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Inhibition of Key Aroma Compound Generated during Ultrahigh-Temperature Processing of Bovine Milk via Epicatechin Addition

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The ability of epicatechin (EC) to inhibit the thermal development of aroma compounds (i.e., Maillard reaction products) formed during ultrahigh-temperature (UHT) processing of bovine milk was evaluated. Volatile extracts were prepared for two UHT-processed milk samples made from (1) raw milk and (2) raw milk containing 0.1% EC by solvent-assisted flavor evaporation (SAFE) and subsequently analyzed by aroma extract dilution analysis (AEDA). Sensory evaluation was also conducted by a trained panel on the intensity of cooked flavor and bitterness in four UHT-processed milk samples (0.00, 0.01, 0.10, and 0.20% EC added prior to processing), as well as a commercial pasteurized milk sample for comparison. AEDA indicated that addition of EC to raw fluid milk prior to UHT processing reduced the overall thermal formation of key aroma-active compounds in comparison to the traditional UHT milk sample. The largest changes in FD values were reported for methional, furfural, 2-isopropyl-3-methoxypyrazine, 2-acetyl-1-pyrroline, and 2-acetyl-2-thiazoline (Maillard-type aroma compounds) with 32-, 8-, 8-, 4-, and 4-fold reductions in formation, respectively. Sensory evaluation also revealed that all EC-containing UHT milk samples had statistically ($P < 0.05$) lower cooked flavor intensity in comparison to the control, whereas the 0.2% EC sample was statistically similar to a pasteurized milk sample. Furthermore, addition of EC at or below 0.1% in UHT fluid milk did not significantly increase the bitterness intensity.

KEYWORDS: AEDA; flavonoids; UHT milk aroma, epicatechin; GCO; aroma inhibition

INTRODUCTION

Processed food products and commodities commonly undergo thermal treatment during production to increase product stability or shelf life, food safety, ease of distribution, and eating quality. Although these outcomes are positive, for some food products, thermal processing can also have a negative impact on the eating quality due to alteration of the flavor attributes. Consequently, the extent of heat treatment applied to a food product can be limited by unwanted flavor development, which can directly influence the overall product stability. For example, practically all fluid milk in the domestic marketplace is sold as a pasteurized product (perishable), even though ultrahigh-temperature (UHT)-processed milk has the advantage of being a shelf-stable product. UHT milk products, however, have not been accepted by the North American consumer due to, in part, thermally induced changes in the milk flavor properties (*1*, *2*). UHT milk products have a stronger flavor property than traditionally pasteurized milk, which is considered to be a product defect in the current marketplace, as consumers tend to prefer a "clean" and relatively bland fluid milk product (i.e., pasteurized milk). Consequently, although UHT milk products have been produced and distributed in North America for over 60 years, they have not seen growth or acceptance by consumers. The Canadian market saw a decline in the percentage of UHT fluid milk sales between their introduction and 1980 (*2*). The ability to inhibit (control) flavor development during UHT processing of fluid milk would therefore offer the advantage of product stability without the negative flavor aspects of traditional UHT milk. Furthermore, improvements in the flavor stability of flavor milk products have been also reported by Potenini and Peterson (*3*) and Gassenmeier (*4*) for UHT versus pasteurized milk products.

Key changes in the volatile composition of dairy products during thermal treatment have been (as anticipated) associated with the Maillard reaction. For example, Scanlan et al. (*5*) reported maltol, furfural, acetophenone, diacetyl, and tentatively phenylacetaldehyde in heated milk; Shibamoto et al. (*6*) reported furan and pyrazine derivatives in milk heated at 90 °C, whereas Adhikari and Singhal (*7*) showed increasing levels of 5-hydroxymethylfurfural, one of the initial reaction products in the Maillard reaction, upon UHT processing and continuing during storage of UHT-processed milk. Using aroma extract dilution analysis (AEDA), Iwatsuki et al. (*8*) identified 2,6-dimeth-

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Table 1. Aroma-Active Compounds of Ultrahigh-Temperature-Processed Milk Detected during Aroma Extract Dilution Analysis—Neutral/Basic Fraction

		LRI			FD values	
no.	compound	DB-5	DB-Wax	odor[a]	control[b]	treatment[b] (0.1% EC)
1	methional[c]	909	1452	potato	128	4
2	2-acetyl-1-pyrroline[d]	922	1336	roasted/popcorn	32	8
3	1-octen-3-one[c]	978	1299	mushroom/earthy	1	0
4	Furaneol[d]	1056	2041	caramel	32	16
5	inknown 1	1083		foul	8	1
6	2-isopropyl-3-methoxypyrazine[d]	1098	1434	roasted/dairy	8	1
7	2-acetyl-2-thiazoline[c]	1100	1759	roasted/popcorn	32	8
8	(*E*,*Z*)-2,6-nonadienal[d]	1145	1577	fatty	4	2
9	(*E*)-2-nonenal[d]	1162	1535	oxidized	2	2
10	(*E*,*E*)-2,4-nonadienal[d]	1211	1688	cardboard	2	1
11	unknown 2	1220		acidic	1	1
12	unknown 3	1239		caramel-like	2	0
13	δ-octalactone[c]	1283	1973	peach	4	2
14	unknown 4	1298		floral	4	2
15	decanoic acid[c]	1382	2276	soapy	4	4
16	skatole[c]	1389	2504	foul	8	4
17	γ-decalactone[c]	1485	2139	sweet/perfumey	2	2
18	δ-decalactone[c]	1494	2204	coconut	64	32
19	γ-6-(*Z*)-dodecenolactone[c]	1651	2385	perfumey	32	16

[a] Odor descriptions at the GC-sniffing port during GCO. [b] Raw milk (with or without 0.1% EC) was preheated to 87.8 °C, homogenized (2500 psi) at a final heat of 141.1 °C, then held for 6 s (final temperature was 138.3 °C), and immediately cooled to 16.7 °C. [c] Compound positively identified (LRI, MS, authentic). [d] Compound tentatively identified (LRI, odor).

Table 2. Aroma-Active Compounds of Ultrahigh-Temperature-Processed Milk Detected during Aroma Extract Dilution Analysis—Acidic Fraction

		LRI			FD values	
no.	compound	DB-5	DB-FFAP	odor[a]	control[b]	treatment[b]
20	furfural[c]	833	1455	roasted	16	2
21	isobutyric acid[c]	792	1554	foul	4	4
22	butyric acid[c]	824	1628	sour	512	512
23	3-methylbutanoic acid[c]	875	1651	sour/acid type	128	128
24	hexanoic acid[c,d]	1020	1847	sour/cheesy	512	512
25	heptanoic acid[c]	1076	1946	sour	1	1
26	octanoic acid[c,d]	1186	2052	foul	1	1
27	nonanoic acid[c,d]	1277	2127	sour	1	1
28	homo-Furaneol[e]	1146	2079	burnt sugar	1	1
29	sotolon[e]	1099	2177	caramelly	32	32
30	4-chloro-3,5-dimethylphenol[c]	1384	2561	perfumey/floral	256	256
31	phenylacetic acid[c]	1255	2581	floral	32	32
32	3-phenylpropionic acid[c,d]	1344	2608	floral/perfumey	128	128

[a] Odor descriptions at the GC-sniffing port during GCO. [b] Raw milk (with or without 0.1% EC) was preheated to 87.8 °C, homogenized (2500 psi) at a final heat of 141.1 °C, then held for 6 s (final temperature was 138.3 °C), and immediately cooled to 16.7 °C. [c] Compound positively identified (LRI, MS, authentic). [d] Compound present in both N/B and acidic fractions. [e] Compound tentatively identified (LRI, odor).

ylpyrazine, 2-ethylpyrazine, 2-ethyl-3-methylpyrazine, and methional as potent compounds (highest FD values) due to the UHT heating process; these compounds were thought to contribute to the off-flavor of UHT-processed milk.

Recently, Peterson and Totlani (*9*) reported that the addition of polyphenols (i.e., epicatechin or epigallocatechin gallate) to model Maillard reaction systems and food products dramatically reduced the formation of thermally generated Maillard-type aroma compounds. They suggested that the chemical properties of phenolic-type compounds can alter (inhibit) flavor development during thermal processing. In a further study, Totlani and Peterson (*10*) suggested that the inhibition epicatechin exhibited on overall mechanisms of Maillard-type pathways and flavor formation may be, in part, due to quenching of Maillard reaction intermediate products.

The objectives of this study were to determine if the addition of a specific polyphenolic compound (epicatechin) to raw milk would inhibit the thermal generation of Maillard-type aroma compounds and reduce the perceived level of cooked flavor intensity of UHT-processed fluid milk.

MATERIALS AND METHODS

Chemicals included 99% epicatechin (EC) (Zhejiang Yixin Pharmaceutical Co., Zhejiang, China), sodium chloride (J. T. Baker, Philipsburg, NJ), sodium sulfate (EMD Chemicals, Inc., Gibbstown, NJ), and caffeine (Bell Aromatics, Inc., Northbrook, IL). Aroma compounds in **Tables 1** and **2** were obtained from the following commercial sources: no. **1**, **3**, **4**, **6**, **8**−**10**, **15**−**18**, **20**−**28**, and **30**−**32** (Sigma-Aldrich Chemical Co., St. Louis, MO); no. **13**, **29**, and 2-methylpentanoic acid (internal standard for acidic fraction; TCI America, Portland, OR); no. **7** (Pyrazine Specialties, Inc., Atlanta, GA); no. **19** (Silesia, Hoffman Estates, IL); *n*-octane-d_{18} [internal standard for neutral/basic (N/B) fraction, 99% Isotopic; Alfa Aesar, Ward Hill, MA]. Repurified (1×) diethyl ether (DEE) was prepared using 99.9+% anhydrous diethyl ether (Burdick & Jackson, Muskegon, MI) and distilled via packed column distillation (30 cm, 4 mm glass beads, distilled in a 40 °C water bath).

Compound **2** (2-acetyl-1-pyrroline) was not commercially available but was extracted from pandan leaves (*Pandanus amaryllifolius* Roxb.), which were obtained from the local market. The extraction procedure is described below.

Milk Samples. Raw whole bovine milk was obtained from the Pennsylvania State University Creamery (University Park, PA).

Sample/Material Preparation. *Extraction of Compound **2** (2-Acetyl-1-pyrroline).* Pandan leaves (190 g) were ground in liquid nitrogen. The ground leaves were added to 50 mL of distilled/deionized water and extracted with diethyl ether (2 × 350 mL). The organic layer was dried with anhydrous sodium sulfate, filtered, and subsequently concentrated to 30 mL. The concentrate was further purified using high-vacuum distillation ($<10^{-3}$ Pa) and the volatile fraction collected, dried with anhydrous sodium sulfate, filtered, and concentrated to 1 mL for analysis.

UHT Processing. Whole raw milk and whole raw milk with three different levels of epicatechin (0.01, 0.1, and 0.2% w/w) were placed into 4 L amber glass bottles with Teflon-lined lids (VWR, West Chester, PA) and shipped overnight on ice to Microthermics Inc. (Raleigh, NC) for UHT processing (model UHT-HTST Lab 25 HVH Hybrid). The processing conditions were as follows: preheated to 87.8 °C, homogenized (2500 psi) with a final heat of 141.1 °C, held for 6 s (final temperature was 138.3 °C), immediately cooled to 16.7 °C, and filled (sterile hood) into previously sterilized 1 L Pyrex bottles with Teflon-lined lids. The UHT-processed milk samples were then shipped overnight on ice back to the sender and stored for 3 weeks at 1 °C in the dark prior to chemical and sensory analysis. A storage time of 3 weeks was selected prior to analysis as this was found to be adequate time for the aroma profile of UHT milk to become more stable (or more typical of a commercial product). It was presumed that within the first 2 weeks reactive sulfur-containing compounds were degrading (i.e., hydrogen sulfide, methanethiol, dimethyl sulfide).

UHT Milk Extracts for AEDA. The UHT milk (control) and 0.1% EC UHT milk (treatment) samples were selected for analysis. Volatile extracts were prepared according to a modified version of the method reported by Cadwallader et al. (*11*) for nonfat dried milk. 2-Methylpentanoic acid (33 μL/5 mL in diethyl ether) was added as an internal standard for the acid fraction, whereas *n*-octane-d_{18} (70 μL/5 mL in diethyl ether) was added as an internal standard for the N/B fraction; the control and the treatment samples were spiked with each solution (3 μL/990 g of UHT milk) and subsequently stored overnight prior to further sample preparation. Each UHT milk sample (990 g) was extracted with 1× repurified diethyl ether (5 × 175 mL) in a 250 mL Teflon centrifuge bottle (Nalgene, Rochester, NY). Initially sodium chloride (59.4 g/165 g of milk) was added to the milk samples, followed by solvent addition, and the mixture was subsequently agitated for 1 h with an orbit shaker table at 40% of maximum speed (model 3540, Labline Instruments, Inc., Melrose Park, IL). The samples were then centrifuged for 20 min at 4 °C and 5000*g* (IEC B-20A, Damon/IEC Division, Needham Heights, MA), and the diethyl ether layer was carefully removed using Pasteur pipets. The diethyl ether extracts for each sample were pooled together, dried with anhydrous sodium sulfate, filtered, and concentrated to ∼110 g via packed column distillation (30 cm, 4 mm glass beads, distilled in a 40 °C water bath). The concentrate was then subjected to high-vacuum distillation using a solvent-assisted flavor evaporation (SAFE) apparatus as previously described by Engel et al. (*12*). The distillate was subsequently fractioned into neutral/basic and acidic (A) fractions. For the N/B fraction the distillate was washed with 0.5 M $NaHCO_3$ (3 × 120 mL), and the organic layer was collected, rewashed with a saturated NaCl solution (2 × 55 mL), and dried with anhydrous sodium sulfate. For the A fraction the aqueous layer (from 0.5 M $NaHCO_3$ wash) was pooled and acidified to a pH of ∼2.25 using a 1 N HCl solution, subsequently re-extracted with 1× repurified diethyl ether (3 × 150 mL), and dried with anhydrous sodium sulfate. Both the N/B and A fractions were further concentrated to ∼350 μL using a packed column and spinning band distillation. The final volumes of the concentrated samples were adjusted with DEE to obtain equivalent internal standard peak areas via GC-FID or GC-MS between the control and treatment concentrates for both N/B and A fractions, respectively (all adjustments were <50 μL DEE).

GCO/AEDA. GCO was performed using a Hewlet-Packard 5890 series II GC equipped with a flame ionization detector, autosampler (HP 7673), and sniffing port. DB-5 (30 m/0.25 mm/0.25 μm) and DB-FFAP (30 m/0.25 mm/0.25 μm) columns were used for analysis of the N/B and A fractions, respectively. GC conditions were as follows: inlet temperature was 200 °C, detector temperature was 250 °C, and sniffing port temperature was 230 °C; 1 μL of sample was injected in splitless mode. The effluent was split 1:1 between the FID and sniffing port with deactivated capillary tubing (1 m length/0.15 mm i.d.; SGE, Austin, TX). The effluent was swept out of the sniffing port with a stream of nitrogen at 40 mL/min. The oven profile for the N/B fraction (DB-5) was 30 °C for 2 min, ramped to 250 °C at 3 °C/min, and held at 250 °C for 2 min, whereas the acidic fraction was held at 40 °C for 2 min, then ramped at 5 °C/min to 230 °C, and held at 230 °C for 6 min. Two experienced panelists smelled through each dilution of each fraction with two repetitions per dilution. For AEDA, samples were diluted 1:1 with high-purity DEE. The dilutions were done until neither panelist found any odorants, and the highest value was reported as the dilution factor value (*13*).

Gas Chromatography−Mass Spectrometry. Sample extraction was analogous to the method given above under UHT Milk Extracts for AEDA, with the exception that they were further concentrated to 5 μL. Each sample was injected on an Agilent 6890 (Agilent Technologies, Inc., Wilmington, DE) gas chromatograph equipped with a Hewlett-Packard mass spectrometer (HP5972, Avondale, PA). All samples were run on two columns of different polarities: DB-5ms (60 m/0.25 mm/0.25 μm) and DB-Wax (60 m/0.25 mm/0.25 μm)/DB-FFAP (30 m/0.25 mm/0.25 μm) for the N/B and A isolates, respectively. GC conditions for all runs were as follows: inlet temperature, 200 °C; 1 μL of sample injected in pulsed splitless mode (14 psi 0.75 min); hydrogen carrier gas at a constant flow of 0.7 mL/min. MSD conditions were as follows: capillary direct interface temperature, 260 °C; mass range, 35−200 amu; EM voltage (Atune). The oven profile on the DB-5ms capillary column was 30 °C for 2 min, then ramped to 250 °C at 2 °C/min, and held for 2 min. The N/B fraction was run on a DB-Wax with the oven profile of 30 °C for 2 min and ramped to 230 °C at 3 °C/min, at which it was held for 6 min. The A fraction was run on a DB-FFAP; the oven profile was identical to that used for the DB-Wax with the exception of the initial temperature (40 °C).

Identification of Odorants. Positive identifications were made by comparing linear retention indices (LRI), mass spectra, and odor properties of unknowns with published data and mass spectra. Unknowns were also compared to authentic compounds analyzed under identical conditions. Tentative identifications were based on LRI values and odor properties as compared to published data and authentic compounds.

Sensory Analysis. A panel of 10 trained judges was used to evaluate the intensity of cooked flavor in UHT milk. The panel consisted of graduate students and staff of Pennsylvania State University, ranging in age from 23 to 45 years. Panelists were selected on the basis of previous panel experience and availability.

Panelists were trained in five sessions with very low level cooked, pasteurized, and high level cooked milks, commercial UHT, evaporated milk, and microwaved milk, as well as control and treatment samples. This allowed the panelists to become familiar with different cooked intensities. References consisted of milk microwaved to specific temperatures and the control sample (UHT milk). Pasteurized milk with a "clean" flavor was microwaved for reference levels 2 (60−63 °C) and 5 (70−73 °C), whereas reference level 7 was the control UHT milk. Panelists were also provided with pasteurized milk as a blank to show a clean, noncooked flavor.

In a separate session, panelists were trained on bitter flavor, using caffeine solutions as references. Reference concentrations were based on standard values; three levels were provided to panelists (0.05, 0.08, and 0.096% w/w in water), corresponding to values of 2, 5, and 7, respectively (*14*).

The evaluations were performed 3 weeks after UHT processing of the milk samples. The panelists evaluated cooked flavor in samples that consisted of control, treatment at three levels (0.01, 0.1, and 0.2% EC), and pasteurized milk. Evaluations of bitterness were performed on the control and three levels of treatment. The bitterness evaluations were performed in sessions separate from the cooked flavor evaluations. All evaluations were done using Compusensefive (v 4.2, Guelph, ON, Canada) with a 15 cm scale for intensity measurements, with 0 consisting of none of the attributes (cooked or bitterness) and 15 being

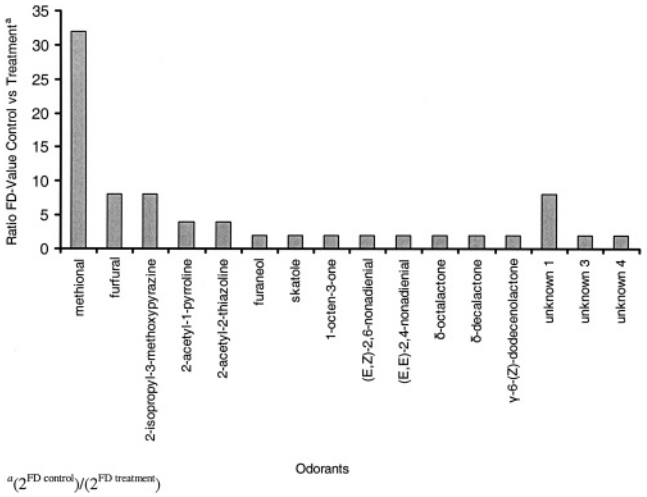

Figure 1. Ratio of flavor dilution (FD) values for the control UHT milk versus UHT-treated milk (0.1% EC); only odorants with a ratio of ≥1 FD value are illustrated. [a] $2^{FDcontrol}/2^{FDtreatment}$.

very high levels. Evaluations were done in duplicate over two sessions. Sample design for both panels was a randomized complete block, and all data analysis (ANOVA and Tukey's multiple-comparison test ($\alpha = 0.05$)) was performed using SAS (v 8.2, Cary, NC).

Microbial Testing. Microbial analysis was conducted on both control and treatment using 3M Petrifilm, aerobic count plates, and yeast and mold count plates, (3M Co., St. Paul, MN). The 3M Petrifilm aerobic count plates were used to enumerate total aerobic microbial plate count (TPC). For counts in 3M AC plates, 1 mL of each dilution 1:10, 1:100, and 1:1000 of milk samples was plated using phosphate buffer, KH_2PO_4 (0.0425 g/L, adjusted to pH 7.2, Butterfield's buffer; Weber Scientific, Hamilton, NJ). Yeast and mold count was done using the Petrifilm YM method (*15*, *16*). Samples were incubated at 32 °C for the aerobic plate count and at 21−25 °C for the yeast and mold, and colonies were enumerated after 48 h and 3−5 days, respectively.

RESULTS AND DISCUSSION

The odor-active compounds identified by AEDA for UHT-processed milk (control) and UHT-processed milk with 0.1% EC added prior to processing (treatment) are shown in **Table 1** (N/B fraction) and **Table 2** (A fraction). Furthermore, any compounds that reported an FD difference ≥1 between the control and treatment milk samples are illustrated in **Figure 1**. Overall addition of EC prior to UHT processing inhibited the formation of select aroma compounds in comparison to the control UHT milk. EC had the greatest inhibitory effect on the Maillard-derived compounds (methional, 2-isopropyl-3-methoxy pyrazine, 2-acetyl-1-pyrroline, 2-acetyl-2-thiazoline, and furfural) in comparison to those derived from lipid oxidation (nonadienal and nonenal) or lipid decomposition [δ-octalactone, δ-decalactone, and γ-(*Z*)-6-dodecenolactone].

Of the Maillard-derived compounds, methional showed the greatest reduction (32-fold), whereas 2-isoproyl-3-methoxy-pyrazine, furfural, 2-acetyl-1-pyrroline, 2-acetyl-2-thiazoline, Furaneol, and skatole reported 8-, 8-, 4-, 4-, 2-, and 2-fold reductions, respectively. Iwatsuki et al. (*8*) reported finding methional, skatole, and furfural in UHT milk. Furfural has also been reported in other UHT milk studies (*5*, *17*, *18*). All of these Maillard reaction products have also been shown to contribute to off-flavor development in spray-dried milk powder during storage (*11*, *19*, *20*).

Interestingly, addition of EC (a strong antioxidant) had little effect on the overall formation of lipid oxidation products (*E*,*Z*)-2,6-nonadienal, (*E*,*E*)-2,4-nonadienal, and (*E*)-2-nonenal, which reported a difference of 1 dilution (both nonadienals) or no differences (nonenal) between the control and treatment samples. This suggested that the primary changes in the flavor properties associated with UHT milk are derived from Maillard-type reactions and to a much smaller extent from lipid oxidation, which would be anticipated if one assumes the activation energies of lipid oxidation reactions are lower in comparison to Maillard-type reactions in fluid milk, as has been previously reported in dehydrated carrots (*21*).

Finally, small differences in inhibition were also reported between thermal lipid degradation products δ-octalactone, δ-decalactone, and γ-(*Z*)-6-dodecenolactone, which reported a 2-fold reduction for the treatment versus control UHT milk samples. Furthermore, the acid compounds showed no difference in the FD values between the control and treatment samples.

Table 3. Mean Scores for Cooked Flavor and Bitterness in Milk Samples

product	cooked flavor[a,b] (LSD = 1.61)	bitterness[b,c] (LSD = 1.78)
control	5.11 A	0.19 B
treatment with 0.01% EC	3.14 B	0.28 B
treatment with 0.1% EC	2.88 B	0.70 B
treatment with 0.2% EC	2.52 BC	3.30 A
pasteurized	1.19 C	NT[d]

[a] A 15 cm scale was used with 0 = no detectable cooked (pasteurized) and 15 = very cooked ($n = 10$). [b] Means in the same column having the same letter are not significantly different ($\alpha = 0.05$). [c] A 15 cm scale was used with 0 = no bitterness and 15 = very bitter ($n = 9$). [d] Not tested.

The results from the sensory evaluation are presented in **Table 3** and were in agreement with the AEDA. The cooked flavor intensity for the control (UHT milk) was rated as significantly higher ($\alpha = 0.05$) than all three treatment UHT milk samples (0.2, 0.1, and 0.01% EC containing samples), as well as the pasteurized milk sample. Furthermore, the intensity of cooked flavor perceived was inversely proportional to the level of EC added prior to processing. At the highest level of EC (0.2%), there was no significant difference in cooked flavor between the treatment and pasteurized milks. Bitterness was evaluated in the control and treatment samples as polyphenols are known to have bitter taste attributes. There was no significant increase in perceived bitterness between the control and two lowest levels (0.01 and 0.1%) of EC addition. However, at the 0.2% EC level, a significantly higher level of bitterness was perceived by the panel.

Microbial analysis was also conducted for each UHT milk sample at the time of AEDA and sensory evaluation because the bottles were filled in a sterile hood, which could not be considered to be completely aseptic. Zero colony-forming units for both aerobic plate count and yeast/mold count were reported for samples (data not shown), and consequently microbial activity was not associated with the noted differences in flavor properties of the UHT samples.

In conclusion, the results from this study were in agreement with those reported by Peterson and Totlani (*9*), which indicated specific flavonoids (epicatechin or epigallocatechin gallate) inhibited the formation of Maillard-type aroma compounds in a model Maillard reaction system and two food matrixes, granola bars and cocoa. Consequently, this information may provide new modes of control for flavor formation in food systems. Furthermore, flavonols (i.e., epicatechin) have been shown to be beneficially to health. Holt et al. (*22*) and Schramm et al. (*23*) have recently reported efficacious doses of flavanols and procyanidins (based on platelet function) to be 220 and 148

mg, respectively, 2−6 h after initial consumption. This indicates that a single serving of milk (240 mL) at the 0.1% EC level would provide 240 mg of EC, possibly adding health benefits without imparting bitterness and controlling unwanted flavor formation in UHT milk products.

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