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The effect of green tea extract on lipid oxidation of canola oil during deep-fat frying

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THE EFFECT OF GREEN TEA EXTRACT ON LIPID OXIDATION OF CANOLA OIL DURING DEEP-FAT FRYING

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by

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ABSTRACT

THE EFFECT OF GREEN TEA EXTRACT ON LIPID OXIDATION OF CANOLA OIL DURING DEEP-FAT FRYING

by Haiyan Huang

The objective of this study was to compare the effectiveness of GTE (green tea extract) as an antioxidant with that of BHA and α-tocopherol. Sensory qualities (color, odor, and overall acceptance), thiobarbituric acid (TBA) values and refractive indexes of canola oil samples were monitored during deep-fat frying of French fries. Deep-fat frying was performed in canola oils treated with both 200 ppm and 500 ppm GTE, 200 ppm BHA, and 500 ppm α-tocopherol. Canola oil without any addition of antioxidant served as the control. Overall, 4480 grams of French fries were fried for each treatment in a 168-minute frying process.

The results of this study suggest that GTE have antioxidant properties against lipid oxidation of canola oils during deep-fat frying in both tested concentrations, although the effects were not statistically significant. The antioxidation efficiency of GTE was not as effective as that of BHA and α-tocopherol during the frying process.

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The author gratefully acknowledges: Dr. Panfilo Belo, her graduate advisor, for his assistance, patience, and guidance throughout all phases of this research, Dr. Miriam Saltmarch and Dr. Lucy McProud for their guidance and support with manuscript organization, and Mrs. Judith Schallberger for her timely help in the laboratory.

DEDICATION

This thesis is dedicated to my wonderful husband, Ron Chen, and my daughter Karen, whose support and comfort helped me through all the difficult times. None of this would have been possible without them.

PREFACE

The following is a publication style thesis. The second chapter is written in journal format according to the "JFS Style Guide for Research Papers" (1996) and will be submitted to the Journal of Food Science. Chapter I and III are written according to guidelines outlined in the Publication Manual of the American Psychological Association, 4th. Edition, 1994.

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CHAPTER 1

INTRODUCTION AND REVIEW OF LITERATURE

Introduction

Lipid oxidation is one of the major causes of food spoilage. It is of great economic concern to the food industry because it leads to the development, in edible oils and fat-containing foods, of various off-flavors and off-odors generally called rancid, which renders these foods unacceptable or reduces their shelf life. In addition, oxidative reactions can decrease the nutritional quality of food, and certain oxidation products are potentially toxic. On the other hand, a limited degree of lipid oxidation under certain conditions is sometimes desirable, as in the production of typical cheeses or fried-food aromas (Nawar, 1985, p. 176).

Antioxidants are substances that can delay the onset or slow the rate of oxidation of autoxidizable materials. Literally hundreds of compounds, both natural and synthesized, have been reported to possess antioxidant properties (Nawar, 1985, p. 198). Green tea is one of them.

Green tea is one of the most popular beverages in Southeast Asian countries. The polyphenols, or tea tannins, constitute the major portion of fresh leaf (Lunder, 1992, p.116). Studies have been done to investigate the antioxidant properties of major phenolic and polyphenol components of green tea in different model systems (Chen, Chen, Ma, Fung, & Wang, 1996; Ho, Chen, Huang, Zhang, & Rosen, 1992; Tanizama, Toda, Sazuka, Taniyama, Hayashi, Arichi, & Takino, 1984; Wu, 1993; Xie, Huang, Chen, & Ho, 1993; Zhao, Li, He, Cheng, & Xin, 1989). The results indicate those polyphenol

components of green tea (concentration ranged from 200 ppm to 3000 ppm) have strong antioxidant activities.

Frying is one of the most popular food processing methods in the fast food industry. Antioxidants such as BHA, butylate hydroxytoluene (BHT), tertiary butylhydroquinone (TBHQ), and α-tocopherol have been used to improve the stability of oils during frying. However, the use of synthetic antioxidants such as BHA and BHT have decreased in popularity due to the controversial issue of their carcinogenesis as well as a general rejection of synthetic food additives by the public. Tocopherols, the most widely distributed antioxidants in nature are much less effective than BHA or BHT as food antioxidants (Xie et al., 1993). Therefore, the search for the development of other antioxidants of natural origin is highly desirable.

Objective

The objective of this study was to compare the effectiveness of green tea extract (GTE) as an antioxidant with that of BHA and α-tocopherol during deep-fat frying of French fries in canola oil. Sensory qualities (color, odor, and overall acceptance), TBA value and refractive index of canola oil samples were monitored during deep-fat frying of French fries.

Significance of the Study

Although antioxidant properties of GTE have been extensively studied in various model systems, data on its effectiveness as an antioxidant in actual deep-fat frying are very limited. In the course of deep-fat frying, food contacts hot oil (about 180°C) in the presence of air for various periods of time. The finished product usually contains 5-40%

absorbed oil. Thus deep-fat frying, more than any other standard process or handling method normally administered to lipid-containing foods, has the greatest potential for causing chemical changes in fat (Nawar, 1985, p.210). It is possible that the addition of GTE will contribute an antioxidative effect to a frying oil and its products during frying operations. The results of this study will contribute to the available information on the antioxidative effects of GTE on frying oils. If the antioxidative effects of GTE on a frying oil and its products is better than those of synthetic antioxidants and tocopherols, it will provide a great potential commercial benefit to the food industry. Also, in major tea production countries such as China and India, the development of tea antioxidant will lead to increased uses of tea and have a great economic impact.

Review of Literature

Mechanisms of Lipid Oxidation

Much evidence has been introduced to show that autoxidation of fats proceeds via typical free radical mechanisms as characterized by: (a) marked inhibition in rate by chemical species known to interfere with other well-established free radical reactions; (b) catalysis by light and by free radical-producing substances; (c) high yields of the hydroperoxide, ROOH; (d) quantum yields exceeding unity when the oxidation reactions are initiated by light; and (e) a relatively long induction period observed when starting with the pure substrate (Nawar, 1985, p.176).

According to Nawar (1985), the mechanism of lipid oxidation involves three stages of reactions: initiation of the chain reaction, chain propagation, and chain termination. In the initiation step, free radicals are formed by hydroperoxide

decomposition, by metal catalysis, by exposure to light or singlet oxygen. Upon the formation of sufficient free radicals, the chain reaction is propagated by the abstraction of hydrogen atoms at positions α to double bonds. Oxygen addition then occurs at these locations, resulting in the production of peroxy radicals ROO•, and these in turn abstract hydrogen from α-methylenic groups RH of fatty acids to yield hydroperoxides ROOH and R• groups. The resultant R•groups react with oxygen, and the sequence of reactions is repeated. In the termination step, the relatively unstable hydroperoxides enter into numerous and complex breakdown and interaction mechanisms responsible for the production of a myriad compounds of various molecular weights, flavor thresholds, and biological significance.

Food Antioxidants

Antioxidants are of interest to food scientists and food manufacturers. Control of nonenzymatic lipid oxidation, which often limits the shelf-life of manufactured foods, is usually achieved by adding antioxidants to food. The antioxidants to be used are determined by various factors including legislation, effectiveness and cost.

The effectiveness of antioxidants varies depending on the food and conditions of processing and storage. According to Gordon and Kourimská (1995), BHA has good stability and is an effective antioxidant in fried foods, but it contributes little to increase the stability of oils containing tocopherols. BHT is very effective in animal fats but is less effective in vegetable oils and may be lost during frying because of its steam volatility. TBHQ is known to be a very effective antioxidant for vegetable oils, and it is stable at high temperatures, but its antioxidant activity in fried foods is little better than that of

BHA. BHA and BHT are the most widely used synthetic antioxidants, however, in recent years their use has been questioned because of their carcinogenic effect on laboratory-tested animals.(Xie et al., 1993).

Tocopherols are the most important natural antioxidants commercially available. They are the most widely distributed antioxidants in nature and they constitute the principal antioxidant in vegetable oils. They are believed to inhibit lipid peroxidation in vivo by trapping peroxyl radicals (Burton, 1994). Unfortunately, tocopherols are much less effective than BHA or BHT as food antioxidants (Xie et al., 1993). Therefore, the search for and development of other antioxidants of natural origin is highly desirable. A variety of compounds with oxidation inhibition activity have been studied and proposed for use in foods. These compounds include the natural flavorings such as extracts of rosemary and sage and compounds found in wood smoke. More recent research in this area has investigated items such as rice bran oil and the water-soluble and fat-insoluble polyphenolic catechins present in green tea for use as food antioxidants (UOP Food Antioxidant, 1997). Since tea polyphenols are believed to have human health benefits as well as antioxidant capabilities, the use of these compounds might have some advantages over traditional antioxidants.

Green Teas as Antioxidants

Antioxidant Components

Aside from water, tea is the most consumed beverage in the world. Tea is the plant, leaf, or beverage originating from what is now considered a single species: *Camellis sinensis* (L.) O. Kuntze. Two major varieties are recognized: *sinensis* and

assamica (Graham, 1992). The three major types of teas are green teas, oolong teas, and black teas. Green teas are mostly consumed in Asian countries, while black teas are more popular in Western countries.

According to Graham (1992), the term green tea refers to the product manufactured from the fresh leaf while preventing oxidation of the polyphenolic components. Black tea manufacture is carried out so as to ensure a high degree of enzymatically catalyzed aerobic oxidation of the leaf polyphenols followed by a series of chemical condensations. Oolong tea is partially oxidized.

Tea composition varies with climate, season, horticultural practices, variety, and the age of the leaf. The polyphenols constitute the most interesting group of tea leaf components, especially the catechin group of the flavanols(Graham, 1992). Generally, the content of the total polyphenols of a tea depends on its tea type: green and black teas are in the range of 20 to 35, respectively (Lunder, 1992, p.116). Xie et al. (1993) reported that total flavanols accounted for 25% and 31% of total dry extracts in green teas and oolong teas, respectively, whereas total flavanols only account for 10% of total dry extracts in black teas. According to Lunder (1992), the most important polyphenols in tea are the catechins, which include (+) - catechin, (-) - epicatechin (EC), (+) - gallocatechin, (-) - epigallocatechin, (-) -epicatechingallate and (-) - epigallocatechingallate (EGCG). He suggested that the antioxidant activity of green teas be positively related to the content of epigallocatechin.

The catechins are colorless, astringent, water-soluble compounds. They are readily oxidizable, although their oxidation potentials vary. This property has been

exploited through their use as food antioxidants. They retard rancidity in fats and oils by quenching free radical peroxide activity brought about by aerobic oxidation (Graham, 1992).

Antioxidant Mechanism and Effects

The antioxidant mechanism recognized for phenolic compounds involved quenching of peroxyl (ROO•) radicals in the propagation step leading to the formation of hydroperoxides in the free radical sequence (Satue, Huang, & Frankel, 1995). According to Satue et al. (1995), phenolic compounds could also inhibit further decomposition of hydroperoxides by reacting with alkoxyl radicals (RO•), which are responsible for the generation of volatile compounds such as hexanal contributing to rancid odor. The study done by Yeo, Ahn, Lee, Lee, Park, and Kim (1995) suggested that the antioxidative effect of tea extracts is due to inhibition of peroxidation through free radical scavenging and binding action of ferrous ions by mainly tea polyphenol compounds.

According to Wu (1993), antioxidant properties of tea extracts have been tested in various model systems. GTE has scavenging action on singlet oxygen and the higher the concentration of GTE in the photooxidation reaction system, the stronger the singlet oxygen scavenging action. Ho et al. (1992) found that in general, GTE (200 ppm) showed stronger antioxidant activities than the semifermented tea extracts and black tea extracts and that the strong antioxidant activities of green tea were mainly due to the higher content of EGCG. Chen et al. (1996) found that various concentrations of ethanol extracts of green, yellow (slightly fermented tea), and white teas, ranged from 500 ppm to 300 ppm strongly inhibited oxidation of canola oil, while oolong teas exhibited only moderate

antioxidative activity. Ethanol extracts of black, dark-green, and ginseng teas studied showed little or no protection to canola oil from lipid oxidation, probably due to the complete destruction of natural polyphenols by fermentation during manufacturing processes.

A study of the antioxidant properties of the major polyphenol components of tea showed that EC is the main antioxidant component of tealeaf (Tanizama et al., 1984). The inhibitory concentration of EC was nearly equal to that of BHA and lower than that of dl-α-tocopherol (the tested antioxidant concentration was 1000 ppm). The study done by Xie et al. (1993) showed that flavanol is the major polyphenol component with the strong antioxidant property and lipoxygenase inhibitory effect in a concentration of 200 ppm. Zhao et al. (1989) reported that in a stimulated polymorphonuclear leukocytes system, the water extract fraction from green tea and green tea polyphenols (200 ppm) had a much stronger scavenging effect on the active oxygen radicals than that of vitamin C and vitamin E. However, Sethi, Saltmarch, Belo, and McProud (1997) reported that GTE (200 ppm) did not have significant antioxidative effect in canola oil during extensive heating, while BHA (200 ppm) showed strong antioxidative effect, as measured by sensory qualities and thiobarbituric acid (TBA) values.

Although much is known regarding the mechanisms by which GTE imparts stability to pure oils in model systems, further investigation is needed to clarify its function in complex foods during processing such as deep-fat frying of French fries.

The Chemistry of Frying

Chemical Changes Caused by Frying and Assessments to Oil Quality

The cooking performance and quality of vegetable oils at elevated temperatures are of interest to oil processors and commercial frying operators as well as individual consumers. According to Nawar (1985), the following classes of compounds are produced from the oil during frying: (a) volatiles such as aldehydes, ketones, hydrocarbons, lactones, alcohols, acids and esters; (b) nonpolymeric polar compounds of moderate volatility (e.g., hydroxyl and epoxy acids); (c) dimeric and polymeric acids, and dimeric and polymeric glycerides; and (d) free fatty acids. Some of the chemical changes caused by frying are sought by the process to provide the sensory qualities typical of fried food. On the other hand, extensive decomposition, resulting from lack of adequate control of the frying operation, can be a potential source of damage not only to the sensory quality of the fried product, but also to its nutritional value.

Oil performance, stability and quality can be measured by sensory analyses as well as by chemical and instrumental techniques. Techniques to measure TBA value, peroxide value, viscosity, free fatty acid, sensory quality, refractive index, smoke point, foaming, polymer formation, and specific degradation products have been applied to monitor thermal and oxidative decomposition of oils during the frying process with various degrees of success.

According to Warner and Frankel (1985), although chemical and physical measurements are useful in determining the oxidative stability of oils, sensory evaluation of the odor and flavor quality of vegetable oils is considered to be the ultimate method of

assessing oil quality. Instrumental and chemical tests determine oil autoxidation, but sensory analysis measures oxidized flavors as well as those from other sources (Warner, 1985). A number of researchers (Dobbs Vaisey-Genser, & Diamant, 1978; Hawrysh, Erin, & Lin, 1989a; Hawrysh, Shand, Tokarska, & Lin, 1988; Vaisey-Genser & Ylimaki, 1985) have used trained panelists to assess the oxidative stability of canola oils via measurements of odor and flavor intensity and/or the strength of individual odor/flavor notes. Combined with chemical and/or instrumental data, sensory analysis is the final judgment of oil quality (Jackson, 1981).

Federal Regulations on the Application of Antioxidants to Frying Oils

Vegetable fats and oils are frequently used in deep-fat frying operations. Unsaturated sites of the fatty acids in fats and oils are the most susceptible sites for heat-induced and radical-based fat oxidation. Antioxidants have been used to improve the stability of oils during heating and frying. According to the Office of the Federal Register National Archives and Records Administration (1996), the current approved levels of use of BHA, BHT, and TBHQ in food in the U.S. is 200ppm mixed or alone. Since α-tocopherol is a natural antioxidant, there is no limitation for its addition to food (Nawar, 1985, p.200). In 1987, the Codex Committee on fats and oils recommended the following maximum for food additives: 75 mg/kg for BHT, 175 mg/kg for BHA, and 500 mg/kg for tocopherols (Patterson, 1989).

Canola Oil as a Frying Medium

Polyunsaturated fatty acid composition of canola oil. Canola oil is used to identify oil obtained from low erucic acid, low glucosinolate rapeseed. The unique

polyunsaturated fatty acid composition of canola oil differentiates it from other oils. In general, canola oil has a higher oleic acid (C18:1) content (55%) and lower linoleic acid (C18:2) content (26%) than most other vegetable oils. Canola oil also has a high content (8-12%) of linolenic acid (C18:3) compared to vegetable oils such as soybean, sunflower, olive, and corn, which have 8.0%, 0.2%, 0.8%, and 0.7%, respectively (Anonymous, 1979; Sheppard, Iverson, & Weihrauch, 1978). The rate of oxidation of lipid fatty acids increases in relation to their degrees of unsaturation. Sebedio, Bonput, Grandgirard, and Prevost (1990) suggested that an oil was not considered fit for frying if it contains more than 2% linolenic acid (C18: 3). Labuza (1971) stated that the rate of oxidation of linolenic acid (C18:3) is twice that of linoleic acid (C18:2) and 25 times that of oleic acid (C18:1). Forss (1972) also reported that C18: 2, C18: 3, and arachidonic acids (C20: 4) are important precursors for off-odor and off-flavor development in foods since they readily form hydroperoxides. Therefore, the high unsaturated fatty acid content, especially C18:3, in canola influences oil stability and quality.

Effects of antioxidants on stability of canola oil. Canola oil undergoes oxidation and thermal degradation when it is heated to frying temperatures in the presence of air. In addition, heated canola oil develops an unpleasant room or heated odor that has been described as painty with buttery, sweet, sulfurlike, and fishy notes (Dobbs et al., 1978; Eskin, 1989). Mckeag (1977) suggested that the heated room odor of canola oil may be due to oxidation of linolenic acid.

Phenolic antioxidants such as BHA and BHT, either in combination or individually, have been commonly added to canola oil during processing to retard

oxidative changes due to storage and heat. Recently, questions regarding the efficacy of these phenolic antioxidants have arisen. Researchers (Hawrysh et al., 1988; Hawrysh & Lin, 1989; Tokarska, Hawrysh, & Clandinin, 1986; Vaisey-Genser & Ylimaki, 1985) have concluded that BHA/BHT is not effective in promoting canola oil stability. Thus, addition of BHA/BHT to canola oils at maximum levels allowed by the FDA, does not appear to be beneficial for either canola oil processors or consumers.

Antioxidants such as ascorbyl palmitate (AP) and α-tocopherol, either in combination or individually, may offer advantages over other antioxidants in terms of efficacy, safety, and positive labeling connotations. Hawrysh & Lin (1989) found that combinations of dl-α-tocopherol and AP (100 ppm each) extended canola oil stability for up to eight days of Schaal oven storage. However, dl-α-tocopherol at 200 ppm was generally ineffective in retarding oxidation in stored canola oils. Evaluations of the efficacy of dl α-tocopherol alone or together with AP in light-exposed canola oils also suggested that these antioxidants did not delay off-odor and off-flavor development (Hawrysh, Erin, & Lin, 1989b).

The studies on canola oils show that the efficacy of specific antioxidants in retarding flavor deterioration and oxidative changes in stored and/or heated canola oils may vary depending on the particular stability test selected and the analytical procedures employed. Changes in the flavor and oxidative stability of antioxidant treated canola oil that occur during accelerated storage tests are not indicative of those that take place during practical storage (Hawrysh et al., 1988; Hawrysh et al., 1989a) or that result from heating (McMullen, 1988; Vaisey-Genser & Ylimaki, 1985). Further studies of the

quality and stability of antioxidant treated canola oils exposed to a variety of processing conditions are needed to determine the cause(s) for differences in antioxidant efficacy. Comparisons of flavor/odor and oxidative quality of canola oils stabilized with natural and/or unrestricted antioxidants are also pertinent.

CHAPTER 2

JOURNAL ARTICLE

Authors' Title Page

THE EFFECT OF GREEN TEA EXTRACT ON LIPID OXIDATION OF CANOLA OIL DURING DEEP-FAT FRYING

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ABSTRACT

The effectiveness of green tea extract (GTE) as an antioxidant was compared with that of butylated hydroxyanisole (BHA) and α-tocopherol during deep-fat frying of French fries in canola oils. Pure canola oil served as the control. Overall, 4480 grams of French fries were fried for each antioxidant treatment in a 168-minute frying process. Sensory quality, thiobarbituric acid (TBA) values, and refractive indexes of the canola oil samples were monitored during the frying process. GTE had antioxidant properties against lipid oxidation during the experiment period. However, its antioxidation efficiency was not as good as that of BHA and α-tocopherol during the entire frying process.

Key Words: polyphenol, green tea extract, antioxidant, deep-fat frying, canola oil

INTRODUCTION

Antioxidants such as BHA, butylate hydroxytoluene (BHT), tertiary butylhydroquinone (TBHQ), and α-tocopherol have been used to improve the stability of oils during frying. However, synthetic antioxidants such as BHA and BHT have decreased in popularity due to the controversial issue of their carcinogenesis as well as a general rejection of synthetic food additives by the public. Tocopherols, the most widely distributed antioxidants in nature are much less effective than BHA or BHT as food antioxidants (Xie et al., 1993). Therefore, the search for the development of other antioxidants of natural origin is highly desirable.

Green tea is one of the most popular beverages in Southeast Asian countries. The polyphenols, or tea tannins, constitute the major portion of fresh leaf (Lunder, 1992, p.116). Studies have been done to investigate the antioxidant properties of major phenolic and polyphenol components of green tea in different model systems (Tanizama et al., 1984; Zhao et al., 1989; Ho et al., 1992; Wu, 1993; Xie et al., 1993; Chen et al., 1996). The results indicate those polyphenol components of green tea (concentration ranged from 200 ppm to 3000 ppm) have strong antioxidant activities.

Canola oil is used to identify oil obtained from low erucic acid and low glucosinolate rapeseed. The high unsaturated fatty acid content, especially C18:3, in canola oil makes it more sensitive to lipid oxidation because the rate of oxidation of lipid fatty acids increases in relation to the degree of unsaturation (Sheppard et al. 1978; Anonymous, 1979).

Phenolic antioxidants such as BHA and BHT, either in combination or

individually, have been commonly added to canola oil during processing to retard oxidative changes due to storage and heat. Recently, questions regarding the efficacy of these phenolic antioxidants have arisen. Researchers (Vaisey-Genser and Ylimaki 1985; Tokarska et al., 1986; Hawrysh et al. 1988; Hawrysh and Lin,1989) have concluded that BHA/BHT is not effective in promoting canola oil stability. Thus, addition of BHA/BHT to canola oils at maximum levels allowed by the FDA, does not appear to be beneficial for either canola oil processors or consumers.

Antioxidants such as ascorbyl palmitate (AP) and α-tocopherol, either in combination or individually, may offer advantages over other antioxidants in terms of efficacy, safety, and positive labeling connotations. Hawrysh & Lin (1989) found that combinations of dl-α-tocopherol and AP (100 ppm each) extended canola oil stability for up to eight days based on the Schaal oven storage test (Association of Official Analytical Chemists, 1984). However, dl-α-tocopherol at 200 ppm was generally ineffective in retarding oxidation in stored canola oils. Evaluations of the efficacy of dl-α-tocopherol alone or together with AP in light-exposed canola oils also suggested that these antioxidants did not delay off-odor and off-flavor development (Hawrysh et al., 1989b).

The review of stabilized canola oils shows that the efficiency of specific antioxidants in retarding flavor deterioration and oxidative changes in stored and/or heated canola oils may vary depending on the particular stability test selected and the analytical procedures employed. Changes in the flavor and oxidative stability of antioxidant treated canola oil that occur during accelerated storage tests are not indicative of those that take place during normal storage conditions (Hawrysh et al., 1988; Hawrysh

et al., 1989a) or that result from heating (Vaisey-Genser & Ylimaki, 1985; McMullen, 1988). Further studies of the quality and stability of antioxidant treated canola oils exposed to a variety of processing conditions are needed to determine the cause(s) for differences in antioxidant efficiency. Comparisons of flavor/odor and oxidative quality of canola oils stabilized with natural and/or unrestricted antioxidants are also pertinent.

Although antioxidant properties of GTE have been extensively studied in various model systems, data on its effectiveness as an antioxidant in actual deep-fat frying tests are limited. In the course of deep-fat frying, food contacts hot oil (about 180°C) in the presence of air for various periods of time. The finished product usually contains 5-40% absorbed oil. Thus deep-fat frying, more than any other standard process or handling method normally administered to lipid-containing foods, has the greatest potential for causing chemical changes in fat (Nawar, 1985, p.210). It is possible that the addition of GTE will contribute an antioxidative effect to a frying oil and its products during frying operations. The results of this study will contribute to the available information on the antioxidative effects of GTE on frying oils. If the antioxidative effects of GTE on a frying oil and its products are better than those of synthetic antioxidants and tocopherols, this will have great potential for providing commercial benefit to the food industry. Also, in major tea production countries such as China and India, the development of tea antioxidant will lead to a wider variety of utilization of tea and have a greater economic impact.

The objective of this study was to compare the effectiveness of GTE as an antioxidant with that of BHA and α-tocopherol. Sensory qualities (color, odor, and

overall acceptance), TBA values and refractive indexes of canola oil samples were monitored during deep-fat frying of French fries.

MATERIALS AND METHODS

Materials

The Green Tea Extract

Green tea (Long Jing) was purchased from a local Chinese tea market. GTE was prepared according to the method described by Ho et al. (1992) with some modifications. One hundred grams of dried green tea was ground and soaked in 400 ml of 200 proof ethanol overnight, and then homogenized for five minutes using a tissue homogenizer. The homogenate was shaken for two hours in an automatic shaker at 50°C and then filtered. The filtrate was collected and the residue was subjected to a second extraction using 400-ml ethanol. Filtrates from the first and second extraction were combined and concentrated in a rotary evaporator at 60°C. The resulting concentrate was dried overnight in a vacuum oven at 63°C. The dried extract was then dissolved in distilled water to a concentration of 0.4g / 100ml. One hundred milliliters of the solution were then extracted three times with 200-ml hexane to remove the chlorophyll. The aqueous phase was then freeze-dried and the resulting freeze-dried extract was dissolved in ethanol. This ethanolic extract containing 1.11g GTE/100ml was used in the frying experiments.

Other Materials

Canola oil was purchased from a local market (Wesson brand, 100% pure, Lot # 69048NCA 9433). Freshly peeled and cut potatoes (3/8", Kenebeck) were purchased

from a local food service company three hours before the frying process started. These potatoes were stored in water in five-gallon plastic tubs after they were peeled and cut and during delivery. One hour prior to frying, 160-gram samples were wrapped in plastic wrap and stored in the refrigerator and subjected to frying. BHA and α-tocopherol were purchased from Sigma Chemical Co., all other reagents were of analytical grade.

Methods

Experimental Design

To compare the antioxidant property of GTE with that of BHA and α-tocopherol, four canola oil frying media containing 200 ppm GTE, 500 ppm GTE, 200 ppm BHA, and 500 ppm α-tocopherol were prepared. Canola oil without any antioxidant was used as a control. Most studies on the antioxidative effect of GTE used 200 ppm. However, Sethi et al. (1997) did not find that 200 ppm GTE have significant antioxidative effect on lipidoxidation of canola oil. Therefore, in the present study, both 200 ppm and 500 ppm GTE treatments were used to compare the antioxidative effect of these concentrations.

The frying experiment was performed in five identical 4-liter capacity commercial electric fryers containing 3.5 liters of canola oil with the corresponding antioxidants. Freshly peeled and cut potatoes, 160 grams per batch were fried for 4 minutes at 180°C. Each batch was drained for 2 minutes by holding the frying basket over the fryer. A total of 28 batches or a total of 4480 grams of potatoes was fried for a total of 112 minutes of actual frying time (the draining time was not included). Actual heating time (including 2 minutes of draining per batch) of frying oil per treatment was 168 minutes. A 50-ml oil sample was obtained from every 4 batches or every 16 minutes of frying time. A total of

8 samples per treatment were obtained. These frying and sample collection procedures were similar to those described by Goburdhum & Jhurree (1995) with some modifications based on the primary trial of this study.

Oil samples were stored in glass bottles at -18°C prior to sensory and objective analysis. No fresh oil was added back to replace oil samples and lost during the frying and draining.

Evaluation of the Canola Oil Quality

Refractive indexes of the oil samples were measured at 25°C according to the standard methods outlined by the Association of the Official Analytical Chemists (1984). TBA values of the oil samples were measured according to the method outlined by Botsoglou, et al. (1994). The results were the mean of duplicated measurements.

Sensory evaluations of the oil samples were carried out using a 17-member panel (four males and 13 females, 20 to 50 years old), made up of semi-trained panelists who were enrolled in a food sensory evaluation technique class in the Department of Nutrition and Food Science at San Jose State University. Samples of canola oil, 10 ml each, were given to the panelists in identical, coded, covered, small plastic cups at room temperature. The panelists were asked to evaluate the odor, brown color intensity, and overall acceptance (based on odor, color, and clearness of the samples) on the score sheets according to the instructions (see Appendixes A, B, and C for detail information). Four sensory evaluation sessions were conducted within a two-week period. During each evaluation session, the panelists were asked to evaluate ten randomly coded samples in a small, quiet room under identical lighting and temperature conditions. Care was taken to

ensure that the canola oil samples were similar in temperature at the time of evaluation. The panelists were instructed to uncover each sample one cup at a time to ensure that the odor of the sample being evaluated would not be affected by that of other samples.

Statistical Analysis

Microsoft Excel™ 5.0 was used for statistical analysis in this study. Two-factor analysis of variance (ANOVA) was performed to determine if there were significant differences in the sensory qualities, TBA values, and refractive indexes between different frying periods and different antioxidant treatments at 95% confidence level. Trend line analysis was performed for samples from each antioxidant treatment. Slopes (rate constants) of the trend lines were calculated to compare the antioxidant effects of different antioxidant treatments. Correlation coefficients (r) were calculated to determine the correlations between the sensory quality, TBA value, and refractive in each antioxidant treated canola oil and different frying period. According to Burgard & Kuznicki (1990), correlation coefficients in the range of 0.4 to 0.9 were considered as moderate to good correlation between the two groups of data evaluated.

RESULTS AND DISCUSSION

Total Phenolics in the Green Tea Extract

The polyphenol content of the GTE was determined according to the method described by Lau et al. (1989). Before hexane extraction was used to remove the chlorophyll content, the polyphenol content in the dried extract was only 65.74%. However, after hexane extraction, the final GTE contained 92.05% polyphenol. Based on this purity, the actual polyphenol concentrations in the GTE-treated canola oil in this

study were 184 ppm (for 200 ppm GTE) and 460 ppm (for 500 ppm GTE).

Sensory Evaluations

Odor

Results of the odor scores of the samples are listed in Table 2. Analysis of variance of the data (see Table 7) showed that there were significant differences in the odor scores of the canola oil samples, between different frying time ($p<0.001$) and different treatment ($p<0.05$). Statistically, the odor scores of the control samples were significantly lower than those of the BHA and α-tocopherol. The odor scores of both GTE-treated canola oil samples were not significantly different from those of the BHA-treated, α-tocopherol-treated, and control oil samples. Good correlations were found between the odor scores of the canola oil samples and frying time in all five treatments (see Table 5).

As expected, the odor quality of canola oil decreased with frying time or the amount of potatoes fried (Figure 1). However, addition of antioxidants such as BHA, α-tocopherol, and GTE decreased the rate of odor deterioration, although it was not statistically significant in the case of GTE. Based on the scale (see Appendix A), an oil sample is considered to be in poor quality (slightly oxidized, burnt, grassy) if its odor score is less than "6". The BHA treated oil samples were judged to have poor quality only after 88 minutes of frying. The α-tocopherol-treated, GTE 500 ppm treated, GTE 200 ppm treated, and control canola oil samples were judged to have poor quality only after 84 minutes, 76 minutes, 68 minutes, and 56 minutes of frying, respectively.

The odor quality of pure canola oil samples (control) decreased more rapidly than

any other antioxidant treated oils (from 7.6 at 0 minute, to 4.2 after 112 minutes of frying), indicating that it had the fastest rate of formation of volatile oxidation products. This is proven by the pure canola oil samples having the highest slope on the trend line (see Table 7). It was found to have a slightly rancid, slightly painty odor at a frying time 112 minutes, while at the same frying time, all of the antioxidant-treated canola oil samples had only a slightly reverted odor.

The canola oil samples treated with 200 ppm GTE had poorer odor quality than any other canola oil samples in the first 48 minutes of the frying process, probably due to the odor of the GTE and the ethanol that act as a solvent (at frying time 0 minute). However, its trend line had the lowest slope among all the treatments (see Table 6), indicating the slowest rate of formation of volatile oxidation products.

It should be noted that there was not significant difference between the odor scores of the two GTE-treated canola oil samples. Therefore, in terms of delaying the extensive formation of volatile oxidation products in canola oil during the frying process, the stronger concentration of GTE didn't show stronger effects.

Color

The results of the brown color intensity evaluation of the samples are listed in Table 3. Analysis of variance of the data (see Table 8) showed that there were significant differences in the color scores of the canola oil samples, between different frying times ($p<0.001$) and different treatments ($p<0.001$). Good corrrelations were observed between the color scores of the canola oil samples and frying times in all five treatments (see Table 5). Overall, for the same antioxidant treatment, as frying time increased the brown

color intensity of the oil samples increased.

Statistically, the α-tocopherol treated canola oil samples had significant less brown color intensities than other oil samples throughout the frying process, followed by the BHA treated canola oil samples (see Figure 2). Canola oil treated with 500 ppm GTE had the highest brown color intensities throughout the frying process. Samples from canola oil treated with 200 ppm GTE had less brown color intensity than those from the control only after 96 minutes of frying, indicating that GTE treatment did not have any effect on the prevention of brown color formation in canola oil during the entire frying process. However, the results of higher brown color intensities in the GTE treated oil samples might be the result of the pale yellow color associated with the GTE instead of the oxidation products from canola oil. It should also be noted that there was not any fresh oil added back to the canola oils during the frying process. This would have influenced the pattern of changes in the brown color intensity of the oil samples.

The brown color intensity of the control samples increased 3.6 times during the entire frying process, while those of the GTE 500 ppm treated, BHA-treated, GTE 200 ppm-treated, and α-tocopherol-treated oil samples increased 3 times, 3 times, 2.7 times, and 2.6 times, respectively. These results indicated that the control oil samples turned brown more rapidly than any other antioxidant-treated canola oil samples.

Overall Acceptance

The results of the overall acceptance evaluation are listed in Table 4. Analysis of variance (see Table 9) showed that there were significant differences in the overall acceptance scores of the canola oil samples, between different frying times ($p<0.001$) and

different treatments ($p<0.01$). Good correlations were found between the overall acceptance scores of the canola oil samples and frying times in all five treatments (see Table 5). These results along with the results from odor and color evaluations indicated that sensory evaluations were dependable methods for assessment of canola oil quality in the present study.

As expected, the overall acceptance level of the samples decreased as frying time increased, for all five treatments (see Figure 3). Statistically, both the BHA-treated and α-tocopherol-treated canola oil samples were found significantly more acceptable than other canola oil samples by the panelists. Both the GTE (500 ppm and 200 ppm) treated canola oil samples and the control samples was found unacceptable (scored 5 or less according to Appendix C) after 64 minutes of frying, while the BHA and α-tocopherol treated canola oil samples were still acceptable until 100 minutes of frying time, indicating that the addition of GTE did not have any effect on extending the quality life of the canola oil used in deep-fat frying. Also, the overall acceptance scores of the GTE-treated oil samples were lower than the control samples from frying time 0 to 64 minutes. This was possibly because the pale yellow color and odor that was associated with the GTE was not acceptable by the panelists.

In comparing the two GTE treatments, statistically, the overall acceptance scores of the 500 ppm GTE-treated canola oil samples were not significantly higher than those of the 200 ppm canola oil samples. Suggesting that higher GTE concentration didn't have stronger antioxidation effects.

TBA Values

The TBA test is one of the most widely used tests for evaluating the extent of lipid oxidation. Oxidation products of unsaturated fatty acid produce a color reaction with TBA. It is believed that the chromagen results from condensation of two molecules of TBA with one molecule of malonaldehyde (MDA). In general, TBA-reactive material is produced in substantial amounts only from fatty acids containing three or more double bonds. Various compounds, other than those found in oxidized systems, have been found to interfere with the TBA test by producing the characteristic red pigment upon reaction with the reagents. However, in many cases, the TBA test is applicable for comparison of samples of a single material at different states of oxidation (Nawar, 1985, p 193-194).

Analysis of variance of the data (see Table 10) showed that there were significant differences in the TBA values of the canola oil samples, between different frying times ($p<0.01$) and different treatments ($p<0.001$). Good corrrelations were found between the TBA values of the canola oil samples and frying times in all other treatments but α-tocopherol (see Table 5). Overall, for each antioxidant treatment, as frying time increased, the TBA values of the samples increased. These results suggested that the TBA test was a dependable method for assessment of canola oil quality in the present study.

In the present study, the BHA treated canola oil samples had the lowest TBA values (expressed as by microgram MDA/ gram of oil samples) throughout the frying process, followed by the α-tocopherol-treated canola oil samples, and the GTE (500 ppm)-treated canola oil samples (see Figure 4). Statistically, only the BHA and α-

tocopherol-treated canola oil samples had significant lower TBA values than the control samples while the GTE-treated oil samples and the control samples did not show significant difference in their TBA values.

The control canola oil samples had lower TBA values than the GTE 200 ppm-treated canola oil samples from 0 to 80 minutes of frying, and had higher TBA values afterward. Both of the trend lines for the BHA and α-tocopherol-treated canola oil samples had the lowest slope (see Table 6), followed by the trend line of the GTE 500 ppm-treated canola oil samples, and the trend line of the GTE 200 ppm-treated canola oil samples. The control canola oil samples had the highest slope among all the trend lines, suggesting that GTE showed antioxidant properties for preventing the extensive formation of MDA in the treated canola oil samples during the deep-fat frying process, especially in the later stage of the frying process. Also, the higher concentration (500 ppm) of GTE showed stronger antioxidant activities than the lower concentration (200 ppm) as measured by the TBA values in the treated oil samples, although the differencese were not statistically significant.

Refractive Indexes

Refractive index is believed to be related to the degree of saturation of a frying medium (Nawar, 1985, p219). However, Tyagi and Vasishtha (1996) found that refractive index was not a good indicator for oil quality assessment, because data on the refractive indexes of the frying media (soybean oil) with or without antioxidants indicated that these values were not significantly different at $P \leq 0.05$. In the present study, results from ANOVA (see Table 11) showed that there was no significant

difference in the refractive indexes between different antioxidant treated canola oil samples obtained from the same frying time ($p = 0.23$). However, there were significant differences in the refractive indexes between the canola oil samples obtained from different frying times ($p<0.05$).

Except for the control, good correlations between the refractive indexes of the oil samples and frying time were found in all antioxidant treatments (see Table 5). Results from the present study seem to agree with Tyagi and Vasishtha (see Figure 5), because the control canola oil samples did not have good correlations between their refractive indexes and frying times. One possible explaination for this is that the addition of antioxidant might have played an important role in the pattern of the change in refractive indexes in the canola oil samples.

The results from the present study did not show that GTE in the concentrations of 200 ppm and 500ppm have very strong antioxidative effect on lipidoxidation of canola oil during deep-fat frying of French fries, as compared to BHA and α-tocopherol. This is somehow contradictory to the results from previous researches on GTE. The explaination on this is that in the present study, actual frying process was conducted instead of the model system. Also, sensoy evaluation and TBA test were used for the assesment of the canola oil quality instead of the traditional rancimat method.

CONCLUSION

Polyphenol extract from green tea showed antioxidant properties against lipid oxidation of canola oil during deep-fat frying of French fries, as measured by sensory properties and TBA values of the canola oil samples. However, these antioxidant effects

were not statistically significant. During the entire frying process, the antioxidant efficiency of GTE was not as effective as that of BHA and α-tocopherol for the tested concentrations and frying conditions. The higher GTE concentrations showed slightly stronger antioxidant activity than the lower GTE concentrations, as evaluated by odor intensities and TBA values of the samples during the frying process, although the differences were not statistically significant. The pale yellow color and odor of the GTE might have affected the sensory quality of the GTE-treated oil samples.

Based on the conclusion, it is recommended that various concentrations of GTE be used in actual commercial frying conditions to test its efficiency as an antioxidant in different frying media. Further purification of the GTE may be necessary to improve the color quality of the GTE-treated frying medium. Evaluation of the fried products should be conducted along with the evaluation of the frying medium because they are the foods to be consumed. Scale-up production and further sensory, consumer, and marketing research are essential to confirm the demand for this prototype food antioxidant.

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APPENDIX A

ODOR EVALUATION OF CANOLA OILS

Judge Name / Initials : _____

Date: _____

Please smell the reference first. The odor of the reference has been assigned a value of **"10"**. Then, assign values to the samples according to the following descriptions:

Odor value	**Description of the odor**
10 (excellent)	**Completely bland.**
9 (good)	**Trace of odor, but not recognizable.**
8	**Slightly buttery, nutty.**
7 (Fair)	**Slightly beany, slightly hydrogenated.**
6	**Slightly Oxidized burnt, grassy.**
5 (Poor)	**Slightly reverted.**
4	**Slightly rancid, slightly painty.**
3	**Fishy, buggy**
2	**Intensive objectionable flavors.**
1 (Repulsive)	

Sample code:					
Assigned value:					

APPENDIX B

COLOR EVALUATION OF CANOLA OILS

Judge Name / Initials : _____

Date: _____

Please look at the reference first. The brown color intensity of the reference has been assigned a value of **"10"**. Then, assign values to the samples in proportion to the perceived brown color intensity relative to the reference (i. e. if the brown color intensity of a sample is twice as much as that of the reference, the assigned color value for this sample will be "20"; if the brown color intensity of a sample is half as much as that of the reference, the assigned color value for this sample will be "5"). You may use any number you wish including fractions and decimals, except zero and negatives.

Sample code:					
Assigned value:					

APPENDIX C

OVERALL ACCEPTANCE OF CANOLA OILS

Judge Name / Initials : _____

Date : _____

Please evaluate the reference first. The overall acceptance (base on odor, color and clearness) of the reference has been assigned a value of **"9"**. Then, compare the sample with the reference and put a cross mark on the scale for each sample, base on its overall acceptance in comparison to that of the reference (i.e. if the overall acceptance of a sample is the same as that of the reference, the cross mark on the scale for the sample will be on "9" on the scale). You may put the cross mark on any position on the scale. In the case that the overall acceptance of a sample is greater than that of the reference, please make a note next to the right of the scale and assign an approximate value that fits the sample.

Sample code: Scale: 9 - 6 Acceptable ,

5 - marginal, 4 -1 unacceptable

_____ 1 2 3 4 5 6 7 8 9

_____ 1 2 3 4 5 6 7 8 9

Table 1—The amount of French fries fried for different frying times

Frying Batch	Frying Time (minutes)	Amount of French Fries fried (g)
0	0	0
4	16	640
8	32	1280
12	48	1920
16	64	2560
20	80	3200
24	96	3840
28	112	4480

Table 2 — Effect of frying time on the odor quality of canola oil treated with BHA, α-tocopherol, and GTE[a]

Frying time (min)	Antioxidant treatment				
	Control	BHA	α-Tocopherol	GTE 200 ppm	GTE 500 ppm
0	8.8±1.5	9.1±1.6	9.7±0.5	7.7±1.7	7.8±2.3
16	6.3±2.3	7.6±2.2	7.1±1.0	5.9±1.6	7.3±1.4
32	7.2±1.7	6.6±2.2	6.2±2.2	6.5±2.0	6.0±1.9
48	4.6±1.9	6.8±1.4	5.8±1.6	6.2±2.2	5.9±2.4
64	5.7±2.3	6.4±1.8	5.9±2.2	6.2±2.1	5.8±2.4
80	5.5±2.3	5.8±1.7	6.6±2.1	5.8±1.8	5.4±2.2
96	4.0±1.9	6.2±2.0	5.9±1.9	4.8±2.5	6.4±2.1
112	5.4±2.6	5.9±2.4	6.1±1.5	6.3±2.1	5.9±2.5

[a] Values are average ± standard deviation scores of the 17 sensory panelists using Hedonic type of sensory test (see Appendix A for the sensory test score information).

Table 3 — Effect of frying time on the brown color intensities of canola oil treated with BHA, α-tocopherol, and GTE[a]

Frying time (min)	Antioxidant treatment				
	Control	BHA	α-Tocopherol	GTE 200 ppm	GTE 500 ppm
0	14.3±5.4	16.3±7.6	10.8±3.4	22.6±10.2	30.4±22.3
16	20.6±9.6	19.5±10.5	19.3±9.8	34.2±21.1	33.3±22.8
32	29.0±14.4	25.1±16.0	19.8±7.3	28.4±13.4	43.6±25.4
48	35.2±16.8	31.4±19.9	30.9±18.2	41.7±21.5	45.5±23.3
64	38.1±19.4	28.5±17.1	25.6±14.9	42.2±21.7	49.9±25.3
80	46.5±24.1	41.1±25.1	30.9±16.1	44.2±20.1	60.3±45.2
96	48.2±23.5	38.2±21.9	42.6±34.4	48.8±25.8	54.7±29.8
112	51.0±26.3	46.2±24.0	34.7±18.4	51.8±29.7	58.5±30.1

[a] Values are average ± standard deviation scores of the 17 sensory panelists using megnitude estimation type of sensory test (see Appendix B for the sensory test score information).

Table 4 — Effect of frying time on the overall acceptance of canola oil treated with BHA, α-tocopherol, and GTE[a]

Frying time (min)	Antioxidant treatment				
	Control	BHA	α-Tocopherol	GTE 200 ppm	GTE 500 ppm
0	8.2±0.8	8.4±0.8	8.6±0.8	6.4±1.8	6.3±2.1
16	6.5±2.0	6.8±1.9	6.0±1.4	4.4±1.7	6.7±1.3
32	6.4±1.8	6.2±1.5	5.8±2.0	5.9±1.8	4.8±1.2
48	3.9±1.7	6.2±2.0	5.6±1.3	5.1±1.9	4.7±1.9
64	5.2±2.1	5.7±1.7	5.9±2.1	5.0±1.6	5.0±2.4
80	4.6±1.6	5.3±2.1	5.7±2.3	4.7±1.7	4.0±2.2
96	3.4±1.9	5.6±2.1	4.9±1.8	4.3±2.1	4.8±2.1
112	4.2±2.2	4.6±2.4	5.2±2.0	4.9±2.0	4.3±2.4

[a] Values are average ± standard deviation scores of the 17 sensory panelists using unstructured line type of sensory test (see Appendix C for the sensory test score information).

Table 5—Correlation coefficients between sensory qualities, TBA values, and refractive indexes of the canola oil samples and frying time

Treatment	Odor	Color	Overall acceptance	TBA	Refractive index
Control	-0.76	0.99	-0.86	0.78	-0.08
GTE 200 ppm	-0.62	0.94	-0.57	0.63	0.73
GTE 500 ppm	-0.71	0.95	-0.79	0.43	0.51
α-Tocopherol 500 ppm	-0.67	0.90	-0.75	0.25	0.64
BHA 200 ppm	-0.86	0.96	-0.92	0.56	0.59

Table 6— Slopes of the trends of sensory qualities, TBA values, and refractive indexes for different antioxidant treatment

Treatment	Odor	Color	Overall acceptance	TBA	Refractive index
Control	-0.47 ± 0.40	5.37 ± 0.92	-0.57 ± 0.34	$3.6 \times 10^{-2} \pm 7.0 \times 10^{-3}$	-1E-06 ± 3.6E-06
GTE 200 ppm	-0.21 ± 0.26	3.88 ± 1.36	-0.17 ± 0.24	$2.9 \times 10^{-2} \pm 8.9 \times 10^{-3}$	$2.0 \times 10^{-4} \pm$ 4.8E-05
GTE 500 ppm	-0.24 ± 0.24	4.26 ± 1.44	-0.31 ± 0.23	$1.9 \times 10^{-2} \pm 1.0 \times 10^{-2}$	$4.0 \times 10^{-4} \pm$ 1.1E-04
α-Tocopherol 500 ppm	-0.35 ± 0.39	3.72 ± 1.76	-0.35 ± 0.30	$8.6 \times 10^{-3} \pm 8.2 \times 10^{-3}$	2E-05 ± 5.3E-06
BHA 200 ppm	-0.38 ± 0.22	4.14 ± 1.12	-0.42 ± 0.18	$8.4 \times 10^{-3} \pm 3.0 \times 10^{-3}$	1E-05 ± 4.6E-06

Table 7—ANOVA table for odor in the canola oil samples

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (antioxidant treatment)	4.112976	4	1.028244	2.804412	0.044754	2.714074
Columns (frying time)	35.23244	7	5.033206	13.72746	1.45E-07	2.359258
Error	10.26626	28	0.366652			
Total	49.61168	39				

Table 8—ANOVA table for color in the canola oil samples

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (antioxidant treatment)	1949.685	4	487.4212	42.09185	1.87E-11	2.714074
Columns (frying time)	3968.64	7	566.9485	48.95953	4.84E-14	2.359258
Error	324.2384	28	11.57994			
Total	6242.563	39				

Table 9—ANOVA table for overall acceptance of the canola oil samples

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (antioxidant treatment)	7.643619	4	1.910905	4.468527	0.006429	2.714074
Columns (frying time)	34.21182	7	4.887403	11.42887	9.17E-07	2.359258
Error	11.97382	28	0.427636			
Total	53.82926	39				

Table 10—ANOVA Table for TBA value of the canola oil samples

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (antioxidant treatment)	0.19158	4	0.047895	9.072558	7.87E-05	2.714074
Columns (frying time)	0.168233	7	0.024033	4.552531	0.001697	2.359258
Error	0.147815	28	0.005279			
Total	0.507629	39				

Table 11—ANOVA table for reflective index of the canola oil samples

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (antioxidant treatment)	2.23E-06	4	5.58E-07	1.499329	0.229233	2.714074
Columns (frying time)	6.17E-06	7	8.82E-07	2.367689	0.049307	2.359258
Error	1.04E-05	28	3.73E-07			
Total	1.88E-05	39				

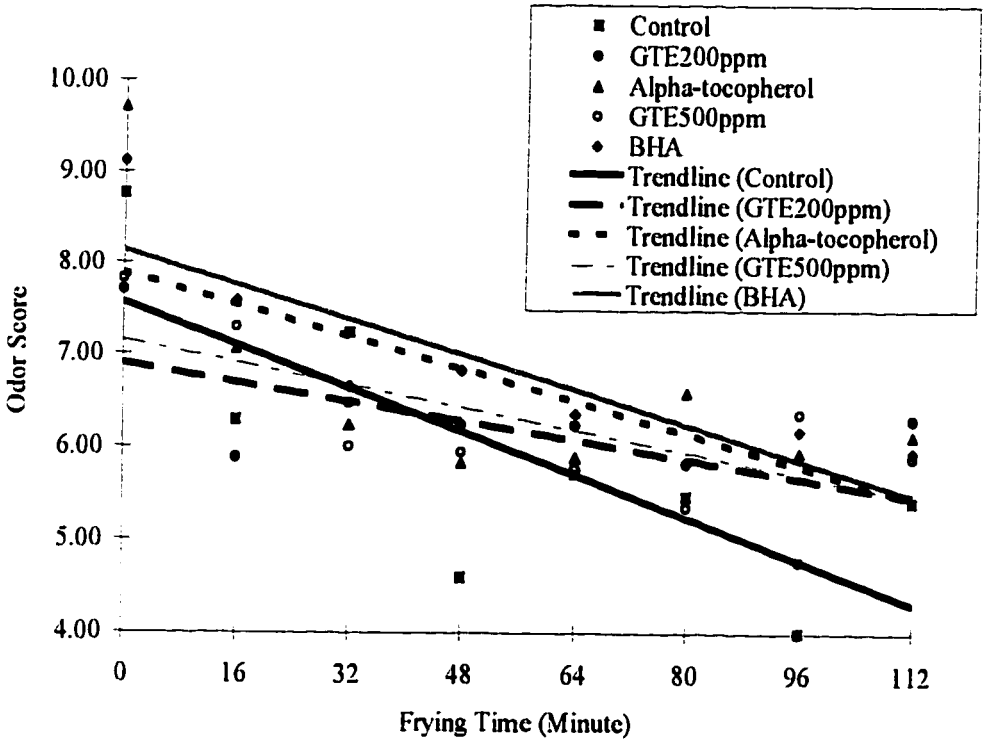

Figure 1— The odor scores of the canola oil samples at different frying times (values are average of 17 judgments).

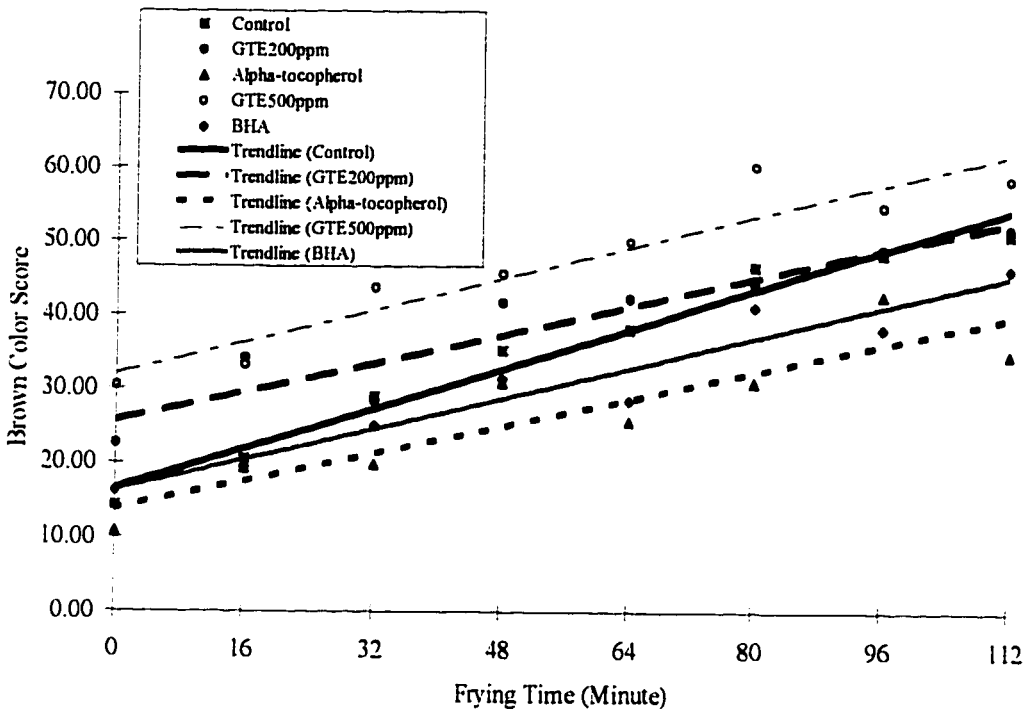

Figure 2—The brown color scores of the canola oil samples at different frying times (values are average of 17 judgments).

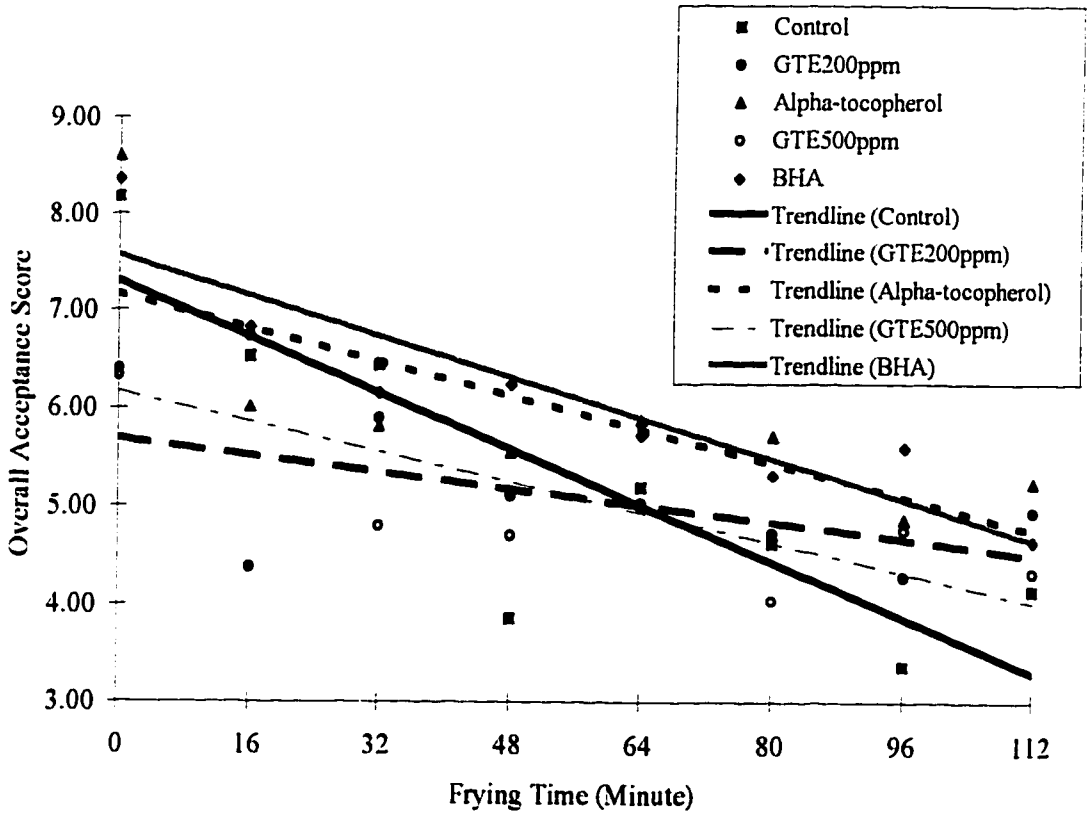

Figure 3—The overall acceptance scores of the canola oil samples at different frying times (values are average of 17 judgments).

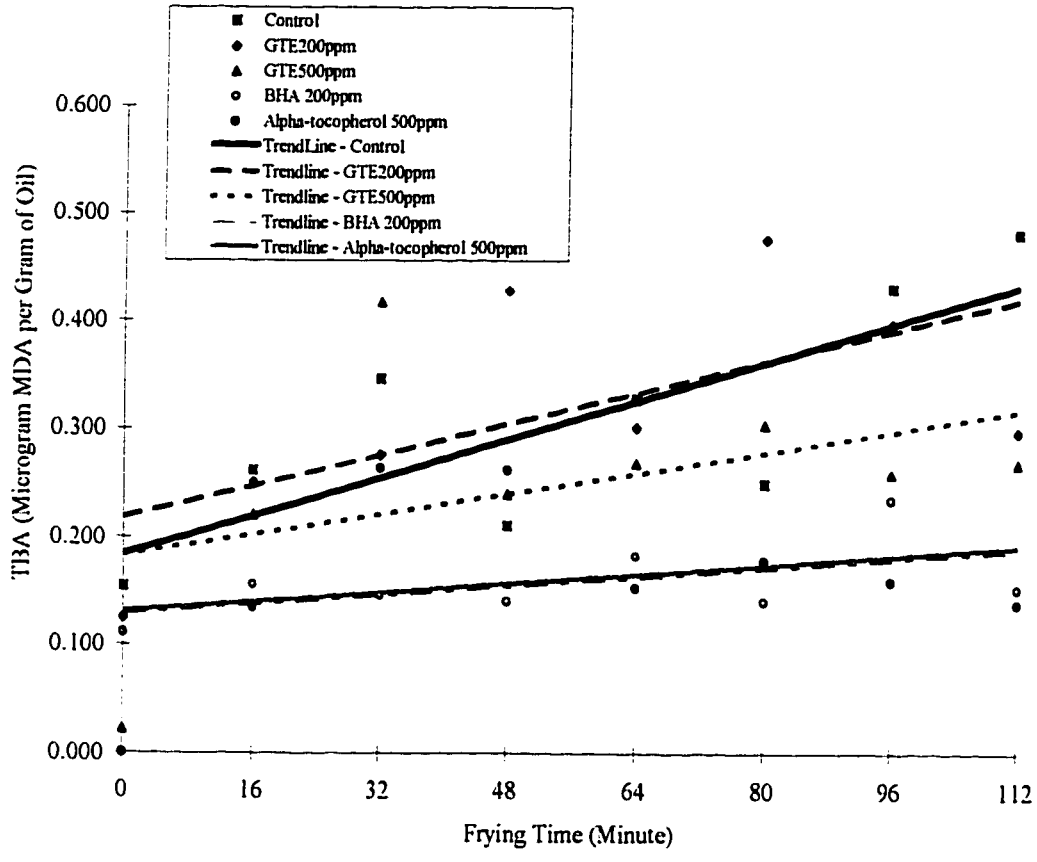

Figure 4—The TBA values (as measured by microgram MDA/gram of oil sample) **of the canola oil samples at different frying times** (values are the mean of those from duplicated samples)

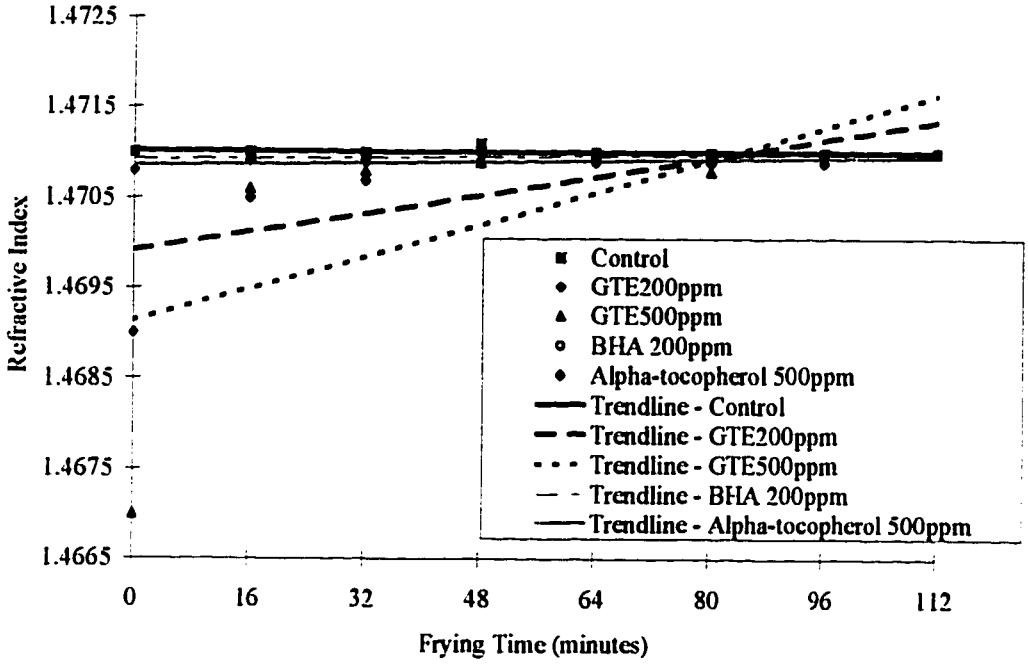

Figure 5—The refractive indexes of the canola oil samples at different frying times (values are the mean of duplicated samples).

Chapter 3

SUMMARY AND RECOMMENDATIONS

Summary

Antioxidant properties of GTE, α-tocopherol, and BHA were evaluated, by measuring the TBA values, refractive indexes, and sensory properties of the antioxidant-treated canola oil samples used to prepare French fries. Canola oil samples without the addition of antioxidant were used as controls. The results of this study indicated that GTE had antioxidant properties against lipid oxidation of canola oil during deep-fat frying. However, during the frying process, its antioxidant efficiency was not as good as that of BHA and α-tocopherol for the tested concentrations and frying conditions. The higher GTE concentration showed stronger antioxidant activity than the lower GTE concentration, as evaluated by odor intensities and TBA values of the samples during the entire frying process. The pale yellow color of the GTE might have affected the sensory quality of the GTE-treated oil samples.

Recommendations

Based on the results of this study, it is recommended that GTE be used in actual commercial frying conditions to test its efficiency as an antioxidant in different frying media. Various concentrations (both lower than 200 ppm and higher than 500 ppm) of GTE may be tested to find out the most effective level.

Further purification of the GTE may be necessary to improve the color quality of the GTE-treated frying medium. A further recommendation is that evaluation of the fried products should be conducted along with evaluation of the frying medium because they

are the foods to be consumed.

The development of a GTE antioxidant could potentially provide a great potential commercial benefit to the food industry. In the present study, it is encouraging to know that polyphenol extract from green tea had antioxidant properties against lipid oxidation of canola oil during deep-fat frying. Scale-up production and further sensory, consumer, and marketing research are essential to confirm the demand for this prototype food antioxidant.

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DATE: March 14, 1997

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"The Effect of Polyphenol Extract from Green Tea on Lipid Oxidation of Canola Oil in Deep-fat Frying"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Serena Stanford, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.