Engineering, Structures and Innovations

Scot Langolis

Section Editor

Smoke Point Testing of Tea-seed Oil (*Camellia oleifera*)

Charles B Allen, Jr, John M. Ruter

Department of Horticulture, 1111 Miller Plant Sciences Building
Athens, GA 30602-7273

jay1102@uga.edu

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Significance to Industry: *Camellia oleifera*, an oilseed crop native to Asia, has recently been adapted for production in the Southeastern United States. The oil derived from the seed, known as tea-seed oil, is a popular cooking oil in its native regions and is known to have a relatively high smoke point. The significance of the smoke point is that when an oil reaches this temperature it degrades and increases free radical production [9]. Oxygen derived free radicals are thought to be related to the formation of cancer, inflammation, atherosclerosis, ischemia-reperfusion injuries, aging, Alzheimer's disease, shock, diabetes, cataracts, hypertension, cardiovascular disease, exercise related muscle damage, infertility and other pathological changes [4]. There are an abundance of claims on the smoke point temperatures of various cooking oils, however, little work has been conducted by research institutions on these smoke points and little to no research on tea-seed oil specifically. In this study, smoke point testing was conducted on Camellia oil as well as several popular commercial cooking oils. Based on accepted food standards, the smoke point of tea-seed oil allows it to be classified as an edible oil with high heat tolerance.

Nature of Work: Camellia is a genus of evergreen flowering trees and shrubs native to China, Japan, and other regions of Southeast Asia. Camellia is a member of the family Theaceae and botanical tribe Gordonieae which is characterized by the formation of a seed within a capsule [6]. The various species can be identified by their floral and leaf characteristics. Morphologically, Camellias are large shrubs ranging from 15-70 feet tall at maturity [2]. The crop normally takes two to three years to mature and can produce fruit for fifteen to sixty years [12] with one year from flowering to fruit.

The extract from the seed of *Camellia oleifera* has been used in China and southeast Asia for thousands of years as a sweet seasoning and cooking oil and has been commonly referred to as the "eastern olive oil" [11] due to its associated health benefits. Oil yields have been reported up to 40% [7] of the seed weight and 80 gallons per acre. Roughly one seventh of the Chinese population uses tea-seed oil for cooking purposes [7].

The structure and quantity of various oil constituents are affected by horticultural practices and oil processing allowing the assumption that geography can have an impact on health benefits [6]. Georgia grown Camellia could possibly contain characteristics not seen in Chinese Camellia due to the location in which they were grown. The organization of the University of Georgia's Specialty Oilseeds Committee and Georgia Oilseed Initiative stress importance of oilseeds in Georgia row crop agriculture [7].

As defined by the American Oil Chemists' Society (AOCS), the smoke point is the temperature in which a constant stream of smoke is emitted from the surface of a heated oil [1]. Heating of an oil to its smoke point causes its molecular constituents to degrade creating free radicals. While it is accepted that reactive oxygen species (ROS) are necessary in the fine tuning of metabolic processes, unbalanced and prolonged presence of these species can lead to oxidative stress, apoptotic and necrotic cell death [5]. Free radicals have been shown to react with cyclooxygenase, an enzyme in the body, to produce PGs1 and PGs2 prostaglandins [3]. PGs2 prostaglandins have been linked to pro-inflammatory and pro-carcinogenic responses [3]. Tea-seed oil (*Camellia oleifera)*, is thought to have a relatively high smoke point when compared to other oils while possessing many other health benefits.

Fifteen commercially refined cooking oils were used for testing. They are as follows: Earth Fare Expeller Pressed Grape Seed Oil, Kroger Pure Vegetable Oil, Spectrum Expeller Pressed Walnut Oil, Kroger Pure Sunflower Oil, Hollywood Enriched Gold Peanut Oil, Hollywood Enriched Gold High-Oleic Peanut Oil, Kroger Pure Canola Oil, Kroger Pure Olive Oil, Kroger Corn Oil, Georgia Olive Farms Extra Virgin Olive Oil, Hollywood Enriched Expeller Pressed Safflower Oil, Kinloch Virgin Pecan Oil, Arette Organic Extra Virgin Tea Seed Oil, Kroger Value Shortening, and International Collection Sweet Almond Oil. Crude and centrifuged Georgia grown tea-seed oil were also tested. The sample was centrifuged only to remove the heavy particulates that were found in the crude sample. Smoke point testing was conducted in accordance to AOCS method Cc 9a-48 with slight modifications for the testing apparatus. The height and depth of the apparatus were decreased for proper placement into the fume hood. Dimensions for the testing cup can also be found in this method.

To conduct analysis, 2.2oz (65mL) of oil was measured out into the cup using a serological pipette. Special care was taken not to drip any oil on the rim of the cup or the tripod holding the cup. Stray oil can cause premature smoking and an inaccurate smoke point reading. Temperatures were measured with a Maverick dual sensor ET-85 thermometer. It was secured and angled through the oil for stability and to maximize surface contact with the medium. A standard six inch Bunsen burner with 7/16th inch (11.1 mm) diameter was used as the heating source. The oils were rapidly heated until within 75°F (42°C) of the expected smoke point. Heating is then slowed to a rate of 9-11°F (3-5°C) per minute and observed until smoking appears. At a few degrees before the smoke point is reached, slight puffs of smoke will be emitted from the oil surface. This should be ignored and smoke point will only recorded when stream is constant. Five replications were performed on each oil. Metal wool was used to clean heavy debris from the cup between replications. Crown mineral spirits were used to remove any residual oil from the cup.

Results and Discussion: The results for smoke point testing can be found in Figure 1. Hollywood Enriched Gold Peanut Oil and Hollywood Enriched Expeller Pressed Safflower oil had the highest smoke points. An analysis of variance (ANOVA) was performed and found no significant difference between these two oils ($p<0.0001$). Centrifuged and crude *Camellia* oils had the lowest smoke points. These low smoke points can be attributed to the many particulates and pro-oxidants that can be found in unrefined oils. Commercially refined *Camellia* oil did, however, have a higher smoke point temperature than both extra virgin and pure olive oils. There was no difference seen between the following oils: sunflower and pecan, walnut and vegetable, almond and canola, high-oleic peanut and shortening, shortening and corn, and corn and commercial Camellia.

Knowing the smoke point temperature of a cooking oil determines the temperature range in which the oil best performs. Table 1 shows the recommended uses for each oil based on their smoke points. Recommendations are based on information provided by the cooking oil industry, specifically Spectrum Organics, and the United States Department of Agriculture Food Safety and Inspection Service (USDA-FSIS). The smoke point is indicative of the level of heat stress the oil can withstand. Oils with low smoke points, below 250^{o}F (121^{o}C), are best when used with no heat such as in salad dressings or poured onto a finished dish [8]. Medium heat oils have smoke points ranging from 250-350^{o}F (121-176^{o}C). These oils are best used for light sautéing and making sauces. Oils with smoke point temperatures 350-410^{o}F (176-210^{o}C) are ideal for medium-high heat. They should be used for higher heat sautéing and baking [8]. High heat oils, 410^{o}F (210^{o}C) and above, can be used as all-purpose cooking oils and are ideal for usage in deep fat frying [10]. Further research should be conducted to get more accurate values of other popular commercial cooking oils with a wider range of smoke points.

The results of this study allow for the consumer to make a more informed decision of which cooking oil to use based on the heat required for cooking, minimizing exposure to dangerous free radicals. With a smoke point of 410^{o}F (210^{o}C), commercially refined Tea-seed oil can be classified as a cooking oil with high heat tolerance. This high smoke point allows the oil to be used in various applications while resisting degradation and maintaining oxidative stability.

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Table 1: Heat recommendations for various edible cooking oils

Heat Recommendation	Oil
No Heat- below 250^{o}F (121^{0}C)	N/A
Medium Heat- 250-350^{o}F (121-176^{o}C)	Crude Camellia Centrifuged Camellia
Med-High Heat- 350-410^{o}F (176-210^{o}C)	Extra Virgin Olive Pure Olive Grapeseed
High Heat- 410^{o}F (210^{o}C) and above	Commercial *Camellia* Corn Shortening High-Oleic Peanut Canola Almond Vegetable Walnut Pecan Sunflower Safflower Peanut

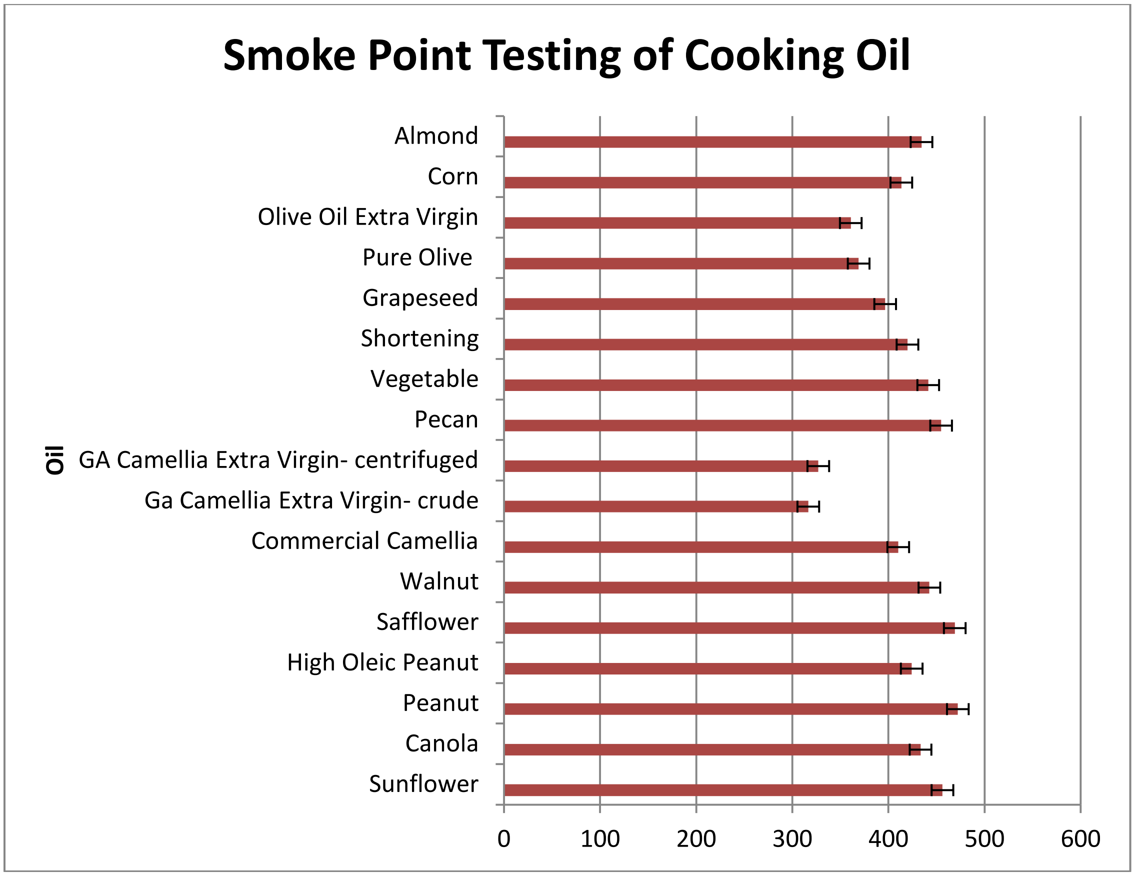

Figure 1: Smoke point temperatures of various cooking oils ± standard error.

Effect of Plant Canopy Shape on Plant Count Accuracy Using Aerial Imagery

Josué Nahún Leiva[a], Jim Robbins[a], Ying She[b], Dharmendra Saraswat[c], Reza Ehsani[b].

[a]Department of Horticulture, University of Arkansas, Fayetteville, AR 72701
[b]Citrus Research and Education Center/IFAS, University of Florida
700 Experiment Station Road, Lake Alfred, FL 33850
[c]Department of Biological Agricultural Engineering, University of Arkansas
Fayetteville, AR 72701

jrobbins@uaex.edu

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Significance to the Industry: Collection of inventory data is time consuming, often inaccurate, and costly. Although some improvements have been made to the process, it still relies heavily on manual methods. The long-term objective of this research program is to develop an automated method to collect and process inventory data using aerial images. This set of experiments is focused on evaluating the effect of plant canopy shape on plant count accuracy. Based on the combined result from these separate experiments, a commercially available software program and another under development, appear to be fairly robust with regard to this single factor (canopy shape). The algorithms trained using the two software programs did not find any differences when plant canopy shape was evaluated with images taken at 12 m.

Nature of Work: In general, the nursery industry lacks an automated inventory control system (2). The process of collecting inventory data in a nursery is labor intensive involving the physical counting of thousands of plants. Due to the time involved in manually counting plants, growers often count only a portion of their crop (1). Aerial images combined with image processing software have been used in agricultural and environmental applications. Since nurseries grow a wide range of plants this may require several counting algorithms. This study was designed to evaluate the effect of plant canopy shape on counting accuracy of container-grown plants.

Container-grown plants were spaced in staggered rows with a canopy separation of 5 cm between canopy edges. Two species of juniper (*Juniperus chinensis* L. 'Sea Green' and *Juniperus horizontalis* Moench 'Plumosa Compacta') growing in #2 black polyethylene containers (Plastics Inc., Jacksonville, TX) were used in the study the foliage, texture, and color was similar. Henceforth, the canopy for 'Plumosa Compacta' will be referred as 'regular' and 'Sea Green' canopy as 'irregular'. For each canopy shape treatment, a set of 64 containers (8 × 8) were established outdoors on black polypropylene fabric ground cover (Lumite, Inc., Alto, GA) on 13 November, 2013 at Greenleaf Nursery, Park Hill, OK . Treatment sets were replicated five times in a randomized complete block design (RCBD) for a total of 10 sets. Two images of each set were taken and then used for algorithm evaluation. Six sets of four fully separated plants were positioned between treatment sets and were used to train an algorithm using MATLAB® (MathWorks Inc., Natick, MA) (MATLAB). Two additional sets of 49 containers (7 × 7), one with ‘Sea Green’ juniper and the other with ‘Plumosa Compacta’, were positioned adjacent to the treatment sets and were used to train the algorithm using FA, and henceforth referred to as training sets.

Data collection: Images were obtained by extending a Bil-Jax 3632T boom lift (Haulotte Group, Archbold, OH) to 12 m above ground level. The camera was handheld and the distance from the sensor to the ground was obtained using a measuring tape. Each time the boom was re-positioned, sensor height relative to the ground was verified. The sensor was positioned over the center of every block, resulting in both sets for that block being included in the image. Image spatial resolution was calculated based on 20 cm square white boards positioned around the treatment blocks, resulting in 0.15 cm/pixel.

Variables: When FA was used, 3 variables were measured using the final count and output image as follows: a) Total count b) False positives: counts that do not represent a target plant (e.g. multiple counts, weeds or other objects within the ground cover that were counted as a plant), and c) Unidentified: target plants that were not counted.
The algorithm trained using MATLAB does not generate an output image, therefore, only total count is reported. Means were separated using an analysis of variance followed by a Student’s t-test based on the experimental design described above using SAS 9.3 (SAS Institute Inc., Cary, NC). No statistical comparison was made between results obtained using the two software packages.

Environmental parameters: Mean environmental parameters including light intensity (140 LUX), relative humidity (24.4%), temperature (15.6° C), and ground wind speed (0-4 km/h) were measured using a Mini Environmental Quality Meter (Sper Scientific, Scottsdale, AZ) at the time of image collection. A subjective estimate of cloud cover was determined to be less than 5%.

Sensor: A Sony Alpha NEX-7 (Sony Corporation of America IR, San Diego, CA), 24.3 megapixels color digital frame camera, with an 18-55 mm lens was used as the sensor. The shooting mode was set as manual with an ISO of 200, shutter speed of 1/250 seconds, and f value of 8. Autofocusing and aspect ratio of 3:2 were fixed. Flash, object tracking, and face detection were turned off. Prior to processing, images were cropped using Adobe Photoshop Elements 6 (Adobe System Incorporated, San Jose, CA) leaving only the set of interest for that particular image.
Algorithm training using Feature Analyst® (FA): A total of two algorithms were trained, one for each canopy shape. Each algorithm was applied to all images regardless of canopy shape. The general process of training the algorithms is the same described in (3).

Algorithm training using MATLAB: A counting algorithm was written using MATLAB (R2013b). Procedures described by (3) were used to train this algorithm, with the exception that a different ratio was used to extract plants from the background: 2*G-B-R.

Results and Discussion:

Algorithm trained using images displaying plants with regular canopy shape: An algorithm was trained using a training image displaying junipers with a regular canopy shape using FA and then applied to images displaying junipers with regular and irregular canopy shapes. There were no significant differences (*P*≤ 0.05) between canopy shape treatments for the three variables measured when the data were analyzed using FA (Table 1). When data were analyzed with the algorithm trained using MATLAB, there was no significant difference (*P*≤ 0.05) between total count for both canopy shape treatments (Table 2).

Algorithm trained using images displaying plants with irregular canopy shape: An algorithm was trained using a training image displaying junipers with an irregular canopy shape and then applied to images displaying junipers with regular and irregular canopy shapes. There were no significant differences (*P*≤ 0.05) between canopy shape treatments for the three variables measured when data were analyzed using FA (Table 3). When images were analyzed with the algorithm trained in MATLAB, total count did not show a significant difference (*P*≤ 0.05) between canopy shape treatments (Table 4).

When data were analyzed with FA and the MATLAB algorithm, there was no difference between variables measured when an algorithm trained with an image displaying regular or irregular plant canopy shape was applied to images displaying either of the plant canopy shapes. Even though the canopy shape of ‘Sea Green’ is less compact than ‘Plumosa Compacta’, visible individual lateral branches are eliminated when applying the erosion procedure. The erosion procedure reduces object size by determining if pixels are enclosed within an object (4).

When using FA, one set of training samples was selected by the user from one training image and then the training set was used to analyze different images. Expectations were that this user input was going to decrease the accuracy of results, however, if there is an effect related to this procedure, it appears to have a minimal effect on count accuracy for juniper plants.

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Table 1. Count accuracy for container-grown junipers with regular (*Juniperus horizontalis* 'Plumosa Compacta') and irregular (*Juniperus chinensis* L. 'Sea Green') canopy shapes when training an algorithm with images displaying junipers with regular canopy shape using Feature Analyst®

Canopy Shape	Total count (%)	False positives (%)	Unidentified (%)
Regular	97%	0%	3%
Irregular	98%	0%	2%

Table 2. Count accuracy for container-grown junipers with regular (*Juniperus horizontalis* 'Plumosa Compacta') and irregular (*Juniperus chinensis* L. 'Sea Green') canopy shapes when training an algorithm with images displaying junipers with regular canopy shape using MATLAB®

Canopy shape	Total count (%)
Regular	100%
Irregular	102%

Table 3. Count accuracy for container-grown junipers with regular (*Juniperus horizontalis* 'Plumosa Compacta') and irregular (*Juniperus chinensis* L. 'Sea Green') canopy shape when training an algorithm with images displaying junipers with irregular canopy shape using Feature Analyst®

Canopy Shape	Total count (%)	False positives (%)	Unidentified (%)
Regular	98%	0%	2%
Irregular	98%	0%	2%

Table 4. Count accuracy for container-grown junipers with regular (*Juniperus horizontalis* 'Plumosa Compacta') and irregular (*Juniperus chinensis* L. 'Sea Green') canopy shapes when training an algorithm with images displaying junipers with irregular canopy shape using MATLAB®

Canopy shape	Total count (%)
Regular	97%
Irregular	102%