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Evaluating the Andean blueberry (*Vaccinium meridionale* Swartz) powder in the preparation of ice cream: Improving the antioxidant capacity and the total phenolic content

Evaluación del polvo de arándano Andino (*Vaccinium meridionale* Swartz) en la preparación de helado: Una mejora a la capacidad antioxidante y del contenido de fenoles totales

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ABSTRACT

This study evaluated the content of total phenolic compounds, antioxidant capacity, and functional properties of an ice cream formulated from Andean blueberry (*Vaccinium meridionale Swartz*) powder. The antioxidant capacity of pulp and powder from Andean blueberry was performed by using ABTS*+ and DPPH methods. The blueberry powder was obtained by convection drying, and the rheological and thermal properties of the ice cream were determined by rotational rheology and differential scanning calorimetry (DSC), respectively. The stability of ice cream was evaluated at -15 °C during storage for 30 days, measuring color, texture, antioxidant capacity, and phenolic compounds. The results showed a moisture content of 77.64% (w.b), 13.59 °Brix, pH of 3.0, and titratable acidity of 1.35% for the Andean blueberry pulp. The color parameters L*(10.2), a*(3.5), and b*(7.4) indicated the typical dark-purple color of this fruit. Andean blueberry powder shows a moisture content of 5.20% (w.b), solubility of 58.24% in water, and color parameters' values of L*(16.0), a*(16.9) and b*(8.1), with 1.43 mg GAE g^{-1} of total phenol, while, for the pulp, it was 4.31 GAE g^{-1}. The antioxidant capacity ranged between 200 and 161 µmol TEs g^{-1} dry mass for pulp and from 56 to 49 µmol TEs g^{-1} dry mass for powder. Adding powder from Andean blueberry in the ice cream decreases overrun and delays the melting time. Finally, the ice cream showed good stability during storage time, keeping the color, and texture properties such as hardness, total phenolic compounds, and antioxidant capacity.

Keywords:
Agraz powder
Ice cream
Nutraceutical
Polyphenols
Stability

RESUMEN

Este estudio evaluó el contenido de compuestos fenólicos totales, la capacidad antioxidante y las propiedades funcionales de un helado formulado a partir de polvo de arándano andino (*Vaccinium meridionale Swartz*) obtenido por secado convectivo. La capacidad antioxidante de la pulpa y del polvo se llevó a cabo utilizando los métodos ABTS*+ y DPPH. Las propiedades reológicas y térmicas del helado se determinaron mediante reología rotacional y calorimetría diferencial de barrido, respectivamente. Se evaluó la estabilidad del helado a -15 °C durante 30 días, se midió el color, la textura, la capacidad antioxidante y los compuestos fenólicos. Los resultados mostraron un contenido de humedad de 77,64% (b.h), 13,59 °Brix, pH de 3,0 y una acidez titulable de 1,35% para la pulpa. Los parámetros de color L*(10,2), a*(3,5), b*(7,4) mostraron el típico color púrpura oscuro de esta fruta. El polvo presentó un contenido de humedad de 5,2% (b.h), solubilidad en agua de 58,24% y los parámetros de color L* de 16,0, a* de 16,9 y b* 8,1, con 1,43 mg GAE g^{-1} de fenoles totales, mientras que en la pulpa fue de 4,31 GAE g^{-1}. La capacidad antioxidante osciló entre 200 y 161 µmol TEs g^{-1} de masa seca para pulpa y entre 56 y 49 µmol TEs g^{-1} de masa seca para polvo. La adición de polvo de arándano andino disminuye el overrun y retrasa el tiempo de derretimiento. El helado mostró buena estabilidad durante el tiempo de almacenamiento, manteniendo el color, la dureza, los compuestos fenólicos totales y su capacidad antioxidante.

Palabras clave:
Polvo de agraz
Helado
Nutracéutico
Polifenoles
Estabilidad

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Ice cream is a sweet-tasting product consumed frozen, with a creamy consistency due to air incorporated in its structure. In addition to water and sugar, it contains dairy components, aromatic substances, colorants, thickeners, stabilizers, and emulsifiers. Allied Market Research (2018) estimates that the global ice cream market will reach US $ 97.301 million by 2023, with an annual growth rate of 5.4% from 2017 to 2023. Currently, consumers are more disposed to pay for plant-based ice cream prepared from natural ingredients, which offer more benefits than traditional or conventional ice cream (Sloan 2019). This aspect has increased the interest of researchers in developing products that combine health and nutrition, incorporating the nutraceutical properties of some natural ingredients. For example, Ginger (*Zingiber officinale*) has been added to ice cream formulation, leading to the obtaining of a product with less total lipids, high antioxidant capacity, and more content of phenolic compounds (Gabbi et al. 2018). The addition of polyphenols may improve cardiovascular functions, and physical performance, and offset oxidative stress in healthy individuals, athletes, the elderly, and in patients suffering from some chronic and degenerative diseases (Sanguigni et al. 2017). Nevertheless, these kind of compounds can also cause significant changes in the rheological and sensory properties of products (Borrin et al. 2018). Çam et al. (2013) evaluated the addition of phenolic compounds extracted from the peel of pomegranate and the oil of its seed. They reported significant changes in the pH, total acidity, and color of the samples. However, the most outstanding results were notable improvements in antioxidant and antidiabetic activities, as well as the increase in phenolic compounds. In another study, Kavaz et al. (2016) used dried Besni grape, reporting changes in the content of phenolic compounds and viscosity, but without changes in the sensory acceptability, taste, or texture. Phenolic compounds are secondary metabolites of the plants, which are classified as flavonoids and non-flavonoids, and are constituted by a structure of phenyl benzopyran with two phenyl rings liked by a heterocyclic pyran ring, which can inhibit the reactive oxygen species (de la Rosa et al. 2019). Andean blueberry (*Vaccinium meridionale Swartz*) commonly known as agraz is a source of phenolic compounds that can be consumed fresh, in liqueurs, jams, or desserts. Physiologically, this plant is a small shrub whose fruits are globose berries of green color in an immature state and dark purple, almost black, in its mature state. It has a diameter that oscillates between 7 and 15 mm (Buitrago et al. 2015). Like other Vaccinium, they have a high content of phenols (8875.3 µg g^{-1} sample) and anthocyanins (5386.4 µg g^{-1} sample), with high antioxidant capacity with value of 278.2 µmol TEs g^{-1} determined from ABTS and 85.1 µmol TEs g^{-1} using DPPH (Moyer et al. 2002). To evaluate the antioxidant capacity, it is recommended to use two methodologies to obtain reliable results. The ABTS method analyzes hydrophilic antioxidants, and the DPPH method analyzes the lipophilic antioxidants present in the Andean blueberry (Baenas et al. 2020).

Phenolic compounds have a wide range of biological functions and antimicrobial activity, they can chelate iron and copper ions, inhibit lipoxygenase, and avoid the proliferation of cancer cells. Besides, their structure allows the stabilization of free radicals by resonance (Bao et al. 2008). Due to the high consumption level and acceptability of the ice cream by consumers of all ages, we are considering that there is a great opportunity to offer additional benefits to the public, with natural additives that allow for improving the functional character of this product, incorporating fruits with high antioxidant capacity to it, among which it can highlight the Andean blueberry (*Vaccinium meridionale Swartz)*. The current study addressed different aspects of the development of an ice cream added with Agraz powder, evaluating its effect on the thermal and rheological properties, techno-functional properties, the total content of phenolic compounds, and antioxidant capacity.

MATERIALS AND METHODS

Reagents Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), sodium carbonate, potassium persulphate, Folin–Ciocalteau and Chlorogenic $ABTS^{\bullet +}$ (2,20-azino-bis (3-ethylbenzothiaoline-6-sulphonic acid)) reagent were purchased from Merck (USA). Gallic acid, 2,20-azino-bis (3-ethylbenzothiazoline-6- sulphonic acid) diammonium salt (ABTS) was purchased from Sigma Aldrich (St. Louis, MO, USA). Methanol, ferric chloride hexahydrate and liquids were supplied by Fisher Scientific (Fair Lawn, NJ, USA).

Characterization of Andean blueberry pulp

Andean blueberry (*Vaccinium meridionale Swartz*) was acquired in the local market (Antioquia-Colombia). The fruits, packaged in 250 g packs, had an average diameter of 10.4 mm and a ripeness state of 4 (reddish-purple coloration). The fruits were washed, disinfected, and stored in a freezer at -18 °C until used. The color parameters of the pulp were determined by using a X-Rite 939 spectrophotometer (X-Rite, Inc, Michigan, USA). The results were expressed according to CIELAB's (L *, a *, b *) system. The pH, water activity (a_w), moisture content, total titratable acidity, total soluble solids (measured in degrees Brix), and maturity index, were determined according to the AOAC (AOAC 1998) methods 981.12, 978.19, 942.15, 932.05, and 934.06, respectively.

Phenolic compounds

The phenolic compounds were determined using the Folin-ciocalteau method (Singleton et al. 1974). The samples (0.5 g) were mixed with a methanol-water (70:30) solution (30 mL). The absorbance was measured at 760 nm in a spectrophotometer UV/VIS (UV-3000, Shanghai, China). Results were expressed as mg gallic acid equivalents per gram of sample (mg GAEs g^{-1}). All analyses were carried out in triplicate.

Antioxidant capacity by ABTS^{*+} and DPPH assay

The antioxidant capacity was determined by radical ABTS^{*+} capture methodology according to Re et al. (1999). The samples (0.5 g) were mixed with a methanol-water (70:30) solution (30 mL). The absorbance was measured at 734 nm in a spectrophotometer UV/VIS (UV-3000, Shanghai, China). The results were expressed as µmol of Trolox equivalent (TEs) per 100 g dry sample (µmol TEs g^{-1} d.b). The analyses were carried out in triplicate. The DPPH method was used (with some modification) to determine the antioxidant capacity according to Cheung et al. (2003). The extract was obtained from 0.5 g of sample in 30 mL aqueous methanol (70:30) and centrifuged at 8,000xg for 15 min. Then, the supernatant was collected in a 50 mL volumetric flask, and the final volume was measured with 60% methanol: water (70:30) solution. In test tubes, protected from light, 50 µL of the extract was added to 950 µL of DPPH radical 0.25 mM and read at 515 nm in a spectrophotometer UV/VIS (UV-3000, Shanghai, China) after 30 min, using methanol as the blank. The results were expressed as µmol of Trolox equivalent (TEs) per 100 g dry sample (µmol TEs g^{-1} d.b). The analyses were carried out in triplicate.

Andean blueberry powder preparation

Andean blueberry pulp was dried with air heated at 55 °C and a speed of 0.5 m s^{-1}, with a layer thickness of 3 mm, for 24 h (İzli 2017). After the drying process, the samples were cooled with liquid nitrogen and subjected to a size reduction process by using a blade mill (IKA, MF 10.2 Impact Grinding, France). Then, samples were sieved using a Ro-Tap Tyler-type sieve shaker (Model RX29) for 15 min. Samples passed through 30-60 mesh sizes were collected and used in the ice cream formulation.

Andean blueberry powder solubility

The sample (0.5 g) was added to a recipient containing 50 mL of distilled water at 25 °C, and stirred in a vortex at 110 rpm for 30 min, before being centrifuged at 3,100×g for 10 min. The supernatant (25 mL) was transferred to a previously weighed porcelain dish and dried to constant weight in an incubator at 105 °C. The dish was weighed, and the solubility was calculated from the difference in weight.

Ice cream preparation

Hard frozen ice cream formulations A (control) and B, enriched with Andean blueberry powder (1.8%), were formulated and subjected to processing according to the protocols defined in the Laboratory of dairy products of Universidad Nacional de Colombia, Medellín Headquarters: Milk (56%), milk cream (22.45%), sucrose (14.5%), milk powder (6.5%), yolk (0.3%) and stabilizer (0.25%), with fat content of 14% and sweetness of 14.5%. Thus, the ice cream mixes were pasteurized at 85 °C for 25 s, rapidly cooled, and kept at 4 °C for 24 h, for maturation. The ice cream was packed in plastic containers of 20 L and stored in a freezer at -15 °C.

Rheology: Viscosity of the ice cream

The viscosity values were obtained from flow curves. The tests were performed at 5 °C, spindle 6, using a viscometer model DV-III (Brookfield, Engineering Laboratories, Stoughton, MA, USA) with a concentric cylinder geometry. Ice creams (15 g) were carefully sampled without disturbing their structure according to Erkaya et al. (2012). The analyses were carried out in duplicate.

Differential Scanning Calorimetry (DSC)

The thermal characterization of the ice cream was conducted by analyzing the thermograms obtained in a TA Instruments DSC with RCS cooling system (New Castle, DE, USA) according to Hwang et al. (2009). The equipment was calibrated with indium before analysis. An empty aluminum pan was used as the reference. For analysis, 5-6 mg of the samples were weighed in aluminum pans. Scanning of all samples was carried out using the same heating (-30 to 30 °C) and cooling (30 to -30 °C) rate of 5 °C min^{-1}.

Texture properties (hardness)

The evaluation of the textural properties of ice cream was carried out according to Aime et al. (2001). The test was performed in a TA.XT2i texture analyzer (Stable Micro Systems Ltd., Godalming, Surrey, UK). The test and posttest speed was 1 mm s^{-1} using a cylindrical probe, with a diameter of 12 mm and a penetration distance of 30 mm.

Techno functional properties

The overrun was calculated by weighing 100 mL of ice cream before and after whipping. The ice cream was gently scooped into a glass cup of 100 mL and leveled by using a rubber spatula. The mean of three weights was used for overrunning, according to Equation (1):

$$\text{overrun (\%)} = \frac{\text{wt. 100 mL of mixture-wt.100 mL of ice cream}}{\text{wt.100 mL of ice cream (mL)}} \times 100 \quad (1)$$

Melting time, melting resistance, and melting rate

Melting time, melting resistance, and melting rates were determined by using the cone method, according to Góral et al. (2018), with some modifications. The ice cream (100 g) at -18 °C was placed on a mesh (# 100) and taken into a controlled temperature chamber at 25 °C and a relative moisture of 75%. The time for obtaining the first drop of melted ice cream was assumed as melting time. The melting rate (mL min^{-1}) was calculated as the volume of ice cream melted every 5 min, for 45 min.

Stability analyses

The ice cream with Andean blueberry powder added was studied at -15 °C. The parameters of color, texture, phenolic compounds, and antioxidant capacity were measured at 0, 15, and 30 days.

Statistical analyses

The experimental data obtained were expressed as mean ± standard error and subjected to an analysis of variance (ANOVA with α=0.05) for a completely random design, using the STATGRAPHICS Centurion Software (Version XVIII). The differences among mean values were determined by using Tukey's multiple range tests (α=0.05).

RESULTS AND DISCUSSION

Andean blueberry pulp shows a moisture content of 77.64%±0.41 (w.b) and water activity of 0.98, total soluble solid of 13.59±0.22 °Brix, pH=3.0±0.1, titratable acidity of 1.35%±0.2, and a maturity index of 10.10. The color parameters L*(10.2), a*(3.5), and b*(7.4) indicated the typical dark-purple color of a fruit with a sensory-acceptable degree of maturity. Regarding the Andean blueberry (*Vaccinium meridionale*) powder, it reached a moisture content of 5.20%±0.02 (w.b), and significant differences in the color parameters compared to fresh fruit with values for L*, a*, b* of 16.0, 16.9 and 8.1, respectively. The mean value of the total phenols in the pulp was 4.31±0.2 mg GAE g^{-1} (d.b). This value was lower than the total phenols reported by Dróżdż et al. (2017) for the *Vaccinium vitis-idaea* L species, which ranged between 4.68 and 6.61 mg GAE g^{-1} dry sample. Zielinska and Michalska (2016) reported a total phenols for *Vaccinium corymbosum* L of 228±0.07 mg GAE g^{-1}. Phenolic compounds are affected by several factors such as the extraction method, variations in different physiological states, and storage conditions (Garzón et al. 2010). In the current study, the Andean blueberry powder had a solubility of 58.24% in water. The drying process significantly decreased (P<0.05) the total phenols, leading to values of 1.43±0.043 mg GAE g^{-1}. Zielinska and Michalska (2016) evaluated the convective air-drying at 90 °C and microwave vacuum drying of the *Vaccinium corymbosum* L. They reported a total polyphenols content of 2.28±0.07 g GAE g^{-1} dry sample and 1.26±0.02 g GAE g^{-1} dry sample for the unprocessed and dried fruit, respectively. López-Vidaña et al. (2017) reported similar results when they evaluated the effect of temperature in the drying process of agraz (*Vaccinium meridionale* Swartz) in terms of antioxidant capacity. Both studies concluded that after the convection air-drying process, only 35 to 45% of the initial total polyphenols present in the fresh fruit were maintained, the variation in these percentages depends on the time and the temperature of exposure, presenting higher retention in those samples subjected to a higher temperature and less processing time. The results of these studies are comparable with those reported in this study. Since the polyphenols are thermolabile compounds, their degradation during the drying process is expected. Nevertheless, the decrease in the phenols may also be related to the activation of oxidative enzymes during the drying process, such as polyphenol oxidase and peroxidase, which leads to the loss of phenolic complexes (Gümüşay et al. 2015).

Antioxidant capacity

The antioxidant capacity obtained by means of the ABTS*+ and the DPPH methods in the Andean blueberry's (*Vaccinium meridionale* Swartz) pulp, reached values of 200.31 and 161.71 μmol TEs g^{-1} dry mass, respectively. The antioxidant capacity for the powder decreased significantly, with values of 56.79 and 49.76 μmol TEs g^{-1} dry mass for the ABTS*+ and DPPH tests, respectively. These values represent a loss of 30% in the antioxidant capacity of the pulp, due to the action of the drying. This percentage was lower than that reported by Reque et al. (2015), who evaluated the effect of the drying process on different species of the *Vaccinium* family. They reported a loss of antioxidant capacity between 46 and 66%, and values significantly higher by DPPH test, ranging from 2938.05 for juice and 4,958 μmol TEs g^{-1} dry mass for dried fruit, while obtained by ABTS*+ were similar to these reported in this study, with values of 236.74 for the juice and 127.29 μmol TEs g^{-1} dry mass for the dry product. The antioxidant capacity of the Andean blueberry is due to compounds such as Hydroxycinnamic acids (5-O-Caffeoylquinic acid), Anthocyanins (Cyanidin-3-O-hexoside I and Cyanidin-3-O-pentoside), and Flavonols (Quercetin-3-O-hexoside I and Quercetin-3-O-pentoside III) (Baenas et al. 2020). The behavior of the antioxidant capacity determined by the ABTS*+ and DPPH methods showed a similar trend to these observed for the content of total phenols, which decreased with the drying time.

Effect of the addition of Andean blueberry powder on the melting time and melting rate

Ice cream rheology showed a pseudo-plastic behavior, with a continuous breakdown of the structure as a result of the lower resistance to flow after the application of stress (Figure 1). The addition of Andean blueberry powder significantly increases (P<0.05) the viscosity of the ice cream. The viscosity obtained with 1.8% of Andean blueberry is less than that reported in the preparation of ice cream added with cape gooseberry pulp at 10%, which is about 3,430±267 mPa s (Erkaya et al. 2012). Also, Erkaya et al. (2012) evaluated the influence of the addition of cape gooseberry (*Physalis peruviana* L.) on the chemical and sensory characteristics of ice cream. They reported that the percentage of added fruit had a significant effect on apparent viscosity, with values of 1,714±102 mPa s in the control sample and of 4,654±339 mPa s when 15% of cape gooseberry was added. These values

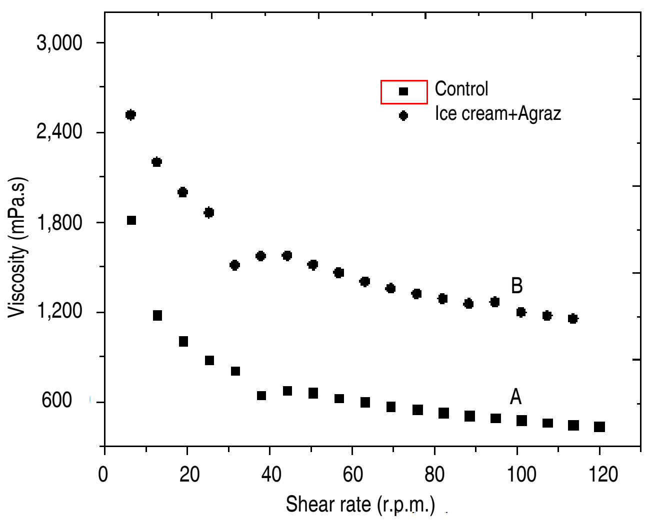

Figure 1. Effect of shear rate on the apparent viscosity of ice creams. **A**. control and **B**. ice cream with agraz.

are comparable with the ones obtained in this study, in which viscosity ranged from 1,814±12.9 mPa s (@ 6 rpm, 5 °C, splinde 6) for the control sample to 2,513±8.05 mPa s (@ 6 rpm, 5 °C, splinde 6) for the ice cream added with Andean blueberry powder. These results agree with those reported by Hwang et al. (2009), who showed changes in the rheological properties of an ice cream added with grape wine lees, and the reduction of the melting rate due to the presence of carboxy methyl cellulose and grape wine lees, which could absorb water and increase the viscosity. In the current study, the increase of the viscosity resulted in a lower overrun than that observed in the control sample (Table 1). It is expected that an ice cream with a low overrun has less air content within the structure, and the product becomes harder. The addition of Andean blueberry powder had a significant effect (P<0.05) on the enthalpy and ice melting temperature (T_f) values. Both decreased in the ice cream formulated with Andean blueberry, reaching values of about 78.86 J g^{-1} and -4.27 °C, respectively (Table 1).

Table 1. Techno functional properties of the ice cream.

	Ice cream with Andean blueberry powder	Control sample
Viscosity (mPa s) (@ 6 rpm, 5 °C)	2513±8.05^a	1814±12.9^b
Melting temperature (°C)	-4.27±0.71^a	-2.79±0.84^a
Enthalpy (J g^{-1})	78.86±2.54^b	103.70±1.05^a
freezable water (%)	21.43±2.85^b	31.76±0.32^a
Overrun (%)	36.01±1.78^b	41.79±0.99^a
Melting time (min)	18.23±0.69^a	12.05±0.65^b
Melting rate (%)	23.47±0.63^b	26.25±0.84^a

Similarly, the addition of Andean blueberry decreases the amount of freezable water in the ice cream, likely due to its water-holding capacity (Suresh et al. 2017). As can be seen in Table 1, the control sample had a higher percentage of freezable water (31.76±0.32%) than that observed in the ice cream added with Andean blueberry powder (21.43±2.85%). This behavior is in agreement with the results previously reported by Hwang et al. (2009), who suggested that the decrease in enthalpy is due to a lower freezable water content in the sample. In contrast, Ullah et al. (2015) increased the antioxidant capacity of ice cream, by adding different percentages of sugarcane juice. However, due to the increase in the amount of water, they obtained a high value of overrun and low viscosity. The addition of Andean blueberry had a significant effect (P<0.05) on the melting time, with a higher value (18.23±0.69 min) than the one obtained in the control sample (12.05±0.65 min). The ice cream with Andean blueberry experienced a reduction in the melting rate of 23.47±0.63% compared to the control sample of 26.25±0.84% (P<0.05). Aboulfazli et al. (2014) suggest that an increase in the sample viscosity causes a decrease in the melting rate. Other additives, such as emulsifiers, when the concentration is increased, cause a delay in the melting time and a low melting rate. Thus, all these findings suggest that Andean blueberry led to an increase in the water-holding, increasing the viscosity, decreasing the overrun, and delaying the melting time. Hence, the Andean blueberry powder could be considered as a natural potential stabilizer.

Stability

Table 2 shows the values of phenol compounds, antioxidant capacity, color, and texture (hardness) obtained for ice cream during storage. The hardness significantly increased (P<0.05) during the storage time, in both the ice cream added with Andean blueberry powder and the control sample, where this behavior could be associated with the decrease in overrun, caused by a lower resistance of the matrix because it contains air within its structure. It should be noticed that the considered good quality ice cream has a hard texture compared to that produced with low-fat content, mainly due to the low overrun. Regarding the color, the L*, a*, and b* parameters showed no statistically significant differences (P>0.05) during the storage time

(Table 2). In contrast, the control sample had significant differences ($P<0.05$) in the b* parameter, showing an increase in the intensity of yellow during storage time. In the current study, the total phenolic compounds had no significant changes ($P>0.05$) during storage time (Table 2). This result is in agreement with that reported by Ścibisz and Mitek (2007), who conducted a stability study at -15 °C for Highbush blueberries (*Vaccinium Corymbosum* L). Likewise, the antioxidant capacity of ice cream measured by the ABTS*+ and DPPH methods had no significant changes ($P>0.05$) during storage time, with values between 22.57 and 25.14 µmol TEs 100 g^{-1} sample by the ABTS*+ and DPPH method, respectively (Table 2). Sharma et al. (2015) improved the antioxidant capacity in an ice cream formulation, by adding wine lees, obtaining values, using the DPPH test, of 1.95 mg of Trolox g^{-1}. Nascimento et al. (2018) reported a high content of total phenols and antioxidant capacity in ice cream added with 2% grape flour, with values of 142.03±10.59 µmol Trolox g^{-1}. The antioxidant capacity depends on several factors, such as the formation and stability of radicals, and the location of antioxidants in the matrix during the different phases of processing. Hence, the concentration and source of the antioxidant, either pulp or dry product, is essential to achieve the highest content of both phenols and the antioxidant capacity. Nevertheless, the increase in the antioxidant capacity can increase the final cost of the product.

Table 2. Stability study of ice cream.

	Ice cream with Agraz			Sample control		
Time (days)	**t=0**	**t=15**	**t=30**	**t=0**	**t=15**	**t=30**
Hardness (N)	19.11±1.24^{c}	21.61±0.22^{b}	23.35±1.12^{a}	15.11±0.49^{e}	17.29±0.79^{d}	19.13±0.20^{c}
Color						
L*	63.32±0,36^{b}	64.63±0.88^{b}	65.65±2.09^{b}	80.31±0.41^{a}	80.92±0.68^{a}	82.7±0.45^{a}
a*	6.33±0.42^{a}	5.92±0.81^{a}	6.62±0.68^{a}	-1.15±0.10^{b}	-1.07±0.13^{b}	-1.01±0.09^{b}
b*	5.97±0.81^{d}	6.18±0.17^{d}	6.26±0.37^{d}	13.76±0.01^{c}	15.12±0.41^{b}	16.41±0.69^{a}
Total phenols (mg GAE 100 g^{-1})	80.28±1.19^{a}	80.49±1.54^{a}	80.85±2.00^{a}	n.d	n.d	n.d
ABTS^{+}* (µmol TEs 100^{-1} g dry mass)	22.57±1.39^{a}	22.88±1.48^{a}	22.83±1.38^{a}	n.d	n.d	n.d
DPPH (µmol Trolox 100^{-1} g dry mass)	25.48±1.03^{a}	25.07±1.90^{a}	25.14±0.68^{a}	n.d	n.d	n.d

Results expressed as mean (n = 3) ± standard deviation. Different lowercase letters in the row indicate significant differences between treatments. n.d = not detected.

CONCLUSION

The incorporation of Andean blueberry powder into ice cream presents a viable strategy for enhancing both the nutritional and functional attributes of Ice cream. The drying process, while causing a reduction in total phenolic compounds and antioxidant capacity compared to the fresh pulp, still allows the powder to significantly improve the ice cream's overall stability and health benefits. The observed increase in viscosity, decrease in overrun, and delayed melting time suggest that the powder acts as a stabilizer. Furthermore, the retention of phenolic compounds and antioxidant capacity in the final product, even after storage, highlights the potential of Andean blueberry powder as a functional food ingredient. The enhancement of the nutritional profile of ice cream without negatively impacting its sensory attributes or stability presents an opportunity for the formulation of desserts that align with consumer preferences. Future research should investigate the optimal levels of agraz powder incorporation into ice cream formulations to achieve the desired sensory attributes and nutraceutical benefits without compromising product stability.

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