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Short communication

Chicoric acid levels in commercial basil (*Ocimum basilicum*) and *Echinacea purpurea* products

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ABSTRACT

Fresh basil (*Ocimum basilicum*) leaves contain chicoric acid, which is the principal phenolic compound in *Echinacea purpurea* and purportedly an active ingredient in dietary supplements derived from *E. purpurea*. Here the concentrations of chicoric acid in dried and fresh basil products available to consumers, and how these concentrations compare to those from *E. purpurea* are reported. A wide range of chicoric acid concentrations (6.48–242.50 mg/100 g or 100 mL) were found in the dried basil flakes, fresh basil leaves, *E. purpurea* extracts, and *E. purpurea* capsules. Fresh basil leaves had higher concentrations of chicoric acid than dried basil flakes. Although *E. purpurea* extracts and capsules contained higher concentrations of chicoric acid than fresh basil leaves, basil could be an economical and more readily available source for chicoric acid for consumers. Additionally, cultivar selection, dehydration processing improvements, and proper storage methods may improve the final chicoric acid levels of future basil crops and products.

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1. Introduction

Chicoric acid (also known as cichoric acid and dicaffeoyltartaric acid) is the main phenolic compound found in *Echinacea purpurea* (all parts of the plant) and in *E. purpurea* products (Molgaard et al., 2003). Chicoric acid is purportedly one of the numerous active ingredients (alkamides, other caffeic acid derivatives, polysaccharides, and glycoproteins) associated with human health benefits from *E. purpurea* dietary supplements (Barnes et al., 2005 and references therein; Molgaard et al., 2003). Despite some studies demonstrating benefits no better than that of placebo (Barnes et al., 2005 and references therein), *Echinacea* dietary supplements remain popular, and from 2000 to 2006 generated $100–200 million in annual sales in the US (Tilburt et al., 2008). Chicoric acid has been studied for its potential to inhibit HIV integrase (Healy et al., 2009; Charvat et al., 2006), to enhance insulin secretion and glucose uptake (Tousch et al., 2008), and to exert antioxidant activity (Dalby-Brown et al., 2005).

Basil (family Lamiaceae) is a popular and readily available culinary herb in the American kitchen and its historic usage, cultivation, essential oil utilization, and phenolic composition has been well reviewed (Makri & Kintzios, 2008). Chicoric acid was recently identified and quantified in basil leaves (Lee & Scagel, 2009). Since basil is a more economical source for dietary chicoric acid than products containing *E. purpurea* (family Asteraceae), this finding prompted us to further investigate the range of chicoric acid concentrations in products available in the US marketplace. Common culinary herbs have been reported to have antioxidant activities (Yanishlieva et al.,

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2006; Capecka et al., 2005; Almela et al., 2006; Javanmardi et al., 2003; Kivilompolo & Hyotylainen, 2007; Nguyen & Niemeyer, 2008; Halvorsen et al., 2006) and antimicrobial activities (Hussain et al., 2008; Gutierrez et al., 2008), suggesting a potential role they may play in human health beyond nutritional value (Justesen & Knuthsen, 2001; Dog, 2006; Craig, 1999).

Although chicoric acid is commonly thought to occur in *E. purpurea* alone (Nusslein et al., 2000), it has been found in numerous sources, including iceberg lettuce, chicory, cat's whisker, basil, among others (Baur et al., 2004; Innocenti et al., 2005; Olah et al., 2003; Lee & Scagel, 2009). In the present study we evaluated the chicoric acid concentrations in dried and fresh basil products available to consumers and how these concentrations compare to those from *E. purpurea* plant and products.

2. Materials and methods

2.1. Samples

Fresh basil samples and dried basil products commonly available to consumers were purchased at local marketplaces in Nampa and Caldwell, ID, USA. Fresh sweet basil samples were separated into leaves (coded B1) and stems upon arrival at the laboratory and immediately frozen in liquid nitrogen and stored at −80 °C. The fresh basil cost $2.90/100 g of fresh product and was available as small (~100 g fresh weight) bundles in the fresh produce section of the market. Dried spice/herb (leaf flake) basil products (coded B2 through B10; $n = 9$) from seven companies were evaluated as the air-dried form obtainable in sealed off-the-shelf containers and from unsealed bulk-purchase containers. Dried flakes were stored at −80 °C until extraction and analysis. On average, dried basil flakes cost $3.50 (US) and, except for the samples from the bulk-purchase containers, were pre-packaged in small glass, plastic, and metal containers with approximately 15 g net weight of flakes in the spice section of the store. Pre-packaged basil containers had a 'sell by' or 'best used by' dates between August 2010 and June 2011.

Living *E. purpurea* plants ($12.00 for a 2.5 L potted plant) and products containing *E. purpurea* ($n = 4$) were purchased at local marketplaces in Nampa and Caldwell, ID, USA at the same time of year as basil samples (September 2008). The entire *E. purpurea* plant (coded E1) was separated into flower head, leaves, stems, and roots and immediately frozen in liquid nitrogen and stored at −80 °C. *E. purpurea* dietary supplements from three companies were evaluated using extracts (coded E2 and E3) and capsules (coded E4 and E5) available in off-the-shelf containers. Samples of *Echinacea* capsules had the gelatin portion removed and only capsule contents (dried powder) were kept for analysis. Extracts and dried powder from capsules were stored at −80 °C until extraction and/or analysis. Extracts and capsules of *Echinacea* cost from $7.00 to $13.00 (US) for 20–50 servings (based on manufacturer recommended serving/dose) and were sold in dark colored glass vials or small plastic containers in the dietary supplement section of the store. Only extracts and capsules indicating *E. purpurea* as the ingredient were purchased. Samples listing expiration dates were labeled to expire between December 2009 and January 2010.

2.2. Reagents, chemicals, and standards

All chemicals for extraction, spectrophotometric analysis, and HPLC (high performance liquid chromatography) analysis were purchased from Sigma Chemical Co. (St. Louis, MO, USA) unless indicated otherwise. Solvents and chemicals used in this study were all analytical and HPLC grade.

2.3. Extraction, spectrophotometric analysis, and HPLC analysis

All solid samples were extracted as described in Lee and Scagel (2009), with the exception of using a mortar and pestle for liquid nitrogen powdering. Primary extraction included a blanching step to eliminate native enzymatic degradation (Lee & Scagel, 2009; Dogan et al., 2005). Ethanol was removed from the *Echinacea* extracts (5.0 mL) using a RapidVap Vacuum Evaporation System (Labconco Corp, Kansas City, MO, USA) before extracts were re-dissolved in water (final 10.0 mL).

Total phenolic (TP) concentration was determined as described by Waterhouse (2002) and expressed as mg gallic acid equivalents/100 g or 100 mL. HPLC/DAD system (HP1100; Agilent Technologies Inc., Palo Alto, CA, USA) and conditions were as described previously (Lee & Scagel, 2009; Lee & Finn, 2007). All aqueous extracts were purified using solid phase extraction (C18 Sep-Pak Plus; Waters Corp., Milford, MA, USA; Lee & Finn, 2007) prior to HPLC injection. Caffeic acid derivatives, monitored at 320 nm, are expressed as mg caffeic acid/100 g tissue or 100 mL of extract. Flavonol-glycosides, monitored at 370 nm, are expressed as mg of rutin (quercetin-rutinoside). Identification and quantification were conducted as previously described (Lee & Scagel, 2009) with the addition of a purified standard for lithospermic acid (also known as lithospermic acid A, Cerilliant Corp., Round Rock, TX, USA). Caftaric acid, chicoric acid, and rosmarinic acid (structures in Fig. 1) values are reported separately and all other peaks including caffeic acid derivatives, cinnamylmalic acid, feruloyltartaric acid, caffeic acid, quercetin-rutinoside, and cinnamic acid derivative were summed together.

All analyses were conducted in triplicates and reported as mg/100 g of tissue or 100 mL of extract. Results are presented relating to the purchased form to allow for direct comparisons of concentrations between marketplace products. Solid sample concentrations are expressed in fresh weight (fw) or dry weight (dw).

Statistica for Windows version 7.2 (StatSoft Inc., Tulsa, OK, USA) was used for statistical analysis. Pearson product moment correlation coefficient (r) was used for TP and total polyphenolic values ($\alpha = 0.05$).

3. Results and discussion

3.1. Identification and quantification of phenolics from fresh basil samples

All 11 peaks previously reported (Lee & Scagel, 2009) were also found in the fresh basil samples examined in this study (in HPLC elution order): (1) caffeic acid derivative, (2) caftaric acid, (3) cinnamylmalic acid, (4) feruloyltartaric acid, (5) caf-

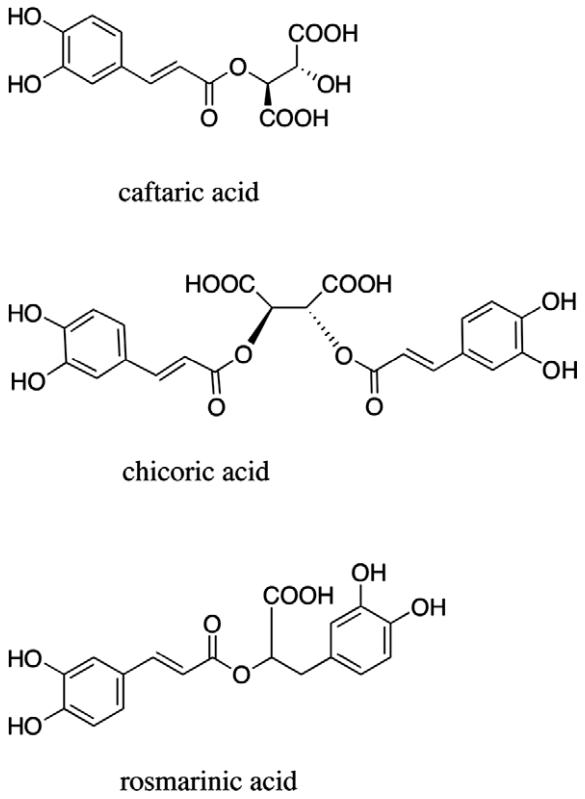

Fig. 1 – Structures of caftaric acid, chicoric acid, and rosmarinic acid reported in this study.

feic acid, (6) caffeic acid derivative, (7) chicoric acid, (8) caffeic acid derivative (possibly lithospermic acid A isomer), (9) quercetin-rutinoside, (10) cinnamic acid derivative, and (11) rosmarinic acid (see Lee and Scagel (2009) for a representative HPLC chromatogram of basil phenolic profile). Previously, the presence of lithospermic acid A in basil leaves was tentatively identified (peak 8) based on UV–VIS spectra (λ_{max} = 330 nm) and MS data ($[M-H]^-$, fragmented ions = 536 *m/z*, 491 *m/z*) (Lee & Scagel, 2009). In the present study, the chromatogram of a purchased lithospermic acid A standard revealed a different elution time than of the previous studies' tentatively identified peak (peak 8) for lithospermic acid A. The previously reported peak 8 eluted around 42.4 min while the purchased standard eluted around 64.7 min. This unknown peak 8 had a mass spectrum and fragmentation pattern identical to lithospermic acid A, as reported by others (Wang et al., 2008; Tada et al., 1996), and to the purchased standard. The unknown peak 8 is a caffeic acid derivative and possibly a lithospermic acid A isomer (Guo et al., 2007); further purification and identification are beyond the focus of the present study.

Fresh basil leaf samples (Table 1) used in this study were similar qualitatively to our previous study (Lee & Scagel, 2009), but slightly different with respect to the different proportions of polyphenolics. In both studies rosmarinic acid and chicoric acid were the two main polyphenolics in fresh sweet basil leaves accounting for 65% and 17% of total polyphenolics, respectively, in sample B1. Rosmarinic acid and chicoric acid were also the most abundant phenolics in fresh leaves from other basil cultivars, including 'Thai basil', 'Genovese Italian', and 'Purple Petra' (Lee & Scagel, 2009). In these cultivars, chicoric acid accounted for 16% (Genovese Italian), 21% (Purple Petra), and 37% (Thai basil) of the total polyphenolics. Quercetin-rutinoside (18.45 mg/100 g fw; 8.7% of total polyphenolics) was found to be the third major peak in B1 fresh leaf samples, and caftaric acid (0.7% of total polyphenolics) was the sixth major peak.

The sweet basil samples used in the current study, and the sweet basil used in the previous study, were both purchased from the same market and were the same brand; however, samples in this study were purchased during September 2008 and samples in the previous study were purchased during September 2007. Phenolic concentrations are known to differ with cultivar (Lee & Scagel, 2009), growing conditions (Perry et al., 2001), harvest handling (Wills & Stuart, 2000), storage conditions (Wills & Stuart, 2000), etc., which may have contributed to the observed differences in proportions of polyphenolics between studies.

Fresh sweet basil leaves had higher concentrations of TP, caftaric acid, chicoric acid, rosmarinic acid, and total polyphenolics than the stems (Table 1). Lower concentrations of phenolics in stems compared to leaves have previously been reported for sweet basil and other basil cultivars (Lee & Scagel, 2009). Rosmarinic acid was measured at the highest concentrations in fresh basil stems (80% of total polyphenolics; Table 1) and chicoric acid accounted for 1.6% of total polyphenolics in fresh basil stems. In our previous study chicoric acid was not detected in the stems of market-purchased sweet basil, 'Genovese Italian', and 'Purple Petra' cultivars; however, chicoric acid was detected in Thai basil stems and accounted for 0.6% of the total polyphenolics (Lee & Scagel, 2009).

3.2. *Polyphenolics in dried basil flakes*

All 11 polyphenolics detected in fresh basil leaves (Table 1) were detected in dried basil flakes; however, the proportions of the individual polyphenolics were different than in the fresh basil leaves and varied between basil flake products (Table 1). Some dried basil flake products contained similar proportions of chicoric acid and rosmarinic acid (e.g., B2, B3, B6), and some dried basil flake products contained more rosmarinic acid than chicoric acid (e.g., B4, B5, B7, B8, B9, B10). Other peaks accounted for 24–42% of the total polyphenolics (Table 1). Rosmarinic acid was the most abundant polyphenolic in eight of the nine basil flake products (chicoric acid was the most abundant in B6); however, the second and third most abundant polyphenolic varied among products tested. For example, chicoric acid was the second most abundant polyphenolic in three basil flake products (B2, B3, and B4) and quercetin-rutinoside was the second most abundant polyphenolic in basil flakes from five products (B5, B7, B8, B9, and B10). For basil flakes from the B6 product chicoric acid was the most abundant polyphenolic followed by rosmarinic acid, quercetin-rutinoside, caffeic acid, and caftaric acid.

On a dry weight basis, dried basil flakes contained between 0.011% and 0.167% rosmarinic acid, and rosmarinic acid accounted for 25–69% of the total polyphenolics in the flakes. In general, dried basil flakes contained similar or lower

Table 1 – Phenolic composition of market-purchased fresh and dry basil and Echinacea purpurea samples.

Plant source, sample form and type[a]	Concentration[b]					
	TP	Caftaric acid	Chicoric acid	Rosmarinic acid	Other peaks	Total polyphenolics
Basil						
Fresh (mg/100 g fw)						
Leaves	651.6 (12.2)	1.54 (0.00)	37.03 (0.19)	138.62 (0.14)	34.61 (0.08)	211.80 (0.39)
Stems	223.4 (3.8)	0.11 (0.00)	0.75 (0.00)	37.62 (0.02)	8.42 (0.02)	46.89 (0.04)
Dry flakes (mg/100 g dw)						
B2	330.3 (4.8)	0.56 (0.00)	16.24 (0.01)	17.72 (0.05)	18.16 (0.02)	52.67 (0.04)
B3	251.7 (4.8)	0.54 (0.00)	10.66 (0.01)	14.13 (0.01)	17.07 (0.03)	42.41 (0.04)
B4	353.9 (1.8)	1.33 (0.01)	16.12 (0.04)	50.24 (0.19)	26.08 (0.25)	93.77 (0.47)
B5	415.0 (6.0)	0.41 (0.00)	6.48 (0.03)	45.91 (0.33)	37.70 (0.52)	90.49 (0.86)
B6	285.8 (7.9)	2.28 (0.02)	15.58 (0.01)	11.43(0.04)	17.14 q(0.01)	46.43 (0.07)
B7	453.1 (7.7)	0.35 (0.00)	6.48 (0.01)	34.72 (0.03)	17.88 (0.07)	59.43 (0.10)
B8	555.3 (5.3)	0.18 (0.00)	9.59 (0.06)	108.34 (0.38)	38.35 (0.13)	156.46 (0.55)
B9	359.7 (6.1)	0.41 (0.00)	10.65 (0.02)	51.64 (0.18)	21.97 (0.02)	84.68 (0.22)
B10	807.2 (7.0)	0.91 (0.00)	14.47 (0.06)	166.83 (0.49)	94.89 (0.29)	277.10 (0.80)
Echinacea						
Fresh (mg/100 g fw)						
Flower head	313.9 (3.0)	9.84 (0.01)	159.62 (0.07)	nd (na)	nd (na)	169.45 (0.06)
Leaves	606.9 (4.5)	nd (na)	390.68 (0.91)	nd (na)	nd (na)	390.68 (0.91)
Stems	277.8 (0.7)	4.71 (0.01)	92.56 (0.10)	nd (na)	nd (na)	97.27 (0.10)
Roots	491.6 (10.0)	4.69 (0.01)	254.56 (0.27)	nd (na)	nd (na)	259.25 (0.27)
Whole plant	444.1 (4.1)	4.48 (0.00)	242.28 (0.29)	nd (na)	nd (na)	246.76 (0.28)
Extract (mg/100 mL)						
E2	156.9 (1.3)	3.16 (0.00)	41.48 (0.10)	nd (na)	nd (na)	44.64 (0.10)
E3	171.1 (0.9)	1.63 (0.02)	23.15 (0.43)	nd (na)	nd (na)	24.78 (0.45)
Capsules (mg/100 g dw)						
E4	484.7 (13.4)	3.56 (0.01)	242.50 (0.06)	nd (na)	nd (na)	246.06 (0.06)
E5	241.6 (2.9)	3.80 (0.02)	68.88 (0.11)	nd (na)	nd (na)	72.68 (0.13)

a Samples were obtained from basil (*Ocimum basilicum*) and *Echinacea* (*E. purpurea*) fresh and processed products. Fresh = fresh plant samples separated based on structure (leaves, stems, roots, flower head, and whole plant) with concentrations expressed in mg/100 g fw. Dry flakes = commercially processed dry flakes of basil from seven manufacturers (B2–B10) with concentrations expressed in mg/100 g dw of dry product. Extract = commercially processed extracts of *Echinacea* (E2 and E3) from different manufacturers with concentrations expressed in mg/100 mL of liquid product. Capsules = dry contents from commercially processed capsules containing *Echinacea* with concentrations expressed in mg/100 g dw of capsule contents.

b Mean values ($n = 3$) followed by standard errors in parentheses. TP = total phenolics determined by spectrophotometry expressed in mg gallic acid equivalents. Other peaks = are the sum of caffeic acid derivative, cinnamylmalic acid, feruloyltartaric acid, caffeic acid, caffeic acid derivative (possibly lithospermic acid A isomer), quercetin-rutinoside, and cinnamic acid derivative. Total polyphenolics as determined by HPLC.

concentrations and proportions of rosmarinic acid than fresh leaves of sweet basil in this study (Table 1) or fresh leaves of basil cultivars in our previous study (fw basis; Lee & Scagel, 2009). The dry basil products used in this study came from seven different companies and their growing conditions, harvesting, and processing procedures may be quite variable. Rosmarinic acid is known to be highly unstable during harvesting and processing (Nusslein et al., 2000); therefore some of the differences we detected in rosmarinic acid concentrations among dry products may be a result of processing methods. Additionally, dry basil flakes were generic in terms of both the cultivar or cultivars used for the product, or whether the product contained only leaves or a combination of stems and leaves. Concentrations of rosmarinic acid can vary among basil cultivars and between stems and leaves (Lee & Scagel, 2009); therefore differences in rosmarinic acid between dried basil products could also be a result of the combination of cultivars and tissues used in the product.

Others have reported higher concentrations of rosmarinic acid in dried samples of basil than we have measured. Kivilompolo and Hyotylainen (2007) reported market-purchased dried basil contained 308.0 mg of rosmarinic acid/100 g dw (determined by HPLC) and in a study investigating the impact of Arbuscular Mycorrhizal Fungi (AMF; Toussaint et al., 2008) on basil, dried research samples (drying conditions unreported) contained 1100–1680 mg of rosmarinic acid/100 g dw (determined by HPLC).

On a dry weight basis, dried basil flakes contained between 0.006% and 0.016% chicoric acid, accounting for 5–33% of the total polyphenolics in the flakes. In general, dried basil flakes contained lower concentrations of chicoric acid than fresh leaves of sweet basil in this study (Table 1) and fresh leaves of sweet basil and other basil cultivars in our previous study (Lee & Scagel, 2009); however, chicoric acid in five dried basil flake products (B2, B3, B4, B5, B9) accounted for a similar or higher proportion (12–31%) of the total polyphenolics than the proportion in fresh sweet basil leaves (17%). In our previous study (Lee & Scagel, 2009), chicoric acid accounted for 16–37% of the total phenolics in fresh leaves of sweet basil and other basil cultivars. This suggests the variation in the

proportion of chicoric acid to total phenolics in dried basil flake products may be similar to the variation found in fresh leaves.

As with rosmarinic acid, concentrations of chicoric acid can vary among basil cultivars and between stems and leaves (Lee & Scagel, 2009); therefore differences in chicoric acid among dried basil flake products could be a result of the combination of cultivars and tissues used in the product. Lower concentrations of chicoric acid in dry samples versus fresh samples were somewhat surprising since dehydration concentrates compounds; thus increasing their concentrations in comparisons to those measured in fresh tissues. Others have reported poor retention of phenolics in Lamiaceae (lemon balm in particular) when plant tissues are air-dried at 32–35 °C for 10 days, before being packed and stored for six months (Capecka et al., 2005). Thus lower concentrations of chicoric acid in dried basil flake products could also be a result of degradation during processing and storage.

3.3. *Identification and quantification of phenolics from fresh E. purpurea 'Rubinstern'*

The two most abundant phenolics (both caffeic acid derivatives) found in fresh *E. purpurea* 'Rubinstern' flower heads, stems, and roots were caftaric acid and chicoric acid (Table 1). Chicoric acid accounted for more than 94% of the total polyphenolics in the entire *Echinacea* plant. Chicoric acid was the only polyphenolic detectable in fresh *Echinacea* leaves, and leaves had higher concentrations of chicoric acid (48% of total plant chicoric acid content) than flower heads, stems, and roots. Fresh *Echinacea* stems contained the lowest concentrations of chicoric acid (7% of total plant chicoric acid content) compared to other tissues. Low concentrations of chicoric acid in stems of *Echinacea* were also reported by Molgaard et al. (2003) and Hudec et al. (2007).

All fresh tissues of *E. purpurea* had higher concentrations of chicoric acid than the fresh sweet basil leaves and stems analyzed in this study (Table 1) or the concentrations previously reported for sweet basil and other basil cultivars (Lee & Scagel, 2009). On a fresh weight basis, sweet basil leaves contained 0.04% chicoric acid and leaves of *Echinacea* contained 0.4% chicoric acid. Leaves of other basil cultivars contained 0.01–0.09% chicoric acid (Lee & Scagel, 2009). Obviously on a fresh weight basis, *Echinacea* is a more concentrated source of chicoric acid; however, other factors make basil a more logistically feasible and perhaps economically preferable source of chicoric acid. For example, basil biomass production may be quicker and easier compared to growing *Echinacea*, whose cultivation difficulties (especially its low germination rate) have been well summarized by Abbasi et al. (2007).

3.4. *Phenolics in E. purpurea products*

Extracts and capsules containing *Echinacea* contained similar polyphenolics as those detected in fresh tissues from *Echinacea* plants (Table 1); however, the proportions of the individual polyphenolics varied between *Echinacea* products and fresh *Echinacea* samples (Table 1). For example, extracts and capsules from *Echinacea* contained similar or higher concentrations and proportions of caftaric acid than measured in fresh *Echinacea* tissues and lower concentrations and proportions of chicoric acid.

Variation in chicoric acid concentrations among *E. purpurea* products has been reported and it is hypothesized that low concentrations of chicoric acid in processed products result from degradation and oxidation occurring during all production steps after harvest (Bergeron et al., 2002; Perry et al., 2001; Wills & Stuart, 2000). Bergeron et al. (2002) demonstrated chicoric acid rapidly degraded in *E. purpurea* root extracts during a four month storage period (reduction of >80% compared to initial levels at time zero) held at 25 °C and degradation could be minimized with the addition of citric acid, malic acid, or a *Hibiscus* flower preparation. Wills and Stuart (2000) reported similar drastic losses in chicoric acid levels in *E. purpurea* after simulating the effects of rough handling during harvest and non-optimal storage temperatures and humidity of *E. purpurea* plant material. Molgaard et al. (2003) evaluated chicoric acid levels of *E. purpurea* extracts and capsules available in the Danish market place, and found concentrations ranged from below detection limit to 389.1 mg/100 mL in extracts ($n = 11$) and to 3460 mg/100 g in capsules ($n = 5$). *Echinacea* products ($n = 4$) examined in our study are within the range of chicoric acid concentrations reported by Molgaard et al. (2003).

Concentrations of chicoric acid in fresh basil leaves, although lower than those in fresh *E. purpurea* tissues, they were comparable to the chicoric acid concentrations of the two *E. purpurea* extracts examined (E2 and E3). Chicoric acid concentrations in basil flakes were lower than concentrations in fresh *E. purpurea* tissues or of *E. purpurea* capsules. According to the product label, the E2 extract was made from juices of fresh flowers, leaves, seeds, and roots of *E. purpurea*, and specified that no stems were used in its manufacture. The E3 extract was described as being produced from the entire *E. purpurea* plant (stems included). Chicoric acid concentrations in fresh stems of *E. purpurea* were lower than that of other tissues (Table 1); therefore lower concentrations in an extract derived from the entire plant may be a result of inclusion of stems in the extraction process. Our results from this small survey of commercially available products, suggest fresh basil may be an equitable replacement for *E. purpurea* extracts to enhance chicoric acid intake; though chicoric acid concentrations in dry basil flake products might be lower than *E. purpurea* extracts.

The *E. purpurea* capsules (E4 and E5) had similar or higher concentrations of chicoric acid than different tissues from fresh *E. purpurea* (when values are expressed as per 100 g of whole plant; flower head – 36.73 mg, leaves – 116.46 mg, stems – 17.71 mg, roots – 71.39 mg) and higher chicoric acid concentrations than *E. purpurea* extracts, fresh basil tissues, or dried basil flakes (Table 1). There was a large difference in chicoric acid concentrations between the two capsules containing *E. purpurea*. According to the product labels, both *E. purpurea* capsules contained the aerial parts of the *E. purpurea* (flower heads, leaves, and stems).

3.5. *Comparison of TP and total polyphenolic values*

Concentrations of TP in dried basil flakes ranged from 251.7 to 807.2 mg of gallic acid equivalents/100 g dw and TP

concentrations in fresh leaves and stems of sweet basil were 651.6 mg of gallic acid equivalents/100 g fw and 223.4 mg of gallic acid equivalents/100 g fw, respectively (Table 1). Others have reported similar (Dogan et al., 2005; Kim et al., 2006; Loughrin & Kasperbauer, 2001) or higher (Javanmardi et al., 2003; Nguyen & Niemeyer, 2008) TP concentrations in basil processed by various methods. Javanmardi et al. (2003) reported TP concentrations in fresh, air-dried samples of 23 basil accessions ranged from 2300 to 6550 mg of gallic acid equivalents/100 g dw. Nguyen and Niemeyer (2008) reported 700–3100 mg of gallic acid equivalents/100 g dw in fresh samples, immediately frozen in liquid N after harvesting, and freeze-drying by vacuum centrifugation. Dogan et al. (2005) reported TP of 280 mg of catechol equivalents/100 g fw in basil freshly harvested from a local garden and immediately frozen at −70 °C until analysis. Kim et al. (2006) reported TP levels of 190–350 mg of gallic acid equivalents/100 g fw in sweet basil samples treated with methyl jasmonate. TP concentrations reported in a study that examined the effects of colored mulches on basil growth and composition ranged from 600 to 740 mg as gallic acid equivalents/100 g dw (Loughrin & Kasperbauer, 2001). Again, demonstrating basil is high in TP if handled carefully prior to analysis.

TP concentrations in both basil and *E. purpurea* were two to eight times higher than the concentrations of total polyphenolics in all sample types (Table 1). Discrepancies between TP concentrations and total polyphenolic concentrations have been reported by others (Lee & Scagel, 2009; Heimler et al., 2009), emphasizing how absolute concentrations of phenolics vary among analytical methods. Concentrations of TP were determined in this study to enable comparisons with previously reported TP concentrations determined using the same method since TP is an alternative method for laboratories that do not have access to an HPLC. Concentrations of TP and total polyphenolics were positively correlated ($r = 0.797$; $p \leqslant 0.05$) suggesting relationships between the different analytical techniques could be developed.

This preliminary survey shows a wide variation in chicoric acid concentrations in basil and *Echinacea* products. Dried basil contains a relatively high level of polyphenolics, like rosmarinic acid (levels ranging from 11.43 to 166.83 mg/100 g dw) and is a popular culinary additive due to not only to its flavor but also its potential bioactivities (Lu & Foo, 2002; reviewed by Petersen and Simmonds (2003), Makri and Kintzios (2008) and Halvorsen et al. (2006). Enhanced value-added or more consistent phytonutritional composition of basil and *Echinacea* products (Dog, 2006; Craig, 1999) may be gained through dehydration process improvements, additional steps for traditional herb preparation (i.e., blanching), and optimizing storage for color retention, phenolics, aroma compounds, essential oils, and antioxidant activity (Rocha et al., 1993; Baritaux et al., 1992; Bergeron et al., 2002; Di Cesare et al., 2003; Capecka et al., 2005; Tanko et al., 2005; Almela et al., 2006; Wills & Stuart, 2000; Perry et al., 2000, 2001).

4. Conclusions

Concentrations of chicoric acid in fresh *E. purpurea* leaves, flower heads, or roots were greater than those in fresh basil or any basil product or *E. purpurea* product evaluated. Concentrations of chicoric acid in fresh basil leaves were similar to those in extracts containing *E. purpurea*, but concentrations of chicoric acid in dried basil flakes were lower than those in fresh basil or any of the *E. purpurea* products evaluated. Our results demonstrated chicoric acid is easily accessible from common fresh and dried food items, such as fresh basil and dried basil flakes. These basil products also have the added benefit of being more readily available and economical compared to *E. purpurea* products.

Currently, dried basil quality is determined by color and aroma retention, but phenolic preservation should also be considered. In the future, a vast range of basil and *E. purpurea* cultivars should be evaluated to identify cultivars with the highest levels of phenolics, since the end products will have somewhat reduced phenolics from processing and storage losses before they reach the consumer.

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