Emirates Journal of Food and Agriculture. 2022. 35(10): 806-814
doi: 10.9755/ejfa.2022.v34.i10.2930
http://www.ejfa.me/

RESEARCH ARTICLE

Phytochemical screening, polyphenols content and antioxidant activity of by-products of two corn variety

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ABSTRACT

Phytochemical screening, polyphenols content, and antioxidant activity of the different parts of the white and purple corn (white corn cob, WCC; white corn leaf, WCL; white corn grain, WCG; purple corn cob, PCC; purple corn leaf, PCL, and purple corn grain, PCG) were evaluated. PCG had a higher content of fat (9.7%) and carbohydrates (77%), while WCG had a higher protein content (15.8%), the leaves had a higher fiber content (37 - 40%). The phytochemical profile was positive for alkaloids, carbohydrates, phytosterols, phenols, and terpenoids in all samples. The total phenolic content, WCC presented the highest ($P < 0.05$) value (225 mg GAE/100 g sample) and in lower concentration in PCG. However, PCG had a higher content of total flavonoids (104 mg CE/100 g sample). The results suggest that agroindustry wastes from corn (cob and leaf) could be considered a potential source of fiber, carbohydrates, and bioactive compounds with antioxidant capacity.

Keywords: Antioxidant capacity; Phytochemical screening; Polyphenols; *Zea Mays*.

INTRODUCTION

In the Mexican economy, corn is the most important crop; since, it constitutes the food base of millions of Mexicans (Rodríguez-Salinas et al., 2020). The states of Jalisco, Mexico, Sinaloa, Chiapas, and Michoacán produce 50% of the corn produced in Mexico. In the State of Oaxaca, 90% of the cultivated area of corn is planted with Creole maize of different races, colors, textures, and crop cycles (Salinas-Moreno et al., 2013). The predominant races are Bolita, Zapalote Chico, Conónico, Olotón and Mushito. In this state, there is a high diversity of grain colors: white (62.9%), yellow (20.1%), blue (7.0%), black (3.4%), orange (2.0%), and red (4.6%) (Salinas-Moreno et al., 2013). In Mexico, 69% of the corn produced is destined for human consumption; 20% livestock sector; 10% industrialization, and 1% seed production (Salinas et al., 2010). Corn is used or consumed as a functional food mainly as tortillas, tlacoyos, and gorditas. Likewise, I have been shown to have a high nutritional value, in addition to presenting pharmacological activities: antidiabetic, antimutagenic, anticancer, and antioxidant effects (Salinas-Moreno et al., 2012; Rodríguez-Salinas, et al., 2020). These effects have also been evaluated in different parts of plants as well as the phytochemical profile to determine the potential of these plants as additives with beneficial properties for the health of consumers (Nguyen et al., 2020; Ahmed et al 2019; Fall et al., 2015). On the other hand, the corn rachis is the heart of the corn. In other countries, it is also known as, cob due to apheresis of yólotl, chócolo, marlo, tusa, zuro, bacal, or coronta, which is an agricultural waste or by-product that is generated in large quantities in the process of separating the grain from the cob and it is estimated that 170 kg of cob was recorded for each shade of corn. From recent data on world corn production in 2020 (1,133.89 million tons) it can be estimated that around 193.55 million tons of cob are generated per year (FAOSTAT, 2021). Thus, agroindustry wastes have become a difficult problem to solve, therefore, every day there is a need to develop alternatives with byproducts of waste and agricultural products little used for human consumption and to give them added value. The use of these wastes would help maximize resources

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Received: 24 February 2022; **Accepted:** 11 September 2022

and the result would be the production of new products. In this sense, in recent years research has been carried out to reduce and take advantage of agro-industrial waste, not only in the processing of animal feed but also in new alternatives to give added value to this waste. Ponce et al. (2021) used agro-industrial waste, including corn husk, as lignocellulosic biosorbents for dyes applying an alkaline treatment. Demonstrating that alkali treatment provided an interesting alternative to produce efficient bioadsorbents from agro-industrial waste. Wang et al. (2021) used corn cob to make graphene-like carbon nanocomposites, synthesized through a high-temperature, hydrothermal carbonization process for application in lithium-ion batteries. Concluding that the carbon nanocomposite can be applied to a lithium-ion battery as an anode material with a low current density. For their part, Ramos et al. (2021) evaluated the thermal behavior and environmental impact of two different corn cob particleboards using two types of glue binders: Polyvinyl acetate (PVA) and Fabricol AG222 (FAG222), in order to use them in the construction industry as a thermally insulating material. Concluding that corn cob particleboard has the potential to be used as a sustainable construction material, considering the values obtained for the thermal performance parameters. The application of this bio-waste as insulating material reveals a consistent path in the circular economy since the particleboards with PVA presented lower thermal transmission, lower thermal conductivity, and higher thermal resistance, corroborated by lower heat fluxes between the external environment and interior, approaching the properties of some commercial products. Gao et al. (2021) evaluated the effect of hydrothermal pretreatment on the structure and components of lignocellulose in Corn Cob, and the performance of hydrolysis, acid production, and methanogenesis during codigestion. Despite the fact that corn is an important part of the Mexican diet, there is little scientific information regarding inedible parts such as leaf, cob, and stigmas that are wastes that could be a source of bioactive compounds and have not been studied. Therefore, the integral use of white and purple corn will contribute to better use of its nutrients and its potential use in the industry as a functional food. Therefore, the aim of the present investigation was to evaluate the physicochemical and antioxidant properties of cob, leaf, and grains of white and purple corn from the Tuxtepec region, Oax, Mexico for possible use as an additive in the food industry.

MATERIALS AND METHODS

Materials

Creole corn of two varieties was used, white corn (*Zea mays* L.) was purchased in the city of Tuxtepec, Oaxaca, Mexico. Purple corn (*Zea mays* L.) was grown and harvested in San Felipe Usila, Tuxtepec, Oaxaca, Mexico. All analytical reagents and solvents used were reagent grade. Fig. 1 shows the general diagram of the characterization of the different parts of white and purple corn evaluated.

Conditioning of the raw material

The leaf and grains of white and purple corn were separated from the cob, manually and subsequently, the cob was ground in a coffee mill (Krupps Model GX4100 2121 Eden Road Millville, NJ 08332 USA) at maximum speed. The cob and the grain were dried in an oven at 60 ºC for 24 h, while the leaves were dried under the shade (at 30 ± 5 ºC for 1 month). After drying, all samples were ground and screened to a particle size of 0.59 mm (30 mesh, U.S.A. standard test ASTM E-11 Specification W.S. Tyler, USA).

Proximal chemical analysis

The chemical composition was performed according to the methods of the AOAC (2005): moisture (925.10), ashes (923.03), fats (920.39), proteins (920.87), raw fiber (925.08), and the carbohydrate content was calculated by difference.

Color and pH analysis

The color determination was measured with a Hunter lab triestimulus colorimeter (MiniScan Hunter Lab, model 45/0L, Hunter Associates Lab., Ind., Reston, Virginia USA). The luminosity values (L^*), a^*, and b^* were obtained, and from which comma (C^*), hue angle (h°), and the total color difference (ΔE) were determined. The pH was measured according to the methodology of Juárez-Barrientos et al. (2017).

Preparation of the extracts

At 600 mg of sample and 6 mL of distilled water was added and stirred in a vortex (Vortex-2 Genie, Model G-560, Scientific Industries, INC, Bohemia, NY USA) for 5 min and filtered under vacuum (Whatman filter paper, no.40, 150 mm φ, Whatman International Ltd., Maidstone UK). Subsequently, the extracts were stored under refrigeration at 4 ºC until use.

Phytochemical screening

The phytochemical profile (Fig. 2) was determined according to the methodology of Tiwari et al. (2011).

Alkaloid test

The extracts (1 mL) were dissolved in hydrochloric acid (3 mL) diluted individually and filtered (Whatman filter paper, no. 40, 150 mm φ, Whatman International Ltd., Maidstone UK). The presence of alkaloids was performed by two methods.

1. Dragendroff's method: The filtrates were treated with Dragendroff's reagent Potassium Iodide solution

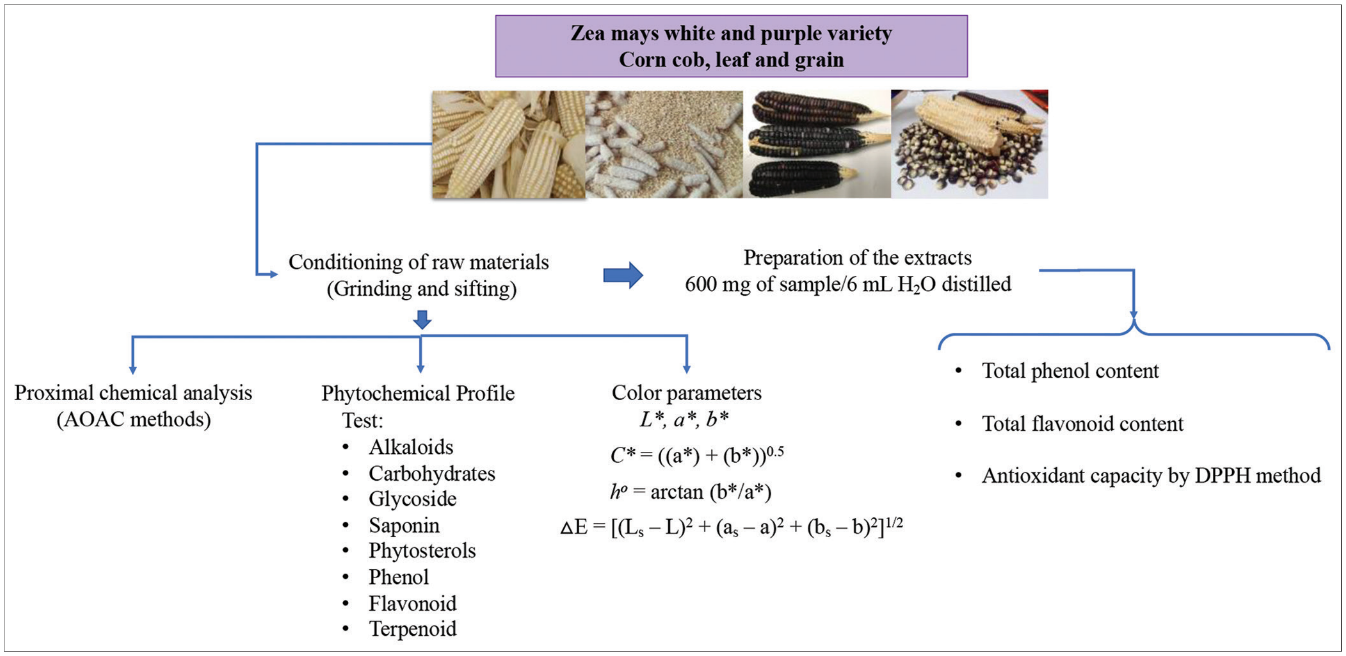

Fig 1. General diagram of the physicochemical and antioxidant characterization of the different parts of white and purple corn.

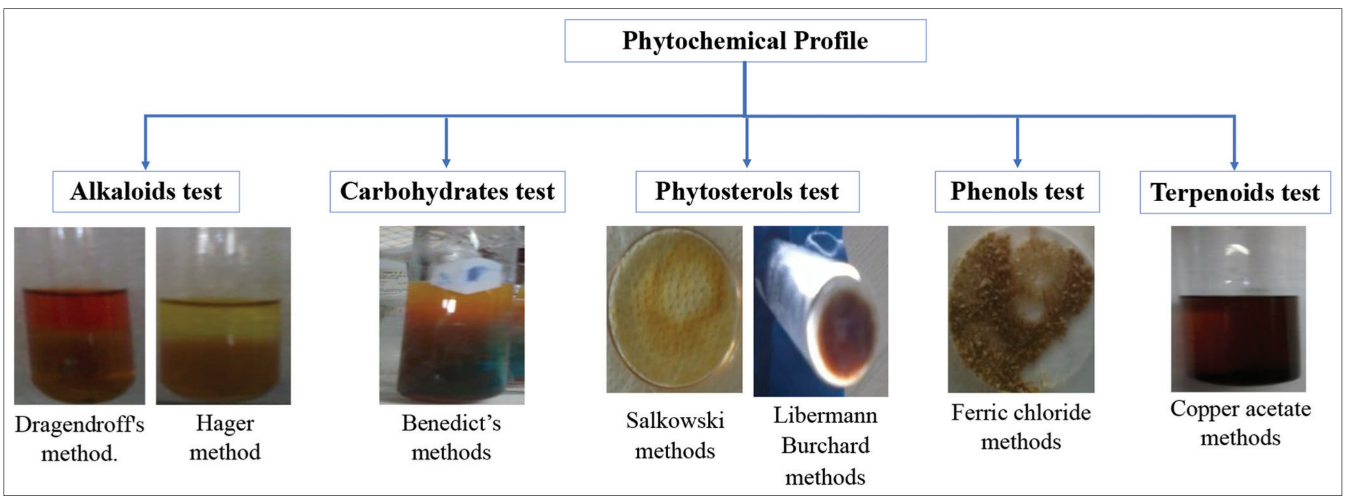

Fig 2. Phytochemical profile of the different parts of white and purple corn.

(1 mL). The formation of a red precipitate indicates the presence of alkaloids.

2. Hager method: The filtrates were treated with the Hager reagent saturated picric acid solution (1 mL). The presence of alkaloids is confirmed by the formation of the yellow precipitate.

Carbohydrate test

The extracts were dissolved individually in 5 mL of distilled and filtered water (Whatman filter paper, no. 40, 150 mm ϕ, Whatman International Ltd., Maidstone UK).

Benedict's method: The filtrates (1 mL) were treated with Benedict's reagent (3 mL) and heated gently. The formation of an orange-red color indicates the presence of reducing sugars.

Glycoside test

The extracts were hydrolyzed with dilute HCl (4 mL), before the glycoside test.

Borntrager modified method: The extracts (1 mL) were treated with ferric chloride solution (1 mL) and immersed in boiling water (100 °C) for about 5 min. The mixture was cooled to 25 °C and extracted with equal volumes of benzene (1 mL). The benzene layer was separated and treated with ammonia solution. The formation of pink in the ammonia layer indicates the presence of anthranol glycosides.

Saponin test

Saponification method: 100 mg of flour is dissolved in 10 mL of distilled water; the mixture is stirred in a vortex for 15 min. The formation of 1 cm of foam layer indicates the presence of saponins.

Foam method: 100 mg of flour is dissolved with 2 mL of distilled water. The mixture is stirred in a vortex for 10 min. If the foam produced persists for 10 min, it indicates the presence of saponins.

Phytosterols test

Salkowski's method: The extracts were treated with chloroform (4 mL) and filtered. The filtrates were treated with a few drops (3 drops) of concentrated sulfuric acid, stirred, and allowed to stand (5 min). The appearance of golden yellow indicates the presence of triterpenes.

Libermann Burchard method: The extracts were treated with chloroform (4 mL) and filtered. The filtrates were treated with a few drops of acetic anhydride (3 drops), boiled at 100 ºC, and cooled at 25 ºC. Concentrated sulfuric acid (3 drops) was added. The formation of a brown ring at the junction indicates the presence of phytosterols.

Phenol test

Ferric Chloride method: Extracts were treated with 4 - 5 drops of ferric chloride solution. Bluish black formation indicated the presence of phenols.

Flavonoid test

Alkaline Reagent method: Extracts (1 mL) were treated with 1 mL of 10% sodium hydroxide solution. The intense yellow formation, which becomes colorless when adding pure hydrochloric acid, indicates the presence of flavonoids.

Terpenoid test

0.8 g of the flours were dissolved with 10 mL of ethanol and stirred in a vortex for 5 min and filtered (Whatman filter paper, no.40, 150 mm φ, Whatman International Ltd., Maidstone UK), 5 mL were taken of the extract, and mixed with 2 mL of chloroform and 3 mL of sulfuric acid. The formation of a brown disc indicated the presence of terpenoids.

Total phenol content

The total phenolic content was determined by the Folin-Ciocalteu method (Rodríguez-Miranda et al., 2011).

Total flavonoid content

The evaluation of total flavonoids was followed by the procedure described by Rodríguez-Miranda et al. (2011).

Antioxidant capacity by DPPH method

The evaluation of the entrapment capacity of the DPPH* radical was followed by the procedure described by Ruiz-Torres et al. (2008).

Statistical analysis

The results obtained were analyzed using the STATISTICA software version. 10.0 (StatSoft Inc., Tulsa, OK USA). The mean and standard deviation were calculated and one-way analysis of variance was performed. The corresponding averages were compared using the Fisher LSD test ($P < 0.05$), with a 95% confidence level.

RESULTS AND DISCUSSION

Chemical composition

The highest ash content was found in WCC and WCG no significant differences were observed ($P > 0.05$) between these samples (Table 1), the lowest ash content was in PCC finding significant differences ($P < 0.05$) between the two varieties of corn. These ash contents are higher than reported by various authors: Cardona et al. (2002) 1.6 y 3.8%, in cob and grain respectively; Córdoba et al. (2013) 2% in cob; Prado-Martínez et al. 2012 0.76% in leaf; Méndez-Montealvo et al. (2005), Barrios and Bosso (2018) and Rodríguez-Salinas et al. (2020) 1.1 - 1.7, 1.26 - 1.61 and 1 - 1.46%, in grain respectively, and lower than reported by Treviño et al. (2011), Danish et al. (2015) and Amer et al. (2021) in leaf (14.7, 7.8 y 9.7% respectively), and Pratheep et al. (2021) in corn cob (12.23%). The highest fat content was found in PCG and the lowest WCC content. Significant differences ($P < 0.05$) were found between the samples (Table 1). These differences are because the grains mainly of white corn are rich in oil and are used in the oil industry because of their high-fat content (Barrios and Basso, 2018). These values are higher than those reported by Cardona et al. (2002) in cob (0.4%) and similar to that reported by Michel-Aceves et al. (2008) (2.49%), in leaf the values are higher than those reported by Treviño et al. (2011) (1.8 - 2.2%), while in grain the fat content in WCG was similar to that reported by Méndez-Montalvo et al. (2005) and Rodríguez-Salinas et al. (2020) (4 - 7 and 6.15%, respectively) but PCG was higher than reported by Barrios and Basso (2018) and Rodríguez-Salinas et al. (2020) in pigmented corn (4.32 - 5.24 and 3.38 - 5.40%, respectively).

The protein content was higher in the parts of white corn, with significant differences ($P < 0.05$) between varieties whose highest value was in WCG and the lowest in PCL. These differences may be due to the type of corn since it has been reported that some varieties with flour endosperm may have high protein values (Méndez-Montalvo et al., 2005).

The results obtained are above those reported by Michel-Aceves et al. (2008) (2.86% in cob); Treviño et al. (2011) (9.3% in leaf), Salinas-Moreno et al. (2013), and Barrios and Basso (2018) (7.28 - 8.81 and 9.5 - 10.9% in grain respectively). However, the protein content in WCG is higher than that reported by Rodríguez-Salinas et al. (2020) (9.72%) for PCG the value obtained in this study is below that reported by this author in pigmented maize (10.16 to 12.57%).

The highest fiber content was found in the leaves of both varieties, significant differences (P < 0.05) were observed in all samples (Table 1). The highest value was in PCL, while the lowest value was found in PCG. The content and composition of dietary fiber vary in different foods, just as in the same food the fiber concentration may differ according to its degree of maturity, refining, or technological treatment (Pak, 2000). The results obtained in cob are found within what was reported by Cardona et al. (2002); Michel-Aceves et al. (2008) and Infante et al. (2016); 32, 35 and 33%, respectively), while in leaf the results are higher than those reported by Cardona et al. (2002) (6.4%) and Infante et al. (2016) (31%).

In WCG and PCG the values were higher than those reported by Rodríguez-Salinas et al. (2020) in white corn grain (1.69%) and pigmented corn (1.20-1.76%), and the results are below the results reported by Méndez-Montealvo et al. (2005) (7 - 13%) but similar to that reported by Barrios and Basso (2018) (2.28 - 3.42%). Significant differences (P < 0.05) were found among all samples in carbohydrate content. In both varieties the highest content was found in the grains, followed by the cob, and in lower concentration in the leaves (Table 1). These differences are due to the type and variety of corn analyzed (Rodríguez-Salinas et al., 2020). The values found in cob are similar to those reported by Cardona et al. (2002) (54.5%), but in grain the values are within that reported by Méndez-Montealvo et al. (2005), Barrios and Basso (2018) and Rodríguez-Salinas et al. (2020) (70.50 – 77.6, 72.81 – 79.57 and 71.30 – 74.88 %, respectively).

Color and pH

The highest value of L^* was presented in WCL (81.71) and the lowest in PCL (63.82) (Table 2). Significant differences (P < 0.05) were observed among all the studied parts. The white coloration (white corn) is due to the presence of starch which is the major component. However, in the case of pigmented corn, the color of the grain in blue, light red, and magenta red corn is due to the fact that anthocyanins are located in the peripheral layers, in the aleurone, or in the pericarp. Therefore, the color tone depends on the type of anthocyanins that dominate the grain (Salinas-Moreno et al., 2012).

It has also been reported that, during grinding and homogenization, the color of the sample changes significantly, where L^* is the most affected parameter (Wrolstad and Smith, 2009). The results obtained in the grain of this work are below to those mentioned by Von-Atzingen et al. (2005) in corn (82.3) and higher than those reported by Salinas-Moreno et al. (2012) for three varieties of corn: blue, light red, and magenta red (38.5 - 51.4), Salinas-Moreno et al. (2013) in the grains of Purple corn of different races from the tropical region, and in maize from the subtropical region of Oaxaca (23.0 - 43.8 and 25.6 - 30.9, respectively), and by Moreira et al. (2015) in white, yellow and purple corn (53.80 – 66.41), but within what was reported by Rodríguez-Salinas et al. (2020) in white and pigmented corn (72.85 - 88.78).

The highest C* value was obtained in WCC while WCL obtained the lowest value. Significant differences (P < 0.05) were observed in all the samples analyzed. In the grain,

Table 1: Chemical composition (dry basic) of the different parts of white and purple corn

Composition (%)	WCG	WCC	WCL	PCG	PCC	PCL
Ash	5.22±0.36^{a}	5.38±0.09^{a}	2.75±0.16^{d}	2.34±0.13^{c}	0.96±0.06^{b}	3.22±0.04^{e}
Fatty	6.09±0.04^{a}	1.48±0.44^{b}	7.82±0.29^{d}	9.70±0.86^{e}	2.48±0.24^{c}	6.07±0.20^{a}
Proteins	15.85±1.96^{e}	5.40±1.16^{bc}	10.07±0.83^{d}	7.10±0.99^{c}	3.75±0.51^{ab}	2.74±0.93^{a}
Fiber	3.74±0.35^{c}	34.72±0.54^{e}	37.68±0.38^{a}	2.62±0.19^{b}	32.85±0.38^{d}	40.55±0.34^{a}
Carbohydrates	68.87±2.18^{e}	53.02±1.26^{c}	40.89±0.41^{a}	77.02±1.46^{f}	59.86±0.84^{d}	47.40±1.26^{b}

The values represent the average of 5 determinations±Standard deviation. Different letters between the same parts of the corn represent significant differences (P<0.05). WCG=white corn grains; WCC=white corn cob; WCL=white corn leaf; PCG=purple corn grains; PCC=purple corn cob; PCL=purple corn leaf

Table 2: Parameters of color and pH of the different parts of white and purple corn

Parameter	WCG	WCC	WCL	PCG	PCC	PCL
L^*	78.12±0.69^{a}	78.43±0.22^{a}	81.71±0.74^{e}	72.86±0.34^{c}	80.52±0.26^{d}	63.82±0.53^{b}
C*	17.33±0.37^{a}	19.61±0.71^{e}	17.28±0.58^{a}	18.38±0.24^{d}	16.46±0.44^{c}	4.70±0.27^{b}
h^{o}	57.70±0.74^{c}	55.96±0.49^{a}	55.37±0.79^{a}	60.79±0.30^{d}	56.84±0.38^{b}	88.28±0.86^{e}
ΔE	27.40±0.44^{b}	28.68±0.51^{c}	24.71±0.69^{a}	32.27±0.30^{d}	25.01±0.38^{a}	35.89±0.55^{e}
pH	6.19±0.08^{a}	6.19±0.03^{a}	6.34±0.04^{a}	6.40±0.17^{a}	5.58±0.36^{a}	6.70±0.01^{a}

The values represent the average of 5 determinations±Standard deviation. Different letters between the same parts of the corn represent significant differences (P<0.05). WCG=white corn grains; WCC=white corn cob; WCL=white corn leaf; PCG=purple corn grains; PCC=purple corn cob; PCL=purple corn leaf values are within what was reported by Salinas-Moreno et al. (2012) (11.1 - 25) and within what was reported by Rodríguez-Salinas et al. (2020) (3.24 – 32.10). While Salinas-Moreno et al. (2013), reported low values as reported in this study, in corn grain of races from tropical regions (4.9 - 9.2) and subtropical (2.2 - 8.8) of the State of Oaxaca., Mexico.

The highest value of *h°* was found in PCL, while the lowest value was in WCL, finding significant differences ($P < 0.05$) in all samples, this is because in the pigmented grains the coloration is not uniform along its surface, with lighter tones towards the face of the germ and the pedicel, so that, when grinding the sample to standardize the tone, the predominant tones are yellow. Espinosa-Trujillo et al. (2006) mention that the impact of the characteristics of the samples on the *h*° could be reduced if different ways of preparing them and placing them on the colorimeter are tested to achieve reproducible readings, and that they correspond to their visual appearance. These results are within the reported by Salinas-Moreno et al. (2013) in corn grain (10.4 - 123.4º) and for the reported by Rodríguez-Salinas et al. (2021) (19.65 – 85.16º).

In ΔE, significant differences ($P < 0.05$) were observed in all the samples analyzed (Table 2), finding the highest value of ΔE in PCL and the lowest value in WCL. This is because the color of corn varies widely between genotypes, and although it is not considered an important property for food use, it greatly influences consumer preference (Antuna-Grijalva et al., 2008). The ΔE in the same raw material is because the chemical characteristics of the vegetables depend largely on the characteristics of the soil from which they were harvested as well as environmental factors, such as drought or lack of nutrients, in addition to the content of Flavonoids present being responsible for natural color, including anthocyanins that are responsible for the colors pink, scarlet, red, blue and violet (Martínez-Malverde et al., 2000; Rodríguez-Miranda et al., 2011). The results found in this study in grain are below those reported by Antuna-Grijalva et al. (2008) in five types of creole corn (37.58 and 66.79, respectively) and higher than reported by Moreira et al. (2015) (7.11 – 9.72). The values obtained from the pH in all the samples were located within the acidic values of the pH scale (Table 2), showing significant differences ($P < 0.05$) between them. The highest pH value was found in PCL, while the lowest value was in PCC. The pH of the flours should range between 6.0 and 6.8; in this case, the pH was within this range, so, having low acidity, indicate a good state of preservation. These results are found within the values reported by Rodríguez-Zevallos and Soto-Chávarri (2006) in precooked white and yellow amylaceous cornmeal (6.2 to 6.5) and higher than reported by Abdoulaye et al. (2019) in grain corn from Ivory Coast (4.51).

Phytochemical profile

The results indicated that all the samples analyzed showed the presence of alkaloids, carbohydrates, phytosterols, phenols, and terpenoids (Table 3), in the glycoside and saponin test, all samples were negative. The WCG showed the lowest presence of phytosterols and phenols, while WCC showed a greater presence of all the compounds analyzed. The presence of these metabolites in the different parts of white and purple corn suggest that they could be a potential source of bioactive compounds with important biological activities since it has been reported that in the case of alkaloids, they have high toxicity against the cells of foreign organisms, which has been studied in the elimination and reduction of human cancer cell lines, and pain medications have been developed from this metabolite (Markert et al., 2008). Steroidal compounds are also of great interest due to the relationship they have with anabolic and sexual hormones, likewise, these compounds have shown antibacterial and antiviral activity (Wadood et al., 2013). These metabolites have also been reported in other extracts such as Castañeda et al. (2004), which showed a low concentration of alkaloids and a moderate concentration of carbohydrates in the methanolic extract of purple corn.

Total phenol and flavonoid content

The WCC (229.20 mg GAE/100 g) presented a greater amount ($P < 0.05$) of phenols than PCC (145.48 mg GAE/100 g) (Fig. 3). The lowest phenolic content was found in PCL and PCG, these differences could be attributed to the genetics of the genotypes, to their physical properties, primarily to the relative relationship of the anatomical parts of the corn, the variety, and the environmental conditions of the plants, as well as the differences in the preparation of the extracts, and the solvents used (Aguayo-Rojas et al., 2012; Urias-Peraldí et al., 2013). These results are superior to those reported by Gorriti-Gutiérrez et al. (2009) who found a total phenolic

Table 3: Phytochemical profile of the different parts of white and purple corn

Phytochemical screening		WCG	WCC	WCL	PCG	PCC	PCL
Test	Method						
Alkaloids	Dragendroff's	+++	+++	+++	+++	+++	+++
	Hager's	+++	+++	+++	+++	+++	+++
Carbohydrates	Benedict's	++	+++	+++	++	++	++
phytosterols	Salkowski's	++	+++	+++	++	+++	++
	Libermann Burchard	+	+++	+++	+++	+++	++
Phenols	Ferric Chloride	+	++	++	+	+++	+
Terpenoids	for terpenoids	+++	++++	++++	+++	++	++

+ = indicates presence of phytochemicals; - = indicates absence of phytochemicals.; +++++ = shows high concentration.; +++ = shows moderate concentration. WCG=white corn grains; WCC=white corn cob; WCL=white corn leaf; PCG=purple corn grains; PCC=purple corn cob; PCL=purple corn leaf

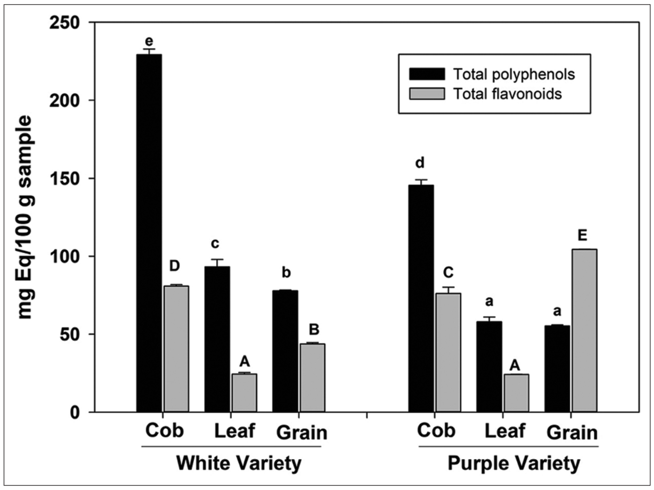

Fig 3. Content of phenols and total flavonoids in cob, leaf and grain of corn of the white and purple variety. Different letters between samples by determination there are significant differences (*P* < 0.05).

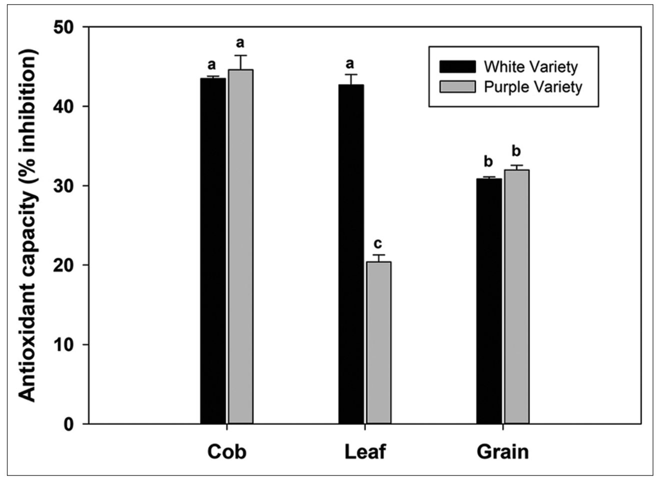

Fig 4. Antioxidant capacity in cob, leaf and grain of corn of the white and purple variety. Different letters between samples there are significant differences (*P* < 0.05).

content between 23.43 and 76.96 mg EGA/100 g in the cob of purple corn and below that reported by Sultana et al. (2008) in yellow corn cob. While the results found in the grain are below those reported by Jiménez-Nevárez et al. (2018), in blue corn grain (215 mg GAE/100 g) and Rodríguez-Salinas et al. (2020) (349.31 – 485.71 mg GAE/100 g).

The highest flavonoid content was found in PCG (104.30 mg CE/100 g), followed by WCC, and in a lower value, it was in the leaves regardless of the variety (Fig. 1). These differences are because the purple corn pigments are mainly extracted from the corn kernel and the crown, as they contain mainly Cyanidin-3-Glucoside (Li et al., 2008). The content of flavonoids WCC and PCC was higher than that reported by Sultana et al. (2008) in yellow corn cob (50 mg CE/100 g) and the case of grains, the results are within that reported by Rodríguez-Salinas et al. (2020) (22.50 – 105.75 mg CE/100 g) and superior to those reported by Quintanilla-Rosales et al., (2017) in pigmented corn genotypes (570.9 – 741.8 mg CE/100 g).

Antioxidant capacity

The cob of both varieties showed greater capacity to trap DPPH* radical (Fig. 4), while PCL was the one with the lowest antioxidant capacity, these results indicate that there is no direct relationship between polyphenol content and antioxidant capacity because other antioxidant compounds such as carotenes that are terpenes responsible for color in the white and yellow varieties of corn, especially in the form of lutein and zeaxanthin can be included in the extract (Gorriti-Gutiérrez et al., 2009; López-Martínez & García-Galindo, 2009), it has also been reported that the antioxidant capacity of the grains is mainly attributed to anthocyanins in red and blue/purple grains, however, phenolic acids and other colorless flavonoids, such as quercetin, which are extracted together with anthocyanins (Salinas-Moreno et al., 2012). Therefore, the free radical inhibitory activity depends on the amount and type of phenolic compounds such as anthocyanins and even carotenoids and other agro-environmental factors to which the plant is exposed, such as infections, UV radiation, conditions environmental conditions, low temperatures, droughts, and water stress, among others, that make plants produce these secondary metabolites as a defense mechanism to stress conditions and as protective agents against pathogens (Mex-Alvarez et al., 2013). The antioxidant capacity in cob was higher than that reported by Sultana et al. (2008) (26%) but in grain below that reported by López-Martínez and García-Galindo (2009) in white corn (40%).

CONCLUSION

The results showed that the inedible parts of corn could be a potential source of fiber and carbohydrates for use in the food industry, besides that they are a potential source of alkaloids, terpenoids, phytosterols, phenols, and glycosides which are secondary metabolites with important biological activities since all samples showed antioxidant activity so it gives added value to these agroindustrial waste.

Authors' contributions

Jesus Rodriguez-Miranda, Arely Carlos-Isidro, and Cecilia E. Martínez-Sánchez: Data Curation-Equal, Formal Analysis-Equal, Investigation-Equal, Methodology-Equal, Software-Equal, Validation-Equal, Writing- original draft-Equal. Erasmo Herman-Lara, Juan G. Torruco-Uco, and Rubén Santiago-Adame: Data Curation-Equal, Validation-Equal, Visualization-Equal, Writing-original draft-Equal. Betsabe Hernandez Santos: Conceptualization-Equal, Funding

Acquisition-Equal, Investigation-Equal, Methodology-Equal, Project Administration-Equal, Validation-Equal, Visualization-Equal, Writing-original draft-Equal, Writing-review & editing-Equal.

REFERENCES

Abdoulaye, T., O. S. Florence, A. Sylvie, S. A. Henri, S. Y. Réné and C. Adama. 2019. Physicochemical, nutritional and techno-functional characterization of flours of millet (*Pennisetum glaucum*), maize (*Zea mays*) and soy (*Glycine max*) grown in the north of Ivory Coast. Int. J. Biot. Trends Technol. 9: 11-17.

Aguayo-Rojas, J., S. Mora-Rochín, E. O. Cuevas-Rodríguez, S. O. Serna-Saldivar, J. A. Gutierrez-Uribe, C. Reyes-Moreno and J. Milán-Carrillo. 2012. Phytochemicals and antioxidant capacity of tortillas obtained after lime-cooking extrusion process of whole pigmented Mexican maize. Plant Food Hum. Nutr. 67: 178-185.

Ahmed, M., M. Ji, P. Qin, Z. Gu, Y. Liu, A. Sikandar, M. F. Iqbal and A. Javeed. 2019. Phytochemical screening, total phenolic and flavonoids contents and antioxidant activities of *Citrullus colocynthis* L. and *Cannabis sativa* L. Appl. Ecol. Environ. Res. 17: 6961-6979.

Amer, M. W., J. S. A. Alhesan, S. Ibrahim, G. Qussay, M. Marshall and O. S. Al-Ayed. 2021. Potential use of corn leaf waste for biofuel production in Jordan (physio-chemical study). Energy 214: 118863.

Antuna-Grijalva, O., S. A. Rodríguez-Herrera, G. Arámbula-Villa, A. Palomo-Gil, E. Gutiérrez-Arías, A. Espinosa-Banda and E. Andrio-Enríquez. 2008. Calidad nixtamalera y tortillera en maíces criollos de México. Rev. Fitotec. Mex. 31: 23-27.

AOAC. 2005. Official Methods of Analysis of AOAC. 18th ed. Association of Official Analytical Chemists, Gathersburg, MD, USA.

Barrios, M. and C. Basso. 2018. Efecto de la fertilización nitrogenada sobre componentes del rendimiento y calidad nutricional del grano de seis híbridos de maíz. Bioagro. 30: 39-48.

Cardona, M. G., J. D. Sorza, S. L. Posada, J. C. Carmona, S. A. Ayala and O. L. Alvarez. 2002. Establecimiento de una base de datos para la elaboración de tablas de contenido nutricional de alimentos para animales. Rev. Colomb. Cienc. Pec. 15: 240-246.

Castañeda, B., L. Ibañez and R. Manrique. 2004. Estudio fitoquímico y farmacológico del *Zea mays* L. amilaceae st (“maíz morado”). Acta. Méd. Sanmartiniana. 1: 1995-2005.

Córdoba, J. A., E. Salcedo, R. Rodríguez, J. F. Zamora, R. Manríquez, H. Contreras, J. Robledo and E. Delgado. 2013. Caracterización y valoración química del olote: Degradación hidrotérmica bajo condiciones subcríticas. Rev. Latinoam. Quím. 41: 171-184.

Danish, M., M. Naqvi, U. Farooq and S. Naqvi. 2015. Characterization of South Asian agricultural residues for potential utilization in future ’energy mix’. Energy Procedia. 75: 2974-2980.

Espinosa-Trujillo, E., M. D. C Mendoza-Castillo and F. Castillo-González, 2006. Diversidad fenotípica entre poblaciones de maíz con diferentes grados de pigmentación. Rev. Fitotec. Mex. 29:19-23.

Fall, A. D., A. N. Sy, J. B. H. Fokou, J. O. Ndiefifomi, M. Dieng, S. I. M. Dieng and E. Bassene. 2015. Phytochemical screening, polyphenol content and antioxidant studies of ethanol leaf extract of *Combretum aculeatum* Vent. Eur. J. Med. Plants. 10: 1-7.

Food and Agriculture Organization (FAO). Available from: https://www.faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor [Last accessed on 2021 Jul 17].

Gao, M., H. Zou, W. Tian, D. Shi, H. Chai, L. Gu, Q. He and W. Z. Tang. 2021. Co-digestive performance of food waste and hydrothermal pretreated corn cob. Sci. Total Environ. 768: 144448.

Gorriti-Gutiérrez, A., J. Arroyo-Acevedo, J. Negrón-Vallarte, B. Jurado-Teixeira, H. Purizaca-Llajaruna, H. Santiago-Aquise, E. TaypeEspinoza and F. Quispe-Jacobo. 2009. Antocianinas, fenoles totales y actividad antioxidante de las corontas del maíz morado (*Zea mays* L.): Método de extracción. Bol. Latinoam. Caribe Plantas Med. Aromát. 8: 509-518.

Hernández-Delgado, S., M. A. Reyes-López, J. G. García-Olivares, N. Mayek-Pérez and C. A. Reyes-Méndez. 2007. Incidencia de hongos potencialmente toxígenos en maíz (*Zea mays* L.) almacenado y cultivado en el norte de Tamaulipas, México. Rev. Mex. Fitopatol. 25: 127-133.

Infante, C., B. Cuadrado, D. De Arco, K. Perez, E. Barrera and M. San Juan. 2016. Evaluación de tusa y cáscara de maíz como sustratos para el cultivo de Pleurotus pulmonarius. Rev. Cienc. y Tecnol. 32: 31-46.

Jiménez-Nevárez, Y., J. Milán-Carrillo, S. Mora-Rochín, A. Montoya-Rodríguez, C. Reyes-Moreno, E. Cuevas-Rodríguez, P. C. Reyes-Fernández and E. M. Milán-Noris. 2018. Características tecnológicas y fitoquímicas de maíz criollo raza elotero de Sinaloa. Invest. Des. en Cienc. Tecnol. Aliment. 3:616-620.

Juárez-Barrientos, J. M., B. Hernández-Santos, E. Herman-Lara, C. E. Martínez-Sánchez, J. G. Torruco-Uco, E. Ramírez-Rivera and J. Rodríguez-Miranda. 2017. Effects of boiling on the functional, thermal and compositional properties of the Mexican jackfruit (*Artocarpus heterophyllus*) seed Jackfruit seed meal properties. Emir. J. Food Agric. 29: 1-9.

Li, C. Y., H. W. Kim, S. R. Won, H. K. Min, K. J. Park, J. Y. Park, M. E Ahn and H. I. Rhee. 2008. Corn husk as a potential source of anthocyanins. J. Agric. Food Chem. 56: 11413-11416.

López-Martínez, L. X. and H. S. García-Galindo. 2009. Actividad antioxidante de extractos metanólicos y acuosos de distintas variedades de maíz mexicano. Nova Sci. 2: 51-56.

Markert, A., N. Steffan, K. Ploss, S. Hellwig, U. Steiner, C. Drewke, S. M. Li, W. Boland and E. Leistner. 2008. Biosynthesis and accumulation of ergoline alkaloids in a mutualistic association between *Ipomoea asarifolia* (*Convolvulaceae*) and a clavicipitalean fungus. Plant Physiol. 147: 296-305.

Martínez-Malverde, I., M. J. Periago and G. Ros. 2000. Significado nutricional de los compuestos fenólicos de la dieta. Arch. Latinoam. Nutr. 50: 5-18.

Méndez-Montealvo, G., J. Solorza-Feria, M. Velázquez del Valle, N. Gómez-Montiel, O. Paredes-López and L. A. Bello-Pérez. 2005. Composición química y caracterización calorimétrica de híbridos y variedades de maíz cultivadas en México. Agrocienc. 39:267-274.

Mex-Alvarez, R. M. J., N. J. Bolívar-Fernández, P. M. Garma-Quen, J. Tut-Heredia and K. I. Romero-Guillén, 2013. Actividad antioxidante de cinco variedades de maíz cultivadas en Campeche, México. Bol. latinoam. Caribe Plantas Med. Aromát. 12: 558-571.

Michel-Aceves, A. C., M. A. Otero-Sánchez, R. D. Martínez-Rojero, N. L. Rodríguez-Morán, R. Ariza-Flores and A. Barrios-Ayala. 2008. Producción masiva de Trichoderma harzianum Rifai en diferentes sustratos orgánicos. Rev. Chapingo Ser. Hortic. 14: 185-191.

Moreira, R., F. Chenlo, S. Arufe and S. N. Rubinos. 2015. Physicochemical characterization of white, yellow and purple maize flours and rheological characterization of their doughs. J. Food Sci. Technol. 52: 7954-7963.

Nguyen, M. T., V. T. Nguyen, V. M. Le, L. H. Trieu, T. D. Lam, L. M. Bui,

T. H. Nhan and V. T. Danh. 2020. Assessment of preliminary phytochemical screening, polyphenol content, flavonoid content, and antioxidant activity of custard apple leaves (*Annona squamosa* Linn.). In IOP Conf. Ser. Mater. Sci. Eng. 736: 1-6.

Pak, D. N. 2000. Fibra dietética en verduras cultivadas en Chile. Arch. Latinoam. Nutr. 50: 97-101.

Ponce, J., J. G. da Silva Andrade, L. N. dos Santos, M. K. Bulla, B. C. B. Barros, S. L. Favaro, N. Hioka, W. Caetano and V. R. Batistela. 2021. Alkali pretreated sugarcane bagasse, rice husk and corn husk wastes as lignocellulosic biosorbents for dyes. Carbohydr. Polym. Technol. Appl. 2: 100061.

Prado-Martínez, M., J. Anzaldo-Hernández, B. Becerra-Aguilar, H. Palacios-Juárez, J. D. J. Vargas-Radillo and M. Rentería-Urquiza. 2012. Caracterización de hojas de mazorca de maíz y de bagazo de caña para la elaboración de una pulpa celulósica mixta. Madera Bosque. 18: 37-51.

Pratheep, V. G., E. B. Priyanka, S. Thangavel, J. J. Gousanal, P. B. Antony and E. D. Kavin. 2021. Investigation and analysis of corn cob, coir pith with wood plastic composites. Mater. Today: Proc. 45: 549-555.

Quintanilla-Rosales, V. L., K. Galindo-Luna, F. Zavala-García, J. A. Pedroza-Flores, J. B. Heredia, V. Urías-Orona, M. D. Muy-Rangel and G. Niño-Medina. 2017. Fenólicos solubles de tipo flavonoide y capacidad antioxidante en genotipos criollos pigmentados de maíz (*Zea mays*). ITEA, Inform Téc. Económ. Agra. Rev. Asoc. Interprof. Des. Agra. (AIDA). 113: 325-334.

Ramos, A., A. Briga-Sá, S. Pereira, M. Correia, J. Pinto, I. Bentes and C. A. Teixeira. 2021. Thermal performance and life cycle assessment of corn cob particleboards. J. Build. Eng. 44: 102998.

Rodríguez-Miranda, J., J. M. Rivadeneyra-Rodríguez, E. Ramírez-Rivera, J. M. Juárez-Barrientos, E. Herrera-Torres, R. O. Navarro-Cortez and B. Hernández-Santos. 2011. Caracterización fisicoquímica, funcional y contenido fenólico de harina de malanga (*Colocasia esculenta*) cultivada en la Región de Tuxtepec, Oaxaca, México. Cienc. Mar. 15: 37-47.

Rodríguez-Salinas, P. A., F. Zavala-García, V. Urías-Orona, D. Muy-Rangel, J. B. Heredia and G. Niño-Medina. 2020. Chromatic, nutritional and nutraceutical properties of pigmented native maize (*Zea mays* L.) genotypes from the Northeast of Mexico. Arab. J. Sci. Eng. 45: 95-112.

Rodríguez-Zevallos, A. R. and L. Soto-Chávarri. 2006. Características fisicoquímicas y comportamiento reológico de harinas precocidas de maíz amiláceo (*Zea mays* L.) blanco y amarillo. Pueblo Continente. 17: 11-16.

Ruiz-Torres, N. A., F. Rincón-Sánchez, V. M. Hernández-López, J. D. Figueroa-Cárdenas and M. G. F. Loarca-Piña. 2008. Determinación de compuestos fenólicos y su actividad antioxidante en granos de maíz. Rev. Fitotec. Mex. 31: 29-31.

Salinas, M. Y., R. J. Soria and T. E. Espinosa. 2010. Aprovechamiento y distribución de maíz azul en el Estado de México. INIFAP. 42: 1-56.

Salinas-Moreno, Y., F. Aragón-Cuevas, C. Ybarra-Moncada, J. Aguilar-Villarreal, B. Altunar-López and E. Sosa-Montes. 2013. Caracterización física y composición química de razas de maíz de grano azul/morado de las regiones tropicales y subtropicales de oaxaca. Rev. Fitotec. Mex. 36: 23-31.

Salinas-Moreno, Y., F. J. Cruz-Chávez, S. A. Díaz-Ortiz and F. Castillo-González. 2012. Granos de maíces pigmentados de Chiapas, características físicas, contenido de antocianinas y valor nutracéutico. Rev. Fitotec. Mex. 35: 33-41.

Sultana, B., F. Anwar, M. R. Asi and S. A. S. Chatha. 2008. Antioxidant potential of extracts from different agro wastes: Stabilization of corn oil. Grasas Aceites. 59: 205-217.

Tiwari, P., B. Kumar, M. Kaur, G. Kaur and H. Kaur. 2011. Phytochemical screening and extraction: A review. Int. Pharm. Sci. 1: 98-106.

Treviño, J., M. T. Hernández and R. Caballero. 2011. Estudio del valor nutritivo de las hojas y tallo del maíz híbrido de tallo azucarado E-10. Pastos. 4: 286-292.

Urias-Peraldí, M., J. A. Gutiérrez-Uribe, R. E. Preciado-Ortiz, A. S. Cruz-Morales, S. O. Serna-Saldívar and S. García-Lara. 2013. Nutraceutical profiles of improved blue maize (*Zea mays* L.) hybrids for subtropical regions. Field Crop. Res. 141: 69-76.

Von Atzingen, M. C. and M. E. Machado Pinto e Silva. 2005. Evaluación de la textura y color de almidones y harinas en preparaciones sin gluten. CYTA. J. Food. 4: 319-323.

Wadood, A., M. Ghufran, S. B. Jamal, M. Naeem, A. Khan and R. Ghaffar. 2013. Phytochemical analysis of medicinal plants occurring in local area of Mardan. Biochem. Anal Biochem. 2: 1-4.

Wang, Q., H. Tian, J. Miao, C. Zhang, J. Zhang, Y. Zhang and Y. Guo. 2021. A waste corn cob core-derived SiO_2 @ graphene-like carbon nanocomposite and its application in lithium-ion battery. J. Mater. Sci. Mater. Electron. 32: 1-11.

Wrolstad, R. E. and E. D. Smith. 2009. Color Analysis. In: E. S. Nielsen (Ed.), Food Analysis. 4th ed. Springer Purdue University, West Lafayette, USA. p. 575-586.