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Comparative Study of Physicochemical and Technological Characteristics in Some White and Yellow Corn Hybrids

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ABSTRACT

This study aimed to assess the quality characteristics of two white corn hybrids SC131, and TWC 321, and three yellow corn hybrids: SC176, SC181, and TWC354. The impact of those hybrids in tortillas processing were investigated. The white corn hybrid SC131 had the largest significant thousand kernel weight. The whole meal yellow corn hybrids considerably contained more protein, fats, ash, crude fiber, and total carotenoids content than white corn whole meal. White corn had more starch and amylose. Yellow corn whole meal had greater levels of potassium, zinc, iron, and phosphorus. Protein digestibility value was higher in yellow corn than white corn hybrids. The yellowness values of the yellow corn tortillas were greater than white corn tortillas. All tortilla samples prepared with white and yellow corn flour had high overall acceptability scores, with SC131 being the most acceptable hybrid. These results could be useful in identifying the suitable corn hybrids with required nutrients content, toward targeting specific industrial uses and accordingly recommending its cultivation in breeding programs.

1. Introduction

Corn (*Zea mays* L.), a major grain crop in the Poaceae family, is used in the food and feed industries for various products. Its output includes starch, dextrose, high fructose corn syrup, glucose syrup, corn oil, flakes, and animal and poultry feed (Gul et al., 2021). It is considered the queen of cereal crops and the third most popular cereal grain globally because of its high yield and nutritional value. Approximately 1163.50 million Tons of maize are produced worldwide across more than 170 nations on an area of 203.47 million hectares. Globally, maize consumption is predominantly for feed (61%), followed by industrial uses (22%), and food (17%), reflecting its crucial role in the global agricultural economy (FAOSTAT, 2022). Corn, often known as maize, is considered Egypt's third-most significant basic food crop, behind rice and wheat. In Egypt, 930.0 thousand hectares of the total agricultural land are utilized for cultivating maize with an average of 8.064 tons produced per hectare. Corn's adaptability allows it to grow in a range of agroecological environments (FAOSTAT, 2022). One notable variation in corn is the kernel's color, which can be white, yellow, red, or black. Corn contains an abundance of macronutrients, such as starch, fibers, protein, and fats, as well as micronutrients, such as ß-carotene, magnesium, phosphorus, and copper (Ranum et al., 2014). Corn can be broadly categorized into two types that are produced extensively: yellow and white corn, based on the color of the endosperm, and the primary corn type in many regions of Africa, Central, and South America is white corn grains (Mukri et al., 2018). Globally, white corn grains are favored over yellow corn for human consumption, even though yellow corn is mostly used as animal and poultry feed (Ekpa et al., 2018). The food processing and corn meal sectors also find white corn beneficial (Gwirtz and Garcia-Casal, 2014). Yellow corn is rich in β-carotene, a yellow-orange pigment that gives fruits, vegetables and some grains their yellow color (Kaul et al., 2019). Besides adding yellow corn to a food product, a number of biologically active substances add unique biological value and functional characteristics.

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These substances could contain antioxidants like carotenoids, which are essential for scavenging free radicals and promoting cellular health (Saini et al., 2021). Milling of corn kernels produces corn flour, a multipurpose and extensively utilized ingredient worldwide. Corn flour is distinguished by its color (white, yellow, red, and black), and somewhat sweet taste that goes well with a range of recipes such as corn bread, tortillas, pasta, and other different baked items, as well as gluten-free products (El Khoury et al., 2018 and Kumari, 2019). Individuals diagnosed with gluten disorders must strictly follow a gluten-free diet (Wang et al., 2017). The market for corn tortillas and tortilla chips has seen global growth (Cortés-Gómez et al., 2005). It is considered an excellent source of calories due to its high starch content and adequate level of micronutrients such as zinc, iron, fibers, and vitamins (Martínez-Velasco et al., 2018 and Serna-Saldivar, 2015). It is valued for its ability to produce flavorful, well-textured products (Woomer and Adedeji, 2021). Some corn hybrids have affected processing efficiencies, potentially lowering industrial conversion costs (Anderson and Almeida, 2019). Another advancement for corn hybrids could be that the structure, physical features, chemical, nutritional, and technological properties, along with the morphology of the corn starch, have a great impact on the texture, appearance, and nutritional value of food products, which determines how they can be used (Anderson and Almeida, 2019 and Serna-Saldivar and Carrillo, 2019). Thus, the study objective was designed to evaluate the selected white and yellow corn hybrids for their physical, chemical, and technological characteristics in relation to those hybrid types, which affect their suitability for bakery products like tortilla preparation.

2. Materials and Methods

Materials

Two white corn hybrids, namely SC131, and TWC321, and three yellow corn hybrids namely SC176, SC181, and TWC354 were obtained from the Maize Research Department, Field Crops Research Institute, Agricultural Research Center, Egypt. The pancreatin and pepsin enzymes, amylose, and β-carotene standards were obtained from the Sigma-Aldrich-Chemical Company (St. Louis, USA). The grade of the other chemicals was analytical reagent.

Methods

Weight of thousand kernels, and constituent parts of corn kernels

Following the AACC (2002) methods, the weight of 1000-kernels and their separate parts (endosperm, germ, and pericarp) percentages were calculated. The thousand weight of kernels were measured using a digital balance and expressed in grams. Kernel corn parts were estimated by submerging corn kernels in water for 12 hs, and then parts were separated. The kernel parts were dried at 60°C for 12 hs, and the percentage of each part was calculated.

Corn milling

In order to get corn whole meal for chemical analysis, corn grains were inspected to remove broken grains and extraneous materials, and then were milled to obtain whole meal by a high-speed grinder (MDY-2000, China). The corn whole meal samples were sealed in polyethylene bags and stored in a freezer until further investigation.

Analysis of corn whole meal

Measurement of color

The color of the corn whole meal, and tortilla samples was assessed using a hand-held Chromameter (model CR-400, Konica Minolta, Japan). The outcomes were given as follows: b^* (yellowness to blueness), a^* (redness to greenness), and L^* (lightness).

Proximate chemical composition

The AOAC (2019) method assessed the amount of fat, protein, ash, moisture, and crude fibers in samples. The amount of total carbohydrates present on a dry weight basis was calculated by difference. The total carbohydrates=100 - (protein + fat + ash + crude fibers). Averages of three replicates were used to determine the proximate composition values. The energy value (kcal/100g) was calculated using the P×4.0+F×9.0+C×4.0 equation, and the P, F, and C for protein, fat, and carbohydrate contents, respectively, in percentage terms. By employing Agilent Technologies Microwave Plasma Atomic Emission Spectrometers (Model 4210 MPAES, USA), the concentrations of potassium, iron and zinc were assessed in samples in accordance with the procedure described in the AOAC (2019). The colorimetric method of Trough and Mayer (1929) was used to determine phosphorus content. The Juliano (1971) method was used to determine the amylose content, and the percentage of amylopectin was calculated by subtracting amylose percentage. The content of starch was determined according to Ranganna (1977). Total carotenoids content was measured using the Santra et al. (2003) method.

Protein digestibility of whole meal

The in vitro protein digestibility of whole meal corn was determined by the enzymatic digestion of samples with pepsin, and pancreatin for Akeson and Stahmann (1964). The protein in the supernatant was estimated using the Kjeldahl method AOAC (2019). The percentage of protein digestibility was calculated by the ratio of nitrogen in the supernatant to nitrogen in the sample as the following equation:

Protein digestibility (%)=[(N in supernatant - N in Blank)/N in sample]×100, Where N is Nitrogen.

Tortilla preparation

For tortilla preparation, the whole meal was sieved using a 60-mesh sieve to get fine flour (the maximum particle size range was around 250 microns). 200 grams of yellow corn flour were placed on the hot plate with 2 milliliters of corn oil and were combined for two minutes using the method stated by Rendon et al. (2009) with minor modification. The combination of corn flour and oil was mixed with 120 milliliters of boiling water, and the mixture was stirred until a dough was formed. The dough was divided into portions, each weighing thirty-five grams. Every component was shaped into a thin, spherical layer (one-millimeter thickness), and then was baked for thirty seconds on the first and forty seconds on the second side at 250°C on a hot plate. After that, samples were allowed to cool at around 25°C for three minutes, and the tortilla was backed in polyethylene bags until chemical composition, color parameters analysis and sensory evaluation.

Sensory evaluation

The sensory evaluation was done by fifteen well-trained panelists from the Food Technology Research Institute, Agricultural Research Center. A hedonic scale with seven points was employed according to Meilgaard et al. (2007). The greatest rating was seven for like very much, and the lowest rating was for dislike very much.

Statistical analysis

The acquired data were subjected to an ANOVA analysis of variance. The means were compared using Duncan's multiple range test at 5% level. The chosen data for corn analysis were subjected to a correlation test by using SPSS version 21 (Elliott and Woodward, 2007).

3. Results and discussion

The weight of a thousand kernel, and the individual parts of corn hybrid kernels

Table 1 presents corn hybrids' thousand kernel weight and kernel component parts (endosperm, germ, and pericarp). The results showed that white corn hybrid SC131 had the highest thousand kernel weight followed by TWC321 (357.0 and 352.10g, respectively). In contrast, yellow TWC354 had the lowest thousand kernel weight (328.0g). These findings follow the same pattern as those by Kljak et al. (2020) who reported that the weight of 1000-kernels varied from 270.0 to 397.0 g. Based on the data, the endosperm is considered the biggest portion of grains, and results showed that there were significant differences between white and yellow corn hybrids in endosperm percentage. White hybrids TWC321 followed by SC131, had significantly the highest endosperm percentage (82.03 and 81.82%, respectively), while yellow corn hybrids SC181 and SC176 had the lowest endosperm percentage (79.40 and 79.16%, respectively), and the results suggested that white corn hybrids may be suitable for corn flour production. Significant variations were observed in the germ percentages between the two types of hybrids. The highest germ percentage was found in yellow corn hybrids SC176 and SC181 (12.96 and 12.84%, respectively), and this could be useful for oil production. The white corn hybrids TWC321 hybrid had the lowest germ percentage followed by the SC131 hybrid. In the same Table, results showed that there were no significant differences ($p>0.05$) among corn hybrids pericarp percentage, which ranged from 7.63 to 7.88%. The findings are consistent with El-Mekser et al. (2020). According to Berger and Singh (2010), corn kernel consists of three main parts: pericarp (5.0–6.0%), germ (10.10–12.0%), and endosperm (80.0–85.0%).

Table 1. The weight of thousand kernels and the constituent kernel parts of corn hybrids

Corn hybrids	1000-Kernels weight (g)	Endosperm (%)	Germ (%)	Pericarp (%)
White SC131	357.00^{a}±0.14	81.82^{a}±0.18	10.45^{c}±0.10	7.73^{a}±0.25
White TWC321	352.10^{b}±0.85	82.03^{a}±0.09	10.32^{c}±0.07	7.65^{a}±0.17
Yellow SC176	336.50^{c}±0.70	79.16^{c}±0.07	12.96^{a}±0.05	7.88^{a}±0.10
Yellow SC181	330.20^{d}±1.14	79.40^{c}±0.03	12.84^{a}±0.04	7.76^{a}±0.06
Yellow TWC354	328.00^{d}±1.10	80.21^{b}±0.13	12.16^{b}±0.03	7.63^{a}±0.09

The data are means ± standard deviation of three measurements, and means in the same column with different letters are significantly different at 0.05.

Corn hybrid's whole meal characteristics

Color values of the corn hybrids

Table (2) displays the corn hybrid whole meal $L*$, $a*$, and $b*$ values. Significant variations were noticed in the color properties among the corn hybrids, which may influence the final food product. The SC131 hybrid had the highest $L*$ value (91.10), followed by TWC321 (90.62). The redness result for white corn hybrids flour was close to zero (0.18 and 0.29), suggesting that red color did not predominate over the green color. Because of the high concentration of carotenoids, yellow SC176 and 181 hybrid had the highest yellowness values (33.57 and 31.70, respectively), corresponding to their yellow color. The white corn SC131 has the lowest $b*$ value (12.33). Ranum et al. (2014) mentioned that the corn kernels' color varies from white to yellow, red, or black. Kljak et al. (2012) declared that the total carotenoids content and the $b*$ value had a strong positive relationship. Additionally, Chandler et al. (2013) revealed a correlation between the yellow or orange hue of endosperm and the presence of carotenoids.

Table 2. Color values of corn hybrids whole meal

Corn hybrids	$L*$	$a*$	$b*$
White SC131	91.10^{a}±0.03	0.29^{c}±0.06	12.33^{d}±0.13
White TWC321	90.62^{a}±0.03	0.18^{c}±0.03	12.86^{d}±0.06
Yellow SC176	81.57^{d}±0.35	3.56^{a}±0.05	33.57^{a}±0.52
Yellow SC181	82.49^{c}±0.58	3.46^{a}±0.05	31.70^{b}±0.06
Yellow TWC354	84.76^{b}±0.06	3.11^{b}±0.01	28.73^{c}±0.57

*L stand for lightness, (a) for redness, and (b) for yellowness. The data are means ± standard deviation of three measurements, and means in the same column with different letters are significantly different at 0.05.

Chemical composition and total carotenoids of corn hybrids whole meal

The chemical composition and total carotenoids content of corn meal whole are presented in Table 3. All white and yellow corn hybrids in the study had moisture contents below 10%, with values ranging from 9.24 to 9.39%, this may be indicated that they were appropriate for long-term storage. The results are aligning with previous literature (Enyisi et al., 2014). According to Kumari et al. (2020), flours with lower moisture content keeps longer on the shelf life because microbes or other biochemical reactions are less likely to cause it to spoil. The findings showed that yellow corn had a higher protein content than white corn. The variation in protein content between the two types of corn can contribute to agronomic practices, diverse environmental conditions, and the corn types. Yellow hybrid SC181 had the highest protein content (9.48%). This outcome is consistent with Arora et al. (2024).

In addition, yellow SC176 has a noticeably higher fat content (4.17%) than other corn hybrids. While, white TWC321 corn hybrid has the lowest fat content (3.00%). El-Mekser et al. (2020) reported that the fat range in corn flour was 3.25-4.22%. From the data in Table 2, the crude fiber contents in the two types of corn varied between 2.45 and 2.63%. The yellow corn hybrids showed higher fiber contents relative to white corn hybrids. These results were in line with those of Mlay et al. (2005), since the yellow corn flour bran has higher fiber contents. There were significant differences between yellow and white corn hybrids in ash content. The ash content of yellow corn, as indicated in Table 3, is significantly higher than that of white corn; it ranged from 1.22 to 1.39% for SC131 and SC176, respectively. The results are agree with the findings of El-Mekser et al. (2020). Ash content is particularly related to the mineral composition existing in a food material and is a measure of the total amount of mineral ingredients in food goods (Adigwe et al., 2023). The composition of corn species and subspecies varies significantly due to geographical and environmental factors (Qamar et al., 2017). Starch content ranged from 64.58 to 65.72%, which is in the range of those findings by Arnold et al. (2019); Nankar et al. (2016) and Weiss et al. (2023). The white hybrid SC131 had the highest starch content, followed by TWC321. Besides, the starch content in corn negatively correlated with protein content (Weiss et al., 2023). The largest-sized corn grains have the highest starch content because grain mass influences starch formation more than grain color (Özdemir et al., 2023). Results in the same Table showed that the total carotenoids in the yellow corn hybrid were higher than those in the white corn hybrid; SC176 had the highest amount of total carotenoids (11.80 mg/kg). Processing, maturity phases, and genetic variables affect corn composition (Rios et al., 2014). Varied corn hybrids have dramatically varied quantities of phytonutrients such as carotenoids (Pelissari et al., 2008). There is a correlation between the presence of carotenoids and the yellow color of the endosperm and changes in the carotenoid profile in the corn kernel have been linked to genotype and environment interaction (Chandler et al., 2013 and Rios et al., 2014).

Table 3. Proximate chemical composition and total carotenoids content of corn hybrids whole meal o (on dry weight basis)

Corn hybrids	Moisture (%)	Protein (%)	Fats (%)	Crude fibers (%)	Ash (%)	Starch (%)	Total carotnoids (mg/kg)
White SC131	9.24^{b}±0.03	8.72^{d}±0.04	3.25^{c}±0.08	2.46^{b}±0.06	1.22^{c}±0.03	65.72^{a}±0.08	2.12^{d} ±0.03
White TWC321	9.39^{a}±0.08	8.58^{e}±0.05	3.00^{d}±0.14	2.45^{b}±0.09	1.29^{bc}±0.07	65.06^{b}±0.35	2.33^{d}±0.13
Yellow SC176	9.34^{ab}±0.02	9.27^{b}±0.03	4.17^{a}±0.06	2.63^{a}±0.08	1.39^{a}±0.08	64.91^{bc}±0.06	11.80^{a}±0.13
Yellow SC181	9.30^{ab}±0.04	9.48^{a}±0.05	3.68^{b}±0.08	2.58^{ab}±0.07	1.37^{ab}±0.06	64.71^{cd}±0.09	11.37^{b}±0.09
Yellow TWC354	9.29^{ab}±0.02	9.14^{c}±0.06	3.33^{b}±0.05	2.51^{ab}±0.06	1.30^{abc}±0.01	64.58^{d}±0.11	10.16^{c}±0.11

The data are means ± standard deviation of three measurements, and means in the same row with different letters are significantly different at 0.05.

Amylose, and amylopectin content of corn hybrids

Amylose, amylopectin content and amylose/amylopectin ratio of the corn hybrids are shown in Figure 1. Amylose is a linear glucose polymer, and normal corn starch is composed of 30% primarily linear amylose and 70% highly-branched amylopectin, which are organized in granules with a semi-crystalline structure of double helices (Jiang et al., 2010 and Takeda et al., 1987). Figure 1 shows that the variation in corn hybrids affects the amylose content, and there were significant differences between corn hybrids. White corn hybrids flour had higher amylose content relative to yellow corn hybrids. The amylose percentage varied from 23.13 to 27.65%. Regarding the amylopectin percentage in corn hybrid, the data ranged between 72.35 and 76.87%, Yalçın et al. (2020) reported that amylose and amylopectin contents were between 25-28% and 72-75%, respectively, while the amylopectin/amylose varied between 0.30 and 0.38. The corn amylose/ amylopectin ratio is near 0.38 (Özdemir et al., 2023). The amylose/ amylopectin ratio, and structure arrangement, form, and position of the starch molecules and interactions with other molecules measure the physicochemical and functional properties of starch (Shevkani et al., 2017 and Yalçın et al., 2020). Yalçın et al. (2020) observed that the amylose/amylopectin ratio is an important factor that also influences starch digestion.

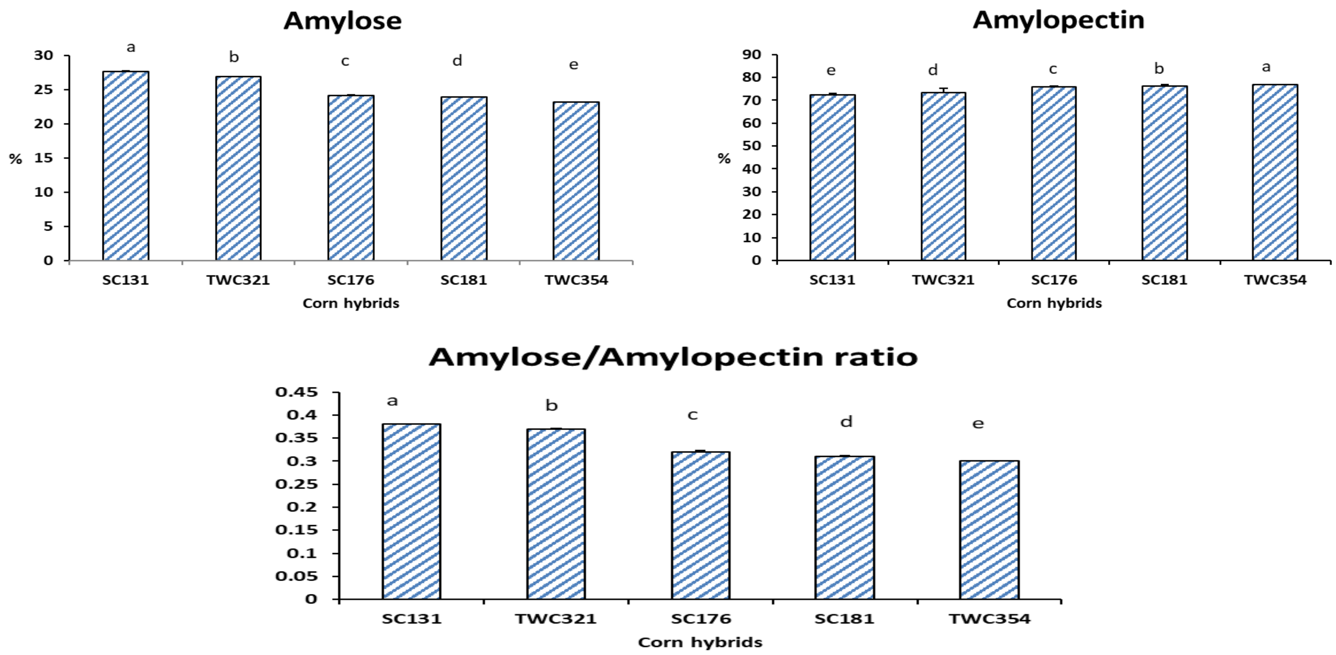

Figure 1. Amylose, amylopectin content, and amylose/amylopectin ratio of corn hybrids
The data are means ± standard deviation of three measurements, and means with different letters are significantly different at 0.05.

Minerals content of corn hybrids whole meal

Table 4 shows the corn hybrids' mineral content (potassium, phosphorus, zinc, and iron). The yellow corn hybrid SC176 had the highest levels of potassium, iron, and zinc with values of 292.0, 2.62, and 1.60 mg/100g, respectively, while the highest phosphorus content was 194.0 mg/100 g in the yellow hybrid SC181. The results indicated that the yellow corn hybrids contained more minerals than white hybrids. These findings align with those of Qamar et al. (2017), who found that white and yellow corn flour have a higher concentration of most minerals.

Table 4. Minerals content (mg/100g) in whole meal corn hybrids

Corn hybrids	Potassium	Phosphorus	Iron	Zinc
White SC131	263.50^{c} ±2.12	183.0^{bc}±1.40	2.38^{bc}±0.06	1.38^{b}±0.06
White TWC321	265.50^{c}±4.95	180.0^{c}±2.82	2.26^{c}±0.03	1.27^{c}±0.042
Yellow SC176	292.0^{a}±5.65	189.0^{ab}±1.42	2.62^{a}±0.03	1.60^{a}±0.03
Yellow SC181	283.50^{ab}±4.94	194.0^{a}±5.65	2.58^{a}±0.04	1.52^{a}±0.02
Yellow TWC 354	273.0^{bc}±4.24	186.0^{abc}±1.38	2.45^{b}±0.070	1.40^{b}±0.02

The data are means ± standard deviation of three measurements, and means in the same column with different letters are significantly different at 0.05.

Correlations between some physical, and chemical components of corn hybrids

Table 5 shows the correlations between the data for corn hybrids' physical and chemical composition, minerals, and total carotenoids. The 1000-kernel weight had a strong positive correlation with protein and amylose contents (r= 0.872 and 0.988, respectively, at p= 0.05) and a medium positive correlation with fat content (r= 0.582), which may be related to the corn hybrid types and agronomic practice.

Table 5. Correlation coefficients between some physical and chemical components of some corn hybrids*

Item	1000 Kernel weight	Endosperm	Germ	Peric-arp	Prot-ein	Fats	Crude fibers	Ash	Starch	Amylose	Lightness	Yellowness	Total carotenoids	Potassium	Phosphorus	Iron	Zinc
1000 kernel weight	1																
Endosperm	0.850*	1															
Germ	0.880	-0.995*	1														
Pericarp	-0.102	-0.485	0.400	1													
Protein	0.872*	0.957*	0.961*	0.382	1												
Fats	0.582	-0.896*	0.869*	0.641*	0.788*	1											
Crude fiber	-0.323	-0.565	0.551	0.378	0.484	0.647*	1										
Ash	-0.322	-0.471	0.449	0.413	0.440	0.482	0.709*	1									
Starch	0.624	0.277	-0.311	0.197	-0.255	0.004	0.036	-0.278	1								
Amylose	0.988*	0.866*	-0.896*	-0.115	-0.850*	-0.622	-0.392	-0.335	0.613	1							
Lightness	0.874*	0.992*	-0.994*	-0.422	-0.944*	-0.868*	-0.599	-0.526	0.357	0.896*	1						
Yellowness	-0.913*	-0.986*	0.993*	0.367	0.944*	0.848*	0.553	0.473	-0.391	-0.932*	-0.994*	1					
Total carotenoids	-0.926*	-0.982*	0.991*	0.348	0.946*	0.826*	0.536	0.443	-0.404	-0.944*	-0.990*	0.999*	1				
Potassium	-0.653*	-0.915*	0.895*	0.582	0.798*	0.908*	0.453	0.386	-0.205	-0.686*	-0.894*	0.868*	0.856*	1			
Phosphorus	-0.696*	-0.823*	0.822*	0.374	0.854*	0.673*	0.245	0.238	-0.093	-0.665*	-0.782*	0.781*	0.782*	0.772*	1		
Iron	-0.671*	-0.937*	0.908*	0.676*	0.896*	0.909*	0.657*	0.466	0.002	-0.689*	-0.902*	0.879*	0.873*	0.852*	0.788*	1	
Zinc	-0.568	-0.898*	0.865*	0.699*	0.816*	0.936*	0.541	0.406	0.096	-0.598	-0.853*	0.828*	0.813*	0.902*	0.817*	0.950*	1

*Correlation between variables is significant at the 0.05 level (2-tailed).

Furthermore, there was a positive correlation between the 1000-kernel weight and percentages of endosperm and germ (r=0.850 and 0.880, respectively). Besides, a significant positive correlation was found between endosperm and amylose content (r=0.866). The germ and fats percentages positively correlated (r=0.869), while minerals content correlated positively with pericarp percentage in corn hybrids. Starch content had a negative correlation with protein content, and these results could lead to different industrial uses of corn hybrids depending on such components. Weiss et al. (2023) stated that the starch content in corn negatively correlated with protein content. On the other hand, there were strongly negative correlations between lightness and total carotenoids content (r = -0.990). At the same time, yellowness was strongly correlated positively (r= 0.999) with carotenoids, and this is due to the differentiation in color of corn hybrids. The results are in line with Pinto et al. (2009). The presence of total carotenoids is correlated with the endosperm's yellow color, and the variation in corn carotenoids content has been affected by the interactions between genotype and environment (Chandler et al., 2013 and Rios et al., 2014).

In vitro protein digestibility of corn hybrids whole meal

Figure 2 presents the protein digestibility of corn hybrids. Protein digestibility significantly ($p<0.05$) varied and ranged between 52.50 and 57.61%. Yellow corn hybrids had higher protein digestibility than white corn hybrids, and yellow TWC 354 had the highest, followed by yellow SC176 (57.61 and 56.88%, respectively). TWC321 was the lowest hybrid in protein digestibility (52.50%). Muleya et al. (2023) reported that corn hybrids' protein quality depends on the agronomic practice used, the type of hybrids and protein characteristics. In vitro digestion models are commonly used to examine the digestibility and release of food components under simulated gastrointestinal circumstances. Zein, the main storage protein, which is sensitive to enzyme was correlated with the variations in protein digestibility (Hur et al., 2011 and Weaver et al.,1998).

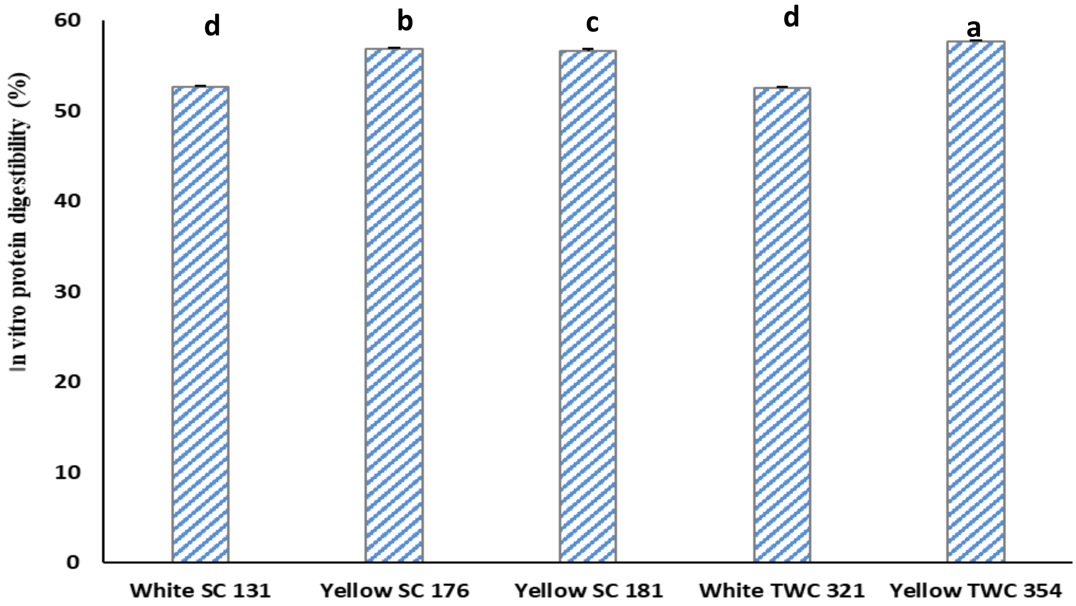

Figure 2. Protein digestibility of corn hybrids

The data are means ± standard deviation of three measurements, and means with different letters are significantly different at 0.05.

Sensory acceptability of tortilla

Tortillas are regarded as a great energy source due to their higher carbohydrates content. They have also become increasingly popular because they are a great solution for people who need gluten-free products (Serna-Saldivar, 2015). Table 6 presents the sensory attribute scores (appearance, color, taste, odor, and overall acceptability) of tortilla samples prepared from white and yellow corn hybrids. According to the findings, white and yellow corn tortillas did not significantly differ in terms of appearance, taste and odor characteristics. However, the panelists considered the yellow tortillas better in color, and this resulted may be attributed to a higher carotenoids content in yellow hybrids corn. In addition, there was not a noticeable distinction in the tortilla's taste scores, which varied from 5.75 to 6.20. The overall acceptance scores of all tortilla samples prepared with white and yellow corn whole meal were high aligning with the findings of Arora et al. (2024).

Table 6. Sensory acceptability scores of tortillas

Samples	Appearance (7)	Color (7)	Taste (7)	Odor (7)	Overall acceptability (7)
White SC131	6.65^{a}±0.41	5.75^{b}±0.42	6.20^{a}±0.25	6.55^{a}±0.43	6.45^{a}±0.28
White TWC321	6.59^{a}±0.38	5.75^{b}±0.48	6.15^{a}±0.24	6.45^{a}±0.44	6.30^{ab}±0.25
Yellow SC176	6.35^{a}±0.40	6.30^{a}±0.34	5.80^{a}±0.58	6.25^{a}±0.75	6.15^{ab}±0.41
Yellow SC181	6.40^{a}±0.39	6.20^{a}±0.42	6.00^{a}±0.61	6.30^{a}±0.42	6.25^{ab}±0.26
Yellow TWC 354	6.30^{a}±0.58	5.95^{ab}±0.50	5.75^{a}±0.48	6.20^{a}±0.58	6.10^{b}±0.39

The data are means ± standard deviation of fifteen, and means in the same column with different letters are significantly different at 0.05.

Color values of tortilla

Color is a key quality attribute of tortillas, due to its visual impact at the moment of sale. It indicates the product's freshness and, in some cases, the quality of the raw ingredients. Table (7) displays the corn tortillas' *L**, *a**, and *b** values. The results indicated that the yellow hybrid's *L** values, which varied from 64.65 to 66.55 tortilla samples, were lower than those of white hybrid tortilla samples. Nonetheless, yellow hybrid tortillas showed greater *a** and b* values; the tortilla prepared from SC176 had the highest *a** and *b** values (4.18 and 38.60, respectively) , which could be attributed to the flour containing an abundance of carotenoids. This result is in line with the findings of El-Mekser et al. (2020). The food product color can play an essential role in the acceptability of product taste, and it may also affect consumer acceptance of tortilla, purchasing rate, and decision, as people tend to associate specific colors with particular tastes (Claudia et al., 2012 and Zellner et al., 2018).

Table 7. Tortilla color values

Samples	*L**	*a**	*b**
White SC131	76.6^{a}±0.85	0.44^{c}±0.02	20.75^{c}±0.35
White TWC321	76.50^{a}±1.27	0.50^{c}±0.03	22.00^{c}±0.28
Yellow SC176	64.65^{b}±0.64	4.18^{a}±0.09	38.60^{a}±0.56
Yellow SC181	66.00^{b}±0.14	3.98^{b}±0.04	38.50^{a}±0.42
Yellow TWC 354	66.55^{b}±0.63	3.86^{b}±0.08	35.80^{b}±0.56

**L* stand for lightness, (*a*) for redness, and (*b*) for yellowness. The data are means ± standard deviation of three measurements,

Nutritional constitutes of tortillas

Table 8 preresents the nutritional constituents of tortillas prepared from five hybrids, defined by protein, fats, crude fibers, ash, carbohydrate content, and energy value. The protein content varied throughout all samples, ranging from 8.01 to 8.93%. The highest protein level was found in tortilla samples prepared from yellow hybrid SC181 flour. Tortillas from SC176 had the highest fat level (4.61%), whereas those from TWC321 had the lowest fat percentage (3.42%). The range of crude fiber content in tortillas was 2.51–2.67%, and the highest fiber content was observed in the SC176 tortilla. SC176 and SC181 yellow tortillas had the highest values for ash (1.44 and 1.42%, respectively). The tortilla from the TWC321 hybrid had the highest total carbohydrate content (84.71%), followed by SC131 (84.38%). Contrarily white TWC321 tortilla had the lowest energy value (401.66 kcal/100g). In general, the findings demonstrated that yellow hybrid tortillas contained more level of protein and fat than white hybrid tortillas, while white tortillas had the highest content of total carbohydrates. The results align with the findings of El-Mekser et al. (2020).

Table 8. Nutritional constitutes of tortillas

Constitutes / Hybrids	Moisture (%)	Protein (%)	Fats (%)	Crud fibers (%)	Ash (%)	Total carbohydrates (%)	Energy value (kcal/100g)
White SC131	30.16^{a}±0.14	8.15^{d}±0.04	3.68^{c}±0.07	2.51^{b}±0.06	1.28^{b} ±0.03	84.38^{a} ±0.08	403.24^{c}±0.46
White TWC321	30.09^{a}±0.05	8.01^{e}±0.04	3.42^{d}±0.14	2.51^{b}±0.09	1.35^{ab}±0.07	84.71^{a}±0.35	401.66^{d}±0.03
Yellow SC176	29.42^{b}±0.04	8.71^{b}±0.04	4.61^{a}±0.07	2.67^{a}±0.01	1.44^{a} ±0.01	82.57^{c}±0.08	406.61^{a}±0.47
Yellow SC181	29.37^{bc}±0.07	8.93^{a}±0.06	4.10^{b}±0.08	2.62^{ab}±0.03	1.42^{a}±0.01	82.93^{c}±0.07	404.34^{b}±0.25
Yellow TWC354	29.29^{c}±0.04	8.58^{c}±0.05	3.86^{c}±0.03	2.55^{ab}±0.05	1.35^{ab}±0.01	83.66^{b}±0.01	403.70^{bc}±0.42

The data are means ± standard deviation of three measurements, and means in the same column with different letters are significantly different at 0.05.

4. Conclusion

Regarding the nutritional analysis of the current study, yellow corn hybrids have higher amounts of protein, crude fiber, and minerals. Besides, they are a rich source of carotenoids, particularly SC176. Increasing amounts of carotenoids in widely consumed staple foods are important for human health because they help prevent vitamin A deficiency. In contrast, while white corn hybrids have higher amounts of amylose, and total carbohydrates. Each tortilla sample made with white and yellow corn flour had an acceptable score overall; SC131 hybrid was the most well-liked hybrid, which could lead to maximum utilization of those hybrids. Overall, with the research findings, the study could acclaim corn manufacturers in the selection of hybrid to maximization their production and profits. The development of corn hybrids could be potential avenues for future research to open new markets for corn food products, especially gluten-free ones to cover all consumer and manufacturer needs.

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