Research Article Open Access

Functional Foods in Health and Disease

Foods and beverages made from Mexican Purple Corn: a means to increase anthocyanins' intake.

Carmen Gabriela Mendoza-Mendoza[1], Ramón Marcos Soto-Hernández[2], Ma. del Carmen Mendoza-Castillo[3]*, Adriana Delgado-Alvarado[4], and Francisco Javier Sánchez-Ramírez[5]

[1]PREGEP-Plant Physiology, Colegio de Postgraduados, Texcoco, Edo. de México, 56230, México; [2]PREGEP-Botany, Colegio de Postgraduados, Texcoco, Edo. de México, 56230, México; [3]PREGEP-Plant Genetics, Colegio de Postgraduados, Texcoco, Edo. de México, 56230, México; [4]Campus Puebla, Colegio de Postgraduados, Puebla, Puebla, 72760, México; [5]Plant Breeding, Universidad Autónoma Agraria Antonio Narro, Saltillo, Coahuila, 25315, México

***Corresponding Author:** Ma. del Carmen Mendoza-Castillo, D. Sc., PREGEP-Plant Genetics, Colegio de Postgraduados, Campus Montecillo, Texcoco, Edo. de México, 56230, México

Submission Date: August 8th, 2023; **Acceptance Date**: November 9th, 2023; **Publication Date:** November 16th, 2023

Please cite this article as: Mendoza-Mendoza C. G., Soto-Hernández R. M., Mendoza-Castillo M. C., Delgado-Alvarado A, Sánchez-Ramírez F. J. Foods and beverages made from Mexican Purple Corn: a means to increase anthocyanins' intake. *Functional Foods in Health and Disease* 2023; 13(11): 632-647. DOI: https://www.doi.org/10.31989/ffhd.v13i11.1194

ABSTRACT

Background: Anthocyanins (AAs) are natural pigments and bioactive compounds that are of broad interest due to their potential beneficial effects on health. In the market, while some foods, such as berries, provide important amino acid (AA) intakes, there is a growing trend to explore new sources. In Mexico, there is the Mexican Purple Corn, a variant capable to produce AAs in all the organs of the corn ear. We overlook that the preparation of foods and beverages from these raw materials may represent the development of potential functional foods and a means to increase the dietary intake of AAs.

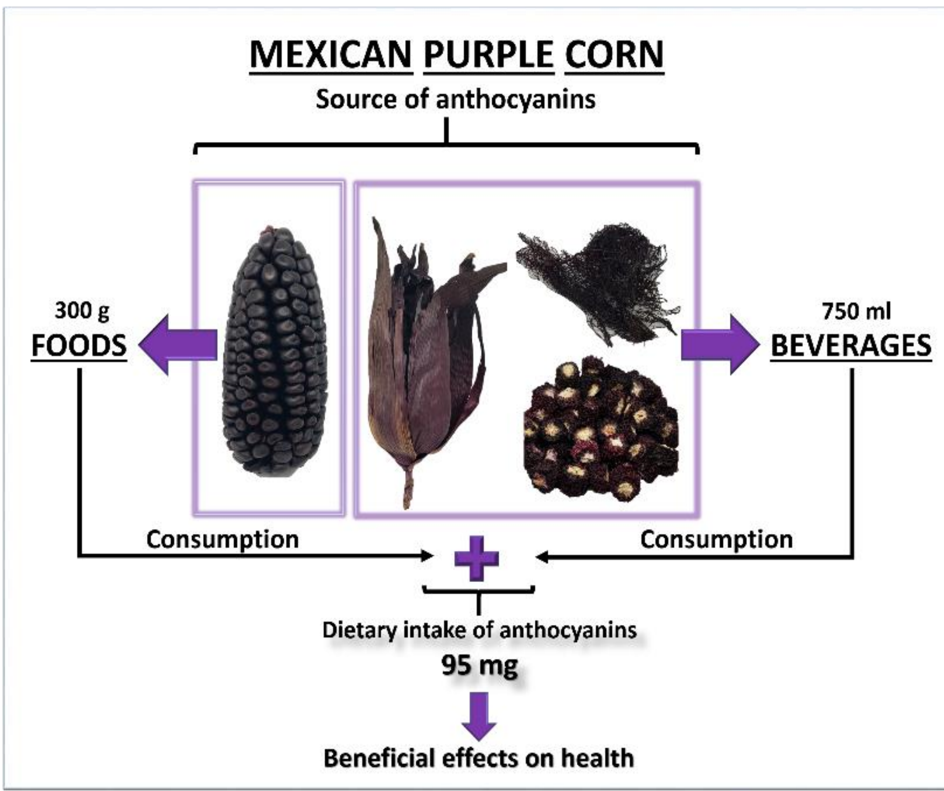
Methods: We used spectrophotometry to quantify the total anthocyanins content (TAC) of three foods made from purple kernels, and six beverages prepared from corn husks+corncobs or corn silks. Foods consisted of elote (Mexican street corn or corn on a cob), a snack, and tortillas, while beverages involved what we named functional beverages, infusions, and hot teas. We compared their TAC values and estimated the AAs intake.

Results: Foods and beverages exhibited total antioxidant capacities (TACs) ranging from 3.0 mg to 119.5 mg per 100 g of biomass ($p \leq 0.05$). Notably, most beverages demonstrated higher TACs than foods. The corn husks+corncobs infusion recorded the highest TAC, succeeded by functional beverages derived from amino acid (AA) extracts of corn husks+corncobs

(67.04 and 93.12 mg of TAC per 100 g of biomass, $p \leq 0.05$). Among hot teas and infusions, maceration in the latter resulted in a higher AA extraction. For foods, TACs varied from 4.3 to 38.4 mg of TAC per 100 g of biomass, and, similar to beverages, the preparation process influenced TAC. The roasted snack exhibited a higher AA content.

Conclusion: Mexican Purple Corn shows promise as a source for foods and beverages rich in amino acids (AAs). This crop represents an option to increase the daily intake of this flavonoid, and to acquire its potential bioactive effects. On a regular day, we can obtain 95 mg of TA from 300 g of purple corn-based foods, and 750 mL of different beverages made from corn husks, corncobs, and corn silks.

Keywords: Mexican Purple Corn, anthocyanins, corn husks, corncobs, corn silks, dietary source of anthocyanins.



INTRODUCTION

During the elapsed period of the 21st century, it has been quite evident that humankind is facing a severe health crisis. In fact, it has worsened since 2020 when we were unexpectedly affected by the Covid-19 pandemic [1-2]. Historical data corroborate that in the last forty years, there has been a continuous increase in the incidence of chronic diseases (ChrDis) such as type 2 diabetes, cardiovascular diseases, different types of cancer, overweight and obesity, as well as clinically silent inflammation [2-4]. In addition, it has been noticed that ChrDis is being diagnosed in people of all ages, genders, ethnic backgrounds, and economic conditions [5]. The efforts made to completely understand the effect of these diseases on the body have shown that ChrDis are not only causing disabilities in the most productive stages of human beings but are also the leading cause of premature death in the world [6]. The expression of ChrDis may, in part, be associated with poor eating habits characterized by unhealthy diets and low nutritional quality [7]. Currently, in all regions of the planet, the human population lives with the burden of malnutrition, which can be expressed as a nutritional disorder caused by a deficient intake of energy or nutrients, or as an unbalanced and excessive intake of them. While the situation is indeed serious, modifying lifestyles and eating patterns can decrease the risk factors of experiencing one or more chronic diseases by a quarter [8]. Nevertheless, it is also a reality that the disruption of agri-food systems and the prioritization of food industry interests significantly contribute to the dramatic increase in the burden of chronic diseases [9].

Fortunately, the scientific community, social organizations, decision-makers, and consumers are more aware of the problem and have acted to promote the search for solutions, finding that both changes in the design of public policies and the consumption of healthy foods are significant resources to prevent this type of diseases [10]. In relation to food, there is a strong demand for it to be healthy, safe, and nutritious. Additionally, it is desirable that its consumption promotes or imparts a beneficial effect on health. This trend has led to the development of the functional food (FF) concept, which often refers to products that provide a specific health benefit, beyond the basic function of supplying nutrients [11]. Functional foods (FF) aim to enhance one or more physiological functions in the human body, consequently improving overall physical condition, reducing the risk of disease, or providing a therapeutic effect on existing conditions [12]. They can be natural foods, foods to which some component has been added, removed, or modified, or even foods to which compounds' bioavailability has been improved.

Indeed, diverse phytochemicals are being studied because of their useful bioactive properties, among them, there are anthocyanins, which are a type of flavonoid and a natural pigment that gives the red, pink, blue, or purple coloration to different plant tissues [13]. Several studies state that anthocyanins have a wide spectrum of biological and pharmacological properties that make them attractive for their incorporation into foods and beverages since in addition to conferring color, increasing stability, and extending the shelf life of these products, they can act as effective agents in the prevention and treatment of ChrDis [14-16]. These water-soluble and non-toxic secondary metabolites have also shown a broad potential for their use as natural colorants with a high possibility to replace artificial dyes; however, in the context of this paper, the relevance of anthocyanins lies in their promising beneficial effects on health. To mention a few, some of the most outstanding benefits reported on the consumption of anthocyanins are their capacity to act as an antioxidant, their cardioprotective, neuroprotective, anti-inflammatory, antidiabetic, anti-obesity, anti-aging, and anticancer effects, as well as their antimicrobial and antitumor activity [18-22]. As a matter of fact, anthocyanins have a positive impact on the prevention and treatment of several diseases such as type 2 diabetes, some types of cancer, high blood pressure, inflammation, and improvement of visual acuity and cognitive behavior [15].

In the particular scenario of Mexico, an alarming morbimortality profile of the population has been described. The National Health and Nutrition Survey (ENSANUT) carried out in 2021, showed that in the adult population (adults over 20 years old) there is a high prevalence of obesity, high blood pressure and type 2 diabetes, this being 72.4%, 28.4% and 15.8%, respectively [22]. In recent years, Mexico has unfortunately claimed leading positions globally in both childhood and adult obesity. Within Latin America, it stands as the primary consumer of soft drinks and ultra-processed foods, known for their excessive content of calories, sugars, sodium, saturated fats, or trans fats, undeniably contributing to negative impacts on human health [24-25]. Although the Mexican population is likely to have an interest in the adoption of a healthy diet, eating patterns are notoriously difficult to change and are even more difficult to sustain due to the prevalence of an obesogenic environment and, because of the incidence of different levels of food insecurity in 60.8 % of Mexican households [10,22]. However, it is considered that the study, advertisement, and use of the functional properties of anthocyanins could represent a means to support the reduction, prevention, and measure to favor the control of the ChrDis burden in the country.

Considering that Mexican Purple Corn has a pronounced capacity to synthesize and accumulate anthocyanins [25-26], in this research, we suggest that this corn variant possesses a great potential to be used as a dietary source of anthocyanins. To corroborate the above, we carried out the quantification of total anthocyanins in foods and beverages made from the organs of the corn ear (kernels, corncobs, corn husks, and corn silks). The stated objective of our study was to measure the TAC of foods and beverages made from both daily edible and commonly non-edible organs of Mexican Purple Corn, in order to set the evidence of its attributes as a dietary source of AAs and its potential as a source of functional foods.

MATERIALS AND METHODS

Mexican Purple Corn-based foods and beverages: We evaluated three foods made from purple kernels (collected at the milk stage or harvest index of corn growth), and six beverages prepared from corn husks+corncobs or corn silks (using the mature corn ear) (Table 1). The required raw material to prepare the proposed foods and beverages was produced in the 2021 agricultural cycle at the Colegio de Postgraduados-Campus Montecillo, Mexico (19°27'54"N 98°54'20"W) and corresponded to corn ear organs obtained from two genetically improved populations of Mexican Purple Corn, identified as population-1 and population-2 (Table 1).

Table 1. Foods and beverages made from Mexican Purple Corn

Id	Food or Beverage	Corn ear organ	Preparation
1	Elote^{-1}	Kernel^{R3}	Boiled
2	Elote^{-2}	Kernel^{R3}	Boiled
3	Snack^{-2}	Kernel$^{(H)}$	Roasted
4	Tortillas^{-1}	Kernel$^{(H)}$	Nixtamalized and cooked
5	Functional beverage^{-2a}	Corn husks+corncobs$^{(H)}$	Boiled in water for 40 minutes
6	Functional beverage^{-2b}	Corn husks+corncobs$^{(H)}$	Boiled in water for 40 minutes
7	Corn silks hot tea^{-1}	Corn silks$^{(H)}$	5 min steep in boiling water
8	Corn silks hot tea^{-2}	Corn silks$^{(H)}$	5 min steep in boiling water
9	Purple corn hot tea^{-1}	Corn husks+corncobs$^{(H)}$	5 min steep in boiling water
10	Corn silks infusion^{-1}	Corn silks$^{(H)}$	8 h maceration in water
11	Corn silks infusion^{-2}	Corn silks$^{(H)}$	8 h maceration in water
12	Purple corn infusion^{-1}	Corn husks + corncobs$^{(H)}$	8 h maceration in water

Id: identification number of the food or beverage. Corn growth stage of collection: $^{(H)}$=after physiological maturity or ^{R3}= milk stage. $^{-1}$: corn ear organs of the purple corn population-1. $^{-2}$: corn ear organs of the purple corn population-2. ^{a}: anthocyanins extract mixed with lime juice. ^{b}: anthocyanins extract mixed with lime juice+guava pulp.

Foods consisted of elote which is a Mexican street corn or corn on the cob (Id 1 and 2, Figure 1A), a snack (Id 3, Figure 1B), and tortillas (Id 4, Figure 1C). They were cooked in boiling water (Id 1 and 2), roasted (Id 3) or nixtamalized and cooked on a hot griddle (Id 4). Beverages (Figure 1D to Figure 1G) involved what we named functional beverages (Id 5 and 6), hot teas (Id 7 to 9) and infusions (Id 10 to 12). We prepared the functional beverages by mixing anthocyanins extracts with lime juice (Id 5; 50 mL of lime juice dissolved in 800 mL of anthocyanins extract) or with lime juice+guava pulp (Id 6; 50 mL of lime juice + 15 g of guava pulp dissolved in 800 mL of anthocyanins extract). The anthocyanins extracts were obtained from 200 g of purple corn husks+corncobs (ratio 1:2) boiled in 4.0 L of water for 40 minutes. Likewise, hot teas were prepared with finely ground corn silks (Id 7 and 8; 1 g in 250 mL of water), or with a mixture of chunks of purple corn husks+corncobs (Id 9; 3 g in 250 mL of water). The preparation of the hot teas consisted of pouring boiling water over the anthocyanin source and letting it stand for 5 min. Other beverages under study were the infusions made with pulverized corn silks (Id 10 and 11; 1 g in 250 mL of water) and the mixture of corn husks+corncobs previously mentioned (Id 12; 3 g in 250 mL of water). The infusions preparation consisted of soaking the source of anthocyanins in water (maceration) for a period of 8 hours.

Figure 1. Foods and beverages made from Mexican Purple Corn. (A) Elote (Mexican street corn or corn on a cob), (B) Snack, (C) Tortillas, (D) Anthocyanins extract obtained from corn husks+corncobs, (E) Functional beverages made from anthocyanins extract, (F) Corn husks+corn cobs infusion, (G) Corn silks infusion.

Extraction and quantification of total anthocyanins: The extraction of the pigment from foods (Id 1 to 4) was carried out using the methodology described by Mendoza-Mendoza et al. [25], with some modifications. Briefly, the process consisted of a double extraction with 96 % ethanol and 1.5 N hydrochloric acid (85:15 v/v), using a food sample-solvent ratio of 1:1.7 (Id 1 and 2), 1:25 (Id 3) and 1:2 (Id 4). Once the solvent was added to the food samples, the mixture was sonicated twice using an Ultrasonic Cleaner, AS5150B for 15 min. The flavonoid extraction by this method in the purple corn-based beverages (Id 5 to 12) was not necessary since they were prepared (and thus water extracted once) as we indicated in the previous section. The ratio of biomass:water used was 1:18.5 (Id 5 and 6), 1:250 (Id 7, 8, 10 and 11) and 1:83.5 (Id 9 and 12).

The quantification of anthocyanins was conducted by spectrophotometry. The absorbance measurements were done at 535 nm using a Thermo Scientific® Varioskan Flash microplate reader. We calculated the total anthocyanin content using the following formula:

$$〚\boldsymbol{TAC}〛 \wedge *= ((\boldsymbol{A} \cdot \boldsymbol{MW} \cdot \boldsymbol{DF} \cdot \mathbf{1000}))/(\boldsymbol{\varepsilon} \cdot \mathbf{1})$$

Where TAC* = total anthocyanin content, expressed in mg of total anthocyanins (TA) L^{-1}; A = absorbance, MW = 449.2 g mol^{-1}, DF = dilution factor, and ε = 26900 L. MW and ε corresponded to cyanidin-3-glucoside.

Subsequently, TAC* values were transformed to mg of TA 100 g^{-1} of biomass (biomass was equivalent to roasted kernels, elote kernels, tortillas, corn husks+corncobs, or corn silks). We took into consideration the weight of the food sample (in g), the volume of the extract obtained by the double extraction process (in mL), and the percentage of the dry weight of the raw material required to prepare them (% DW). In the case of beverages, to transform TAC* we used the weight of the tissue used to prepare them (in g), the volume of water used to obtain the AAs extract or the volume of water to prepare the hot teas and infusions (in mL), and the % DW. We identified this value as TAC, and it was the trait that we used to compare the input of anthocyanins by foods and beverages.

Intake of anthocyanins: In order to know the dietary intake of AAs by the consumption of diverse foods and beverages we estimated the quantity of AAs by a determined portion size. The intake of anthocyanins (IA) was expressed in mg of TA 100 g^{-1} (in foods) or mg of TA 100 mL^{-1} (in beverages). IA values of purple corn-based foods were equivalent to the calculated TAC values; nevertheless, in the case of beverages, it was necessary to transform TAC into mg of TA 100^{-1} mL of beverage.

Statistical analysis: We performed ANOVA under a completely randomized experimental design, as well as the corresponding comparisons of means with the Tukey test ($p \leq 0.05$). The statistical analysis of the data was done with the SAS 9.0 Statistics Software [27].

RESULTS

ANOVA and TAC in foods and beverages: The analysis of variance carried out to assess the potential of purple corn as a dietary source of AAs indicated that there were statistical differences ($p \leq 0.01$) among the total anthocyanin content (TAC) of foods and beverages made from Mexican Purple Corn (Table 2).

Table 2. Mean squares of ANOVA for anthocyanins content in purple corn-based foods and beverages

SV	Df	MS
Mexican Purple Corn-based foods and beverages	11	29934**
Replications	31	531 ns
Error	187	315

SV: source of variation, Df: degrees of freedom, MS: mean squares for anthocyanins content, **: $p \leq 0.01$, ns: not significant.

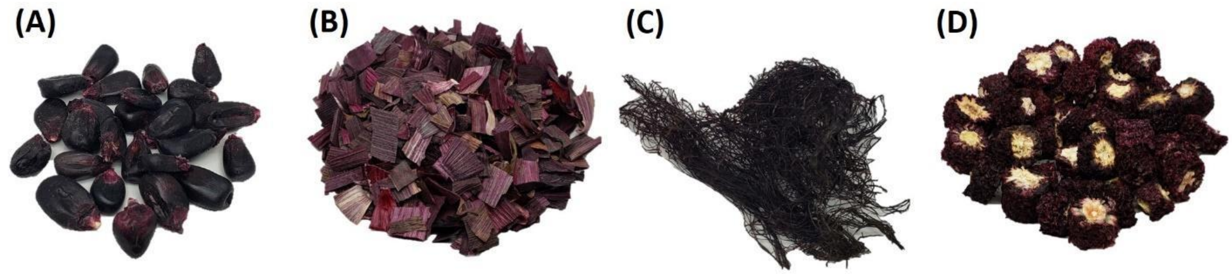


Figure 2. Presence of anthocyanins in (A) kernels, (B) corn husks, (C) corn silks, and (D) corncobs of Mexican Purple Corn

The presence of AAs in all foods and beverages showed that it is likely to use Mexican Purple Corn as a dietary source of AAs and as a potential source of functional foods (Figure 1). It confirmed that we can take advantage of the AAs accumulated in edible corn ear organs like kernels, and commonly non-edible organs such as corn husks, corncobs, and corn silks (Figure 2). Observing the corn ear organs utilized in food product preparation, we noted that corn husks and corncobs exhibited notable Total Antioxidant Capacities (TACs) in certain anthocyanin-rich beverages derived from them (ID 12, 5, and 6). While some foods and beverages made from purple kernels and corn silks displayed lower TACs, it is noteworthy to emphasize that there is still potential to harness the crop's capacity for amino acid (AAs) production in these tissues.

In regard to TAC values, we found that foods contained from 4.35 to 38.46 mg of TA 100^{-1} of biomass ($p \leq 0.05$) while beverages registered a broader TAC interval from 3.08 to 119.55 mg of TA 100^{-1} of biomass ($p \leq 0.05$) (Table 3). In general, most of the beverages had higher TACs than foods. The purple corn infusion (Id 12) made from corn husks+corncobs had the highest TAC and was followed by the functional beverages (Id 5 and 6), which had 67.04 and 93.12 mg of TA 100 g^{-1} of corn husks+corncobs, respectively ($p \leq 0.05$). In contrast, the lower TACs belonged to the corn silks hot teas (Id 7 and 8), which ranged from 3.08 to 8.03 mg of TA 100 g^{-1} of corn silks. A comparison between the TAC of infusions and hot teas evidenced that infusions had more AAs ($p \leq 0.05$) (Table 3). Among evaluated foods, the snack showed the highest TAC (38.46 mg of TA 100 g^{-1} of roasted kernels); nevertheless, it was statistically similar to the AAs tracked in boiled elote (23.91 and 36.05 mg of TA 100 g^{-1} of elote kernels). Tortillas had the lowest TAC with a value of 4.35 mg of TA 100 g^{-1} of tortillas.

Furthermore, we noticed that there was an effect of the food preparation process in the pigment concentration in both foods and beverages, since the corn ear organs were exposed to heat, high temperatures or high pH levels. Also, the particle size of the tissue (pulverized (Figure 1G) or chunks (Figure 1D and Figure 1F)), and the time of AAs extraction (from minutes to hours) were conditions that affected their TAC. It was observed that kernels, as the structures of the corn ear intended for consumption as tortillas, underwent a more extensive transformation process compared to non-edible structures. The latter did not necessitate a drastic transformation; only a reduction in particle size was sufficient.

Table 3. Mean values of total anthocyanins content in foods and beverages made from Mexican Purple Corn

Id	Food or Beverage	TAC (mg of TA 100 g^{-1} of biomass)
1	Elote[-1]	36.05d
2	Elote[-2]	23.91de
3	Snack[-2]	38.46d
4	Tortillas[-1]	4.35e
5	Functional beverage[-2a]	93.12b
6	Functional beverage[-2b]	67.04c
7	Corn silks hot tea[-1]	8.03e
8	Corn silks hot tea[-2]	3.08e
9	Purple corn hot tea[-1]	5.93e
10	Corn silks infusion[-1]	40.54d
11	Corn silks infusion[-2]	20.21de
12	Purple corn infusion[-1]	119.55a
	HSD	21.91

Id: identification number of the food or beverage. [-1]: corn ear organs of the purple corn population-1. [-2]: corn ear organs of the purple corn population-2. [a]: anthocyanins extract mixed with lime juice. [b]: anthocyanins extract mixed with lime juice +guava pulp. TAC: total anthocyanins content. One piece of elote (corn on a cob) may contain from 93 to 110 g of kernels (unpublished data). TAC values followed by different lowercase letters indicate that there were statistical differences ($p \leq 0.05$). HSD: honestly significant difference.

IA from Mexican Purple Corn-based foods and beverages: Beverages showed a higher TAC than foods; however, in their particular case, TAC values did not reflect the intake of AAs by the consumption of 100 mL of beverage, instead, TAC indicated the content of AAs extracted from 100 g of tissues used for their preparation. In consequence, we perceived that, although the infusion of purple corn (Id 12) had the highest TAC (119.55 mg of TA 100 g^{-1} of corn husks+corncobs), the IA from 100 mL of infusion was 1.436 mg of TA (Table 4).

Table 4. Intake of anthocyanins from Mexican Purple Corn-based foods and beverages

Id	Food or Beverage	IA (mg of TA 100 g^{-1} or 100 mL^{-1})
1	Elote[-1]	36.05[(2)]
2	Elote[-2]	23.91[(3)]
3	Snack[-2]	38.46[(1)]
4	Tortillas[-1]	4.35[(5)]
5	Functional beverage[-2a]	5.036[(4)]
6	Functional beverage[-2b]	3.780[(6)]
7	Corn silks hot tea[-1]	0.032[(11)]
8	Corn silks hot tea[-2]	0.012[(12)]
9	Purple corn hot tea[-1]	0.071[(10)]
10	Corn silks infusion[-1]	0.164[(8)]
11	Corn silks infusion[-2]	0.081[(9)]
12	Purple corn infusion[-1]	1.436[(7)]

Id: identification number of the food or beverage. [-1]: corn ear organs of the purple corn population-1. [-2]: corn ear organs of the purple corn population-2. [a]: anthocyanins extract mixed with lime juice. [b]: anthocyanins extract mixed with lime juice +guava pulp. IA: intake of anthocyanins. [( )]: Ranking of foods and beverages according to their IA value; positions [(1)] and [(12)] were assigned to the highest and lowest values of IA, respectively.

The IA values helped us redefine which foods and beverages contributed with a higher input of AAs. We observed that when we took TAC as a reference, the best food products were some beverages (Id 12, 5, and 6, Table 3); nevertheless, an order rearrangement happened when the parameters of reference were the IA values (Table 4). Under this approach, the top five food products with the higher contents of AAs were all the studied foods and one of the functional beverages (Id 5). We estimated that by the consumption of 100 g or 100 mL, the AAs supply could be from 4.35 to 38.46 mg of TA (Table 4).

Contribution of Mexican Purple Corn to the dietary intake of anthocyanins: Based on the IA value of food products, we chose six of them to estimate the dietary intake of anthocyanins (DIA) from Mexican Purple Corn. We selected three foods (Id 1, 3, and 4), and three beverages (Id 5, 10, and 12) since they were outstanding by their IA values (Table 4). We also considered certain consumption habits reported in the Mexican population as reference points. This includes per capita consumption of tortillas, the significance of corn as a staple food, and the traditional use of herbal beverages for treating certain health conditions. Thus, we estimated that this crop could provide a maximum intake of 101.32 mg TA day^{-1} by consuming 236.6 g of purple corn tortillas (between 4 and 6 tortillas), 250 ml of corn silks infusion, 100 g of snack, 250 mL of one of the functional beverages, 100 g of elote kernels (about one piece of elote) and, 250 mL of the purple corn infusion. Another recommendation, looking forward to a more rational and balanced portion size of tortillas, would be to reduce it to 100 g. This modification would provide a daily intake of 95.42 mg of TA (Table 5).

Table 5. Suggested portion sizes and dietary intake of anthocyanins from Mexican Purple Corn-based foods and beverages

Id	Food or Beverage	Portion size (g or mL)	DIA (mg of TA)
1	Elote^{-1}	100	36.05
3	Snack^{-2}	100	38.46
4	Tortillas^{-1}	100	4.35
5	Functional beverage^{-2a}	250	12.56
10	Corn silks infusion^{-1}	250	0.41
12	Purple corn infusion^{-1}	250	3.59

Id: identification number of the food or beverage. $^{-1}$: corn ear organs of the purple corn population-1. $^{-2}$: corn ear organs of the purple corn population-2. [a]: anthocyanins extract mixed with lime juice. DIA: dietary intake of anthocyanins.

DISCUSSION

Mexican Purple Corn attributes as a dietary source of anthocyanins: The presence of AAs in foods and beverages made from Mexican Purple Corn supported that this type of corn is a source of AAs and that it has great potential for utilization in the elaboration of food products. Regardless of the content of AAs, we perceive that there is broad interest in studying and taking advantage of the anthocyanin-pigmented corns [28], among which, the corn of purple kernel has been recognized to possess the greatest potential to accumulate the pigment. For this reason, in the world, purple corn from different geographical origins is being explored [18, 25, 29, 30]. and has been described as an important and economic source of AAs, from which several by-products like food, nutraceuticals, biofuels or livestock feed can be obtained [31-33].

Results proved that it is feasible to promote the consumption of purple corn as a means to increase the intake of antioxidants, since even though it was not assayed, there is evidence that AAs are associated with strong antioxidant activity [16]. In addition, we consider that Mexican Purple Corn acquires more relevance due to its capacity to accumulate AAs in other organs of the plant (Figure 2B to Figure 2D). Hence organs of the corn ear that are not usually used or consumed can be utilized, not only to extract the pigment but, as we have proposed, to prepare rich-anthocyanins beverages.

Besides the content of AAs tracked in foods and beverages under study, we identified other attributes in Mexican Purple Corn, as:

a. Lower cost. Although berries are a very enjoyable and popular food all over the world and stand out for their high antioxidant content, they are also expensive foods that are not affordable for the entire population, especially in a country like Mexico where there is a high percentage of food insecurity largely caused by family economic conditions [22]. For this reason, the fact that purple corn accumulates AAs in different organs of the plant enables us to consider it as a cheaper and more accessible dietary source of AAs than berries. Even in households where its acquisition may not be a limitation, consuming purple corn (both as food and as extracts) would broaden the sources of anthocyanins intake.

b. Longer shelf life. The corn kernels and the rest of the ear organs can be preserved and stored without processing for a longer period than berries, which require extremely careful and technical postharvest handling [34]; while corn requires less rigorous storage conditions. It is enough to avoid an excess of environmental humidity, the occurrence of direct radiation and to confer protection against the incidence of pests through the use of containers (the kernel requires the greatest caution).

c. Diversity of culinary uses that are culturally relevant. Among the corn ear organs, the kernel displays many ways to be consumed, while in berries it is observed that their uses are limited, because, although they can be frozen or made into purees, jams, and nectars, among others, its main form of consumption is fresh. Corn has great versatility in the preparation of dishes, which reflects the deep connection that exists between the Mesoamerican cultures and this cereal. Apart from that, Serna-Saldivar [35] reported that in recent decades, in other cultures, there has been a constant increase in the use of special types of corn for food preparation, since they have found in this cereal a combination that gives them flavor and unique properties. It's no coincidence that currently, tortillas and corn chips are recognized worldwide. In fact, their popularity rivals that of potato chips.

d. Alternative foodstuff. Given the prevalence of certain health conditions and trends of consumption [2-4,6-7], we consider that purple corn besides being a source of antioxidants, could represent an interesting ingredient for the formulation of gluten-free food products (which can be offered to celiac patients) and, a food with potential use in bakery, where purple corn flour can be used to make products such as gluten-free and eggless muffins, which makes them suitable foods for people allergic to eggs or people of vegan consumption patterns [36]. Likewise, the presence of color in corn opens the outlook for the development of products that are attractive to the eye and simultaneously, due to its anthocyanin content, can promote human health [37].

e. Sustainable crop cereal: The chance to utilize the rest of the corn ear organs such as the corn husks, corncobs, and corn silks to obtain AAs is highlighted at a time when we must reconsider how food is produced and consumed. With the consumption proposal for these organs, we not only harvest the kernels but also utilize products from the crop cycle that were traditionally discarded. This presents an opportunity to promote the conservation, plant breeding, and utilization of this native corn variant.

f. Functionality of corn anthocyanins: Several bioactive properties have been reported in AAs obtained from corn. Some of them are its antioxidant capacity that slows cell aging, its role in reducing blood glucose levels, its ability to scavenge free radicals and inhibit obesity, its protective effect against nephropathies developed by type 2 diabetes patients, beneficial effects to improve gut microbiota, and a possible therapy in the treatment of specific types of cancer such as breast and prostate cancer [18, 38-42].Building upon the aforementioned arguments and drawing on statements by Ponder et al. [16] regarding alternative dietary sources of amino acids (AAs), it is imperative to disseminate the information that corn and its products constitute valuable components of a healthy diet.

Foods from Mexican Purple Corn: Moreover, their TAC, we consider that the analyzed tortillas, snack, and purple elote are foods with features that may be of interest to the consumer, like their attractive color of natural origin (Figure 1). As well, we contemplate that if they are consumed regularly, due to the presence of AAs they could promote good health. Specifically, we contend that Mexican society stands to gain from the potential health benefits associated with corn anthocyanins, as elucidated earlier. This becomes especially crucial given the substantial impact of chronic diseases on the population [22,24-25]. In addition, we count that purple corn-based foods represent affordable options for the intake of this important flavonoid, thus there is a worldwide development and consumption of rich-anthocyanin foods, most of which are expensive and not within everyone's reach [33].

Concerning food preparation, we observed that traditional methods of preparing tortillas and elote involve the presence of conditions that affect the anthocyanins' stability such as heat, high temperature and pH. In the case of tortillas, the alkaline pH during nixtamalization and kernels transformation into masa impacted the stability of anthocyanins [43], while in the cooking process of elote, both the increase in temperature and the presence of water were conditions that affected its TAC [44]. We quantified from 23.91 to 36.05 mg of TA 100 g^{-1} elote kernels, depending on the purple corn population (Table 3). Harakotr et al. [44] indicated that under this preparation procedure, anthocyanins are kept in the cooking water. In the purple corn snack, due to its TAC (38.46 mg of TA), it seems that a less drastic effect occurred during the food preparation, which consisted in subjecting the kernel to a high temperature for its roasting.

Although alternative processes to enhance amino acid (AAs) content in tortillas [45] and elote [44] have been proposed, we perceive that the traditional cooking methods for these foods offer technologies that are more easily adopted by the average consumer. Moreover, we suggest that to increase their TAC, there should be an optimization of food manufacturing processes and we should continue the breeding process of this crop.

Notably, we identified advantages in the tortillas and the purple corn snack; the former represents a staple food of major significance in the diet of the Mexican society, of which daily consumption is between 215 and 236.6 g of tortillas *per capita* [35]. If these tortillas were made from purple corn, in addition to providing carbohydrates, fibers, proteins, calcium, and niacin, among other components contained in the common tortilla, it would also mean an intake of 9.35 to 10.25 mg of TA. This would enrich the functional properties that the tortilla made by traditional nixtamalization already owns. Regarding the purple corn snack, we consider that since it is a minimally processed food, free of synthetic dyes and artificial antioxidants, it could represent a healthier snack than the ultra-processed snacks that are made from nixtamalized corn plus other ingredients, which, due to the new warning labels used in Mexico, are known to contain an excess of calories, sodium, saturated fats, as well as several additives and artificial colorants that negatively affect human health [47]. We believe that the proposed foods may contribute positively to the reconstruction of the traditional Mexican diet, characterized by being diverse, healthy, and nutritious.

Beverages from Mexican Purple Corn: Although there are beverages made from purple corn, such as the atole agrio (sour atole) from San Juan Ixtenco, Tlaxcala, Mexico (a ceremonial drink) and the chicha morada (representative of Peru), this research group made an innovative proposal by preparing them with corn husks, corncobs, and corn silks (Figure 1D to Figure 1G). In this sense, except for the corn silks that have been described as medicinal [48], there is no precedent for the use of corn husks and corncobs.

Among the suggested beverages we found that the most promising were the beverages made from corn husks+corncobs (Id 12, 5, and 6) in which we quantified between 67.04 and 119.55 mg of TA 100 g^{-1} of biomass. Lower TACs were observed in infusions and hot teas (Table 3). As seen in the case of foods, our results showed that the beverage manufacturing process is a key step in the quantity of extracted anthocyanins, which was higher when the tissue was left to macerate for 8 h or when the purple corn tissues were immersed in boiling water for 40 minutes; in contrast, the lowest TACs were detected in the hot teas (Table 3). To increase the AAs concentration in these beverages, we contemplate that some modifications could be made in the manufacturing procedure, such as a further reduction of the particle size of the organs (in Id 5, 6, and 12), an increase in the time of steep in hot water of the organs (especially in hot teas), and a raise in the amount of biomass used (particularly in corn silks beverages). Even though there are reports of more sophisticated and efficient methodologies to extract and preserve the stability of AAs [28, 49], an important contribution of our proposals is that these beverages can be made by simple methodologies that are cheap and easy to implement in consumers' households. In this way, consumers may increase their anthocyanins intake.

Currently, there is a notable increase in the consumption of beverages of high biological value; buyers demand that drinks not only serve to quench their thirst or supply nutrients to the body but likewise be an easy mode to ingest antioxidants. Under these considerations, beverages made with Mexican Purple Corn have great potential to be accepted by consumers.

In the case of infusions and hot teas made with purple corn silks, their adoption as a natural remedy is considered viable, because, even though it was not directly reported in purple corn silks, there is evidence that corn silks act as a diuretic agent, reduce hyperglycemia, have antidepressant and anti-fatigue effects, and are generally used to make teas and supplements to treat urinary infections [48]. Said health benefits have been mainly attributed to the presence of flavonoids and terpenoids (discovered in yellow-golden silks). Some inquiries carried out on purple corn silks have found that they can be used in the prevention and treatment of obesity [50], just like a natural colorant, a flavoring agent, or as a source to make value-added products like snacks, corn silk teas or cosmetics [28].

DIA from Mexican Purple Corn: We estimated that this crop could provide an intake of 95.42 mg TA day^{-1} by the consumption of 300 g of purple corn-based foods, and 750 mL of different beverages made from corn husks, corncobs, and corn silks (Table 5). The intake of anthocyanins was considerably higher than the interval reported worldwide, which fluctuates between 18 and 43 mg day^{-1} [51].

This first examination allowed us to discover that Mexican Purple Corn possesses attributes that can be used to increase the anthocyanins intake. At the same time, it set the evidence to prospect its potential as a source of functional foods and beverages. Moreover, we consider that future research is required to corroborate the functional properties and bioavailability of anthocyanins in the proposed foods and beverages, as it has been done in rich anthocyanins extracts from other species, where factors like timing, dose and, intake duration are studied [52].

CONCLUSIONS

We verified that Mexican Purple Corn has a wide potential to be used to increase anthocyanins' intake. This cereal is an economical and sustainable source of anthocyanins, from which diverse food products of cultural relevance or that meet the needs of consumers with specific health conditions and particular eating patterns may be obtained. We suggest that the consumption of corn anthocyanins can promote good health due to its functional properties and that the foods and beverages studied in this research represent a healthy alternative to the consumption of ultra-processed products and soft drinks that negatively affect the health of the population. Nevertheless, further studies on the functional properties and nutritional features of purple corn are required. Although we found that the anthocyanins concentration was affected by the foods and beverages preparation, the Mexican Purple Corn still provides an intake of 95 mg of TA day^{-1}, which could be enhanced by optimizing the food and beverage manufacturing processes and by continuing the plant breeding of the germplasm to increase the anthocyanins' yield in the corn ear organs.

Abbreviations: AAs: anthocyanins, TAC: total anthocyanins content, ChDis: chronic diseases, FF: functional food, TA: total anthocyanins, IA: intake of anthocyanins, DIA: dietary intake of anthocyanins.

Competing Interests: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions: CG Mendoza-Mendoza: conceptualization, investigation, material preparation and data analysis, writing of the first draft of the manuscript. RM Soto-Hernandez: methodology, data curation and validation. MC Mendoza-Castillo: conceptualization, investigation, material preparation, validation. A Delgado-Alvarado: methodology, data curation, validation. FJ Sánchez-Ramírez: data analysis, writing and editing of the manuscript. All authors reviewed and edited previous versions of the submitted manuscript.

Acknowledgements and funding: Authors express their gratitude to CONAHCYT (Consejo Nacional de Humanidades, Ciencia y Tecnología) and Colegio de Postgraduados because they were institutions that allowed the development of this study. Likewise, we appreciate the support of Dr. Agapito Pecina Martínez in crop field management.

REFERENCES

1. Zhou Y, Chi J, Lv W, Wang Y: Obesity and diabetes as high-risk factors for severe coronavirus disease 2019 (Covid-19). Diabetes Metab Res Rev 2020, 37:e3377. DOI: https://doi.org/10.1002/dmrr.3377
2. World Health Statistics 2022. Monitoring health for the SDGs (Sustainable Development Goals). [https://www.who.int/publications/i/item/9789240051157] Retrieved November 15, 2022.

3. Ortega FB, Lavie CJ, Blair SN: Obesity, diabetes, and cardiovascular diseases compendium: Obesity and Cardiovascular Disease. Circ Res 2016, 118:1752-1770. DOI: https://doi.org/10.1161/CIRCRESAHA.115.306883
4. Shivappa N: Diet and chronic diseases: is there a mediating effect on inflammation? Nutrients 2019, 11:1639. DOI: https://doi.org/10.3390/nu11071639
5. Anderson E, Durstine JL: Physical activity, exercise, and chronic diseases. A brief review. Sport Med Health Sci 2019, 1:3-10. DOI: https://doi.org/10.1016/j.smhs.2019.08.006
6. James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, Abbastabar H, et al.: Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017. Lancet 2018, 392:1789-1858. DOI: https://doi.org/10.1016/S0140-6736(18)32279-7
7. Habiba L, Belahse R: Health problems associated to nutrition and lifestyle changes in the COVID-19 era. Bioac Comps Health and Dis. 2023, 6:26-37. DOI: https://doi.org/10.31989/bchd.v6i3.1038
8. Alzate-Yepes T: La educación alimentaria como eje transversal de la salud y la nutrición. Persp Nutr Human 2022, 24: 9-14. DOI: https://doi.org/10.17533/udea.penh.v24n1a01
9. Branca F, Lartey A, Oenema S, Aguayo V, Stordalen GA, Richardson R, Arvelo M, et al.: Transforming the food systems to fight non-communicable diseases. BMJ 2019, 364(Suppl1):24-29. DOI: https://doi.org/10.1136/bmj.l296
10. Barquera S, Campos-Nonato I, Hernández-Barrera L, Pedroza A, Rivera-Dommarco JA: Prevalencia de obesidad en adultos mexicanos, 2000-2012. Salud Púb Méx 2013, 55(Suppl2):151-160.
11. Alongi M, Anese M: Re-thinking functional food development through a holistic approach. J Funct Foods 2021,81:104466. DOI: https://doi.org/10.1016/j.jff.2021.104466
12. Gul K, Singh AK, Jabeen R: Nutraceuticals and functional foods: the foods for the future world. Critical Rev Food Sci Nut 2016, 56:2617-2627. DOI: https://doi.org/10.1080/10408398.2014.903384
13. Khoo HE, Azlan A, Teng TS, Meng LS: Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits. Food and Nutr Res 2017, 61:1361779. DOI: https://doi.org/10.1080/16546628.2017.1361779
14. Escalante-Aburto A, Mendoza-Córdova MY, Mahady GB, Luna-Vital D, Gutiérrez-Uribe JA, Chuck-Hernández C: Consumption of dietary anthocyanins and their association with a reduction in obesity biomarkers and the prevention of obesity. Trends in Food Sci and Tech. 2023, 140:104140. DOI: https://doi.org/10.1016/j.tifs.2023.104140
15. Yousuf B, Gul K, Abas WA, Singh P: Health benefits of anthocyanins and their encapsulation for potential use in food systems: a review. Critical Rev Food Sci Nutr 2016, 56:2223-2230. DOI: https://doi.org/10.1080/10408398.2013.805316
16. Ponder A, Hallmann E, Kwolek M, Średnicka-Tober D, Kazimierczak R: Genetic differentiation in anthocyanin content among berry fruits. Current Iss. Mol. Biol 2021, 43:36-51. DOI: https://doi.org/10.3390/cimb43010004
17. Castro-Acosta ML, Lenihan-Geels GN, Corpe CP, Hall WL: Berries and anthocyanins: promising functional food ingredients with postprandial glycaemia-lowering effects. Proceed Nutr Soc 2016, 75:342-355. DOI: https://doi.org/10.1017/S0029665116000240
18. Gálvez RL, Christopher A, Sarkar D, Shetty K, Chirinos R, Campos D: Phenolic composition and evaluation of the antimicrobial activity of free bound phenolic fractions from peruvian purple corn (*Zea mays* L.) accession. J Food Sci 2017, 82:2968-2976. DOI: https://doi.org/10.1111/1750-3841.13973
19. Cory H, Passarelli S, Szeto J, Tamez M, Mattei J: The role of polyphenols in human health and food systems: a mini-review. Front Nutr 2018, 5:87. DOI: https://doi.org/10.3389/fnut.2018.00087
20. Salehi B, Sharifi-Rad J, Cappellini F, Reiner Z, Zorzan D, Imran M, Sener B, et al.: The therapeutic potential of anthocyanins: current approaches based on their molecular mechanism of action. Front Pharma 2020, 11:1300. DOI: https://doi.org/10.3389/fphar.2020.01300
21. Herrera-Balandro DD, Chai Z, Beta T, Feng J, Huang W: Blueberry anthocyanins: an updated review on approaches to enhancing their bioavailability. Trends Food Sci and Tech 2021, 118:808-821. DOI: https://doi.org/10.1016/j.tifs.2021.11.006
22. Encuesta Nacional de Salud y Nutrición 2021 sobre Covid-19. Resultados Nacionales [https://www.insp.mx/resources/images/stories/2022/docs/220801_Ensa21_digital_29julio.pdf] Retrieved August 2, 2022.

23. Barquera S, Véjar-Rentería LS, Aguilar-Salinas C, Garibay-Nieto N, García-García E, Bovecchio A, Perichart O, et al.: Volviéndonos mejores: necesidad de acción inmediata ante el reto de la obesidad. Una postura profesional de la salud. Salud Púb Méx 2022, 64:225-229. DOI: https://doi.org/10.21149/11630
24. García-Chávez CG, Monterrubio-Flores E, Ramírez-Silva CI, Aburto TC, Pedraza LS, Rivera-Dommarco J: Contribución de los alimentos a la ingesta total de energía en la dieta de los mexicanos mayores de cinco años. Salud Púb Méx 2020, 62:166-180. DOI: https://doi.org/10.21149/10636
25. Mendoza-Mendoza CG, Mendoza-Castillo MC, Delgado-Alvarado A, Sánchez-Ramírez FJ, Kato-Yamakake TA: Anthocyanins content in the kernel and corncob of Mexican purple corn populations. Maydica 2020, 65:1-10.
26. Mendoza-Mendoza CG, Mendoza-Castillo MC, Delgado-Alvarado A, Castillo-González F., Kato-Yamakake TA, Cruz-Izquierdo S: Antocianinas totales y parámetros de color en líneas de maíz morado. Rev. Fit. Mex 2017, 40:471-479.
27. SAS Institute Inc., SAS Campus Drive, Cary, North Carolina, USA. 2009.
28. Colombo R, Ferron L, Papetti A: Colored corn: an up-date on metabolites extraction, health implication, and potential use. Molecules 2021, 26:199. DOI: https://doi.org/10.3390/molecules26010199
29. Salinas-Moreno Y, Esquivel-Esquivel G, Ramírez-Díaz JL, Alemán-de la Torre I, Bautista-Ramírez E, Santillán-Fernández A: Selección de germoplasma de maíz morado (Zea mays L.) con potencial para extracción de pigmentos. Rev Fit Mex 2021, 44:309-321.
30. Paulsmeyer MN, Vermillion KE, Juvik JA: Assessing the diversity of anthocyanin composition in various tissues of purple corn (*Zea mays* L.). Phytochem 2022, 201:113263. DOI: https://doi.org/10.1016/j.phytochem.2022.113263
31. Paulsmeyer M, Chatham L, Becker T, West M, West L, Juvik J: Survey of anthocyanin composition and concentration in diverse maize germplasm. J Agric Food Chem 2017, 65:4341-4350. DOI: https://doi.org/10.1021/acs.jafc.7b00771
32. Somavat P, Li Q, Gonzalez ME, Liu W, Singh V: Coproduct yield comparisons of purple, blue and yellow dent corn for various milling processes. Indust Crops Prod 2016, 87:266-272. DOI: https://doi.org/10.1016/j.indcrop.2016.04.062
33. Calderaro A, Barresca D, Bellocco E, Smeriglio A, Trombetta D, Laganà G: Colored phytonutrients: role and applications in the functional foods of anthocyanins. In Phytonutrients in Food: From Traditional to Rational Usage. 1st edition. Edited by Nabavi SM, Suntar I, Barreca D, Khan H. United Kingdom: Woodhead Publishing; 2020:177-195. DOI: https://doi.org/10.1016/B978-0-12-815354-3.00011-3
34. Huynh NK, Wilson MD, Eyles A, Stanley RA: Recent advances in postharvest technologies to extend the shelf life of blueberries (*Vaccinum* sp.), raspberries (*Rubus idaeus* L.), and blackberries (*Rubus* sp.). J Berry Res 2019, 9:687-707. DOI: https://doi.org/10.3233/JBR-190421
35. Serna-Saldivar SO: History of corn and wheat tortillas. In Tortillas Wheat Flour and Corn Products. 1st edition. Edited by Rooney LW, Serna-Saldivar SO. USA: Woodhead Publishing and AACC International Press; 2015:1-28. DOI: https://doi.org/10.1016/B978-1-891127-88-5.50001-3
36. Colombo F, Lorenzo DC, Petroni K, Silano M, Pilu R, Falletta E, Biella S, et al.: Pigmented corn varieties as functional ingredients for gluten-free products. Foods 2021, 10:1770. DOI: https://doi.org/10.3390/foods10081770
37. Turturică M, Oancea AM, Răpeanu G, Bahrim G: Anthocyanins: naturally occurring fruit pigments with functional properties. AUDJG-Food Tech 2015, 39:9-24.
38. Li J, Lim SS, Lee JY, Kim JK, Kang SW, Kim JL, Kang YH: Purple corn anthocyanins dampened high-glucose-induced mesangial fibrosis and inflammation: possible renoprotective role in diabetic nephropathy. The J Nutrit Biochem 2012, 23:320-331. DOI: https://doi.org/10.1016/j.jnutbio.2010.12.008
39. Finkel ML, Sanchez S, Mak T, Granstein J, Lefkowitz A: Anthocyanin-rich purple corn extract and its effects on the blood pressure of adults. J Ev-Based Complement Alter Med 2013, 18:237-242. DOI: https://doi.org/10.1177/2156587213482942
40. Herrera-Sotero MY, Cruz-Hernández CD, Oliart-Ros RM, Chávez-Servia JL, Guzmán-Gerónimo RI, González-Covarrubias V, Cruz-Burgos M, et al.: Anthocyanins of blue corn and tortilla arrest cell cycle and induce apoptosis on breast and prostate cancer cells. Nutr and Cancer 2020, 72:768-777. DOI: https://doi.org/10.1080/01635581.2019.1654529
41. Moreira V, Stanquevis R, Amaral EP, Lajolo FM, Hassimotto NMA: Anthocyanins from purple maize (*Zea mays* L.) downregulate lipopolysaccharide-induced peritonitis in mice by modulating the MyD88 signaling pathway. PharmaNutr 2021, 16:100625. DOI: https://doi.org/10.1016/j.phanu.2021.100265

42. Xu H, Liu M, Liu H, Zhao B, Zheng M, Liu J: Anthocyanins from purple corn ameliorated obesity in high fat diet-induced obese mice through activating hepatic AMPK. J. Funct Foods 2021, 84:104582. DOI: https://doi.org/10.1016/j.jff.2021.104582
43. Magaña-Cerino JM, Peniche-Pavía HA, Tiessen A, Gurrola-Díaz CM: Pigmented maize (*Zea mays* L.) contains anthocyanins with potential therapeutic action against oxidative stress - A review. Polish J Food Nutr Sci 2020, 70:85-99. DOI: https://doi.org/10.31883/pjfns/113272
44. Harakotr B, Suriharn B, Tangwongchai R, Scott MP, Lertrat K: Anthocyanin, phenolics and antioxidant activity changes in purple waxy corn as affected by traditional cooking. Food Chem 2014, 164:510-517. DOI: https://doi.org/10.1016/j.foodchem.2014.05.069
45. Escalante-Aburto A, Ponce-García N, Ramírez-Wong B, Torres-Chávez PI, Figueroa Cárdenas JD, Gutiérrez-Dorado R: Specific anthocyanin contents of whole blue maize second-generation snacks: an evaluation using response surface methodology and lime cooking extrusion. J Chem 2016, 2016: 5491693. DOI: https://doi.org/10.1155/2016/5491693
46. Barros C, Buenrostro M: Tlacualero Alimentación y cultura de los antiguos mexicanos. México: Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán; 2016.
47. Tolentino-Mayo L, Sagaceta-Mejía J, Cruz-Casarrubias C, Ríos-Cortázar V, Jauregui A, Barquera S: Compresión y uso del etiquetado frontal nutrimental Guías Diarias de Alimentación de alimentos y bebidas industrializados en México. Salud Púb Méx 2020, 62:786-797. DOI: https://doi.org/10.21149/11568
48. Hasanudin K, Hashim P, Mustafa S: Corn silk (*Stigma maydis*) in healthcare: a phytochemical and pharmacological review. Molecules 2012, 17:9697-9715. DOI: https://doi.org/10.3390/molecules17089697
49. Jayaprakash S, Raja S, He J, Paramannil M: Functional relevance of bioactive compounds in purple maize: a contemporary extraction progressions and prospective applications. Cereal Res Commun 2023, 51:263-282. DOI: https://doi.org/10.1007/s42976-022-00311-z
50. Chaiittianan R, Sutthanut K, Rattanathongkom A: Purple corn silk: a potential anti-obesity agent with inhibition on adipogenesis and induction on lipolysis and apoptosis in adipocytes. J Ethnopharm 2017, 201:9-16. DOI: https://doi.org/10.1016/j.jep.2017.02.044
51. Castro-Acosta ML, Lenihan-Geels GN, Corpe CP, Hall WL: Berries and anthocyanins: promising functional food ingredients with postprandial glycaemia-lowering effects. Proceed Nutr Soc 2016, 75:342-355. DOI: https://doi.org/10.1017/s0029665116000240
52. Theodorus WME, Bilgic P, Montanari S, Sahin MA: Two weeks daily intake of anthocyanins-rich New Zeland blackcurrant extract enhances whole-body fat oxidation during supine rest in healthy males. Diet Supp and Nutr 2023, 2:30-40. DOI: https://www.doi.org/10.31989/dsn.v2i8.1124