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Original

Color and chemical composition and of green corn produced under organic and conventional conditions

Composição química e cor de milho verde cultivado em sistemas de produção orgânico e convencional

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Abstract

The present study aimed to evaluate the chemical properties of green corn, grown in both organic and conventional farming systems, using a completely randomized factorial design. Four corn varieties (AG 1051, BR 106, SWB 551 and VIVI) of green corn kernels were evaluated for color, proximate composition, total calories, carotenoids and bioactive amines. The farming system affected some chemical and physical characteristics of green corn, but this effect was dependent upon variety. In general, organic green corn kernels were reddish (a* color component) and had higher levels of β-carotene compared to the conventional ones, suggesting that these characteristics are related. Moreover, organic green corn had higher levels of total carbohydrates and total energy compared to conventional varieties. On the other hand, crude fiber levels were higher in conventional grains - an unexpected result that deserves further investigation. Finally, the levels of cadaverine and spermine bioactive amines were not affected either by the corn variety or by the farming system.
Keywords: *Zea mays; varietal differences; nutritional quality; bioactive compounds.*

Resumo

Avaliaram-se as características químicas de milho verde cultivado em sistemas de produção orgânico e convencional. Utilizou-se um delineamento inteiramente casualizado em esquema fatorial 4 × 2, com quatro cultivares (AG 1051, BR 106, SWB 551 e VIVI) em dois sistemas de cultivo (orgânico e convencional), duas ou três repetições. Os parâmetros físico-químicos analisados foram cor, composição centesimal, valor energético total, teor de carotenoides e aminas bioativas. O sistema de produção tem influência sobre as características químicas do milho verde, mas esse efeito é na maioria dos casos específico para cada cultivar. Pode-se generalizar que os grãos advindos de culturas orgânicas apresentam tom mais avermelhado (a*) e maiores teores de β-caroteno, sendo possível que esses dois atributos estejam relacionados. Além disso, milho verde orgânico tem maior teor de carboidratos e teor energético. Em contrapartida, o teor de fibras foi mais alto no cultivo convencional, e esse dado inesperado merece maior investigação. Os teores das aminas bioativas acadaverina e espermina não foram afetados pelo sistema de produção ou cultivar.
Palavras-chave: *Zea mays; cultivar; qualidade nutricional; aminas bioativas.*

1 Introduction

Corn (*Zea mays)* is one of the most important vegetables grown in the world because of its productivity, chemical composition and nutritional value (FANCELLI; DOURADO NETO, 2003). Harvesting at the green stage has increased not only because of its profitability, but also because of its multiple purposes, such as in natura consumption and food product ingredients (MATOS et al., 2007). Common corn varieties, with normal endosperm kernels, dent texture and yellow in color are usually used in the Brazilian production of green corn, which has a pasty texture and is destined to in natura consumption (SAWAZAKI et al., 1979). The sweet corn variety can also be used to produce green corn due to its different sugar composition, which confers greater sweetness and suitable texture to green corn kernels (MATOS et al., 2007).

There is a current trend among consumers to improve their health not only by increasing vegetable consumption (ASTROG, 1997; OLSON, 1999), but also by selecting food items that were produced using healthy farming practices (RIGON, 2002). Indeed, food production methods are directly related to its nutritional value; therefore, food production practices that improve and guarantee its quality must be implemented in the field (KOKUSZKA, 2005). In this context, organic agriculture has emerged as an alternative to the conventional agricultural model, which compromises the environment. It promotes the efficient use of natural resources, seeking sustainability and the maximization of social welfare (BRASIL, 2003; MAZZOLENI; NOGUEIRA, 2006). Organic agriculture uses cultural, biological and mechanical practices as a substitute to synthetic materials at every phase of the process (BRASIL, 2003). Many studies have

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reported the importance and potential of organic fertilization to fully replace chemical fertilization in corn farming (GALVÃO, 1995; BASTOS, 1999; MAIA, 1999). Furthermore, the value of organically grown corn of good quality can be 30% higher than that of conventionally grown corn (VIGLIO, 1996).

Although corn is produced and consumed in the main Brazilian regions, information on the effects of organic farming on different varieties of green corn is still scarce (ARAÚJO et al., 2000). Therefore, the present study aimed at comparing the physicochemical characteristics of green corn produced through organic and conventional cropping systems.

2 Materials and methods

2.1 Experimental design

The experiment was carried out in a completely randomized factorial design with four corn varieties (AG 1051, BR 106, SWB 551 and VIVI) and 2 cropping systems. The earlier two varieties were described as dent corn and the other two as sweet corn. The experiment was carried out at EMBRAPA Maize and Sorghum, in Sete Lagoas, State of Minas Gerais, during the 2007/2008 growing season, under both farming studied systems (organic and conventional), following recommended practices. The organic and conventional crops were kept at least 500 m apart, following the recommendation in Brasil (2003).

Seventy days after planting, a composite sample of immature kernels was obtained from 10 ears of each variety, randomly collected in each plot in both farming systems. The harvest was done manually early in the morning. The ears were at a similar maturation stage. The ears with husk were taken to the laboratory in temperature-controlled containers and kernels were cut out using a stainless steel knife. Each replicate was quartered and homogenized in a blender to combine the composite samples used in the analyses. The samples were stored in closed sterile flasks at -18 °C. Chemical analyses were performed in the Quality Control Laboratory of EMBRAPA Maize and Sorghum and in the Food Biochemistry Laboratory at FAFAR/UFMG, in Belo Horizonte, MG. Three sample replicates were used to evaluate color and proximate composition, and also to calculate total energy. Two replicates were used to determine carotenoids and bioactive amines.

2.2 Physicochemical analyses

Color: the L*, a*, and b* components in the samples were assessed with the application of the Hunter scale using a digital colorimeter (Color tec PCM). The L* component is a measurement of brightness that ranges from white (100) to black (0), thereby differentiating light and dark color; the a* component indicates green-red chromacity and ranges from -a* to +a*; and b*, which indicates blue-yellow chromacity, ranges from -b* to +b*.

Proximate composition: percent moisture, ash, crude fiber, total protein (N x 6.25) and crude fat were determined using the recommended methods described in AOAC (ASSOCIATION..., 2000). Total carbohydrate was determined by subtracting the sum of moisture, crude fat, total protein, crude fiber and ash content (%) from one hundred (100). The results were expressed on a fresh weight basis. Dry matter was determined by subtracting moisture content from one hundred (100).

Total calories: this figure was calculated using the Atawer conversion factor for 4 $kcal.g^{-1}$ protein, 4 $kcal.g^{-1}$ carbohydrate and 9 $kcal.g^{-1}$ lipid (LIMA et al., 2007).

Carotenoids: the chromatographic/spectrophotometric protocol described by Rodriguez-Amaya and Kimura (2004) was used to determine the total carotenoids and β-carotene levels in the samples. The results were expressed on a fresh weight basis ($\mu g.g^{-1}$).

Bioactive amines: the samples were analyzed for the following amines: putrescine, cadaverine, tyramine, histamine, serotonin, agmatine, spermidine, spermine, phenethylamine and tryptamine. These amines were extracted with 5% trichloroacetic acid, separated using an ion exchange column (CLAE) and determined fluorometrically using excitation at 340 nm and emission at 445 nm (VALE; GLÓRIA, 1997).

2.3 Statistical analyses

The resulting data were analyzed using ANOVA factorial, followed by the Tukey´s means separation test when $p \leq 0.05$.

3 Results and discussion

3.1 Color

The visual aspect of products destined to human consumption is of fundamental importance for their commercialization (CHITARRA; CHITARRA, 2005). In the case of green corn, the visual appearance is one of the main characteristics that affects consumers' acceptance. Corn color may vary as a function of genetic origin, farming conditions, processing and storage (PEREIRA FILHO; CRUZ; GAMA, 2003). In the present study, a combination of farming systems and corn varieties affected both L* and b* color components, whereas the a* component was affected by the individual action of the factors (two-way ANOVA; L*: $F_{variety} = 44.154$, $p = 0.00000$; $F_{farming} = 23.95$, $p = 0.00016$; $F_{interaction} = F = 23.023$, $p = 0.00000$; b*: $F_{variety} = 43.603$, $p = 0.00000$; $F_{farming} = 6.048$, $p = 0.02569$; $F_{interaction} = 29.339$, $p = 0.00000$; a*: $F_{variety} = 6.632$, $p = 0.00404$; $F_{farming} = 16.852$, $p = 0.00083$; $F_{interaction} = 2.954$, $p = 0.06410$) (Table 1).

Since the L* component indicates brightness, all corn varieties grown by conventional farming methods presented higher luminosity compared to those farmed using the organic system. Nevertheless, the L* component values obtained in the present work were generally higher than those found in other studies on green corn (72.23 on the Hunter scale) (LEME, 2007). Higher L* values are expected for green corn compared to ripe corn, because the former is lighter in color.

The a* component (green-red chromacity) was higher in corn produced organically, i.e., organic green corn kernels were more reddish compared to the conventional corn kernels variety. Some authors have associated chromacity intensity differences to pigment levels in different vegetables (CARVALHO et al., 2005). The main plant pigments are chlorophyll, carotenoids and anthocyanins (CHITARRA; CHITARRA, 2005). Perhaps, the reddish color of organic corn may indicate the presence of these elements. Indeed, β-carotene levels were higher in organic corn compared to conventional corn (Table 2), although colorimetric studies are needed to confirm this finding.

The farming system did not affect the b* color component in the kernels of any corn variety. According to Pereira Filho, Cruz and Gama (2003), ears of corn with light-colored kernels (cream to light-yellow) are preferred for in natura consumption at the green stage. Both dent corn varieties studied (AG 1051 and BR 106) were light-yellow in conventional farming, as was BR 106 from organic farming. The darker varieties (sweet corn SWB 551 and VIVI) are mainly used in processing industries such as the canned food industry (LEME, 2007). In conventional farming, AG 1051 was the lightest-colored corn, whereas SWB 551 was the lightest one in organic farming.

Although color response to the different farming systems was not uniform, a general overview of the results reveals that organic corn is likely to develop a reddish color, whereas dent corn varieties are lighter than the sweet corns. Therefore, dent varieties of green corn are indicated for the food industry. BR 106 is the best dent variety to grow organically, whereas AG 1051 is best to be grown conventionally.

3.2 Proximate composition and energy value

The different corn varieties had a wide variation in nutritional composition in terms of protein content, ash, lipids and carbohydrates (GONÇALVES et al., 2003). However, moisture, dry matter, ash and protein contents in the green kernels studied were not affected by any of the factors investigated in the present study (two-way ANOVA, $p > 0.05$). In general, moisture content corresponded to the maturation stage of the kernels (SAWAZAKI et al., 1979), as did the mean ash content (UNIVERSIDADE..., 2006). Protein content was 64% lower than the reference values reported by Taco (UNIVERSIDADE..., 2006), but similar between the treatments. In contrast, other studies on dried kernels showed that agroecological corn has higher protein content compared to the conventional corn (LEME, 2007). This parameter, however, is not of primary importance, because even corn varieties with high protein content lack lysine and tryptophan - two important essential aminoacids for human growth (PAES, 2008).

Other studies on the nutritional quality of organic products confirm that the agroecological farming system reduces nitrate levels and increases the content of dry matter, minerals and other nutrients (DIVER, 2002; BOURN; PRESCOTT, 2002; ISMAIL; FUN, 2003). In the present study, only carbohydrate levels and energy value were higher in the green corn produced in the organic cropping system compared to the conventional one, whereas crude fiber levels were higher only in the green corn kernels resulting of conventional farming (two-way ANOVA, carbohydrate: $F_{variety} = 0.319$, p = NS; $F_{farming} = 5.405$, $p = 0.03356$; $F_{interaction} = 2.912$, $p = 0.06650$; energy value: $F_{variety} = 0.264$, p = NS; $F_{farming} = 4.979$, $p = 0.04032$; $F_{interaction} = F = 3.073$, $p = 0.05773$; crude fiber: $F_{variety} = 3.702$, $p = 0.03386$; $F_{farming} = 6.242$, $p = 0.02375$; $F_{interaction} = 1.048$, $p = 0.39848$) (Table 3). Since organic farming promotes nitrogen availability - which, in turn, directly increases photosynthesis and carbohydrate production

Table 1. L*, a* and b* color components (mean ± sd; N = 3) of corn kennels grown using conventional or organic farming.

Variable	AG 1051	BR 106	SWB 551	VIVI
L*				
Conventional	83.1 ± 1.3^{Aa}	78.5 ± 0.6^{Bb}	75.6 ± 1.0^{Ca}	83.1 ± 0.4^{Aa}
Organic	79.1 ± 0.8^{Bb}	82.6 ± 1.8^{Aa}	72.9 ± 1.1^{Cb}	76.4 ± 1.7^{Bb}
a*				
Conventional	0.8 ± 0.1$_{A}$	0.7 ± 0.1$_{AB}$	0.5 ± 0.1$_{B}$	0.7 ± 0.2$_{B}$
Organic†	1.0 ± 0.0	0.9 ± 0.0	0.8 ± 0.1	0.7 ± 0.1
b*				
Conventional	33.6 ± 3.9^{Cb}	36.8 ± 1.1^{Ca}	53.5 ± 0.8^{Aa}	41.9 ± 0.8^{Ba}
Organic	39.4 ± 0.4^{Aa}	36.5 ± 0.7^{Ba}	40.2 ± 2.0^{ABb}	42.4 ± 2.2^{Aa}

†Indicates difference between the farming systems; means followed by different lowercase letters in a column are different; means followed by different uppercase letters in a row are different (Tukey test, $p < 0.05$). The results are expressed on a fresh weight basis.

Table 2. Total carotenoids and β-carotene (mean ± sd) in corn kernels grown using conventional or organic farming.

	AG 1051	BR 106	SWB 551	VIVI
Total carotenoids (μg.g-1)				
Conventional	25.11 ± 7.37^{Aa}	18.54 ± 3.75^{Ab}	24.92 ± 0.07^{Ab}	26.10 ± 1.93^{Aa}
Organic	22.8 ± 3.03^{Ba}	42.17 ± 5.55^{Aa}	41.40 ± 9.23^{Aa}	25.51 ± 3.02^{Ba}
β-carotene (μg.g-1)				
Conventional	0.15 ± 0.03$_{B}$	0.23 ± 0.01$_{B}$	1.30 ± 0.52$_{A}$	0.15 ± 0.01$_{B}$
Organic†	0.28 ± 0.05	0.38 ± 0.07	1.70 ± 0.33	0.35 ± 0.06

†Indicates difference between the farming systems; means followed by different lowercase letters in a column are different; means followed by different uppercase letters in a row are different (Tukey test, $p < 0.05$). The results are expressed on a fresh weight basis.

Table 3. Crude fiber, crude fat, total carbohydrate and total energy (mean ± sd) of corn kennels grown using conventional or organic farming.

	AG 1051	BR 106	SWB 551	VIVI
Crude fiber (mg.100 g^{-1})				
Conventional	$2.04 \pm 0.25_{AB}$	$2.29 \pm 0.15_{A}$	$1.72 \pm 0.29_{AB}$	$1.94 \pm 0.49_{B}$
Organic†	1.50 ± 0.06	2.12 ± 0.24	1.69 ± 0.48	1.38 ± 0.32
Crude fat (mg.100 g^{-1})				
Conventional	0.9 ± 0.1^{Aa}	0.9 ± 0.2^{Aa}	0.9 ± 0.1^{Ab}	1.0 ± 0.3^{Aa}
Organic	0.7 ± 0.2^{Ba}	0.8 ± 0.2^{Ba}	1.3 ± 0.2^{Aa}	0.7 ± 0.1^{Bb}
Carbohydrate (mg.100 g^{-1})				
Conventional	8.5 ± 1.8	15.1 ± 2.4	14.4 ± 1.4	13.9 ± 2.6
Organic†	20.6 ± 7.5	17.1 ± 2.2	15.4 ± 6.7	13.9 ± 2.0
Total energy (kcal)				
Conventional	51.1 ± 0.7	75.8 ± 8.2	75.2 ± 4.5	74.5 ± 7.3
Organic†	97.8 ± 32.7	84.0 ± 6.5	80.7 ± 23.9	70.9 ± 7.2

†Indicates difference between the farming systems; means followed by different lowercase letters in a column are different; means followed by different uppercase letters in a row are different (Tukey test, $p < 0.05$). The results are expressed on a fresh weight basis.

(MARTINEZ, 2005), increases in the carbohydrate content of organic green corn is probably a result of improved soil fertility; the plant imports more nutrients from the rich soil and produces better-quality kernels (SILVA et al., 2008). Food fiber consists of vegetable polysaccharides (e.g. cellulose, hemicellulose, pectins, gums, oligosaccharides and lignin) that are produced through photosynthesis (CATALANI et al., 2003), following genetic features. Therefore, like carbohydrates, fiber content was expected to increase in response to the high nutritional quality of the organic soil. However, it was found that fiber content in conventional green corn was greater than organic green corn. This result was unexpected, even though climatic conditions affect fiber content in food (ARAÚJO; ARAÚJO, 1998; BARIKMO; OUATTARA; OSHAUG, 2004). Therefore, this finding deserves further investigation.

The interactive effect of farming system and corn variety was significant only for crude fat (CF) (two-way ANOVA: $F_{variety}$ = 2.88, p = 0.06820; $F_{farming}$ = 0.736, p = NS; $F_{interaction}$ = 3.948, p = 0.02771) (Table 2). The CF levels did not differ between the varieties farmed conventionally, but it was higher in SWB 551 sweet corn SWB 551 grown organically. Comparing varieties farmed in the different systems, it was found that SWB 551 grown conventionally and VIVI grown organically had the lowest CF contents. Differences among CF within corn varieties are somewhat expected because of the genetic manipulation that enables the production of corn with different oil content to be used for specific purposes. For instance, corn with high oil content can be used to provide high energy value for bird and swine feed (PAES, 2008).

Organic fertilization may fully replace chemical fertilization in corn production (GALVÃO, 1995; BASTOS, 1999; MAIA, 1999). In general, the present study showed that organic green corn had higher carbohydrate content and total energy, but lower fiber content, than that of organic green corn. Additionally, as shown by crude fat content, this characteristic depends not only on the farming system, but also on corn variety. In organic farming, the 551 SWB variety had the highest oil content, whereas the VIVI variety grown in a conventional system had the lowest content.

3.3 Carotenoids

High carotenoid content has been considered a primary characteristic to either increase the commercial value of a specific corn variety or select lines for genetic enhancement programs. In the present study, total carotenoid levels found in all samples were within the range previously reported for corn (PAES; GUIMARÃES; SCHAFFERT, 2006). However, these values under the conditions of this study were affected by corn variety and farming system interaction (two-way ANOVA: $F_{variety}$ = 4.126, p = 0.02404; $F_{farming}$ = 20.222, p = 0.00037; $F_{interaction}$ = F = 9.45, p = 0.00079) (Table 2). Varieties grown under conventional conditions presented similar carotenoid content in green kernels. However, there was a significant difference between the varieties produced in the organic cropping system for carotenoid composition of the kernels. Within this system BR 106 and SWB 551 had the highest carotenoid contents. Perhaps, the soluble chemical fertilizers used in conventional farming may have caused an imbalance in the plants, because these fertilizers are directly absorbed, thereby modifying the nutritional elements and metabolic processing (CHABOUSSOU, 1987; BONILLA, 1992). Corn carotenoids are produced by plant metabolism and conventional farming may compromise this process. In organic farming, the plants are likely to incorporate extra nutrients into their chemical composition (MELLO; VITTI, 2002), besides their rich diversity, soil nutrients become gradually available to the plant through the mineralization process. As a result, the food produced is more nutritious.

The content of β-carotene in the kernels was affected by the individual effect of corn variety and farming system (two-way ANOVA: $F_{variety}$ = 47.005, p = 0.00000; $F_{farming}$ = 55.734 p = 0.02923; $F_{interaction}$ = F = 0.438 p = NS) (Table 2). Within the corn varieties, sweet corn SWB 551 had the highest β-carotene level. Green kernels produced organically had higher β-carotene levels (0.68 ± 0.63 μg.g^{-1}) than those produced conventionally (0.46 ± 0.56 μg.g^{-1}). Ismail and Fun (2003) found a similar response for cabbage and mustard grown in organic farming. This finding suggests that the organic farming system promotes β-carotene production in vegetables and, consequently, produces higher nutritious food, which can be useful in controlling

Table 4. Active bioamines (mean ± sd) of corn kernels grown using conventional or organic farming.

Bioamine (mg. 100 g^{-1})	AG 1051	BR 106	SWB 551	VIVI
Spermidine				
Conventional	3.06 ± 0.56^{Aa}	3.29 ± 0.14^{Aa}	3.45 ± 0.41^{Aa}	3.03 ± 0.49^{Ab}
Organic	2.62 ± 0.16^{Ba}	2.39 ± 0.38^{Bb}	2.99 ± 0.34^{ABa}	4.05 ± 0.87^{Aa}
Putrescine				
Conventional	3.89 ± 0.69^{Ba}	3.07 ± 0.05^{Ba}	5.56 ± 0.80^{Aa}	3.87 ± 0.71^{Bb}
Organic	3.88 ± 0.81^{Ba}	2.31 ± 0.47^{Ca}	5.49 ± 0.42^{Aa}	5.73 ± 0.46^{Aa}
Total amines				
Conventional	8.51 ± 1.72^{Ba}	10.25 ± 2.58^{ABa}	12.31 ± 0.50^{Aa}	10.27 ± 0.60^{ABb}
Organic	8.76 ± 2.21^{Ba}	7.55 ± 0.29^{Bb}	13.71 ± 1.27^{Aa}	13.19 ± 0.67^{Aa}

[†]Indicates difference between the farming systems; means followed by different lowercase letters in a column are different; means followed by different uppercase letters in a row are different (Tukey test, $p < 0.05$). The results are expressed on a fresh weight basis.

nutritional deficit, especially vitamin A deficiency. There may also be a relation between the high β-carotene content and the reddish color detected in organic corn.

3.4 Bioactive amines

Certain amines can be used as parameters for food quality control (CACCIOPPOLI et al., 2006) because elevated levels of bioactive amines are found in plants submitted to different stressful conditions, such as mineral deficiency (ANGOSTO; MATILLA, 1993). The present study found the cadaverin, spermine, spermidine and putrescine bioamines in green corn, but did not detect histamine, tyramine, serotonin, agmatine, phenethylamine or tryptamine.

The main cadaverine (2.42 ± 1.56) and spermine (0.82 ± 0.29) levels were not affected by farming system, corn variety or interaction of these factors (two-way ANOVA, $p > 0.05$). Therefore, these amines could be used as quality indicators for any of the corn varieties evaluated, grown in any of the studied farming systems. In fact, many studies have reported the use of bioactive amines for quality control of several food products (VIERIA; THEODORO; GLÓRIA, 2007).

The interaction of farming systems and corn varieties affected the levels of putrescine, spermidine and total amines in green corn (two-way ANOVA; putrescine: $F_{variety} = 24.984$, $p = 0.00000$; $F_{farming} = 1.085$, $p = 0.31303$; $F_{interaction} = F = 5.234$, $p = 0.01043$; spermidine: two-way ANOVA: $F_{variety} = 3.081$, $p = 0.05735$; $F_{farming} = 1.060$, $p = 0.31855$; $F_{interaction} = F = 4.752$, $p = 0.01484$; total amines: $F_{variety} = 12.742$, $p = 0.00016$; $F_{farming} = 0.662$, p = NS; $F_{interaction} = 4.039$, $p = 0.2576$) (Table 4). In general, the highest and lowest levels of these amines were found in organic corn. The highest bioamine levels were detected in the SWB 551 and VIVI varieties, whereas the lowest levels were found in AG 1051 and BR 106. This result is consistent with other evidences that corn attributes are affected by a combination of factors.

Putrescine and spermidine are found in all eucaryotic cells (FLORES; PROTACIO; SIGNS, 1989). According to Simon-Sarkadi and Holzapfel (1995), putrescine is a microbiological indicator of acceptable values (1.3 to 2.0) in fish and meat products. Putrescine levels in green corn were much higher than this. Thus, an acceptable limit for bioactive amines in vegetables has to be established, given that these elements are a threat to health.

4 Conclusions

The farming system affects the chemical characteristics of corn harvested at the green stage, but this response is likely specific to the difference in corn variety backgrounds. Thus, it can be generalized that kernels grown using organic farming have a reddish color (a* component) and high β-carotene content, suggesting that these variables are correlated. Furthermore, organic green corn has a higher carbohydrate content and a higher total energy value than those of conventional corn. In contrast, fiber content was higher in conventional corn, and this unexpected result requires further investigation. A higher content of bioactive amines was detected in sweet corn, especially in SWB 551.

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