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Original Article

Comparison of carotenoid content in fresh, frozen and canned corn

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Abstract

The carotenoid content of fresh, commercially canned and frozen samples of two cultivars, White Shoepeg (WS) and Golden Whole Kernel (GWK) corn (*Zea mays*), from the same production field was studied. WS and GWK corn samples were harvested daily over a five-day-period and randomly selected for analysis as fresh, frozen or canned. Major carotenoids detected were lutein and zeaxanthin, and to a lesser extent, α-, β-cryptoxanthin, α-, and β-carotene. Fresh GWK corn contained higher amounts of lutein, zeaxanthin and total carotenoids (330, 209 and 702 μg/100 g fresh weight) versus fresh WS corn (5.5, 28.5, and 35.5 μg/100 g fresh weight). In both canned WS and GWK corn, levels of lutein, zeaxanthin, and total carotenoids were similar to their respective fresh counterparts. Detectable levels of zeaxanthin in WS corn increased 67.4% ($P = 0.042$) and total carotenoids in both WS and GWK corn were increased after freezing by 63.3% ($P = 0.002$) and 5.3% ($P = 0.003$), respectively. This work indicates that canning does not decrease carotenoid content in corn and that freezing may increase carotenoid content in WS corn which can further influence bioavailability and health benefits.

Keywords: Carotenoids; Lutein; Zeaxanthin; Canning; Freezing; Corn

1. Introduction

Carotenoids are groups of compounds that are commonly found in fruits and vegetables and are responsible for yellow, orange, and red pigmentations. The health benefits of dietary carotenoids are well documented (Basu et al., 2001). Carotenoids such as lycopene have achieved

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a great deal of attention due to their antioxidant abilities and links with reduced chronic disease risks (Siems et al., 1999; Clinton, 1998; Sies and Stahl, 1998; Giovannucci et al., 1995). Other carotenoids, such as the xanthophylls, lutein and zeaxanthin, have garnered interest due to their association with eye health (Mozaffarieh et al., 2003). Lutein and zeaxanthin are the only carotenoids found in the macula and their unique presence has been proposed to protect the eye from free radicals and near-to-UV blue light (Wenzel et al., 2003; Eichler et al., 2002; Stahl and Sies, 2002). Studies have also shown that dietary intakes of lutein and zeaxanthin can reduce the risks of cataracts and age-related macular degeneration (AMD), which is the leading cause of blindness among the elderly (Landrum et al., 1996, 1997; Eye Disease Case Control Study Group, 1993; Seddon et al., 1994; Chasan-Taber et al., 1999; Brown et al., 1999).

Corn contains significant amounts of lutein, zeaxanthin, and other carotenoids and is a popular vegetable in the American diet. Corn is readily available as fresh, canned or frozen. Processing of corn is used to increase its shelf life but as a consequence, a significant loss of nutrients may occur via heat degradation or leaching. Several researchers have analyzed nutrient content in fresh and processed vegetables (Martin, 1977; Makhlouf et al., 1995; Morrison, 1975; Favell, 1998; Klein and Kurilich, 2000), however few have evaluated the carotenoid content in processed corn compared to fresh corn from the same origin under commercial processing conditions.

The objective of the study was to examine the fate of several carotenoids in White Shoepeg (WS) and Golden Whole Kernel (GWK) corn subsequent to commercial canning and freezing from samples taken from the same production field under similar growing conditions over a five-day-period in one growing season.

2. Materials and methods

2.1. Corn growing conditions

WS and GWK corn (*Zea mays*) was grown and harvested under commercial contract in Glencoe, Minnesota and harvested over a five-day-period in September 2002. Corn planting was staggered so that the corn maturity was similar for each of the five harvest days. The production field was approximately 100 acres and was harvested using modern commercial harvesting equipment. Raw products were loaded into trucks and transported to the processing facility where they were husked, sorted, inspected and conveyed to automatic cutters operating at 4500 ears per hour. Remaining silk, damaged kernels, worms and other defects were removed with froth washers. Cut corn product was then pumped to a dewatering belt, further inspected and separated for freezing or canning.

2.2. Fresh corn

For fresh corn, 10 unhusked ears of each variety of corn were randomly selected daily from the harvested samples, placed into Ziploc plastic bags and sent overnight on ice for carotenoid analysis. Kernels from fresh corn samples were manually cut from the cob and analyzed for carotenoid content.

2.3. Canning

Cut corn was discharged into 250 lb. capacity stainless steel vibrating hoppers and commercially canned with a sugar/salt brine solution (average of 0.85% NaCl and 2.3% sucrose). WS corn was dispatched into 303×308 sized cans and GWK corn was dispatched into 300×407 sized cans with a FMC Pocket Filler (Continental) at 81°C and closed with a 220 Closer (Continental). Cans were then conveyed through continuous cookers for 12 min at 126.7°C in accordance with the registered FDA process. After cooking, cans were then cooled in water to a center can temperature of 32.2–45.6°C. Five cans each of WS and GWK corn samples were randomly selected each day and sent for carotenoid analysis.

2.4. Corn freezing

Corn kernels for freezing were steam blanched at 87.8–93.3°C with an average dwell time of 3 min. WS and GWK corn was commercially frozen using a blast tunnel freezer (FrigoScandia) with an ammonia refrigeration system. The freezing temperature was in the range of −17.8°C to −23.3°C with an average dwell time of 7–9 min. A random, daily sample of 5 lb of frozen WS and GWK corn was placed into plastic Ziploc bags and shipped overnight on dry ice for analysis.

2.5. Carotenoid analysis

Corn samples were analyzed for carotenoid content by Craft Technologies (Wilson, NC).

2.5.1. Sample preparation

Portions of fresh, frozen and canned (corn and brine solution) WS and GWK corn were homogenized to uniformity and evaluated for carotenoid content for each day of harvest (Fig. 1). A 5 g aliquot was taken from the homogenized sample and extracted with methanol:tetrahydrofuran (1:1). A portion was saponified using ultrasonic agitation in ~12% potassium

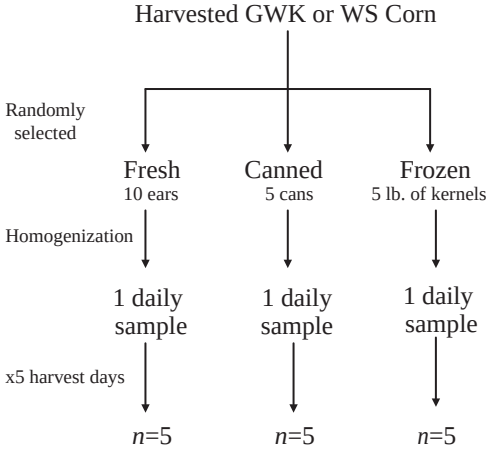

Fig. 1. Sample collection protocol.

hydroxide containing 1% pyrogallol and ascorbic acid as antioxidants. The free carotenoids were extracted into hexane:ethyl acetate (9:1). A portion was dried under nitrogen, dissolved in ethyl acetate and diluted with mobile phase.

2.5.2. HPLC

The HPLC system consisted of a computer data system, an autosampler maintaining samples at 20°C, a column heater at 31°C, and a programmable ultraviolet visible detector (ThermoSeparation Products, Fremont, CA). The separation was performed isocratically on a Spherisorb ODS2 column (3 μm, $4.0 \times 250\,mm^2$ with titanium frits, ES Industries, West Berlin, NJ) protected by a Javelin guard column containing the same stationary phase (Thermo-Keystone, Bellefonte, PA). The mobile phase consisted of acetonitrile/dioxane/50 methanol:50 isopropanol/triethylamine (80/15/5/0.1) at a flow rate of 1.0 mL/min. The alcohol component contained 150 mM ammonium acetate. A photodiode array (PDA) detector was programmed to measure carotenoids at 450 nm. Linear calibration curves were prepared consisting of three concentrations of analytes which spanned the levels of carotenoids commonly found in vegetables. The calibrants included lutein, zeaxanthin, β-cryptoxanthin, lycopene, α-, and β-carotene. Quantification and quality control were performed by external standard calibration using peak areas. Single injections were performed and compared with spectrophotometric measurements for accuracy and consistency.

2.6. Statistical analysis

An analysis of variance was performed to test significance at $P < 0.05$ using Statview software version 5.0 (SAS Institute, Inc., Cary, NC).

3. Results

3.1. Carotenoid content in fresh WS and GWK corn

Fresh WS and GWK corn was analyzed using HPLC to determine the carotenoids present and establish baseline carotenoid levels before processing (Fig. 2). In WS and GWK corn, the

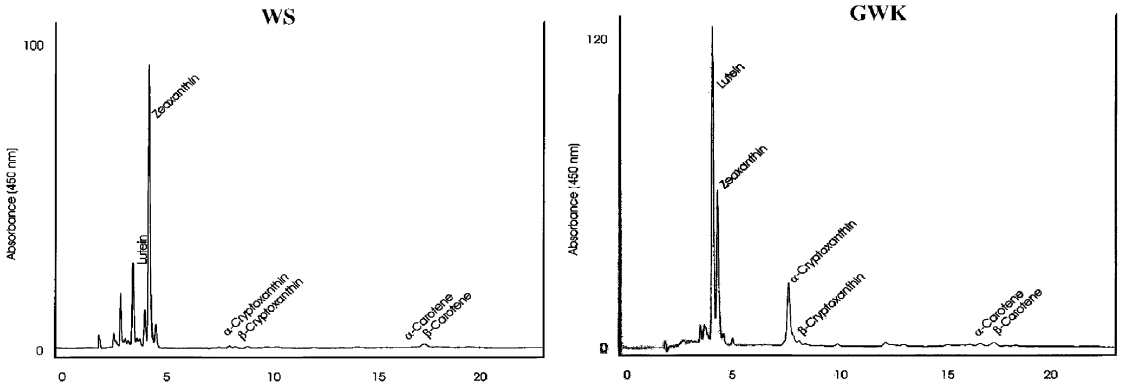

Fig. 2. HPLC chromatograms of WS and GWK corn.

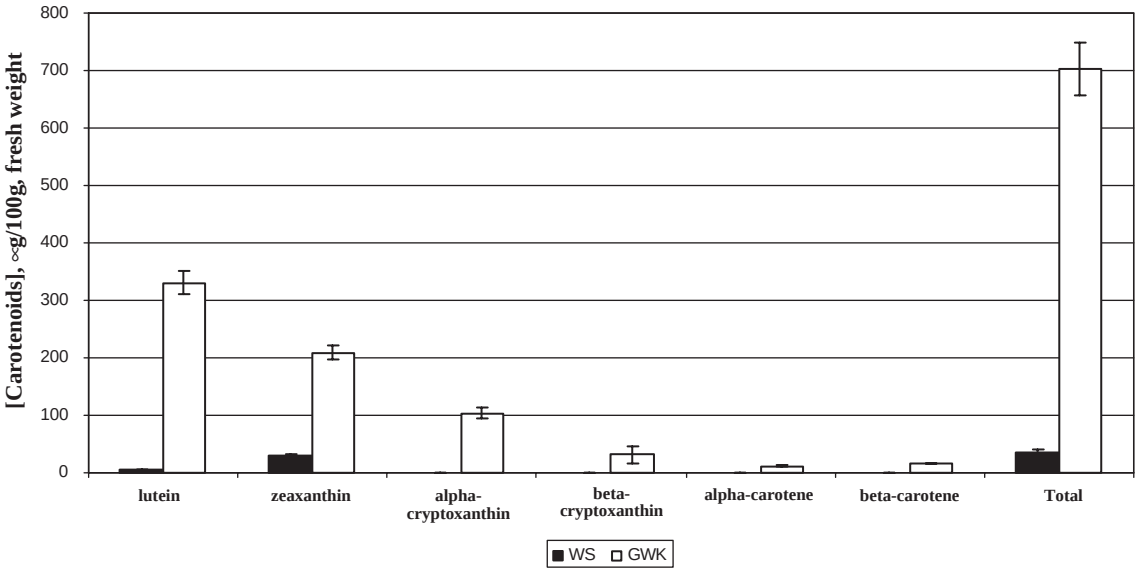

Fig. 3. Carotenoid content in fresh WS and GWK corn.

Table 1
Carotenoid concentrations in WS and GWK corn (μg/100 g fresh weight)

		Lutein	Zeaxanthin	α-cryptoxanthin	β-cryptoxanthin	α-carotene	β-carotene	Total
WS	Fresh	5.5±1.2	28.5±5.2	0.3±0.1	0.4±0.1	0.04±0.0	0.82±0.08	35.5±6.3
	Canned	6.6±0.5	30.5±3.4	0.3±0.1	0.5±0.2	0.05±0.1	0.68±0.17	38.7±6.4
	Frozen	6.3±1.1	47.7±10.2	0.5±0.1	0.9±0.2	0.23±0.1	2.37±0.42	57.9±10.0
GWK	Fresh	330.3±19.8	209.0±12.0	104.0±8.4	31.6±15.5	11.7±1.8	15.69±0.60	702.2±46.6
	Canned	336.4±67.5	215.9±42.2	97.4±26.0	42.8±10.0	4.4±0.6	11.66±2.47	715.8±192.9
	Frozen	361.6±34.2	212.3±36.0	109.1±13.9	33.1±3.9	6.8±1.5	16.68±1.83	739.6±59.9

Values are presented as means ± SEM.
Corn and brine were analyzed in all canned samples with brine content factored out of final calculations.

major carotenoids were lutein and zeaxanthin. Detectable levels of α-, β-cryptoxanthin, α-, and β-carotene were found (Fig. 3). The most abundant carotenoid in fresh WS corn was zeaxanthin comprising 80.3% of total carotenoids followed by lutein (Table 1). In GWK corn, lutein was the most abundant carotenoid comprising 47.1% of total, followed closely by zeaxanthin (29.8%) and α-cryptoxanthin (14.8%). Fresh GWK contained a greater total amount of carotenoids (702 μg/100 g) versus WS (35.5 μg/100 g) as well as greater amounts of each individual carotenoid. Corn was harvested over a five-day-period at comparable levels of maturity and there were no significant day-to-day changes in carotenoid levels during the five-day-period.

Table 2
Percent change in carotenoid levels in frozen WS corn

	Lutein	Zeaxanthin	α-cryptoxanthin	β-cryptoxanthin	α-carotene	β-carotene	Total
% Increase versus fresh WS corn	14.7	67.4	81.3	133.2	455.0	189.5	63.3
P value	0.452	0.042	0.0086	0.0089	0.0086	0.0028	0.0018

Calculations are based on changes from original carotenoid content in fresh WS corn being 100%.
Comparisons were made on a fresh weight basis.

3.2. Effects of canning on carotenoid concentrations in WS and GWK corn

The effects of canning on carotenoids were similar between the two varieties of corn (Table 1). In WS and GWK corn, there were no significant differences ($P = 0.31$ and 0.22, respectively) in total carotenoids between fresh and canned samples. However, there was a 61.9% decrease ($P = 0.0026$) in α-carotene in canned GWK corn versus fresh GWK corn. There were no significant differences observed in each other individual carotenoid in canned WS and GWK versus fresh WS and GWK samples.

3.3. Effects of freezing on carotenoid concentrations in WS and GWK corn

Freezing had little effect on lutein content in WS corn (Table 1). However, there were significant increases in all other carotenoids and in total carotenoids compared to fresh WS corn (Table 2). In GWK, individual carotenoids were similar in fresh and frozen samples, except for α-carotene, which decreased 41.9% ($P = 0.007$) in the frozen samples. Overall, frozen GWK corn contained 5.3% ($P = 0.003$) more total carotenoids versus fresh GWK.

4. Discussion

The purpose of this study was to investigate the levels of carotenoid content in frozen and canned corn compared to fresh corn from the same growing area. Corn is a significant vegetable source of both lutein and zeaxanthin (Holden et al., 1999). Two common commercial varieties of corn, WS and GWK, were chosen to analyze a range of carotenoid levels representing very low-pigmented (WS) and medium-pigmented (GWK) corn samples. There were total carotenoid levels of 35.5 μg/100 g and 702 μg/100 g, respectively, for WS and GWK corn. Higher yellow-pigmented corn can contain 1100–3000 μg/100 g of xanthophylls, thus our lower values are consistent with medium- and low-pigmented corn (Holden et al., 1999; Watson and Ramstad, 1987). Carotenoids lutein and zeaxanthin are responsible for the yellow pigmentation in corn and there was approximately 60-fold more lutein and seven-fold more zeaxanthin in fresh GWK corn compared to fresh WS corn. There was approximately 19 times more total carotenoids in fresh GWK corn compared to fresh WS corn. Aside from the increased amounts of carotenoids in GWK versus WS corn, there were different profiles of relative carotenoid concentrations between the varieties and the ratio of lutein to zeaxanthin differed between the white and yellow corn varieties. WS corn

contained more zeaxanthin and had a lutein:zeaxanthin ratio of 1:5.2, whereas GWK corn contained more lutein and had a lutein:zeaxanthin ratio of 1.6:1. These observations are consistent with the greater pigmentation in the GWK corn samples.

Canning caused no significant changes in carotenoid content of WS and GWK corn. Xanthophylls are sensitive to heat, light, O_2, and pH. Although canning would minimize degradation caused by light, oxygen, and pH, canning temperatures are sufficient to induce carotenoid isomerization (Nguyen et al., 2001; Updike and Schwartz, 2003). Isomers of lutein and zeaxanthin were not measured, although canning has been shown to increase isomer formation of xanthophylls in corn (Updike and Schwartz, 2003). Another potential source of nutrient loss in canning is leaching into brine (Martin, 1977). When corn is removed from the cob, the pericarp is ruptured, which may allow for carotenoids to migrate into the brine solution. Corn and brine were analyzed in the canned samples with brine addition factored out of final μg/100 g carotenoid calculations. Carotenoids are fat-soluble and most likely did not migrate to a significant degree into the brine solution.

Individual carotenoid levels were found to be significantly higher in the frozen WS samples compared to fresh WS, as were total carotenoids. Carotenoid levels in frozen GWK corn were similar to fresh GWK, except for α-carotene, representing no losses due to freezing. α-Carotene concentrations decreased significantly in both frozen and canned GWK corn, but not WS corn although both varieties of corn contained relatively minute amounts of α-carotene. The freezing process included a steam-blanching step which may not significantly reduce nutrients (Selman, 1994). Furthermore, as the kernels never come in contact with any type water bath environment during the freezing process, leaching of carotenoids is minimized.

Fresh, frozen, and canned corn samples were compared on a fresh weight basis, with the original carotenoid content in fresh WS and GWK corn considered to be 100%. At harvest, moisture content of the corn ranged from 71% to 72%. It is common for corn to gain moisture during the canning process. Increases in moisture content in canned corn versus fresh corn have been reported to range from 1.1% to 5.4% (Martin, 1977; Makhlouf et al., 1995; Updike and Schwartz, 2003). If these increases in moisture are applied to the data reported in this paper, individual and total carotenoid levels in canned and fresh WS and GWK corn would remain statistically similar. The blanching and freezing process itself can dehydrate vegetables slightly resulting in water weight losses ranging from 0.3% to 5% (Dicsev, 1972; Norwig and Thompson, 1984). The increases in carotenoid concentrations found in frozen WS and GWK corn may be a result of water loss from the kernels.

5. Conclusion

This study has shown the effects of processing on carotenoids in two popular varieties of commercially available corn grown and harvested under like conditions. Overall, fresh GWK corn contained an average of 702 μg/100 g compared to 35.5 μg/100 g for fresh WS corn. The process of canning did not significantly alter the levels of carotenoids in GWK and WS corn. Frozen samples of corn contained comparable or greater amount of carotenoids. The findings suggest that canned and frozen corn may be an equivalent or superior dietary source of carotenoids compared to fresh corn.

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