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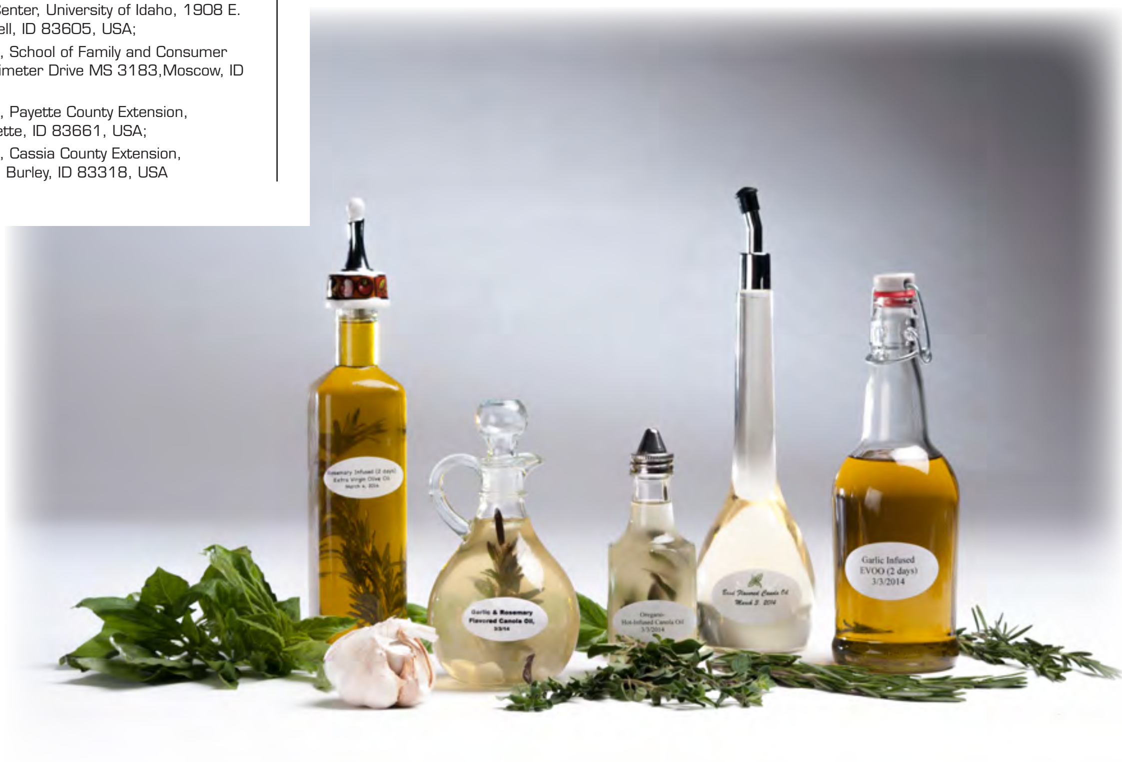

Acidification of Garlic and Herbs for Consumer Preparation of Infused Oils

ABSTRACT

Consumer interest in producing flavored oils by infusing oil with garlic and herbs has grown in recent decades. However, storage of low-acid plant material in oil is a known botulism risk. Commercial production of garlic-in-oil mixtures is safely accomplished by acidifying the garlic to a pH value below the growth range for *Clostridium botulinum*. Procedures were developed that consumers could use to acidify garlic, basil, oregano and rosemary for safe addition to oils for flavor infusion. For garlic, cloves were peeled, chopped and soaked for 24 h in 3% citric acid solution at a ratio of 1 part garlic to 3 parts acid solution, by weight. This procedure reduced the pH of garlic (*Allium sativum L*) samples from 8 cultivars and of elephant garlic (*Allium ampeloprasum*) from an initial pH of 6.0–6.4 to a final pH of 3.7 or less. Garlic samples were obtained over 2 crop years and from three growing regions. For fresh herbs, basil, oregano, or rosemary were immersed in 3% citric acid at a ratio of 1 part herb to 10 parts acid solution, by weight, for 24 h. The initial herb pH of 6.3 to 6.7 was reduced to pH 2.8 to 4.1 by this procedure.

INTRODUCTION

Garlic- and herb-infused dipping oils are increasing in popularity *(8)* for culinary uses such as dipping breads, making salad dressings and flavoring pastas. Consumers who see these attractively displayed, commercially available products may wish to make them at home. As a result, Idaho Extension receives requests for instructions and recipes for making shelf-stable oils infused with garlic and herbs. However, when garlic or herbs are immersed in oil, the low-acid, anaerobic environment that is created is capable of supporting the growth of *Clostridium botulinum*, which can produce a neurotoxin that can be life threatening *(6)*. *C. botulinum* has been commonly isolated from garlic bulbs grown in soil *(14)*.

Cases of botulism from infused oil products have been reported. In 1985, thirty-seven people were diagnosed with botulism after eating meals at a Vancouver, British Columbia restaurant. A chopped garlic-in-soybean oil preparation made at the restaurant was implicated as the cause of botulism *(16)*. The implicated chopped garlic-in-soybean oil product was an aqueous mixture with a pH value above 4.5 and had

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been prepared without heat treatment or chemical (including acid) additives. The processor had labeled the product with instructions to keep it refrigerated. However, it was suspected that the product had been stored at room temperature for several months before being opened.

In 1989, three cases of botulism in Kingston, New York were traced to garlic bread made from a garlic-in-oil product *(7)* that had been processed some time between 1985 and September 1987. It was prepared by mixing chopped garlic, ice water and extra virgin olive oil, without acid or other chemical additives, and was labeled "keep refrigerated." The product had been received as a gift in 1988 and stored, unopened, by the recipient at room temperature for three months. After it was opened, the product was refrigerated for another six months prior to being used in making the garlic bread and the onset of illness. This episode resulted in the Food and Drug Administration requiring companies to stop making garlic-in-oil mixes that were protected only by refrigeration. For safety, the products were required to contain specific levels of microbial inhibitors or acidifying agents *(7)*.

However, cases continued to be reported. In 2003, a thirty-eight-year-old Danish male was diagnosed with botulism after consuming four cloves of garlic from a commercial, ready-to-eat, garlic-in-chili oil dressing that had been manufactured in Germany and sold in Denmark *(5)*. According to the manufacturer, the implicated product had been subjected to heat treatment and was produced on February 19, 2002. It was labeled as "best before February 19, 2004" and "to be refrigerated after opening." Testing revealed a pH value of 4.7. Other low-acid foods added to vegetable oils have also been associated with botulism outbreaks *(3, 17)*.

In a recent review of the food safety issues associated with home-prepared vegetables and herbs stored in oil, Nummer et al. *(8)* described procedures provided in five Extension bulletins for use by consumers when preparing these products. The recommended procedures included freezing, refrigeration for times ranging from 3 to 21 days, acidification, and heat processing. The authors noted that although the Extension recommendations cited research-based information, none were based on specific product research.

Commercially prepared shelf-stable garlic or herbs in oil mixtures are prepared by adding microbial inhibitors or acidifying agents that prevent the growth of *C. botulinum*, as required by the Food and Drug Administration *(19)*. Acidified foods must have a finished equilibrium pH value of 4.6 or below. These products are generally olive oils that have been flavored with extracts of garlic, peppers and herbs (frequently basil, oregano, or rosemary) or with actual garlic, peppers and herbs; other flavorings include dried tomatoes, truffles, balsamic vinegar, olives, figs and cheese.

Acidification of non-acid or marginally acid vegetables is a procedure routinely used by consumers during home food preservation of cucumbers and other vegetables in making fresh pack pickles, preparing tomato-pepper-onion salsa for canning, and ensuring the safety of canned tomato products. Bottled lemon juice, vinegar (5% acidity) and citric acid are acidulants recommended for consumer use. Nummer et al. *(8)* noted that no published research has identified acidification parameters that consumers could use for preparing garlic and herb flavored oils for storage at room temperature in the home environment.

The goal of this research was to develop safe consumer guidelines for acidification of the garlic and herbs to be used in producing infused or flavored oils, so that lack of refrigeration would not result in a deadly product.

MATERIALS AND METHODS

Selection of materials for acidification

To identify the specific materials on which to focus our research effort, twenty-two University of Idaho Extension Master Food Safety Advisors from two southern Idaho locations and eight participants from Colorado in an University of Idaho Extension online food preservation class were asked to rank their top five choices from a list of ten items (basil, dill, garlic, marjoram, oregano, parsley, pepper, rosemary, thyme and mixed herbs) for flavoring infused oils they would like to make at home. The three groups of Extension program participants ranked the same two items, garlic and basil, as their first and second choices. The rankings for third, fourth and fifth choice did not agree as closely among the groups and included mixed herbs and rosemary (all three groups), oregano (two groups) and parsley (one group).

A survey of four Boise, ID area stores was also conducted to identify the ingredients used in commercially available flavored oils. The store survey identified 17 offerings; garlic, the most popular ingredient, was present in 9 of the infused oils; herbs (specific type not always identified) were also ingredients in 9 of the commercial oils. Based on the results of the Extension program participant ranking and on the store survey, garlic, basil, oregano and rosemary were selected for development of acidification procedures that would allow these flavored oils to be produced safely by consumers.

A number of cultivars of garlic and herbs are available to home gardeners, and many have unique characteristics that are prized. Cultivars are generally not labeled when garlic and herbs are sold in grocery stores. To develop acidification parameters, we wanted to use widely varying plant materials to achieve the most universal recommendations.

Garlic (*Allium sativum L.*) has been classified into nine phenotypes, and about 200 named garlic clones, some of which may be genetically identical *(20)*, are commercially available in the United States. In addition, elephant garlic (*Allium ampeloprasum*), similar to true garlic but larger and more mild in flavor, although less common is still popular for use in cuisine and home gardens *(1)*. To insure that the acidification parameters developed would be widely applicable, an effort was made to use a wide variety of garlic samples.

The garlic samples (0. 45 kg) obtained for acidification testing represented thirteen cultivars from eight phenotypic classes (*Allium sativum L.*) and elephant garlic (*Allium ampeloprasum*), all procured from three commercial growers that specialize in garlic. In addition, commercially peeled and packaged garlic was obtained from a grocery store. The phenotype, cultivar, source and year obtained or grown for garlic samples used in acidification trials are shown in *Table 1*. Garlic samples were obtained in the fall of 2009, 2010 and 2012. Garlic bulbs were stored at 4°C and testing was completed within four months of receipt. In addition, two cultivars of garlic, also obtained from these commercial growers, were grown in home gardens at two locations (Korean Red in Boise, ID and Blossom in Pullman, WA) in 2010 to allow freshly harvested samples to be obtained for testing.

Three fresh herbs, basil (*Ocimum basilicum*), oregano (*Origanum vulgare*) and rosemary (*Rosmarinus officinalis*), were tested for acidification. Although a number of named cultivars exist for each of these herbs, it was not possible to obtain specific cultivars in sufficient quantity for testing. Thus, herbs were obtained in local grocery stores. Three brands (HerbCo, Duvall, WA; Safeway O Organics; and HerbThyme Farms, Pico Rivera, CA) of each herb were obtained in June 2012, one each from three different supermarkets for a total of nine samples (3 herbs x 3 brands); the growing locations and cultivars of the herbs were not available. To test regionally grown herbs, one cultivar of each herb (sweet basil, Greek oregano, and ARP rosemary) was grown by Master Gardener volunteers in the xeric garden at the Ada County, Idaho, Extension office during the summer of 2012 and harvested in August. Herbs were tested within five days of purchase or harvest.

TABLE 1. Description and source of garlic used in acidification trials

Phenotypic classification[1]	Cultivar or commercial name	Source and year grown
Asiatic	Asian Tempest	FF[2]-2009; IE[3]-2010; FF-2012;
Creole	Creole Red	FF-2009; FF-2012
Marble Purple Stripe	Brown Tempest	IE-2009; IE-2010; FF-2012
	Metechi	IE-2009; IE-2010; FF-2012
Porcelain	German Porcelain	IE-2009; IE-2010; IE-2012
	Music Pink	FF-2009; IE-2010; FF-2012
	Romanian Red	FF-2009; IE-2010; FF-2012
Purple Stripe	Chesnok	MDG[4]-2012
Rocambole	Killarney Red	FF-2009; FF-2012
Silverskin	Nootka Rose	FF-2009; IE-2010; FF-2012
	Silver White	FF-2009; FF-2012
Turban	Blossom	IE-2009; IE-2010; FF-2012
	Tzan	FF-2009; FF-2012
Not applicable	Commercially peeled and packaged	Grocery store[5]-2009
Not applicable	Elephant garlic	IE-2009; IE-2010; IE-2012

[1]According to Volk et al., 2004
[2]FF = Filaree Garlic Farm, Okanogan, WA
[3]IE = Irish Eyes Garden Seeds, Ellensburg, WA
[4]MDG = My Dad's Garlic, Rupert, ID
[5]Christopher Ranch Brand, Cash & Carry, Boise, ID

Acidulant

Citric acid was used as the acidulant for garlic and herbs because it is familiar to home canners *(18)* and because it imparts less flavor than lemon juice or vinegar. (When the authors conducted a preliminary taste test of infused oils made with garlic acidified with different acids, the lemon juice- or vinegar-acidified garlic oils scored lower than the citric acid-acidified garlic oils.) A 2011 survey of the availability of citric acid in five Idaho locations (two urban and three rural locations) found it to be available to consumers from several sources, including health food stores, pharmacies, and grocery stores. The price varied greatly, from $0.50 to $4.51 per 28 g at thirteen stores (averaging $1.48). The density of 10 separate samples of citric acid purchased during the survey (representing 7 brands) was measured (in triplicate) by weighing the volume in a level teaspoon (5 cc) measure. The density did not vary appreciably among samples at 4.67 ± 0.16 g per five cc. Citric acid solutions were prepared by dissolving USP grade citric acid in tap water.

Acidification target

The acidification target was set to achieve a pH value of 4.2 within a 24 h soak time in citric acid solution. Although the Food and Drug Administration guidance *(19)* sets a finished equilibrium pH value of 4.6 or below for acidified foods, the lower value of 4.2 was selected to add a margin of safety for home production *(9, 15)*. The pH value of 4.2 is commonly used for commercially canned acidified vegetable foods for safety reasons *(2)*.

Garlic acidification

To prepare garlic for acidification, the bulbs were cracked and the individual cloves peeled by hand (except for the commercially peeled sample). A portion of the peeled cloves was set aside for initial pH analysis prior to acidification. To facilitate adequate acidification within 24 h *(19)*, the available surface area for acid penetration was increased by chopping the peeled cloves. (A preliminary trial determined that the pH of whole peeled cloves had decreased only to 4.5 to 4.6 after 24 h in 3% citric acid.) The peeled garlic cloves were chopped by one pass through a 6.35 mm (1/4-inch) Bloomington Industries French Fry Cutter. The resultant chopped garlic varied in size based on the length and thickness of each individual clove.

For all experiments to measure acid absorption by garlic, 20 g of chopped garlic were placed in a citric acid solution, with acid solution concentration and weight varying with the experimental objective. Except for pH measurements of garlic prior to acidification, for which one sample was prepared, all experiments were conducted in triplicate. At the conclusion of the contact time (4, 6 and 24 h at 21° ± 3°C), the garlic and acidulate were poured into a colander and approximately 250 ml of distilled water was poured over the chopped garlic to rinse off residual acid solution. Surface water from the garlic pieces was removed by blotting with a paper towel, and the garlic was crushed in a household garlic press. Approximately 2.5 ml of distilled water was added to the crushed garlic (approximately 20 g) to aid in pH analysis. The pH value of the crushed garlic paste was determined with either a Thermo Scientific Orion 3-Star Plus pH Portable

Acidifying Garlic

Garlic acidification is necessary to produce safe, garlic infused olive oil.

Ingredients:

2/3 Cup	Chopped Garlic
1 Tablespoon	Citric Acid
2 cups	Water

Directions for Preparing an Acid Solution Using Citric Acid:

Pour 2 cups of warm water into a mixing bowl. Add 1 level Tablespoon of granular citric acid to the water and stir gently, allowing all of the citric acid to dissolve into the water.

Crack and peel garlic. Chop the peeled garlic cloves to no greater than 1/4" square. Smaller pieces are fine.

Place 2/3 of a cup of chopped garlic into the acid solution and stir gently. Cover and allow to sit for a minimum of 24 hours.

After 24 hours, remove the garlic from the acid soution, drain in a colander, and rinse by pouring 1 cup of water over the drained garlic. Gently pat dry. Place in a sealable plastic bag or other airtight container. Next day, bring to AFSA for testing.

FIGURE 1. Instructions for Extension volunteer testing of garlic acidification procedure

Meter equipped with a Thermo Scientific Orion NoCal™ pH electrode or an IQ Scientific handheld pH/mV meter model IQ150-77 equipped with an ISFET pH electrode, both calibrated with pH 4 and 7 buffers.

The concentration of citric acid solution, 1% and 3%, and the ratio of garlic to acid solution, 1:2 or 1:3 garlic:citric acid by weight, required to achieve the target pH value of 4.2 or lower within 24 h contact time was investigated using commercially peeled and packaged garlic and the procedure described previously.

After it was determined that the use of 3% citric acid at a 1:3 garlic: citric acid ratio was needed to acidify garlic, these conditions were used in testing the fifteen garlic samples shown in *Table 1*, as already described. The pH value was measured at 4, 6, and 24 h. For garlic sourced in 2009, only pre-acidification pH values were measured; for garlic sourced in 2010, only post-acidification pH values were measured; and for garlic sourced in 2012, both pre- and post-acidification pH values were measured.

To assess whether the curing of garlic, the commonly recommended practice of drying garlic before storage after harvest *(12)*, affected acid absorption, two cultivars of garden grown garlic (Korean Red and Blossom) were used. One-half of the bulbs from each cultivar were tested for acid absorption within four days of harvest and the remaining half were cured by allowing the bulbs to dry at room temperature for three weeks (average dew point temperature was 5.6°C for the period) prior to testing.

To test the garlic acidification procedure for consumer use, ten Extension program participants volunteered to obtain garlic in their usual manner and to prepare acidified garlic following the written instructions shown in *Fig. 1*. They were provided with citric acid if they needed it, or they supplied their own. The volunteers brought a finished sample of their acidified garlic to the Extension office for pH analysis, which was conducted on triplicate samples as described above.

Fresh herb acidification

To identify the acidification parameters for grocery store purchased and Master Gardener grown herbs, 10 g of fresh, whole herbs, as purchased including the stem, was placed in a 400 ml beaker and 100 g of 3% citric acid solution was added. To prevent the herb material from floating, an empty 250 ml beaker was placed in the larger beaker. After 24 h at 21°± 3°C, the beaker contents were poured into a colander to recover the acidified herb from the acidulate; then approximately 250 ml of distilled water was poured over the acidified herb to rinse off residual acid solution. Rinsed herb was blended with 45 g distilled water for 1 min in a food processor (Cuisinart Mini-PrepPlus Processor, Model DLC-2ABC, East Windsor, NJ) and the pH of the resulting slurry was measured with an IQ Scientific handheld pH/mV meter model IQ150-77 equipped with an ISFET pH probe, calibrated with pH 4 and 7 buffers. The pH values of herb materials that were not acidified were measured in a similar manner. The nine samples were tested in triplicate, with one replication completed on each of three days.

Sensory evaluation of oils infused with acidified garlic and herbs

Three small-scale sensory panels, with 27 to 38 panelists each, were conducted to identify consumer reaction to oils infused with acidified garlic and herbs to guide the research variables and the consumer recommendations. Untrained Extension volunteers served as panelists; some of the volunteers served on two or three of the sensory panels.

For the first panel, commercially peeled and packaged garlic (Christopher Ranch brand, Cash & Carry, Boise, ID)

TABLE 2. Identification of acid concentration and ratio of chopped garlic to acid solution (by weight) required to achieve a pH value of 4.2 or less within 24 hours at 21°C

Acidification parameters used with commercially peeled and packaged garlic	Pre-acidification garlic pH, n = 1	Mean pH ± standard deviation after acidification of garlic, n = 3		
		2 h	6 h	24 h
1% citric acid, 1 part garlic: 2 parts acid solution	5.98	5.27 ± 0.02	4.94 ± 0.07	4.35 ± 0.05
1% citric acid, 1 part garlic: 3 parts acid solution	6.10	5.03 ± 0.12	4.59 ± 0.01	4.26 ± 0.11
3% citric acid, 1 part garlic: 2 parts acid solution	6.10	4.33 ± 0.22	4.04 ± 0.02	3.53 ± 0.03

acidified with 3% citric acid was compared to commercially acidified garlic (Christopher Ranch Chopped Garlic, 9 oz. jar, Cash & Carry, Boise, ID) for use in preparing flavored oil. Olive oil (Tosca Olive Pomace Oil, 100% Olive Pomace Oil, Cash & Carry, Boise, ID), 500 g, was infused by adding 50 g of acidified garlic and holding the mixture at 22°C for 48 h. The flavor-infused oils were strained to remove the garlic and stored at 4°C prior to sensory analysis. A total of 28 Extension volunteers (in three Idaho locations) compared the two infused oil samples (10-g sample size coded with three-digit random numbers) in a triangle test in which the citric acid acidified sample was the odd sample. Sample order was randomized for each panelist.

For the second sensory panel, bulk garlic, fresh basil, and fresh rosemary (Kroger Simple Truth Organics) were purchased at a local grocery store (Fred Meyer, Boise, ID) and each acidified with citric acid as already described. The acidified materials were used to infuse four samples of olive oil (Kroger Extra Virgin Cold Pressed). Samples (25 g each) of acidified basil and rosemary were added singly to 250 g aliquots of olive oil. Two additional 250 g portions of olive oil received 25 g each of acidified basil and garlic or 25 g each of acidified rosemary and garlic. The mixtures were held at 22°C for 48 h to allow flavors to infuse the oil. The flavor-infused oils were strained to remove the flavoring material and the oil was stored at 4°C prior to sensory analysis. Oil samples (10 g) were coded with three digit random numbers and served to panelists. Twenty-seven Extension volunteers in two Idaho locations used a 10-point hedonic scale anchored at the ends (1 = dislike; 10 = like) to rate their opinion of the flavored

TABLE 3. Mean pH (± standard deviation for columns 4 and 5) of chopped garlic[1] before and after acidification with 3% citric acid (1:3 ratio by weight) for 24 h at 21°C

Cultivar or commercial name	Pre-acidification (n = 1)		After acidification (n = 3)	
	2009	2012	2010	2012
Asian Tempest	6.08	6.49	3.14 ± 0.04	3.42 ± 0.09
Creole Red	6.03	6.49	Not tested	3.34 ± 0.08
Brown Tempest	6.34	6.36	3.21 ± 0.01	3.33 ± 0.05
Metechi	6.43	6.59	3.26 ± 0.03	3.67 ± 0.07
German Porcelain	6.47	6.27	3.29 ± 0.14	3.46 ± 0.09
Music Pink	6.13	6.52	3.34 ± 0.01	3.63 ± 0.11
Romanian Red	6.16	6.43	Not tested	3.42 ± 0.10
Chesnok	Not tested	6.33	Not tested	3.36 ± 0.17
Killarney Red	6.08	6.28	3.10 ± 0.02	3.60 ± 0.20
Nootka Rose	6.13	6.39	2.97 ± 0.03	3.41 ± 0.04
Silver White	6.02	6.61	Not tested	3.45 ± 0.09
Blossom	6.03	6.22	3.02 ± 0.07	3.28 ± 0.11
Tzan	5.98	6.30	Not tested	3.28 ± 0.06
Christopher Ranch Brand	5.98	Not tested	Not tested	Not tested
Elephant Garlic	6.14	6.09	2.72 ± 0.04	3.48 ± 0.05

[1]The source of each garlic is shown in Table 1

TABLE 4. Mean pH (± standard deviation) of uncured and cured chopped garlic bulbs from two cultivars after acidification with 3% citric acid for 24 h at 21°C (n = 3)

Cultivar	Uncured Bulbs	Cured Bulbs
Blossom	3.59 ± 0.10	3.74 ± 0.15
Korean Red	3.38 ± 0.07	3.49 ± 0.25

TABLE 5. Mean pH (± standard deviation) of retail purchased and garden grown fresh herbs before and after acidification with 3% citric acid solution (1:10 ratio by weight) for 24 h at 21°C

Herb Identification[1]	Pre-acidification pH (n = 9)	After acidification, (n = 9)
Basil		
Brand 1	6.50 ± 0.12	3.15 ± 0.27
Brand 2	6.44 ± 0.06	2.77 ± 0.33
Brand 3	6.49 ± 0.12	2.87 ± 0.11
MG-grown	6.28 ± 0.16	3.18 ± 0.11
Oregano		
Brand 1	6.61 ± 0.06	3.32 ± 0.34
Brand 2	6.48 ± 0.13	3.13 ± 0.04
Brand 3	6.58 ± 0.06	3.20 ± 0.26
MG-grown	6.67 ± 0.08	3.38 ± 0.11
Rosemary		
Brand 1	6.61 ± 0.18	4.11 ± 0.04
Brand 2	6.74 ± 0.15	3.71 ± 0.21
Brand 3	6.64 ± 0.20	4.03 ± 0.19
MG-grown	6.28 ± 0.11	3.91 ± 0.13

[1]Brand identification of samples: Brand 1 = HerbCo, Brand 2 = HerbThyme, Brand 3 = O Organics, MG = Master Gardener grown

oils; the oils could be tasted alone from a spoon, or on white bread. Average rating scores for each sample were calculated.

For the third sensory panel, basil, oregano and rosemary (HerbCo Organic brand, WinCo Foods, Moscow, ID) were acidified separately with 3% citric acid as already described. Each acidified herb was divided into four aliquots to facilitate the use of four infusion methods to flavor canola oil, which was used instead of olive oil because of its bland flavor profile. Three flavor infusions were conducted at 22°C; three 50-g aliquots of each acidified herb were added singly to 500 g aliquots of canola oil (Hytop brand, WinCo Foods, Moscow, ID) and the mixtures held at 22°C for 1 day, 5 days, or 10 days before the herb was removed from the oil by sieving. A hot-infused oil was prepared for each herb by holding the herb-oil mixture (50 g acidified herb plus 500 g canola oil) at 60°C for 5 min before removing the herb by sieve. All infused oils were stored in glass jars under vacuum at 0°C until sensory analysis was conducted. Thirty-eight Extension volunteers (in two Idaho locations) were offered three sets (basil, oregano, and rosemary) of four infused-oil samples for evaluation; they could choose to evaluate 1, 2 or all three sets. Approximately 8 g of each oil sample was served in a plastic sample cup. Each set contained a sample from each of the three 22°C infusions, 1, 5 and 10 days, and the 60°C-infused sample and were tasted in that order. Samples were coded with 3-digit random numbers. Panelists indicated their preference for aroma and flavor on a 5-point hedonic scale (1 = dislike and 5 = like). Panelists could taste the samples

TABLE 6. Mean sensory scores[1] for four attributes of olive oil infused with acidified basil, rosemary, garlic-basil, and garlic-rosemary

Infused oil	General appearance	Color	Aroma	Flavor
Basil infused olive oil	6.6	7.4	5.0	4.9
Rosemary infused olive oil	7.8	7.7	7.3	7.3
Garlic-basil infused olive oil	8.3	7.8	6.5	6.8
Garlic-rosemary infused olive oil	7.5	7.4	7.0	7.2

[1]Ten point scale, 1 = dislike, 10 = like, rated by 27 panelists

TABLE 7. Mean sensory scores for aroma and flavor of canola oil infused with acidified basil, oregano, and rosemary under different time and temperature conditions

Oil infusion treatment	Basil infused canola oil		Oregano infused canola oil		Rosemary infused canola oil	
	Aroma	Flavor	Aroma	Flavor	Aroma	Flavor
22°C Infusion						
1-day infusion	3.3	3.5	3.3	3.4	3.5	3.3
5-day infusion	3.2	3.1	2.9	3.2	3.4	3.3
10-day infusion	3.2	3.4	2.9	3.2	3.4	3.6
60°C infusion	3.6	3.4	3.7	4.0	3.3	2.8

[1]Five point scale, 1 = dislike, 5 = like, rated by 29 to 38 panelists

alone with a spoon or on white bread, as desired, and were served warm water and crackers for cleansing the palate between samples as desired. Average rating scores for each sample were calculated.

Statistical analysis

A Chi-square test was conducted using SAS Version 9.3 *(11)* to determine whether the first sensory panel (triangle test) could differentiate the odd sample more or less than expected by chance. Since the purpose of the second and third sensory panels was to obtain an indication of whether the infused oils were acceptable to consumers, means were calculated for each sensory attribute, but comparative tests of the data were not conducted.

RESULTS AND DISCUSSION

Garlic Acidification

The results of the trials to establish acid concentration, ratio of acid solution to garlic, and contact time are shown in *Table 2*. Untreated commercially peeled and packaged garlic had a pH value of 6. Soaking the chopped garlic in a 1% citric acid solution for up to 24 h, at a ratio of 1:2 or 1:3, did not decrease the pH value of chopped cloves to the target of 4.2 or less. Increasing the citric acid concentration to 3% decreased the pH value of the chopped cloves to less than the target pH within 6 h. As a result, a 3% citric acid solution was used in subsequent trials. A garlic: citric acid solution ratio of 1:3 was also adopted for subsequent trials because it was more effective in lowering pH than a 1:2 ratio (weight basis).

The pH values of garlic prior to acidification, from 13 cultivars plus elephant garlic and commercially peeled and packaged garlic sourced in 2009 and in 2012, are shown in *Table 3*. The pH values of untreated garlic varied from 6.0 to 6.6, with an average of 6.3. The pH values of these garlics (sourced in 2010 and 2012) after acidification in 3% citric acid (1:3 ratio by weight) for 24 h is also shown in *Table 3*. After acidification, the pH values of the chopped garlics varied from 2.7 to 3.7, well below the target of 4.2. All of the acidified chopped garlics, except for one cultivar in 2010 (German Porcelain) and one in 2012 (Killarney Red), were below pH 4.2 after 6 h of soaking in 3% citric acid (data not shown). Soaking chopped garlic in 3% citric acid for 24 h at a ratio of 1:3 (by weight) adequately acidified the fifteen garlic cultivars or types from two growing years, with a good margin of error. It is important to note that preliminary work showed that soaking whole (unchopped) peeled cloves in 3% citric acid did not reduce the pH to 4.2 within 24 h.

The pH value of freshly harvested garlic and of the same garlic sample cured for three weeks from two cultivars grown in 2010 after chopping and acidification in 3% citric acid for 24 h is shown in *Table 4*. Curing of garlic bulbs made them slightly more resistant to absorbing the citric acid solution, but the pH value of cured bulbs were well below the target pH at 24 h. Although the trial was small in size, curing garlic was demonstrated not to affect the ability of chopped cloves to absorb citric acid.

When the lab acidification procedure was prepared in recipe form (*Fig. 1*) and tested by Extension volunteers in their homes using the provided instructions, the pH values of the garlic samples prepared by the volunteers ranged from 2.8 (± 0.1) to 3.4 (± 0.1), well below the target of pH 4.2. Thus, the procedure of soaking garlic at a ratio of 1 part chopped garlic to 3 parts 3% citric acid (by weight) for 24 h was adequate to produce an acidified product that could be used by consumers to prepare safe flavor-infused oils. The provided recipe instructions were understood by the Extension volunteers.

Acidification of fresh herbs

The pH values of fresh grocery store (three brands) and garden grown herbs before and after acidification with 3% citric acid (1:10 ratio by weight) are shown in *Table 5*. The average pre-acidification pH values were 6.4, 6.6, and 6.6 for basil, oregano and rosemary, respectively. After 24 h in 3% citric acid, the average pH values of the herb materials were 3.0, 3.3, and 3.9, respectively. Rosemary, a woody herb, was more resistant to acid absorption than the herbaceous leaves of basil and oregano. The acidification procedure successfully reduced pH of the three herbs to below the target of pH 4.2.

Thus, the results show that an acidification procedure using 3% citric acid can be applied to garlic and to three fresh herbs to achieve pH reduction, using a volume of soak solution appropriate to the material. The procedures of soaking chopped, peeled garlic cloves at a ratio of 1 part garlic to 3 parts acid solution (by weight) and whole, fresh basil, oregano, or rosemary at a ratio of 1 part herb to 10 parts acid solution (by weight) for 24 h were deemed adequate to produce an acidified product that could be used to produce safe flavor-infused oils.

Sensory evaluation of oils infused with acidified garlic and herbs

Small-scale sensory panel evaluations of olive and canola oils infused with acidified garlic, basil, oregano and rosemary were conducted to guide consumer recommendations. In the first sensory panel, garlic-infused olive oils made with commercially acidified garlic and made with garlic acidified with 3% citric acid were compared. In the triangle test, only 12 of 28 panelists correctly selected the odd sample ($P = 0.51$), indicating that the citric acid-acidified garlic did not impart a flavor to the infused oil that was different from the commercially prepared phosphoric acid-acidified garlic. Since panelists were not able to distinguish olive oil infused with garlic that was acidified with citric acid from the same olive oil infused with commercially acidified garlic (acidified with phosphoric acid), the acceptability of citric acid for use in consumer acidification of garlic and herbs for the production of infused oils was verified.

In the second sensory panel, four flavor-infused olive oils (basil, rosemary, basil-garlic, and rosemary-garlic) were rated on a 10-point hedonic scale. The averaged ratings for the attributes of general appearance, color, aroma, and flavor are shown in *Table 6*. Except for color, panelists liked the rosemary infusion and both garlic-containing infusions better than the basil-infused oil. Both rosemary-infused oils appeared to be liked better than the basil-infused oils, but in general, all attributes except for aroma and flavor of the basil-infused oil received average ratings above the scale midpoint. While the herb- and herb-and-garlic-infused oils did not appeal to all panelists, many panelists found them very acceptable, offering comments such as "a clear winner" and "looking forward to making these."

For the third sensory panel, canola oil was infused with acidified basil, oregano or rosemary at 22°C for three time periods or at 60°C for 5 min. Panelists rated the aroma and flavor of the resulting 12 flavored oils on a 5-point scale. The averaged ratings for the attributes of aroma and flavor are shown in *Table 7*. Although the differences were small, panelists' liking of the infused oil aromas tended to dip slightly as the length of infusing time at 22°C increased. For basil- and oregano-infused oils, using a 60°C infusion temperature produced the most liked oil aromas. All of the infused oils, except that produced by infusion of oregano for 5 or 10 days, received average ratings above the scale midpoint.

In general, the averaged panelist hedonic ratings were at or above the scale midpoint for olive and canola oils flavored using garlic, basil, oregano and rosemary acidified to pH values below 4.2.

A limitation of this research is the narrow number of parameters tested to achieve safely acidified garlic and herbs. Consumers like to be creative when preparing food at home and may want to use larger pieces of garlic, additional herbs beyond those tested, and different acidulants. In addition, it would be useful to field test the instructions, including those for herb acidification, with additional consumers who are not Extension volunteers, because the volunteers tend to be very food safety aware.

University of Idaho Extension receives requests from consumers for instructions to flavor food oils with plant-based materials, such as garlic, peppers, and herbs, in the home kitchen. Flavored oils are available commercially, often attractively packaged in specialty food stores, and consumers would like to make similar products. Procedures for preparing flavored oils have been published by state Cooperative Extension units *(4, 10, 13)*, but the food safety control for these products is to refrigerate the product for limited time periods or to freeze it *(8)*, rather than to use the acidification procedure used in preparing commercial products. The procedure identified here for acidifying garlic, basil, oregano and rosemary can be used by consumers to lower the pH values of these plant materials sufficiently to allow the production of flavor infused oils without the risk of botulism and without relying on refrigeration. University of Idaho Extension is publishing practical consumer guidelines based on this research.

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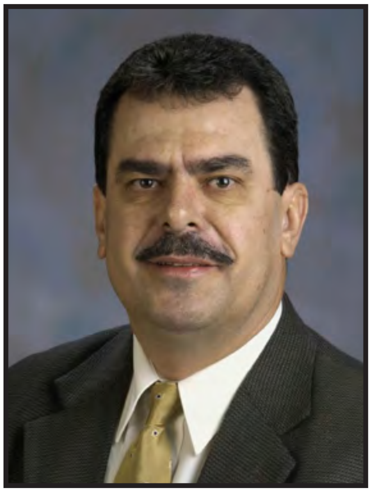
Tribute to John Sofos



IAFP expresses its sincere thanks and appreciation to Dr. John Sofos, who recently retired as Scientific Co-Editor of the *Journal of Food Protection*® after nearly 18 years. Dr. Sofos has been an outstanding Member of the Association since 1975 and has made numerous contributions to *JFP* throughout his years of service. He is a recipient of the Elmer Marth Educator Award in 2003, the President's Recognition Award in 2005, the Fellow Award in 2006, the GMA Food Safety Award in 2007 and the Harry Haverland Citation Award in 2008. Dr. Sofos will be honored at IAFP 2014 with the President's Lifetime Achievement Award. He is a Professor with Colorado State University in Ft. Collins.