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Determination of dietary fiber content of artichoke leaves and flowers

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**DETERMINATION OF DIETARY FIBER
CONTENT OF ARTICHOKE LEAVES AND FLOWERS**

A Thesis

Presented to

The Faculty of the Department of Nutrition and Food Science

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Yi Zheng

May, 2000

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ABSTRACT

DETERMINATION OF DIETARY FIBER

CONTENT OF ARTICHOKE LEAVES AND FLOWERS

by Yi Zheng

The objective of this study was to determine the potential of artichoke leaves and flowers, obtained from an artichoke processing plant, as good sources of dietary fiber. Total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) content of artichoke leaves and flowers were determined using AOAC standard methods.

On a dry basis, the TDF, IDF, and SDF content of artichoke leaves were 53.25, 34.97, and 18.65 g/100g, respectively. Artichoke flowers on the other hand contained 50.42, 32.43, and 20.43 g/100g dry matter of TDF, IDF, and SDF, respectively. Fresh artichoke leaf and flower contained more TDF, IDF, and SDF than some of the most widely consumed vegetables, such as carrots, celery and cucumber. Dry artichoke leaf and flower contained relatively higher amounts of TDF and SDF than oat bran, and they contained more TDF than some high-fiber containing fruits and grains, such as prunes, raisins and high-fiber cereals. Based on the results of this study, artichoke leaves and flowers are potential good sources of total dietary fiber and soluble dietary fiber.

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DEDICATION

This thesis is dedicated to my family for their support throughout my graduate studies in the United States.

PREFACE

The following thesis is written in publication style. The second chapter is written in journal format and will be submitted to the Journal of Agricultural and Food Chemistry.

The first and third chapters are written according to the guidelines in the Publication Manual of the American Psychological Association, fourth edition, 1994.

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Introduction

The term of dietary fiber refers to the remnants of plant cells, polysaccharides, lignin, and associated substances resistant to hydrolysis (digestion) by the alimentary enzymes of humans (Cho, De Vries, & Prosky, 1997). It is of nutritional importance in gastrointestinal disease such as diverticulosis, and management of serum lipid and glucose levels related to chronic conditions such as heart disease and diabetes (Worthington-Roberts & Williams, 1996). Dietary fiber consists of complex carbohydrate-polysaccharides, which are composed of large, complex compounds of many saccharide units. Total dietary fiber is an analytical term for dietary fiber. It is made up of both soluble and insoluble dietary fibers (Kritchevsky & Bonfield, 1995). Insoluble dietary fiber includes cellulose, most hemicellulose, and lignin. Gums, mucilages, algal polysaccharides and most pectins are classified as soluble dietary fibers (Marlett, 1989).

Measuring dietary fiber is the first step in identifying the impact of fiber in the diet. Subsequently, the physical and physiological effects of dietary fiber, including its interactions with other nutrients, can be assessed (Shinnick, Longacre, Ink, & Marlett, 1988). Reviews of dietary fiber analytical methods have appeared in scientific and medical literature (Selvendran & Dupont, 1984; Asp & Johansson, 1984). Methods for determination of dietary fiber may be divided into three categories: 1) enzymatic-gravimetric methods; 2) enzymatic-chemical methods; and 3) nonenzymatic-gravimetric

methods (Cho et al., 1997). The enzymatic-gravimetric methods are the most used methods because they are less time-consuming and more accurate compared to other methods (Prosky, Asp, Schweizer, De Vries, & Furda, 1988). AOAC Official Method 991.43, an enzymatic-gravimetric method, is the basis of the U. S. Department of Agriculture Handbook No. 8 for the analysis of dietary fiber since 1993 (Cho et al., 1997).

The artichoke is one of the most popular vegetables consumed in California (<http://www.caramiafoods.com>). It has a sweet, buttery, somewhat nutty flavor that possesses the ability to change the chemistry of our taste buds to sweeten the flavor of accompanying foods (<http://www.oceanmist.com>). This ability is attributed to the phytochemicals found in the green parts of the plant called cynaropicrin and cynarin (<http://www.rain-tree.com/artichoke.htm>). The artichoke must be shielded from excessive sunlight and protected from winter freezing. The foggy coastal regions of central California have proven to be ideal for their culture. Therefore, most of today's artichokes come from this geographic area (Cook & Sundaram, 1963). Castroville, south of San Francisco, is known as the "Artichoke Center of the World."

Artichokes are almost fat free and are a good source of dietary fiber, vitamin C, folate, and magnesium (Rainey & Nyquist, 1997). Artichoke extracts have been used for centuries in European countries for their choleretic, ureolytic, diuretic and hypocholesterolemic actions (Hammouda, El-Naser, & Shahat, 1993). Silymarin, a compound found in artichoke, has ten times the antioxidant power of vitamin E, helps hepatitis C patients recover faster, and helps reduce the development of UV-related skin

tumors when used as an ointment in animal studies (Cruz, 1998).

The long, arching, and deeply serrated part of the artichoke is the leaves of the artichoke (<http://www.oceanmist.com>). The part called the “choke” is the flowers of the artichoke that are the mass of tough and stringy immature flowerets. The artichoke leaves and flowers are thrown away because fleshy bases of immature flower heads and fleshy bases of the large bracts are the edible parts (McGee, 1984). The artichoke leaves rather than the flowers have been found to be higher in medicinal value (Monograph Artichoke, 1992). The artichoke leaf has a reputation as a cholagogue, diuretic and general stimulant (Mowrey, 1993). Cynarin, the main constituent in the artichoke leaf extract, has shown highly cholagogue effects (increases bile production in the liver), due to the artichoke leaf extracts' ability to increase the flow of bile by sixty percent and as much as four times normal in a 12-hour period (Bartram, 1995). High-dose aqueous extracts from artichoke leaves were found to inhibit cholesterol biosynthesis in primary cultured rat hepatocytes (Gebhardt, 1998). The medicinal values of artichoke leaves are very well documented (Monograph Artichoke, 1992). However, there are few published data on the proximate composition and dietary fiber content of edible portion of raw artichoke available (Galvano & Scerra, 1983). Furthermore, there are no published data on the proximate composition and dietary fiber content of artichoke leaves and flowers.

Objective

Based on fresh weight, the edible parts of artichoke constitute only about one sixth of the total plant. Artichoke processing companies want to find better ways to utilize

remainders of the plant. Determination of nutrient values of artichoke leaves and flowers, the major waste products in the artichoke processing industry, would contribute to this goal. Based on this need, the objective of this study was to determine total, insoluble and soluble dietary fiber content of artichoke leaves and flowers. The amount of dietary fiber of artichoke leaves and flowers was compared to that of oat bran, the most widely used fiber-rich source. In order to compare dietary fiber content (dry weight basis) of artichoke leaves and flowers with that of oat, a proximate analysis was performed to obtain the percentages of main components of artichoke leaves and flowers. Results of this study were intended to provide data on the proximate composition, and the total, insoluble, and soluble dietary fiber content of artichoke leaves and flowers for the artichoke industry.

Significance of the Study

As awareness of the physiological benefits of dietary fiber increases, both the public and health professionals must be provided with data on dietary fiber content of foods. Information on good sources of dietary fiber is also needed so that appropriate dietary guidelines may be adopted and implemented (Southgate, 1992).

Artichoke leaves and flowers are the major waste product in the artichoke industry. Current uses of artichoke leaves in natural medicine include: for all types of liver diseases including those related to alcoholism, dyspepsia, chronic albuminuria, and anemia; for gallbladder disorders; for heart diseases including arteriosclerosis and high cholesterol; and for diabetes and kidney disease (Mowrey, 1993; Bartram, 1995). However, artichoke

leaves and flowers have not been used as fiber-enriched ingredients in foods or drugs. If results of this study were to show that artichoke leaves and flowers were fiber-rich sources, it might not only provide profits for the artichoke industry, but might also provide a new source of fiber for food manufacturers and the pharmaceutical industry.

Review of Literature

Dietary Fiber

History of the Definition

The lack of an internationally acceptable definition for dietary fiber has often complicated the results obtained from experimental data (Cho et al., 1997). The debate on the definition of dietary fiber has been focused on “resistant starch” and lignin (Englyst, Trowell, & Southgate, 1987; Asp, Furda, De Vries, Schweizer, Prosky, 1988; Englyst & Cummings, 1987). All types of dietary fiber have positive physiological effects related to their nondigestability in the small intestine. As a result, considerable time and effort have been applied in reaching a common definition of dietary fiber based on the physiological parameters of edibility and resistance to digestion (Cho et al., 1997).

First, the definition of dietary fiber was crude fiber, defined as “ the residue of plant food left after extraction with solvent, dilute acid, and dilute alkali” (William & Olmstead, 1935, p. 653). Because the definition did not include many of the fiber components normally associated with the physiological activity of the fiber fraction, dietary fiber was first applied by Hipsley (1953) as a term for the constituents of the plant

cell wall, including cellulose, hemicellulose, and lignin. In the 1960s, advances in ruminant research led VanSoest to introduce analytical methods for acid detergent fiber (ADF) and neutral detergent fiber (NDF) (VanSoest, 1963; VanSoest & Wine, 1967). The ADF method solubilizes and digests all components of the food sample, leaving behind the cellulose and lignin residues. The NDF method measured the components of fiber similar to the components of the insoluble dietary fiber fraction isolated in the enzymatic-gravimetric methods used for the determination of total dietary fiber today (Cho et al., 1997). In the 1970s, dietary fiber, which included all indigestible polysaccharides such as gums, modified cellulose, mucilages, oligosaccharides, and pectin, was used to describe the remnants of plant components resistant to hydrolysis by human alimentary enzymes (Trowell, 1974). This definition of dietary fiber was a physiological-botanical definition related to indigestibility in the human small intestine and was focused on plant cell walls. Trowell's dietary fiber definition led to numerous dietary fiber research projects in such areas as nutrition and food technology (Cho et al., 1997).

The definition of dietary fiber included all indigestible dietary polysaccharides in addition to the other fiber components. Some of these indigestible polysaccharides were included in the definition because they had the physiological actions attributed to dietary fiber, but could not necessarily be chemically identified as originating in the cell wall. This definition has gained wide acceptance and has become the basis for the current official AOAC Official Methods. The current definition of dietary fiber is: "Dietary fiber consists

of the remnants of plant cells, polysaccharides, lignin, and associated substances resistant to hydrolysis (digestion) by the alimentary enzymes of humans” (Cho et al., 1997).

Sources

Good sources of dietary fiber are whole grains, fruits, vegetables, seeds, nuts, and skins of plants (Worthington-Robert & Williams, 1996). Currently, the most popular fiber-rich products are those that contain oat bran fiber (Prosky & De Vries, 1992).

Dietary Fiber in Health and Disease

Walker (1947) was one of the first contemporary researchers in the fiber field to report on the profound implications of ingesting dietary fiber. But it remained for Cleave, father of the dietary fiber hypothesis, and Campbell (1966), to observe and report that many of the most common diseases associated with western civilization were rare in the less economically developed countries.

Total dietary fiber is not a major energy-nutrient because humans lack the necessary enzymes to split their particular saccharide links (Worthington-Roberts & Williams, 1996). The bacteria of the GI tract can break some fibers down to water, gas, and short-chain fatty acids. Short-chain fatty acids can be metabolized in both the intestinal mucosa and the liver. Therefore, dietary fibers do generate some energy. However, the energy contribution is limited by the small amount of fiber intake (Livesey, 1990). In spite of almost zero energy contribution, dietary fibers are essential to digestion and health. Fiber may protect against cancers of the breast and prostate, and reduce the risk of heart disease (Worthington-Roberts & Williams, 1996). Also, dietary fibers

enhance the health of the large intestine. Their short-chain fatty acid products promote salt absorption and help maintain mucosal integrity (McBurney & Thompson, 1989).

High fiber diets have been suggested as beneficial for a number of conditions including diverticulitis, hyperlipidemia, and non-insulin dependent diabetes (Anderson & Gustafson, 1988). The American Dietetic Association suggests 20 to 35 grams of dietary fiber daily. Adequate fiber fosters weight control, lowers blood cholesterol, helps prevent and control diabetes, helps prevent and alleviate hemorrhoids, and helps prevent appendicitis and diverticulosis (Worthington-Roberts & Williams, 1996).

However, fiber is like all of the other nutrients in that moderation is the best for human health. Excess fiber displaces energy- and nutrient-dense foods, causes intestinal discomfort and distention, and interferes with mineral absorption (Whitney & Rolfes, 1996). The effect of dietary fiber on mineral balances continues to be a controversial issue (Kelsay, 1986). The mechanism by which dietary fiber influences mineral absorption is related to its physicochemical properties. These properties involve the ability of dietary fiber to: 1) act as a weak cation exchanger; 2) decrease transit time; 3) dilute mineral concentration by increasing fecal bulk; and 4) resist digestion in the large bowel (Kay, 1982). However, it appears that the consumption of 20 g of dietary fiber daily or the gradual increase in the consumption of dietary fiber above this level from mixed food sources does not appear to have a deleterious effect on calcium, magnesium, phosphorous, iron, zinc, or copper balance in healthy adults, provided they are consuming omnivorous diets containing the current recommended levels of protein, vitamin C, and minerals

(Canadian Advisory Committee on Dietary Fiber, 1985). Compared to minerals, there is not much information on the effects of dietary fiber on vitamin availability (Kritchevsky & Bonfield, 1995).

Insoluble Dietary Fiber versus Soluble Dietary Fiber

Dietary fiber can be classified as soluble and insoluble dietary fibers based on their physical or analytical properties. Insoluble dietary fiber is insoluble in cold and hot water, dilute acids, and hot dilute alkali solutions. It includes cellulose, hemicellulose, resistant starch, and chitin (Cho et al., 1997). The primary structure found in insoluble dietary fiber is cellulose.

Solubility of a dietary fiber does not necessarily mean solubility in water. It means dissolved or liquefied in a buffer and enzyme solution, but not necessarily exactly replicating, the aqueous enzyme solutions or slurries present in the human system. Soluble dietary fiber includes hemicelluloses, pectins, β -Glucans, and galactomannan gums (Cho et al., 1997). Until now, human enzyme systems have not been replicated because human alimentary enzymes are not commercially available. The most widespread soluble dietary fiber structure in foods is pectin (Cho et al., 1997).

Natural Sources

In general, soluble dietary fibers occur in higher concentrations in fruits, oats, barley, and legumes. Insoluble dietary fibers are found in higher concentrations in vegetables, wheat, and cereals (Worthington-Robert & Williams, 1996).

Purified Products

Cellulose is an insoluble dietary fiber source, which is resistant to water dissolution and acid and base hydrolysis. This allows cellulose to be processed and purified in a variety of ways before it is used as a food additive (Cho et al., 1997). The majority of products sold as cellulose fiber preparations are derived from woody plants through a pulping and bleaching process. Resistant starch has been produced commercially.

Novelose is a starch-based product that contains 30% insoluble dietary fiber as determined by AOAC Methods. Other commercially available resistant starches are Fibersol and Pinefiber (Yoshio, Kazuyuki, Yasuo, Isao, & Kazuhiro, 1994).

Most of the commercial pectin, a soluble dietary fiber, sold as a food additive for gelling food products is isolated from either apple pumice or citrus peels (which contains up to 30% on a dry basis). Pectin finds a ready market as a food additive because its gelling properties can be controlled by the food manufacturer or processor through temperature, moisture level, sugar level (as a source), and calcium content of the product (Christensen, 1982).

Physiological Effects of Soluble and Insoluble Dietary Fiber

The physiological effects of dietary fiber have led to numerous research studies. However, the insoluble and soluble dietary fibers have different effects and different levels of effect on the human system, depending on the source of the fiber and the manner in which it was prepared for consumption (Cho et al., 1997). Functions of insoluble dietary fibers are holding water, reducing elevated colonic intraluminal pressure, helping to

alleviate or prevent constipation, binding metals, bile acids, and cholesterol, and acting as antioxidants. Functions of soluble dietary fibers are: holding water and increasing stool bulk; reducing elevated colonic pressure; binding bile acids and cholesterol; slowing gastric emptying; and providing material for colonic bacteria with production of gas and volatile fatty acids (Slavin, 1990).

Soluble dietary fibers which form viscous solutions or gels in the stomach and small intestine may act to slow absorption and transit by increasing the viscosity of luminal contents (Edwards, 1990). It was shown that dietary supplementation of soluble dietary fibers may be an acceptable means of treatment for individuals with hypercholesterolemia of diabetes for extended periods without adversely affecting mineral balance (Behall, Scholfield, Lee, Powell, & Moser, 1987). Also, soluble dietary fibers were found to have therapeutic values in reducing cholesterol and improving glucose metabolism without adversely affecting mineral balance of calcium, magnesium, manganese, iron, copper or zinc (Behall, 1990). Similar results were shown in Anderson and Bridge's study (1988). In contrast to the above studies mentioned, soluble dietary fibers were found to play a minor role concerning the postprandial glycaemic and insulinaemic responses following the ingestion of mixed meals (Heaton, Marcus, Emmett, & Bolton, 1988).

Oat products, rich in gums and β -glucans that are soluble dietary fibers, have more potent cholesterol-lowering action than virtually any other widely used food products (Anderson & Gustafson, 1988). Without significantly affecting the protective HDL-cholesterol, oat products selectively lower atherogenic LDL-cholesterol (Anderson &

Gustafson, 1988). Oats and other soluble dietary fiber sources may lower serum cholesterol: 1) by altering bile acid secretion or metabolism through fermentation to short-chain fatty acids which may influence hepatic cholesterol synthesis; or 2) through changes in insulin secretion or hormonal effects (Story, Watterson, & Matheson, 1990). Oat bran seems to affect the rate of glucose absorption from the small intestine because of the high content of soluble dietary fiber in the form of β -glucans. The same was not seen with rolled oats (Story et al., 1990). Oat dietary fiber was digested in the large intestine to a high degree, which results in a pronounced effect on the microbial fermentation in the large intestine (Knudsen, Hansen, Jensen, & Stergard, 1990). Because of the substantial hypocholesterolemic effects of oat bran, it is widely used in the dietary management of hypercholesterolemia. The regular use of oats as part of a low-fat, low-cholesterol diet should reduce the risk for coronary heart disease (Anderson & Gustafson, 1988).

Some studies showed that soluble dietary fibers had adverse physiological effects. The long-term intake of 6% pectin can decrease vitamin E availability in rats (Schaus, De Lumen, Chow, Reyes, & Omaye, 1985). Similar results were also obtained from De Lumen, Lubin, Chiu, Reyes, and Omaye's study (1982). However, the addition of low to moderate hard red spring wheat bran has no detrimental effects on vitamin E status in rats (Mongeau, Behrens, Madere, & Brassard, 1986).

Like soluble dietary fibers, insoluble dietary fibers may have a positive effect on diabetes, reduce the risk of coronary heart disease and obesity, and improve bowel functions (Prosky & De Vries, 1992). Unlike soluble dietary fibers, cellulose, an insoluble

dietary fiber, does not lower plasma cholesterol (Truswell & Beynen, 1992). A negative manganese balance was shown after consumption of cellulose, an insoluble dietary fiber (Behall, 1990).

Wheat bran contains a high proportion of insoluble dietary fiber. It has little or no effect on digestion and absorption of nutrients in the small intestine and is highly resistant to microbial degradation in the large intestine of monogastrics including man (Stephen & Cummings, 1980). Wheat bran is one of the most efficient dietary fiber sources in increasing fecal bulk and in decreasing mouth-to-anus transit time (Spiller et al., 1986). However, increased consumption of wheat bran or whole wheat will not lower cholesterol directly (Truswell & Beynen, 1992).

Natural Fiber versus Purified Fiber

The study of the effects of dietary fiber on health should consider differences between the effects of natural high-fiber whole foods and the effect of isolated or purified fibers (Spiller, 1990). Two major differences exist between a diet containing natural high-fiber and a diet to which an isolated or concentrated fiber has been added: 1) there are many bioactive compounds normally found in foods that may be lost in the isolation process; and 2) a diet containing natural high-fiber supplies more energy from carbohydrates and less energy from lipids (Spiller, 1990).

Purified cellulose-type fiber products are widely used in experimental nutrition. It was shown that various commercially available cellulose products are not equivalent in terms of physico-chemical properties (Penner & Liaw, 1990). The long-term intake of 6%

pectin, a purified soluble dietary fiber, can decrease vitamin E availability in rats (Schaus et al., 1985). However, the addition of low to moderate hard red spring wheat bran has no detrimental effects on vitamin E status in rats (Mongeau et al., 1986). Penner and Liaw (1990) indicated that the results from experimental studies with purified cellulose should not be interpreted in terms of the role of cellulose in other complex food fibers. In general, the cellulose component of a complex food fiber is digested to a greater extent than the cellulose of a purified cellulose product.

Based on results of current studies, one can not attribute that fiber is the only key factor for the beneficial effects on human health when the whole high-fiber foods are used to study the effects of dietary fiber. Another macronutrient or a micronutrient which we do not know yet might be a key factor for the physiological effects instead of the dietary fiber being studied (Prosky & De Vries, 1992).

Artichoke

Botany

Artichoke is commonly known as Globe artichoke, and its scientific name is *Cynara scolymus* L.. It falls under plants of Compositae or Asteraceae family, *Cynara* genus, and *Scolymus* species (<http://www.rain-tree.com/artichoke.htm>). In full growth, the plant spreads to cover an area of about six feet in diameter and reaches a height of three to four feet. Its long, arching, deeply serrated leaves give the plant a fern-like appearance. The Green Globe cultivar accounts for essentially all of the artichokes grown

in the United States. The vegetable we eat is actually the plant's flower bud. If allowed to flower, blossoms measure up to seven inches in diameter and are violet. The size of the bud depends upon where it is located on the plant. The largest are terminal buds produced at the end of the long, central stems (<http://www.oceanmist.com>).

History of Food Uses

The flower petals and fleshy flower bottoms of the artichokes are eaten as a vegetable throughout the world which has led to its commercial cultivation in many parts of South and North America as well as Europe. The artichoke was used as a food and medicine by the ancient Egyptians, Greeks, and Romans. In Rome, they were an important item on the menu at feasts. It wasn't until the 15th century that they made their appearance in the rest of Europe. Early plantings were made in the U.S. by French settlers in Louisiana and the Spanish in the mid-coastal areas of California. They are commercially important vegetables in California (<http://www.rain-tree.com/artichoke.htm>).

Chemical Components and their Therapeutic Properties

The artichoke can modify taste quality. Two isolated chemicals from artichoke hearts, cynarin and chlorogenic acid, were proved to be largely, though not completely, responsible for the artichokes' sweetening ability (Lee, Bartoshuk, & Scarpellino, 1973). The following substances were isolated from the leaves of *Cynara scolymus*: chlorogenic acid, neochlorogenic acid, isochlorogenic acid, caffeic acid, 1-caffeoylquinic acid, 4-caffeoylquinic acid, and cynarin (Dranik & Chernobai, 1966; Hinou, Harvala, & Philianos, 1989). Like most vegetables, artichokes are good for human health.

The thistle-like leaves, not the edible parts— the familiar artichoke heart, which never reach the dinner table are the most beneficial parts for human health. The French have long advocated artichoke juice for its use as a liver tonic, and scientists from Japan to Switzerland have noted the herb's abilities to break down fat and improve bile flow. According to German scientists, these long leaves contain high amounts of caffeoylquinic acids, known as cynarin, which offers powerful nutritional support for the liver (<http://www.prweb.com/releases/1998/prweb3080.htm> & http://www.lef.org/prod_desc/item00445.html).

Cynarin is the active ingredient contained in the plant, and its highest concentration is in the leaves. Cynarin, the main active constituent from the artichoke extract, has cholagogue (increases bile production by the liver), choleretic (increases flow of bile from the gallbladder), choliokinetic action (increases the contractive power of the bile duct), and significant liver regenerating and protecting effects (Adzet, Camarasa, & Laguna, 1987). Research has shown that caffeic acid, a component of cynarin, is almost as effective as pure cynarin, suggesting that caffeic acid is the substance responsible for the choleretic action (Hinou et al., 1989). A polyphenol, 1,4-dicaffeoylquinic acid, extracted from artichoke leaves and also obtained synthetically, has shown choleretic and diuretic properties and interesting effects on cholesterol metabolism. The compound has been found capable of lowering cholesterol blood levels on a single intravenous injection in rabbits, of counteracting the hypercholesterolemia, and reducing the hepatic synthesis of cholesterol in rats (Preziosi & Loscalzo, 1958).

Food Processing

Artichokes are cloned from root stalk. After being hand-picked, stems are trimmed and artichokes are placed in crushed ice for best appearance. For freshness, all packed products are refrigerated at 0°C, and kept under 95% humidity condition within 4 hours of their harvest and maintained at that temperature until shipment (<http://www.oceanmist.com>).

California has the largest artichoke processor, Cara Mia Foods, in the United States. Hand-picked artichokes are received daily at Cara Mia Foods. The first step in the process is to sort them by size to ensure a proper match with the special artichoke trimming equipment. This equipment trims away the outer leaves, the points on the inner leaves, and tough skin on the crown of the artichoke, leaving only the tender artichoke hearts that connoisseurs consider a delicacy. After trimming, every artichoke heart is inspected, and those that do not meet the high standards of quality are discarded.

Next, the hearts are blanched and the glass jars are filled containing the world-famous marinade. The jars are capped, coded, pasteurized, washed, labeled, and put in trays or cases, before being palletized and shipped to one of the warehouses (<http://www.caramiafoods.com>).

Determination of Total, Insoluble, and Soluble Dietary Fiber

The Choice of Methods

The study of the properties, effects, and levels of dietary fiber in foods has achieved great importance in nutrition and food technology (Prosky & De Vries, 1992).

The U.S. Food and Drug Administration and the U.S. Department of Agriculture have made labeling dietary fiber in foods compulsory (U.S. Food and Drug Administration, 1993; U.S. Department of Agriculture, 1993). Currently, analysis methodology of dietary fiber is composed of nonenzymatic-gravimetric methods, enzymatic-gravimetric methods, and enzymatic-chemical methods which include enzymatic-colorimetric, enzymatic-gas-liquid-chromatographic (GLC), and enzymatic-high-performance-liquid-chromatographic (HPLC) methods (Cho et al., 1997).

Nonenzymatic-gravimetric methods include crude fiber, acid detergent fiber (ADF) and neutral detergent fiber (NDF) methodologies. For most foods, these methods do not include a significant portion of TDF (Cho et al., 1997). Although enzymatic-gravimetric methods and enzymatic-colorimetric methods are simple, inexpensive, and easy to perform and do not require highly trained personnel or high capital investment. However, these methods are empirical, and insufficient information on chemical composition and molecular and physical structure is generated for some nutrition research projects (Cho et al., 1997). Enzymatic-GLC/HPLC methods can characterize neutral sugar composition of dietary fiber and calculate dietary fiber fractions. However, these methods are expensive and time consuming, and require highly trained personnel and high capital investment (Cho et al., 1997).

Currently, enzymatic-gravimetric methods are the most used methods because they are less time-consuming and more accurate compared to other methods (Prosky et al., 1988). The AOAC Official Method 991.43, one of the enzymatic-gravimetric methods,

has been the basis of the U. S. Department of Agriculture Handbook No.8 dietary fiber tables since 1993 (Cho et al., 1997).

The Principle of the AOAC Official Method 991.43

The principle of the AOAC Official Method 991.43 is to use duplicate samples of dried foods, and fat-extraction applied if samples contain more than 10% fat. Samples undergo sequential enzymatic digestion by heat stable α -amylase, protease, and amyloglycosidase to remove starch and protein. For TDF determination, the enzyme digestate is treated with alcohol to precipitate SDF before filtering, and TDF residue is washed with alcohol and acetone, dried, and weighed. For IDF and SDF determination, the enzyme digestate is filtered, and residue IDF is washed with warm water, dried, and weighed. For SDF determination, combined filtrate and washings are precipitated with alcohol, filtered, dried, and weighed. TDF, IDF, and SDF residue values are corrected for protein, ash, and blank (AOAC, 1995)

Advantages and Disadvantages of the AOAC Official Method 991.43

By employing the enzymatic-gravimetric method of using an organic buffer system, MES-TRIS buffer, co-precipitation of phosphate with SDF was eliminated when 78% ethanol was added to the enzyme digestate (Cho et al., 1997). Also, by employing this method of using MES-TRIS buffer, less buffer and other reagents were used than the phosphate-based method, resulting in faster filtration times for isolating the dietary fiber residue (Lee & Hicks, 1990). Furthermore, the MES-TRIS buffer system is not sensitive to changes in ethanol concentration, nor is it sensitive to the final pH of the enzymatic

digestate, making the procedure more adaptable to any conditions (Lee & Hicks, 1989). Therefore, the AOAC Official Method 991.43 has been adopted as the basis of the U.S. Department of Agriculture Handbook No.8 dietary fiber tables since 1993 (Cho et al., 1997).

However, using this method still makes it difficult to filter foods containing highly viscous fibers such as psyllium. Two minor method modifications were proposed to deal with this problem: 1) reducing the initial sample size; and 2) using sonication followed by high speed centrifugation before the filtration step (Lee, Rodriguez, Storey, Farmakalidis, & Prosky, 1995).

Sample Preparation

Careful sampling is required to obtain accurate and reproducible values. The chemical and physical properties of foodstuffs exhibit a certain inherent variability among different samples, and variability within a given sample. However, variability can be minimized by proper sampling. Analyses usually are performed on small, discrete samples rather than on the entire amount of a foodstuff. Various techniques (grinding, mixing, etc.) are used to insure that such small samples are representative of the entire material and provide a true measure of its overall content (Aurand, Woods, & Wells, 1987). Grinding can help reduce variability in the weight and size of particles. Usually, a particle diameter of 0.5-1.0 mm is recommended. Good results are obtained if the material is ground to pass through a 35-mesh sieve. None of the samples should be discarded because this could remove components that concentrate in the discarded particles, and lead to erroneous

analyses. Liquid samples can be mixed by magnetic stirrers or sonic oscillators (Aurand et al., 1987).

Sampling of foods represents the most critical stage in all dietary fiber determination procedures (Southgate, 1985). The fibrous material in a food is usually unevenly distributed and care must be taken to ensure that a representative portion of the sample is used for analysis. This means taking a relatively large initial sample and reducing it to a suitable size for analysis. Care must be taken to avoid fractionation of the sample; for example, bran is lighter than endosperm and will separate during grinding. During sample preparation, overheating or excessive shear can depolymerize polysaccharides. Storage conditions should be set to prevent microbial and/or enzymatic degradation, but frozen storage may produce retrogradation of starch which is associated with Resistant Starch, which is the sum of starch and products of starch degradation not absorbed in the small intestine of healthy individuals (European Flair, 1991). The typical sample size for dietary fiber analysis ranges from 200 to 1000 mg dry material. This requires drying and subdivision of the sample (Furda & Brine, 1990). Freeze-drying tends to be the method of choice, but even this method of drying can cause the Resistant Starch to form (Southgate, 1981).

Food Uses of Dietary Fiber

Dietary fiber generates a great deal of interest among adult consumers, food processors, ingredient suppliers, and health professionals. Over 80% of American adults are concerned about the effects of diets, such as the consumption of dietary fiber, on their

future health (International Food Information Council, 1991). Since interest in dietary fiber tends to grow with increasing consumer age, fiber-rich foods will continue to gain visibility in the marketplace as the American population ages. The most recent U.S. Department of Agriculture “National Food Consumption Survey” reveals that Americans eat considerably lower amounts of dietary fiber than the recommended 20 to 35 grams per day (Wright, Guthrie, Wang, & Bernardo, 1991). Further, as the benefits of increased dietary fiber in the diet, from the standpoints of health maintenance and reduction in risk of certain chronic diseases become better understood, more fiber-rich food labeling and marketing opportunities are expected.

Americans should consume more dietary fiber from food products. One alternative is by eating naturally occurring fiber-rich foods such as whole grain cereals, legumes, fruits, and vegetables. Another alternative involves consuming fiber-rich processed foods such as breakfast cereals, and dietary fiber supplements. Cellulose from plants and from paper waste can be enzymatically converted to glucose, supplemented with nitrogen, and used for the growth of yeast and other microorganisms as an animal feed supplement or as a source of protein for humans (Kennedy, 1988). Pectins and gums can be food thickeners and stabilizers (Potter & Hotchkiss, 1996).

Breakfast cereal manufacturers are the most visible in developing and advertising their fiber-rich products (Kritchevsky & Bonfield, 1995). Over the past 20 years, dietary fiber supplemented breads have increased from a small percentage to about 35% of total

bread sales (Vetter, 1988). Current interest in food fiber from a health standpoint can be expected to result in attempts to add fiber to as many foods as possible.

Some studies involved the partial replacement of wheat flour in cakes with wheat bran and middlings (Brockmole & Zabik, 1976; Rajchel, Zabik, & Everson, 1975; Springsteen, Zabik, & Shafer, 1977) and with microcrystalline cellulose (Brys & Zabik, 1976). It was shown that when replacement levels above 40% were used, cakes tended to be gummy, and excessive negative effects on volume and on sensory scores were noted. With levels ranging from 12% to 40% for different fiber sources, cakes generally were at least acceptable, in spite of some sensory effects, especially on color and flavor (Brockmole & Zabik, 1976). Other studies showed that several adjustments are beneficial to the quality of high-fiber breads. Because the fibrous material dilutes the gluten proteins, volume is decreased unless compensation is made; addition of vital wheat gluten solves that problem. In addition to the dilution effect, the fiber tends to cut gluten strands; the addition of sodium stearoyl-2-lactylate is helpful (Pomeranz, Shogren, Finney, & Bechtel, 1977).

One study compared apple fiber with wheat and oat brans in several products, including muffins. Not more than 4% apple fiber could be used in muffins without large adverse effects on volume and density, as compared with 8% of the wheat bran; oat bran was intermediate in its effects (Chen, Rubenthaler, Leung, & Baranowski, 1988). Chen et al. (1988) pointed out that the total dietary fiber content was much higher in the apple fiber preparation than in the cereal bran.

A wide variety of dietary fiber sources are available to the food industry. Almost every conceivable fiber source has been considered as a potential ingredient for fiber-enriched foods. However, not all of these sources of dietary fiber have made it to the marketplace as main commercial ingredients because of functionality, economics, or other reasons related to consumer acceptances (Vetter, 1988). If the artichoke industry could produce dietary fiber extract from artichoke leaves and flowers economically, it could not only provide a new source of dietary fiber, but could also generate a profit on artichoke waste products for the artichoke industry.

CHAPTER 2
JOURNAL ARTICLE

Authors' Title Page

**DETERMINATION OF DIETARY FIBER
CONTENT OF ARTICHOKE LEAVES AND FLOWERS**

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ABSTRACT

The objective of this study was to determine the potential of artichoke leaves and flowers, obtained from an artichoke processing plant, as good sources of dietary fiber. Fresh artichoke leaves and flowers obtained from a major artichoke processing plant were freeze-dried and ground to pass through a 60-mesh sieve before the experiment. Total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) content of artichoke leaves and flowers were determined using AOAC standard methods.

On a dry basis, the TDF, IDF, and SDF content of artichoke leaves were 53.25, 34.97, and 18.65 g/100g, respectively. Artichoke flowers on the other hand contained 50.42, 32.43, and 20.43 g/100g dry matter of TDF, IDF, and SDF, respectively. Fresh artichoke leaf and flower contained more TDF, IDF, and SDF than some of the most widely consumed vegetables, such as carrots, celery and cucumber. Dry artichoke leaf and flower contained relatively higher amounts of TDF and SDF than oat bran, and they contained more TDF than some high-fiber containing fruits and grains, such as prunes, raisins and high-fiber cereals. Based on the results of this study, artichoke leaves and flowers are potential good sources of total dietary fiber and soluble dietary fiber.

Key Words: proximate composition; artichoke leaves; artichoke flowers; oat bran; total dietary fiber; insoluble dietary fiber; soluble dietary fiber.

INTRODUCTION

Because of the potential health benefits of dietary fiber, many Western countries have recommended the increased consumption of such foods rich in dietary fiber as part of their dietary guidelines (Cho et al., 1997). In January 1993, the U.S. Food and Drug Administration and the U.S. Department of Agriculture issued their most recent food labeling regulations. These regulations mandate the labeling of total dietary fiber content, with optional labeling of dietary fiber components (i.e., soluble and insoluble dietary fiber) on food packages (U.S. Food and Drug Administration, 1993; & U.S. Department of Agriculture, 1993).

Determination of total, insoluble, soluble dietary fiber by enzymatic-gravimetric method is simple, inexpensive, and accurate; and involves low capital investment and a low level of personnel training required. However, this method is empirical, and insufficient information on chemical composition and molecular and physical structure is generated for some nutrition research projects (Cho et al., 1997).

The phytochemicals in the artichoke have been well documented and the leaves rather than the flower heads have been found to be of higher medicinal value (Dranik & Chernibai, 1966). Artichoke leaves are long, arching, and deeply serrated ([http:// www.oceanmist.com](http://www.oceanmist.com)). The part called the “choke” is the flowers of the artichoke, which are tough and stringy (McGee, 1984). The enzymes of artichoke leaves have an antidiabetic action (Soliman, 1977). The medicinal activities of leaves are attributed to the presence of caffeoylquinic acid derivatives including neochlorogenic acid, chlorogenic acid,

cryptochlorogenic acid, cynarin, and luteolin (Monograph Artichoke, 1992). The leaf extracts have demonstrated beneficial effects: 1) on the gallbladder by prevention of gallstone formation; 2) on the liver due to stimulate secretion of bile and detoxify the liver; and 3) on the cardiovascular system by lowering the level of cholesterol in the blood (Stary, 1992). In addition, other compounds in the leaves have been shown to possess a hypoglycemic activity (Bianchini, 1975).

Artichoke companies want to find better ways to utilize remainders of the plant. Determination of nutrient values of artichoke leaves and flowers, the major waste products in the artichoke industry, would contribute to this goal. Based on this need, the objective of this study was to determine total, insoluble and soluble dietary fiber content of artichoke leaves and flowers. The amount of dietary fiber of artichoke leaves and flowers was compared to that of oat bran, the most widely used fiber-rich source. A proximate analysis was performed to compare dietary fiber content (dry weight basis) of artichoke leaves and flowers with that of oat bran, and to provide data on proximate composition of artichoke leaves and flowers. Results of this study were intended to provide data on the proximate composition, and the total, insoluble, and soluble dietary fiber content of artichoke leaves and flowers for the artichoke industry.

MATERIALS AND METHODS

Artichoke Leaves and Flowers. Artichoke leaves have fern-like appearance ([http:// www.oceanmist.com](http://www.oceanmist.com)). The flowers of artichoke are the mass of tough and stringy immature flowerets which are thrown away (McGee, 1984). Fresh artichoke leaves and

flowers were obtained from Cara Mia Foods (Castroville, CA). The artichoke leaves and flowers were kept frozen before they were freeze-dried. Freeze-dried samples were ground to pass through a 60-mesh sieve, and the fine powders were stored in closed glass jars before the analysis.

Chemicals. All chemicals, which were purchased either from Sigma Chemical Company (St. Louis, MO) or from the Fisher Scientific Company (Fair Lawn, NJ), were supplied by Cara Mia Foods. All of the reagents were of analytical grade.

Total, Insoluble, and Soluble Dietary Fiber Determination. The scheme of the analytical procedure for the determination of total, insoluble and soluble dietary fiber contents of freeze-dried leaves and flowers of artichoke is shown in the following schematic diagram.

Figure 1. Schematic diagram of TDF, IDF and SDF determination

Digestion. Duplicate 1.000 g freeze-dried artichoke leaf and flower powder samples were weighed, accurate to 0.1 mg, and transferred into 400 ml tall-form beakers. MES-TRIS buffer solution (40 ml), pH 8.2, was added to each beaker. The samples were completely dispersed by using a magnetic stirrer to prevent lump formation, which would make test material inaccessible to enzymes.

Heat-stable α -amylase solution (50 ml) was added to samples, while stirring at low speed. The beakers were covered with aluminum foil, and incubated in 95°C H₂O bath 15 min. with continuous agitation. Timing was started once the bath temperature reached 95°C (total 35 min.). After incubation, the beakers were removed from the bath, and cooled to 60°C. The foil was removed and any ring from inside of the beakers was scraped and any gels in the bottom of the beakers were dispersed with a spatula. The beaker walls and spatulas were rinsed with 10 ml distilled H₂O.

Protease solution (100 ml) was added to each beaker. The beakers were covered with aluminum foil, and incubated 30 min. at 60°C with continuous agitation. Timing was started when the bath temperature reached 60°C. After incubation, the foil was removed, and 5 ml 0.561N HCl was dispensed into each beaker while stirring. pH was adjusted to 4.0-4.7 at 60°C, by adding 1N NaOH solution or 1N HCl solution.

Amyloglycosidase solution (300 ml) was added to each beaker while stirring. The beakers were covered with aluminum foil, and incubated 30 min. at 60°C with constant agitation. Timing was started once the bath temperature reached 60°C.

Two blanks were run with samples to measure any contribution from reagents to residue.

Determination of Total Dietary Fiber. To each digested sample, 225 ml 95% ethanol at 60°C was added. Ratio of ethanol to sample volumes should be 4:1. The beakers were removed from bath, and covered with large sheets of aluminum foil and let stand for 1 hr. at room temperature to allow precipitation.

Celite bed in previously tared crucibles was wetted and redistributed, using 15 ml 78% ethanol from wash bottle. Suction was applied to crucibles to draw Celite onto fritted glass as even mat.

Alcohol-treated enzyme digestate was filtered through crucibles. Using wash bottle with 78% ethanol and rubber spatula, all remaining particles were quantitatively transferred to crucibles. Using vacuum, the residue was washed two times with 15 ml portions of 78% ethanol, 95% ethanol, and acetone. The crucibles containing the residue were dried overnight in 105°C oven. The crucibles were cooled in desiccator ca 1 hr. The crucibles containing dietary fiber residue and Celite were weighed to nearest 0.1 mg, and the residue weight was calculated by subtracting the weight of dry crucible with Celite.

One duplicate of the residue from each sample was used to determine protein, by the AOAC Official Method 930.15, using %N x 6.25 as a conversion factor. For ash analysis, the second duplicate of the residue was incinerated for 5 hr at 525°C in a muffle furnace. Then, it was cooled in a desiccator, and weighed to nearest 0.1 mg. Ash weight was determined by subtracting the weight of crucible and Celite.

Determination of Insoluble Dietary Fiber. Celite bed in previously tared crucibles was wetted and redistributed, using ca 3 ml H₂O. Suction was applied to crucibles to draw Celite into even mat. The enzyme digestate was filtered through crucibles into filtration flasks. The beakers were rinsed, and then the residue was washed two times with 10 ml 70°C H₂O. The filtrate and water washings were combined, and transferred to pretared 600 ml tall-form beakers, and reserved for determination of soluble dietary fiber. Under vacuum, the residue was then washed two times with 15 ml portions of 78% ethanol, 95% ethanol, and acetone each time. The crucibles containing the residue were dried overnight in 105°C oven. The crucibles were cooled in desiccator ca 1 hr. The crucibles containing insoluble dietary fiber residue and Celite were weighed to nearest 0.1 mg, and the residue weight was calculated by subtracting the weight of dry crucible with Celite.

Duplicates of the residues were used to determine protein and ash as in determination of total dietary fiber.

Determination of Soluble Dietary Fiber. The filtrate and water washings, obtained from the previous procedures for the determination of Insoluble Dietary Fiber, were combined, and transferred to pretared 600 ml tall-form beakers. The beakers with a combined solution of the filtrate and water washings were weighed, and volumes were estimated.

Four volumes of 95% ethanol preheated to 60°C were added to each beaker. A portion of 60°C ethanol was used to rinse filtering flask from Insoluble Dietary Fiber

determination. Alternatively, the weight of the combined solution of filtrate and water washings was adjusted to 80 g by the addition of distilled H₂O, and 320 ml 60°C 95% ethanol. Precipitate was allowed to form at room temperature for 1 hr.

Procedures from “Celite bed in previously tared crucibles was wetted and redistributed, using 15 ml 78% ethanol from wash bottle.” to “Ash weight was determined by subtracting the weight of crucible and Celite.” in TDF determination were followed to determine the Insoluble Dietary Fiber.

Calculations of TDF, IDF, and SDF. For each value of TDF, IDF, and SDF, six trials were conducted. Following formulas (AOAC, 1995) were used to calculate the values of TDF, IDF, and SDF.

$B \text{ (mg)} = [(BR_1 + BR_2)/2] - P_B - A_B$, where BR_1 and BR_2 = residue weights (mg) for duplicate blank determinations; and P_B and A_B = weights (mg) of protein and ash, respectively, determined on first and second blank residues.

$DF \text{ (g/100g)} = \{[(R_1 + R_2)/2] - P - A - B\} / [(M_1 + M_2)/2] \times 100$, where R_1 and R_2 = residue weights (mg) for duplicate samples; P and A = weights (mg) of protein and ash, respectively, determined on first and second residues; B = blank weight (mg); and M_1 and M_2 = weights (mg) for samples.

Proximate analysis. For each nutrient component, six trials were conducted. One result of fat content of freeze-dried artichoke flower deviated from the others was discarded. Average nutrient values were calculated, except for the value of carbohydrate

calculated by the difference of the percentages of crude fat, moisture, protein, and ash from 100%.

Moisture content of fresh artichoke leaves and flowers was determined after freeze-drying. The proximate composition of freeze-dried artichoke leaf and flower powder was determined using the AOAC Official methods to obtain the percentages of moisture, crude fat, protein, and ash.

Data analysis. These results were calculated to determine the means and standard deviations of moisture, fat, protein, ash, TDF, IDF, and SDF of freeze-dried artichoke leaf and flower powder. The proximate composition, TDF, IDF, and SDF of fresh artichoke leaves and flowers were computed based on the results obtained from the freeze-dried artichoke leaf and flower powder. Standard errors of the difference between various nutrient means of artichoke flowers and leaves (dry weight basis) were calculated and determined by t-value (at 95% confidence level).

RESULTS AND DISCUSSION

Artichoke leaves contained more TDF and IDF, and less SDF than artichoke flowers (Table 1 & Table 2). The difference in terms of the amount of TDF, IDF, and SDF of artichoke leaves and flowers was significant ($P > 0.05$) (Table 1). The difference might be attributed to higher concentration of cellulose and lignin and less pectin, mucilage, and gums in artichoke leaves than in artichoke flowers. It could suggest that artichoke flowers be used for thickening or adding viscosity for foods (Kritchevsky & Bonfield, 1995)

because of more SDF content, and artichoke leaves be used for controlling calories or adding bulk (Kritchevsky & Bonfield, 1995) because of more IDF content.

Compared to other foods (fresh weight basis) shown in Table 3, fresh artichoke leaves and flowers contained less TDF and SDF than oat bran, the most widely used fiber source. The comparison between oat bran and dry artichoke leaf and flower showed the latter contained more TDF and SDF than the former. The reason is that artichoke leaves and flowers contain 83.7% and 83.4% of moisture, respectively, while oat bran only contains 6.6% of moisture (Table 5). Currently, most fiber-rich sources are low in water content because they are easier to store and transport. On the basis of dry weight, artichoke leaves and flowers contained a relatively larger amount of TDF and SDF than oat bran. Since oat bran is one of the most widely used fiber-rich sources, dry artichoke leaf and flower could both become potential fiber-rich sources based on this study. It was shown that foods that are low in water content, e.g., bran, have a greater propensity to increase stool weight than foods containing a high water content, e.g., carrots (Cho et al., 1997). This might suggest that artichoke leaf and flower could be as good as oat bran in terms of fecal bulking capacity if dried.

In most cases, a proximate analysis is sufficient to provide the general nutrient values of foodstuffs (Woods & Aurand, 1977). The proximate composition of freeze-dried artichoke leaf and flower is shown in Table 1. The proximate composition of fresh artichoke leaf and flower given in Table 2 was calculated based on the data of Table 1. Based on the dry weight, there was a significant difference in moisture, fat and

carbohydrate values, and no significant difference in protein and ash content between artichoke flower and leaf (Table 1).

Artichoke leaves and flowers compared well in proximate composition with edible portions of raw artichokes shown in Table 4, except for less protein content. Also, it is shown that artichoke leaves and flowers (fresh weight basis) contained larger amounts of dietary fiber than the edible portions of artichoke (Table 4). The reason is that only the crude fiber content was determined in Cook and Sundaram's study (1963). Essentially, the crude fiber method measures fiber as a sum of cellulose and lignin in the edible portions of artichoke. For most foods, the residues quantitated by the crude fiber method do not recover a significant portion of what is now considered as total dietary fiber (Cho et al., 1997). It suggests that in addition to cellulose and lignin, artichoke leaves and flowers contain other components of dietary fiber, such as pectin, gums, and mucilage.

Compared to the dietary fiber content of cooked artichoke shown in Table 5, fresh artichoke leaves and flowers contain more TDF and IDF, and less SDF than cooked artichoke. It might be due to more cellulose and lignin and less pectin, gums, and mucilage found in artichoke flowers and leaves. The comparison of the dietary fiber content between fresh artichoke leaf and flower and some vegetables, such as carrots, cucumber and celery, showed the former contained more TDF, IDF, and SDF than the latter (Table 5). Artichoke leaf and flower also contained larger amounts of TDF (dry matter) than some high-fiber containing fruits and grains, such as prunes, raisins, and high-fiber cereal.

CONCLUSION

Based on this study, artichoke leaves contained more TDF and IDF, and less SDF than artichoke flowers. The difference of the TDF, IDF, and SDF content between artichoke leaves and artichoke flowers was significant ($P > 0.05$). Fresh artichoke leaf and flower contained more TDF, IDF, and SDF than some of the most widely consumed vegetables, such as carrots, cucumber, and celery. Dry artichoke leaf and flower contained more TDF than high-fiber containing fruits and grains, such as prunes, raisins and high-fiber cereal.

On fresh weight basis, artichoke leaves and flowers contained fewer amounts of TDF and SDF than oat bran, the most widely used dietary fiber-rich source. However, both artichoke leaf and artichoke flower contained a larger amount of TDF and SDF than oat bran based on the dry weight. Based on this study, artichoke leaves and flowers could be potential good sources of total dietary fiber and soluble dietary fiber.

Table 1. The proximate composition, TDF, IDF, and SDF of freeze-dried artichoke leaf powder (FDALP) and freeze-dried artichoke flower powder (FDAFP) and standard errors of the difference between the nutrient means of FDALP and FDAFP

Nutrient (g/100 g)	FDALP	FDAFP	SE ⁴	t-value ⁵	Difference
Moisture	7.45 ± 0.12 ¹	5.63 ± 0.10 ¹	0.06	31.38	Significant
Protein	17.98 ± 2.02 ¹	16.46 ± 0.32 ¹	0.83	1.83	Not significant
Fat	0.59 ± 0.56 ¹	1.32 ± 0.11 ²	0.21	3.48	Significant
Ash	6.63 ± 2.01 ¹	6.75 ± 0.84 ¹	0.88	0.14	Not significant
Carbohydrate	67.35 ± 1.12 ³	69.84 ± 0.44 ³	0.49	5.08	Significant
TDF	53.25 ± 0.29 ¹	50.42 ± 0.54 ¹	0.22	11.55	Significant
IDF	34.97 ± 1.56 ¹	32.43 ± 0.73 ¹	0.68	3.74	Significant
SDF	18.65 ± 0.48 ¹	20.43 ± 1.14 ¹	0.48	3.71	Significant

¹ Means and Standard Deviations from six trials

² Means and Standard Deviations from five trials

³ By difference (total)

⁴ Standard Error

⁵ $t(a/2) = 2.23$ ($\alpha = 0.05$, degree of freedom = 10)

Table 2. The proximate composition, TDF, IDF, and SDF of fresh artichoke leaf (FAL) and fresh artichoke flower (FAF)

Nutrient (g/100 g)	FAL	FAF
Moisture	83.70 ± 0.20 ¹	83.40 ± 0.44 ¹
Protein	2.93 ± 0.33	2.73 ± 0.05
Fat	0.10 ± 0.10	0.22 ± 0.02
Ash	1.08 ± 0.33	1.12 ± 0.14
Carbohydrate	12.16 ± 0.18	12.53 ± 0.26
TDF	8.68 ± 0.05	8.37 ± 0.10
IDF	5.70 ± 0.25	5.38 ± 0.12
SDF	3.04 ± 0.10	3.39 ± 0.19

¹ Means and Standard Deviations from three trials

Table 3. Determination of TDF, IDF, and SDF in Foods (Fresh Weight Basis) by AOAC Official Method 991.43: Enzymatic-Gravimetric Method (using MES-TRIS Buffer)

Food	TDF (g/100g)	IDF (g/100g)	SDF (g/100g)
Barley	12.25	7.05	5.02
High-fiber cereal	33.73	30.52	2.78
Dry artichoke leaf	53.25	34.97	18.65
Dry artichoke flower	50.42	32.43	20.43
Oat bran	16.92	9.73	7.17
Soy bran	67.14	60.53	6.90
Apricots	1.12	0.59	0.53
Prunes	9.29	4.17	5.07
Raisins	3.13	2.37	0.73
Carrots	3.93	2.81	1.10
Green beans	2.89	2.01	1.02
Parsley	2.66	2.37	0.64
Fresh artichoke leaf	8.68	5.70	3.04
Fresh artichoke flower	8.37	5.38	3.39

Note: Except for TDF, IDF, and SDF content of artichoke flower and leaf, the other data on TDF, IDF, and SDF obtained from “Official Methods of Analysis (16th Ed.)” by AOAC, Chapter 32, p. 7, Association of Official Analytical Chemists. Washington, DC, 1995.

Table 4. Average nutrient composition of edible portion of raw and cooked artichoke

Nutrient (g/100 g)	Fresh raw	Boiled⁴	Steam-Boiled⁵	Pressure-cooked
Moisture	89.5 ± 0.07 ⁶	90.2 ± 0.15	89.2 ± 0.12	88.1 ± 0.11
Protein ¹	3.47 ± 0.12	3.37 ± 0.11	3.69 ± 0.03	3.84 ± 0.04
Fat ²	0.12 ± 0.003	0.11 ± 0.002	0.15 ± 0.005	0.12 ± 0.003
Ash	0.68 ± 0.02	0.53 ± 0.02	0.72 ± 0.01	0.94 ± 0.02
Carbohydrate ³	6.2	5.8	6.2	7.0
Fiber	1.8 ± 0.02	1.9 ± 0.02	1.6 ± 0.02	1.8 ± 0.02

¹ Kjeldahl nitrogen x 6.25

² Ether extract

³ By difference (total)

⁴ Boiled in water to cover

⁵ Steam-Boiled in 1/2 in. water

⁶ Standard error of the mean

Note: From “Nutrients in Raw vs. Cooked Globe Artichokes” by B. B. Cook, and S.

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Table 5. Moisture and Dietary Fiber content of vegetables, fruits, and grains

Food item	Moisture	IDF	SDF	TDF
g per 100 g cooked or raw weight				
Artichoke, cooked	—	3.20	4.36	7.56
Artichoke globe, cooked	82.5	3.17	4.68	7.85
Carrots, cooked	89.0	1.63	1.46	3.08
Green beans, cooked	92.0	2.14	0.71	2.85
Carrots, raw	89.0	2.70	0.41	3.11
Celery, raw	95.7	1.41	0.19	1.59
Cucumber, raw	95.9	0.54	0.21	0.75
Fresh artichoke leaf	83.7	5.70	3.04	8.68
Fresh artichoke flower	83.4	5.38	3.39	8.37
Dry artichoke leaf	7.45	34.97	18.65	53.25
Dry artichoke flower	5.63	32.43	20.43	50.42
Apricots, dried	7.81	—	—	8.29
Prunes, dried	32.4	—	—	7.20
Raisins	6.2	—	—	4.60
Barley	9.4	—	—	17.30
Bran, high fiber cereal	2.9	—	—	35.30
Oat bran, raw	6.6	—	6.03	15.90

Note: Except for moisture and dietary fiber content of artichoke flower and leaf, the other data on moisture and dietary fiber content obtained from “Controlling Dietary Fiber in Food Products” by L. Prosky, and J. De Vries, p. 127 —147, New York: AVI, 1992.

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CHAPTER 3

SUMMARY AND RECOMMENDATIONS

Summary

This study included the determination of total, insoluble, and soluble dietary fiber content and the proximate analysis of artichoke leaves and flowers. On a dry basis, the TDF, IDF, and SDF content of artichoke leaves were 53.25, 34.97, and 18.65 g/100g, respectively. Artichoke flowers contained 50.42, 32.43, and 20.43 g/100g dry matter of TDF, IDF, and SDF, respectively. Based on the fresh weight, the TDF, IDF, and SDF content of artichoke leaves were 8.68, 5.70, and 3.04 g/100g, respectively. Fresh artichoke flowers contained 8.37, 5.38, and 3.39 g/100g of TDF, IDF, and SDF, respectively.

The proximate analysis showed that protein and ash content of artichoke leaves and flowers was not significantly different ($P < 0.05$), while there was a significant difference in moisture, fat and carbohydrate content between them ($P > 0.05$). Artichoke leaves and flowers, the major waste products of the artichoke processing plants, compared well in the proximate composition with edible portions of artichoke, except for the protein content. Compared to cooked artichoke, artichoke leaves and flowers contained more TDF and IDF, and less SDF.

Results of the study showed that artichoke leaves contained more TDF and IDF, and less SDF than artichoke flowers under the freeze-dried and fresh conditions. There was a significant difference in TDF, IDF, and SDF content between artichoke flowers and

leaves. On a dry basis, artichoke leaves and flowers contained a much larger amount of TDF and SDF than oat bran, the most widely used fiber-rich ingredient. Fresh artichoke leaves and flowers contained more TDF, IDF, and SDF than carrots, celery, and cucumber, some of the most widely consumed vegetables. Also, dry artichoke leaf and flower contained larger amounts of TDF than prunes, raisins and high-fiber cereals. Based on this study, it might be suggested that artichoke leaves and flowers might both become new fiber sources of total dietary fiber and soluble dietary fiber.

Recommendations

This study was the first to provide proximate composition data and the amounts of TDF, IDF, and SDF of artichoke leaves and flowers. The current enzymatic-gravimetric methods require a drying and/or a defatting step before the dietary fiber content is determined for foods. The labor-intensive drying and defatting of samples with petroleum ether are additional steps that may affect precision and may not be the best means of removing moisture and fat from the sample before enzymatic digestion. For protein, the correction factor currently used, 6.25 x the Kjeldahl nitrogen value, is somewhat arbitrary (Lee & Prosky, 1995).

Although the AOAC Official Method 991.43, an enzymatic-gravimetric method, can determine the quantity of TDF, SDF, and IDF, it does not provide a detailed characterization of individual fiber components, which is essential for some nutrition research projects. It is recommended that enzymatic-GLC/HPLC methods for quantitation of individual fiber components be used in future studies. This enzymatic-gravimetric

method by employing of using organic buffers, MES-TRIS, resulted in faster filtration time than using phosphate buffers. However, the experiment was still tedious and time consuming to determine the amounts of TDF, IDF, and SDF. It is recommended that more rapid and accurate methods be developed to determine TDF, IDF, and SDF content.

Many scientists addressed the need to continue the modeling laboratory analytical method for dietary fiber on the physiological functioning of the human digestive process. Although current AOAC Official Methods for dietary fiber are based on this premise, it is generally believed that advanced methodology will be able to even more effectively mimic the human system in isolating and quantitating remnants of plant materials resistant to human alimentary enzymes (Cho & Prosky, 1995). It is recommended that future studies use commercial enzymes more similar to those found in the human system.

Based on the results of this study, artichoke leaves and flowers might be good sources of total dietary fiber and soluble dietary fiber. The artichoke industry may consider extracting purified TDF and SDF from artichoke leaves and flowers. Then, the purified TDF or SDF might be used as a concentrated TDF or SDF source to produce TDF-rich or SDF-rich food products by food manufacturers, or as food ingredients to replace or reduce ingredients that are harmful for the overall health of consumers. To develop the artichoke flowers and leaves as a mainstream commercial TDF or SDF source, the functionality, economics, consumer acceptance, and physiological effects of the source should be evaluated (Kritchevsky & Bonfield, 1995). Since each component of TDF has unique functionalities, it is suggested that the composition and physicochemical properties

of TDF from artichoke leaves and flowers be conducted in future studies. Also, artichoke waste products may be produced as either a high-TDF content or a high-SDF content drug by the pharmaceutical industry. However, if any medical claim should be made for the product, the company would have to submit a new drug application to FDA, which would entail the usual lengthy testing procedures (Prosky & De Vries, 1992).

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