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A Comparison of Carotenoid Content and Total Antioxidant Activity in Catsup from Several Commercial Sources in the United States

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Samples of catsup from 13 commercial sources, representing at least 10 U.S. manufacturers, were analyzed for carotenoid content, antioxidant activity, and percentage solids. The solids content of these catsup brand samples varied from 26.31 to 38.06% solids. The lycopene content ranged from 59.42 to 183.36 μg, and total carotenoids were as high as 216.6 μg/g fresh weight, respectively. In addition, both hydrophilic and lipophilic antioxidant activities were measured using the Trolox equivalent antioxidant capacity (TEAC) assay. These measurements of samples of the various catsup brands ranged from 176.5 to 356.8 total TEAC units.

KEYWORDS: Tomato; catsup; lycopene; carotenoid; Trolox equivalent antioxidant activity; solids

INTRODUCTION

Because of recent epidemiological findings that the consumption of tomatoes and tomato products is strongly correlated with a reduced risk of certain cancers (e.g., prostate, gastrointestinal, and epithelial cell) and cardiovascular disease (*1*−*3*), the antioxidant activity and, in particular, the carotenoid content of various tomato products are of interest. The protective effect of consuming tomato products has been attributed to lycopene, the major carotenoid in tomatoes. Lycopene is responsible for the red color of tomato fruit and generally represents more than 80% of its total carotenoid content (*4*, *5*). It was shown to be the strongest biological quencher of singlet molecular oxygen (*6*) and, therefore, presumably the most effective in protecting against oxidative damage from free radicals.

Catsup is a major form of tomato consumption in the United States and the Western world. In the United States, the population has become caught up in an increasingly busy lifestyle, which discourages time-consuming meal preparation at home. In addition, marketing is directed more and more toward children and teenagers. Therefore, fast food restaurants are becoming more and more appealing. The primary reason, however, for increased catsup consumption is a result of the increasing spread of American fast food restaurants throughout the world.

In this country, catsup is available from many sources, including numerous commercial brands sold in supermarkets and grocery stores, health food stores, and fast food restaurants. These sources seemingly offer very similar products that are often hard to distinguish except by brand name. However, in addition to the standard dark red product, which varies in degrees of the depth of its red color, catsup is now available in various colors, without added salt, and with additional spices.

Because of the difficulty in assessing the carotenoid content of catsup by appearance, its delivery of high lycopene content and antioxidant capacity, and general interest in the benefits of tomato products to consumer health, we investigated differences in several products that are commonly available to the public in the United States.

MATERIALS AND METHODS

Sources of Catsup. Catsup from 13 different commercial sources, representing at least 10 U.S. manufacturers, was purchased from major supermarkets, health food stores, and fast food restaurants for analysis. Samples of catsup were removed from unopened containers stored at room temperature until opened and then were stored in the dark at refrigerator temperatures at approximately 5 °C. (Carotenoid compositions and antioxidant activities were stable under these conditions.) The catsup manufacturers represented were major brands, store brands, organic food companies, and companies providing catsup to fast food restaurants in individual servings contained in plastic packets.

Percentage Dry Weight (DW). Moisture contents and DWs were determined, using a model AVC-80 microwave moisture/solids analyzer (CEM Corporation, Mathews, NC). Samples of catsup were placed between two tared glass fiber pads and heated at 50% power for 4.5 min. The moisture content (or percent solids) was determined by the difference in weight after drying.

Carotenoid Analyses. Carotenoids were extracted from catsup samples essentially as described by Ishida et al. (*7*, *8*). Extracts containing carotenoid fractions were dried quickly under a stream of nitrogen and stored at −20 °C. Just before analysis, the dried extracts were dissolved in tetrahydrofuran. The lycopene content was determined in a Beckman model DU 640 spectrophotometer, measuring the absorbance at 470 nm and using a molar extinction coefficient in hexane of 3450. The carotenoid content was analyzed by injecting 25 μL aliquots into a Waters high-performance liquid chromatography (HPLC)

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Table 1. Solids Contents of Commercial Brands of Catsup

brand	% solids	brand	% solids
	major brands[a]		
M1 (SD)[b]	31.65 (0.97)	M4 (SD)	33.05 (0.16)
M2 (SD)	32.21 (0.54)	M5 (SD)	33.25 (0.37)
M3 (SD)	32.86 (0.16)	M6 (SD)	33.77 (0.29)
	organic brands		
O1 (SD)	26.31 (0.30)	O3 (SD)	35.23 (0.34)
O2 (SD)	29.83 (0.33)		
	store brands		
S1 (SD)	32.52 (0.31)	S2 (SD)	32.84 (0.41)
	fast food/vending machine		
F1 (SD)	34.28 (1.30)	F2 (SD)	38.06 (1.30)

[a] M2, hot; M3 and 5, no salt; M4, nonred. [b] Standard deviation, samples analyzed in triplicate.

equipped with a model 2690 Separations Module, model 996 Photodiode Array Detector, and a C_{30} carotenoid column (Waters, Milford, MA) according to the method of Ishida et al. (*7*, *8*). Lycopene recovery using this method was found to be 94.5%; recovery of an external standard echinenone was 92.1%.

Total Antioxidant Activity. The total antioxidant activity of tomato catsups was determined by the 2,2′-azino-bis-(3-ethylbenzthioazoline-6-sulfonic acid) (ABTS)/H_2O_2/horseradish peroxidase decoloration method (*9*, *10*). In this method, ABTS radical cation was generated chemically, and the standard antioxidant or sample being analyzed was added, which resulted in the loss of the $ABTS^+$, which was measured by the decrease in absorbance. We used this method to determine hydrophilic and lipophilic antioxidant activities (HAA and LAA) (*11*, *12*) in catsup, expressed as Trolox equivalent antioxidant capacities (TEAC) (*9*−*12*). To obtain the lipophilic components, catsup samples were extracted, using the method of Ishida et al. (*7*, *8*). Hydrophilic constituents were obtained in the water soluble methanol wash at the beginning of the carotenoid extraction procedure.

RESULTS AND DISCUSSION

Percentage DW. Data obtained on percentage DW of catsup samples are shown in **Table 1**. Values ranged from 26.31 to 38.06%. Catsups are placed into categories of major brands (M), store brands (S), organic brands obtained from organic/health food stores (O), and a fast food chain restaurant or vending machine (F). All but one brand of catsup, an organic brand (O1), were 30% or higher in solids content. The brand of catsup having the lowest solids content was only 69% that of the catsup brand having the highest solids, which was a packaged catsup from a fast food vending machine (F1).

Carotenoid Content. Figure 1 shows mean values of lycopene concentrations in the catsup samples tested. These values were based upon spectrophotometric measurements, which result in an overestimation of lycopene because of the presence of small amounts of other carotenoids whose absorption spectra, which do not have peaks at 470 nm, contribute to this measurement. These values ranged from 59.42 to 183.36 μg/g fresh weight (FW), a more than 3-fold range in concentration. Catsup brands categorized as organic were purchased at a health food store and were highest in lycopene content, even when calculations were made based upon DW, although their order of ranking changed somewhat. (We are reporting lycopene concentrations based on FW because they reflect relative amounts of lycopene as they are actually delivered to the consumer.) The catsup sample obtained from a fast food chain restaurant (F1) was the next highest (fourth) in lycopene content. The brand having the lowest lycopene content in terms of both FW and DW was obtained from a fast food vending machine (F2). These data are all in the same ranges as those reported in the literature (*13*−*17*).

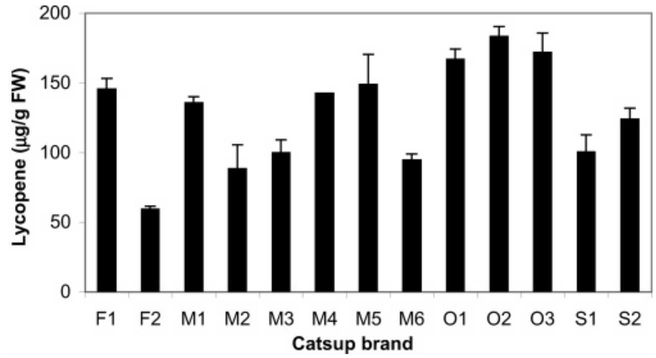

Figure 1. Lycopene content of samples from different brands of catsup. O, brands labeled "organic" obtained from organic health food stores; M, brands produced by major commercial companies; S, supermarket brands; and F, catsup samples from a fast food restaurant or vending machine. Error bars represent the standard deviation of the mean value obtained from four samples taken from each catsup.

The predominant carotenoids detected in our catsup samples were *trans*-lycopene, phytofluene, phytoene, lutein, α- and *β*-carotene, and three or four *cis*-isomers of lycopene. **Figure 2** shows a chromatogram obtained from HPLC analysis of the catsup sample having the largest number of different carotenoids. Tonucci et al. (*14*) measured, in addition, quantities of ζ-carotene, neurosporene, and lycopene-5,6-diol. Schierle et al. (*15*) reported 77−88% all-*trans*-lycopene in two catsups, as well as percentages of three *cis*-isomers. Our estimates of total carotenoid content of catsup samples, as well as lycopene contents analyzed in the present study, are shown in **Table 2**. Our data show that the all-*trans*-lycopene comprised 68.9−100% of the total carotenoids. Note once again that the catsup samples having the highest carotenoid contents were the organic brands, followed again by the catsup from a fast food restaurant (F1). The lowest in carotenoid content, however, was found in the one obtained from a fast food vending machine.

Antioxidant Capacity. Compounds in tomatoes and tomato products having antioxidant capacities that are reported in the literature include lycopene (*6*, *18*−*20*), ascorbic acid (vitamin C) (*21*−*25*), α-tocopherol (vitamin E) (*22*, *26*), *β*-carotene (provitamin A) (*19*, *22*, *25*, *27*), and phenolic compounds (includes flavonoids and hydroxycinnamic acids) (*25*, *28*−*31*). Martinez-Valverde (*31*) identified ferulic and caffeic acids, but not quercetin and chlorogenic acid, as phenolic compounds that were significantly related to the antioxidant capacity of several commercial tomato varieties.

The protective effect of many biological compounds against certain degenerative diseases, e.g., several types of cancers, cardiovascular diseases, cataracts, age-related macular degeneration, and oxidative stress dysfunctions, has been attributed to their antioxidant activity (*17*, *32*, *33*). This activity can protect biological systems against the potential dangers from processes or reactions that can cause excessive oxidative damage from free radicals (*6*, *27*).

As a measure of antioxidant capacity, we quantified both HAA and LAA in catsup samples. These values are depicted in **Figure 3**. According to our measurements, LAA accounts for most of the antioxidant activity of catsup and consists of the antioxidant activity resulting from lycopene and other lipophilic compounds extracted from the catsup. Arnao et al. (*12*) analyzed both HAA and LAA antioxidant activities in tomato, gazpacho, and seven vegetable soups. Their data showed

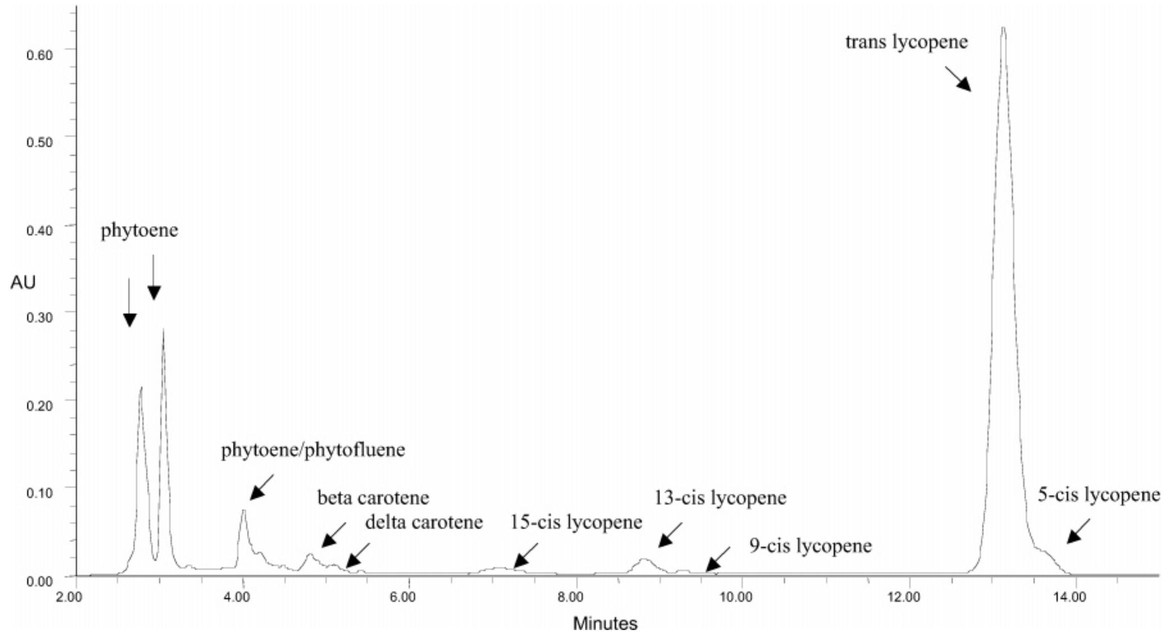

Figure 2. HPLC chromatogram of carotenoids extracted from a catsup sample, showing peaks of separated compounds whose identities were determined by injected standard samples and/or measured absorption spectra. The catsup sample shown here contained the largest number of carotenoid peaks of all of the catsup brands examined.

Table 2. Carotenoid Contents of Commercial Brands of Catsup

brand	*trans*-lycopene[a]	other carotenoids[b]	% *trans*-lycopene	total[b]
		major brands[c]		
M1 (SD)[d]	135.79 (4.44)	25.9	84.0	161.7
M2 (SD)	88.30 (17.34)	33.0	72.3	121.3
M3 (SD)	100.09 (9.29)	45.2	68.9	145.3
M4 (SD)	142.76 (0.75)	29.2	83.0	172.0
M5 (SD)	102.53 (21.56)	ND[e]	82.6	102.5
M6 (SD)	94.67 (4.43)	20.8	82.0	115.5
		organic brands		
O1 (SD)	167.19 (7.01)	35.3	82.6	202.5
O2 (SD)	183.36 (7.07)	0	100	183.4
O3 (SD)	172.10 (13.83)	44.5	79.5	216.6
		store brands		
S1 (SD)	100.48 (12.43)	4.4	95.8	104.9
S2 (SD)	124.12 (7.95)	36.9	77.1	161.0
		fast food/vending machine		
F1 (SD)	145.62 (7.79)	36.5	80.0	182.1
F2 (SD)	59.42 (2.21)	ND	59.4	ND

[a] μg lycopene/g FW. [b] μg carotenoids/g FW, only one analysis. [c] M2, hot; M3 and 5, no salt; M4, nonred. [d] Standard deviation, samples analyzed in triplicate. [e] No data.

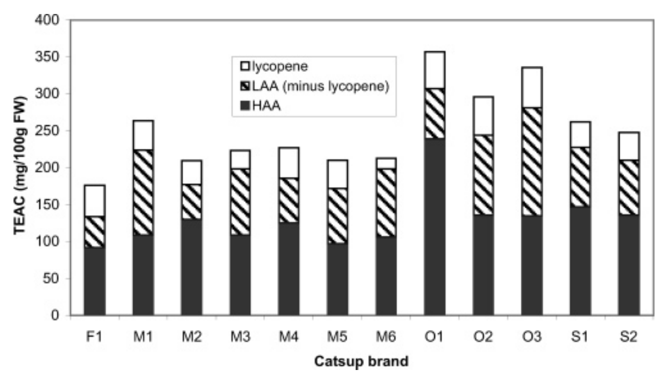

Figure 3. Antioxidant activity of samples from different catsup brands, showing contributions of LAA from lycopene (clear areas), without lycopene (striped areas), and HAA (solid areas). O, brands labeled "organic" obtained from organic health food stores; M, brands produced by major commercial companies; S, supermarket brands; and F, catsup samples from a fast food restaurant or vending machine. The values shown represent the mean obtained from three samples taken from each catsup.

that in tomato soup, LAA represented only about one-fifth of the total antioxidant activity. Of that fraction, the relative antioxidant activity of lycopene plus β-carotene contributed one-third of the LAA. Therefore, the combination of HAA and the major carotenoid content in tomato soup represented 87% of the total antioxidant activity. Ascorbic acid contributed 35% of the HAA. The other two soups had lower HAAs (gazpacho about 63% and seven vegetable soup 43% that of tomato soup).

Our data on LAA and HAA are expressed in **Figure 3** as TEAC (*9*, *10*, *12*, *34*). LAA values ranged from 79.5 (M2) to 201 (O3) TEACs and, as expected, are higher values than those obtained in soups by Arnao et al. (*12*). However, in contrast to tomato soup, which derived about 20% of its antioxidant activity from LAA, the LAA contribution in catsup samples ranged from 37.9 to 59.9% of the total antioxidant activity. These data do not necessarily reflect lycopene content in the catsup samples, although one might expect that the major contribution to LAA would be that from lycopene. However, the percentage of lycopene contributing to LAA varied from 13.7 (M6) to 51.2% (F1). This percentage was calculated based on the relative antioxidant activity of *trans*-lycopene as compared to Trolox, which was determined by Bohm et al. (*10*) to be 2.5. The three brands of catsup having the highest total antioxidant capacities were again the organic brands, but those deriving the greatest relative contribution of lycopene to LAA were F1, O2, and M4, having 51.2, 42.4, and 40.6% contributions from lycopene, respectively.

HAA values obtained in our analyses of catsup samples varied from 92 (F1) to 239 (O1) TEACs. The catsup sample having the highest HAA again was an organic brand (O1), but a store brand (S1) had the second highest HAA, which was only 61.5% that of O1, followed by S2, O2, and O3, which were almost identical in HAA values (56.4−56.9% of O1).

Tomato catsup is an excellent source of lycopene, carotenoids, and antioxidant compounds. A good estimate of lycopene content can be made by the dark red appearance of the product. The organic brands had a much deeper red color than the other brands examined.

Samples of catsup produced by organic food companies were highest in lycopene and total carotenoid contents, total antioxidant activity, and LAA. In addition, two of the three organic brands had the highest HAA, and the third ranked number four.

The catsup brand having the lowest solids content had the highest total antioxidant activity and the highest HAA. This was an organic brand (O1). It ranked third highest in lycopene content and fourth highest in LAA value. Two of the organic catsup brands had the lowest solids content. Therefore, solids content is not a good indicator of the nutritional value of the catsup.

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