCC:SS = 0.67:0.33:1; AG:MCC:SS = 0.67:0.33:1. The ratio was selected in each case to use the minimum amount of carrier in the feed that ensured process viability.

Spray drying process

The liquid formulations were spray-dried using a Mini Spray Dryer B-290 (Büchi, Flawil, Switzerland). The operating conditions were fixed according to preliminary experiments: drying air inlet temperature 130 °C, atomization air volumetric flow rate 400 l/h, feed volumetric flow rate 1.5 ml/min, and drying air volumetric flow rate 35 m³/h.

Chemical and functional properties

A spectrophotometer T60 UV–visible (PG instruments, Leicestershire, United Kingdom) was used in the analytical determinations. For the maqui fruit, all chemical determinations were done using a methanolic extract following the guidelines given by Sette et al. (2017). The maqui aqueous extracts were directly assessed, while the powders were dissolved in water before analysis (0.5 g of maqui powder in 10 ml of distilled water).

SS of the extracts was determined according to method 932.12 (AOAC, 2000) using a refractometer model PAL-1 (ATAGO, Tokyo, Japan).

ACY was determined using the pH differential method (Giusti and Wrolstad 2001). ACY was expressed as mg cyanidin-3-glucoside per liter of extract or 100 g of powder.

TPC was determined using the Folin–Ciocalteu reagent according to Sette et al. (2017). A calibration curve was done using gallic acid as standard. The results were expressed as milligrams of gallic acid equivalents (GAE) per liter of maqui extract. For powders, the TPC was expressed as mg GAE/100 g of powder.

AC was measured using the ABTS bleaching method according to Franceschinis et al. (2014). A calibration curve was constructed using gallic acid as standard. The results were expressed as mg GAE/l.

Moisture content (MC) of powders

Sample moisture content analysis was performed immediately after the spray-drying step by using a moisture analyzer with halogen heating (model M45, OHAUS, Pine Brook, NJ, USA), according to Gallo et al. (2015).

Superficial color

Superficial color was evaluated on maqui powders and determined by measuring tristimulus parameters (CIELAB color space) with a photocolormeter model CR 400 (Minolta, Tokyo, Japan) using illuminant C and 2° observer angle. L^* , a^* , and b^* values were recorded and converted into “global color change” (ΔE^*_{ab}), “chroma” (C^*_{ab}) and “hue angle” (h_{ab}) parameters using the following equations:

$$\Delta E^*_{ab} = \left[(\Delta L^*_{ab})^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2} \quad (1)$$

$$C^*_{ab} = (a^{*2} + b^{*2})^{1/2} \quad (2)$$

$$h_{ab} = \arctg(b^*/a^*) \quad (3)$$

Flow powder indicators

Angle of repose (α) and Carr’s index (CI)

The angle of repose and the Carr’s index were determined according to Gallo et al. (2015). Repose angles between 25–30°, 31–35°, 36–40° and > 41° indicate excellent, good, fair and poor flow properties. CI values < 10%, between 11–15%, 16–20%, 21–25%, 26–31% indicate

excellent, good, reasonable, acceptable and poor flow, respectively (USP 30-NF 25 2007).

Process yield (PY)

PY was calculated as the ratio of the weight of powder collected after each spray-drying experiment to the liquid feed SS.

Statistical analysis

For all experimental determinations, three replicates were measured, and the results were expressed in terms of mean and standard deviation. Analysis of variance (ANOVA) and the Tukey test were performed to establish the presence or absence of significant differences between means and the possible interactions between factors.

Results and discussion

Maqui fruit properties

The following physicochemical properties for the maqui fruit were obtained: moisture = 45.40 ± 0.03 g H₂O/100 g fruit (wb), water activity = 0.924 ± 0.009 , soluble solids = 38.27 ± 0.51 °Brix, pH = 3.90 ± 0.01 and acidity = 1.91 ± 0.65 mg citric acid/100 g fruit (wb). These results revealed that maqui is an acid fruit with low water content in comparison to other berries. González et al. (2015), reported moisture levels between 63 and 66% throughout development until ripening, with a further reduction of 20% in overripe maqui fruits.

Several studies found different contents of bioactive compounds in maqui fruit. These differences can be attributed to various factors such as environment, genotype and maturity stage of the fruits (Fredes et al. 2014a; González et al. 2015). Fredes et al. (2014a) evaluated the total anthocyanin and polyphenol contents of maqui from different geographical regions of Chile during two consecutive growing seasons, ACY values ranging between 660 and 1500 mg cy-3glu/100 g fruit, while TPC was between 1070 and 2050 mg GAE/100 g fruit. González et al. (2015) reported TPC values within the range of 714–1100 mg GAE/100 g of fresh fruit. The results obtained in this study were: ACY = 949 ± 64 mg cy-3glu/100 g, and TPC = 1286 ± 105 mg GAE/100 g; these values are close to the ones previously reported.

Compared to other berries, maqui fruits were described to have higher total phenolic content and antioxidant activity than other species recognized for their high phenolic content. In fact, the maqui TPC was about two, five and nine times higher than the one reported for blueberries,

red raspberries and blackberries, respectively (Franceschinis et al. 2014; Fredes et al. 2014b).

Optimization of extraction process

Supplementary Table S1 shows the response variables (SS, ACY, TPC and AC) obtained with the different values of the variables X_1 , X_2 and X_3 according to the Box–Behnken design.

The regression coefficients for the second-order polynomial equations that relate the responses with the analyzed factors are presented in Table 1. The analysis of variance indicated, for all the responses, that the proposed models were adequate to represent the experimental data. In fact, the determination coefficients (R^2) ranged between 0.97 and 0.99 (Table 1). The interaction effects did not behave as statistically significant for all the responses. The linear terms X_1 and X_2 were significant ($p < 0.01$) to model the antioxidant capacity (AC) of extracts. However, this property was not significantly affected by X_3 . Quispe-Fuentes et al. (2017), showed similar results when analyzing the effect of the extraction time on the antioxidant capacity of maqui berries from Chile. These authors studied three operating conditions of the extraction process: solvent type (methanol, ethanol and acetone), solvent concentration (20, 60 and 100%) and extraction time (15, 127.5 and 240 min). They concluded that after a certain extraction time there would be a final equilibrium between the solutes of the matrix and the extraction solvent; therefore, the time did not show a significant effect.

The “solvent/fruit ratio” factor had a negative impact on the studied responses due to a dilution effect, especially on ACY which also decreased with extraction time. On the contrary, the longer the extraction time, the higher the TPC in the extracts (Supplementary Table S1). The different results observed for ACY and TPC can be related to the fact that TPC includes some other polyphenolic compounds different from the ones computed as monomeric anthocyanins that behave differently in the mass transfer process. Concerning SS in the liquid extracts, the highest values were obtained with experiments n° 12 to 15, which were carried out with the lowest solvent/fruit ratio (2/1).

The effects of the independent variables on the most relevant properties (ACY, TPC and AC) were analyzed through response surface plots (Fig. 1A–C). It is necessary to remark that several phenomena occur simultaneously during the extraction process, among others, the transport of several fruit components (bioactive components, sugars, acids, etc.) towards the surrounding aqueous medium and the partial thermal degradation of bioactive compounds.

As shown in Fig. 1A, the solvent/fruit ratio was the factor of highest influence on the extraction capacity of anthocyanins (Fig. 1A-a). ACY-rich extracts were

Table 1 Coefficients of the second-order polynomial models

	SS	ACY	TPC	AC
X_1	− 2.381**	− 597.503**	− 123.938**	− 48.644**
X_1^2	0.844**	215.857**	50.313**	17.818**
X_2	0.431**	131.501**	73.688**	33.174**
X_2^2	0.044	63.150	17.313**	− 1.897
X_3	0.200**	− 93.402**	21.625**	0.004
X_3^2	− 0.019	23.132	3.688	− 1.381
$X_1 * X_2$	− 0.213**	− 59.846	− 15.875*	2.212
$X_1 * X_3$	− 0.225**	25.402	− 20.000**	− 11.935**
$X_2 * X_3$	0.050	− 50.794	12.000*	6.053
R^2	0.995	0.972	0.986	0.973

* $p < 0.05$, ** $p < 0.01$

obtained with lower solvent/fruit ratios. On the other hand, it can be observed that the extraction temperature had a positive effect on mass transfer (Fig. 1A-b). However, when high extraction temperatures were employed, longer extraction times had a negative effect on ACY content because the extension of the thermal degradation increased. Thus, the two effects of temperature (positive with respect to mass transfer and negative in terms of degradation) were observed for the ACY response. The prevalence of each effect depends on the factors combination.

Figure 1B shows the effects of the extraction operating conditions on TPC. Regarding the effect of the solvent/fruit factor, a similar behavior to the one above discussed for ACY was observed (Fig. 1B-a). However, the temperature factor did not affect TPC values in the same way that affected ACY. It was verified that higher temperatures contributed to a better extraction, even when prolonged extraction times were used (Fig. 1B-b). These results could be attributed to a significant effect of temperature on polyphenol transfer to the surrounding medium, as a consequence of diffusion coefficient increase and tissue degradation (Cacace and Mazza 2003). Other authors, when studying thermal degradation of polyphenol compounds in berry products like blueberry, blackcurrant and maqui pulps (Casati et al. 2017) and pomegranate juices (Fischer et al. 2013), observed a high polyphenol stability even at thermal levels of 70–90 °C for periods of up to 6 h. Therefore, it is likely that during the extraction process performed under the assayed temperatures (25–75 °C), thermal degradation of polyphenols has occurred to a lesser extent compared to the polyphenol transfer towards the liquid medium. Figure 1C shows that operating conditions affected AC in the same way that they influenced TPC. This could indicate that the antioxidant capacity of the extracts is mainly explained by the present polyphenols. This correlation between polyphenol content and

antioxidant capacity was also observed in other fruits or fruit-based products, as, for instance, Indian fruits (Singh et al. 2016), Chilean fruits (Fredes et al. 2014b), and other berries from Argentina (Sette et al. 2017).

The optimal operating conditions obtained from the response surface analysis were: 2/1 solvent/fruit ratio, 75 °C temperature and 75 min time. For these conditions, the predicted variables were: SS = 9.9 ± 0.1 °Brix, ACY = 2859 ± 99 mg cy-3glu/l, TPC = 5990 ± 160 mg GAE/l, and AC = 2560 ± 90 mg GAE/l.

Maqui powders

The optimal extract was combined with different carrier types and concentrations and employed to produce maqui powders by spray drying. The measured process yield and powder properties are shown in Table 2.

The feasibility of a powder to be industrially used for different applications is highly dependent on its flow properties. Powders processed with SD showed the lowest CI ($8.0 \pm 1.7\%$) and α ($30.4 \pm 0.7^\circ$), which indicates excellent flowability. Several studies about powders from different medicinal herbs extracts also showed very good flow properties by using the same carrier and a SD:SS ratio between 0.5:1 and 1:1 (Gallo et al. 2011, 2015). Maqui powders showed *acceptable* flowability (CI values between 23.5 and 30% and α values from 38 to 39°) when M and AG were employed as carriers (even when higher concentrations than that of SD were used). Other authors have also observed poor flowability in powders obtained with M and AG as carrier agents. For instance, Caliskan and Dirim (2016) spray-dried sumac fruit extracts with M (SS = 20–30% w/w) and obtained CI values between 28 and 41%. Bhusari et al. (2014) produced spray-dried tamarind pulp powders with AG and M, being the CI values between 22 and 34%. The flowability values for the maqui powders co-processed with AG and M are in agreement with the previously cited results.

For binary mixtures of carriers, it was observed that the addition of MCC affected the flowability of the powders if they are compared with those produced using pure M or AG. Nevertheless, the flowability was not considerably improved (Table 2).

Regarding process yield, although SD powder exhibited the best performance ($70 \pm 1\%$), the values obtained with M ($67 \pm 1\%$) and AG ($61 \pm 1\%$) were also high. Daza et al. (2016) showed yields in the range of 41–81% after spray drying of cagaita fruit extracts with AG. Tan et al. (2015) reported a process yield between 66 and 72% for spray-dried powder of bitter melon using M and AG. For the maqui powders, the addition of MCC decreased the process yield with respect to those obtained using other drying adjuvants.

Fig. 1 Response surface plots for, ACY (A), TPC (B), and AC (C) as a function of: **a** extraction temperature and solvent/fruit ratio, **b** extraction time and temperature, and **c** extraction time and solvent/fruit ratio

Concerning moisture content, all the spray-dried powders presented values less than 5% in agreement to the common ranges necessary to produce spray-dried fruit extracts resistant to microbiological and oxidative degradations.

High bioactive contents were obtained for all the powders (Table 2), especially those processed with SD

(TPC = 3936 ± 132 mg GAE/100 g, ACY = 1528 ± 41 mg cy-3glu/100 g). Georgetti et al. (2008) have pointed out low phenolic degradation when using SiO₂ as carrier for spray-dried soybean extract. The authors found concentrations of polyphenols between 5 and 11% higher than those obtained using other carriers (maltodextrin and starch). Regarding TPC, it was observed that the addition

Table 2 Process yield (PY), moisture content (MC), angle of repose (α), Carr's index (CI), anthocyanin content (ACY) and total phenolic content (TPC) of maqui powders

Response variables	Samples				
	SD:SS (0.5:1)	AG:SS (1:1)	M:SS (1:1)	M:MCC:SS (0.67:0.33:1)	AG:MCC:SS (0.67:0.33:1)
PY (%)	70 $\pm$ 1 ^a	61 $\pm$ 1 ^b	67 $\pm$ 1 ^c	53 $\pm$ 1 ^d	58 $\pm$ 1 ^e
MC (%)	4.9 $\pm$ 0.3 ^a	2.4 $\pm$ 0.4 ^b	2.5 $\pm$ 1.0 ^b	3.4 $\pm$ 0.3 ^b	2.4 $\pm$ 0.1 ^b
α (°)	30.4 $\pm$ 0.7 ^a	38.3 $\pm$ 0.2 ^b	38.8 $\pm$ 0.4 ^b	35.6 $\pm$ 0.8 ^c	33.9 $\pm$ 0.9 ^c
CI (%)	8.0 $\pm$ 1.7 ^a	30.3 $\pm$ 2.7 ^b	23.5 $\pm$ 2.9 ^b	27.4 $\pm$ 5.6 ^b	27.9 $\pm$ 3.6 ^b
ACY (mg cy-3glu/100 g)	1528 $\pm$ 41 ^a	1284 $\pm$ 27 ^b	1275 $\pm$ 4 ^b	1352 $\pm$ 10 ^c	1345 $\pm$ 10 ^c
TPC (mg GAE/100 g)	3936 $\pm$ 132 ^a	3393 $\pm$ 114 ^b	3039 $\pm$ 66 ^c	3012 $\pm$ 45 ^c	3456 $\pm$ 102 ^b

In each row means with a different lowercase superscript letter are significantly different ($p < 0.05$)

of MCC to both, M and AG, did not generate a statistically significant variation. It should be noted that the bioactive concentration of maqui powders was significantly higher than those obtained from other polyphenol-rich berries such as blueberry (Lim et al. 2011) and black currant (Bakowska-Barczak and Kolodziejczyk 2011), ranging from 1056 to 1250 mg GAE/100 g for a carrier:SS ratio $\approx$ 2:1. When compared with the ACY content of maqui powder reported by Fredes et al. (2018), the values obtained in this work appeared to be considerably higher. These authors used inulin and sodium alginate as carriers in a very high proportion (6.6:1 and 3.4:1, respectively) with a great impact on the powder anthocyanin concentration (280 to 590 mg cy-3glu/100 g).

The color parameters (L^* , a^* , b^*) shown in Supplementary Figure S1 indicate that powders were all found in the fourth quadrant of the CIELAB color space, specifically in the area of dark purple hues, which is in accordance with the color visually observed in the powder images of that figure. According to color coordinates values, two groups could be distinguished. On the one hand, the powders without MCC (SD, M and AG carriers) exhibited a higher luminosity, and the hue angle shifted towards bluer tonalities (h_{ab} values ranged between -9.9 and -13.1 and C^*_{ab} values between 16.9 and 20.6). On the other hand, the addition of MCC slightly reduced the sample luminosity, and the hue angle slightly shifted towards more reddish zones of the color space (h_{ab} value = -5.4 ± 0.5 , C^*_{ab} value = 16.9 ± 0.5). The global color change (ΔE^*_{ab}) calculated between these two groups of samples ranged between 5.3 and 6.2. This indicates a color difference distinguishable for human detection (Lao and Giusti 2017).

Conclusion

This work provides a set of optimal operating conditions in order to obtain maqui aqueous extracts very rich in antioxidants, as well as recommendations to obtain maqui powders by spray drying minimizing the use of drying adjuvants (i.e., aiming to preserve high antioxidants concentration in the powdered product). The given technical processing conditions are valuable for researchers and practitioners. The powder obtained with silicon dioxide as drying adjuvant could be suitable for nutraceutical applications, as it presented excellent flowability, acceptable moisture content, the highest concentration of anthocyanins and polyphenols, and also the highest antioxidant capacity. Moreover, the vivid purple color obtained in all the formulations enables the use of maqui powders as natural colorant for cosmetic products or foods like dairy products and beverages.

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