EFFECT OF DIFFERENT METHODS OF COOKING ON THE ASCORBIC ACID, CHLOROPHYLL CONTENTS AND THE ORGANOLEPTIC QUALITY OF GREEN VEGETABLES: A COMPARISON OF THE CHINESE STIR-FRY METHOD, MICROWAVE METHOD, WATERLESS METHOD, STEAM METHOD AND CONVENTIONAL METHODS OF COOKING

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Science in

Home Economics

by

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ABSTRACT

EFFECT OF DIFFERENT METHODS OF COOKING ON THE ASCORBIC ACID, CHLOROPHYLL CONTENTS AND THE ORGANOLEPTIC QUALITY OF GREEN VEGETABLES: A COMPARISON OF THE CHINESE STIR-FRY METHOD, MICROWAVE METHOD, WATERLESS METHOD, STEAM METHOD AND CONVENTIONAL METHODS OF COOKING

by
Denise Marie Zietlow
Master of Science in Home Economics
January, 1976

The effects of the Chinese stir-fry method of cooking on the ascorbic acid and chlorophyll retention and palatability of spinach, broccoli and green beans were compared with microwave cooking, steaming, waterless cooking, boiling with large amounts of water without a lid and boiling with small amounts of water with a lid.

Significant differences in the quality of vegetables cooked by various methods were found. Stir-fried spinach retained significantly more ascorbic acid than spinach prepared by the other cooking methods. Stir-fried green beans also retained significantly more ascorbic acid than green beans prepared by the other methods, with the exception of the steaming method. The stir-fried broccoli retained a high
percentage of ascorbic acid though the retention was not significantly
greater than that in broccoli cooked by the other methods.

Stir-fried spinach, green beans and broccoli retained signifi-
cantly more chlorophyll than samples prepared by the other cooking
methods, except that the stir-fried broccoli did not differ signifi-
cantly from the broccoli boiled in large amounts of water. A high
correlation was found between chlorophyll retention and color scores
obtained through sensory tests in all three vegetables.

With the exception of color stir-frying was a less acceptable
cooking method than the other cooking methods as judged by the taste
panel. Considering total palatability scores, the microwave method
was ranked most acceptable for spinach and green beans while boiling
in large amounts of water was ranked most acceptable for broccoli
samples.

Stir-frying was found to be an excellent method of cooking for
ascorbic acid and chlorophyll retention in the three vegetables
studied. However, it produces a less acceptable product to the
American palate than other cooking methods.
CHAPTER I

INTRODUCTION

Stir-frying is the most common method of Chinese cooking (Hahn, 1968). The chief difference between American and Chinese vegetable cooking is that the Chinese cooking medium is oil, while the American cooking medium is usually water. Since oil reaches higher temperatures than water, texture can be crisper and colors can be brighter in the stir-fried vegetables (Lee and Spader, 1959).

Stir-frying requires vegetables or other foods cut into uniform slices. Cooking oil is preheated in a wok, a round-bottom cooking vessel, over high heat. The vegetables are added and quickly stirred until ready, rarely more than five minutes (Hahn, 1968).

Objective of this Study

The purpose of this study was to compare the effects of the Chinese stir-fry method of cooking on three green vegetables, spinach, broccoli and green beans, with the microwave, steaming, waterless and boiling methods.

Since stir-frying involves little or no water and a short heating period, one of the objectives of this study was to determine if ascorbic acid and color retention would be greater than is found with traditional American vegetable cooking methods. Without large quantities of water ascorbic acid should not dissolve into the water and
plant acids should not be released and cause the conversion of chlorophylls to pheophytins.

Besides investigating the nutrient and color retention of the stir-fried vegetables, palatability, specifically texture and flavor, was compared to the traditional methods. Stir-frying results in a crisper texture which might not be acceptable to the average American. Also, since the vegetables are cooked in oil, flavor will vary from those prepared in water.

Eheart and Gott (1965) did a study similar to this one. However, they used a modified stir-fry method. Attempts were made during this study to keep the stir-fry method as close as possible to the traditional Chinese way.

Since more and more people are becoming interested in various cultural foods and their methods of preparation a study such as this could provide worthwhile information. Also, tables of food composition serve as aids to dietitians, nutritionists, researchers, educators, etc. and are frequently lacking for cultural foods and for the effects of cultural cooking methods upon foods (Watt and Murphy, 1970). Currently a nutrient bank is being developed where such information can be stored (Murphy, Watt and Rizek, 1973).

Limitations of this Study

Quantities of the vegetable samples necessary for all the analytical and sensory tests could not be purchased at one time due to the time required for testing and the nature of the vegetables. However, sufficient amounts of a vegetable for a specific test to be run in triplicate were purchased at the same time.
The vegetable samples used in the sensory evaluation were served at room temperature rather than the cooked temperature due to time limitations. Samples were served at uniform temperature, however.
CHAPTER II

REVIEW OF LITERATURE

Chemical Composition and Physical Characteristics of Green Vegetables

Structural Components

The basic structural unit of plants is the cell. Parenchyma cells are most commonly found in the edible parts of plants and make up the photosynthetic tissue in green leaves (Fahn, 1974; Meyer, 1960).

Major components of the plant cell are the cell wall, cytoplasm, vacuoles and cell membranes. The cell wall is composed of the polysaccharide cellulose. Its function is to serve as an elastic support and a confining structure for the contents of the cell (Lehninger, 1972). Pectic substances and hemicelluloses act as cementing materials to fill the interstices in the matrix of the cellulose in the cell wall (Charley, 1972).

The cytoplasm is a jelly-like colloidal sol of living matter which contains substances in true solution and others that are colloidal-dally dispersed. The nucleus, mitochondria and plastids are inclusions in the cytoplasm (Charley, 1972). The mitochondria contain oxidative enzymes required for respiratory activities while plastids contain the color pigments. Plastids containing chlorophylls are called chloroplasts (Lehninger, 1972).
Vacuoles are spaces within the cell that develop and increase in size as the cell matures. This causes the cytoplasm to become flattened against the cell wall in a thin layer. Vacuoles contain a sap that has dissolved within it salts, sugars, organic acids, proteins, oxygen, carbon dioxide and pigments (Lehninger, 1972).

The plant cell also contains two cell membranes. One separates the cell wall from the cytoplasm within the cell and the other separates the cell sap from the cytoplasm. Both help regulate the water content of the cell (Charley, 1972).

Intercellular spaces occur between plant cells and provide an exchange of gases between the cell and the environment (Charley, 1972).

Plant Acids

As mentioned above the cell sap contains acids or acid salts which make the plant tissue slightly acidic. Malic and citric are the most common aliphatic acids found in plants (Ranson, 1965).

More than one organic acid will be present in a vegetable, but usually only one predominates. The main acid present in spinach is oxalic acid. Citric acid and a small amount of malic acid are also present. Broccoli contains 1-malic, citric and small amounts of oxalic and succinic acids (Nelson and Mottern, 1931).

Nutritive Values

Vegetables generally have a high moisture content and a low concentration of fat and protein. They are high in carbohydrate. Green vegetables are frequently high in iron, riboflavin, ascorbic acid and carotene (Charley, 1970).
The part of the plant used, root, leaf, stem, fruit, seed, or flower, will determine the nutrient content of the particular plant (Stevenson and Miller, 1967). The specific nutritive value of raw spinach, broccoli and green beans are presented in Table 1 (Church and Church, 1970).

**Plant Pigments**

Carotenoids, chlorophylls and flavonoids are the three main classes of plant pigments. Both the carotenoids and chlorophylls are fat-soluble and located in the grana of the chloroplasts. The flavonoids are water-soluble and present in the cell sap. The carotenoids and chlorophylls are the pigments most commonly found in green vegetables (Charley, 1972).

Carotenoids, which belong to a class of organic compounds known as polyenes, all contain an aliphatic hydrocarbon chain with attached methyl groups and conjugated double bonds. The commonly occurring carotenoids are made up of eight isoprene units (Bickoff, 1957). Carotenoids are yellow, orange and red pigments subdivided into carotenes and xanthophylls (Meyer, 1960).

Chlorophylls give plants their green color. There are two forms of chlorophyll, chlorophyll \(a\) differs from chlorophyll \(b\) only by the replacement of a methyl group with a formyl group on the carbon 3 position (Clydesdale and Francis, 1970).

Chlorophyll \(a\) is a bright blue-green colored pigment and exceeds chlorophyll \(b\) which is yellow-green, in most plant tissues (Charley, 1972). The ratio of chlorophyll \(a\) to \(b\) in plants is about
<table>
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<th>Green Beans</th>
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<td>Protein (g/100 g)</td>
<td>3.2</td>
<td>2.2</td>
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</tr>
<tr>
<td>Carbohydrate (g/100 g)</td>
<td>4.3</td>
<td>4.6</td>
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</tr>
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<td>Fat (g/100 g)</td>
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<tr>
<td>Sodium (mg/100 g)</td>
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<td>Calcium (mg/100 g)</td>
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<td>Phosphorus (mg/100 g)</td>
<td>3.1</td>
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</tr>
<tr>
<td>Potassium (mg/100 g)</td>
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</tr>
<tr>
<td>Magnesium (mg/100 g)</td>
<td>83</td>
<td>106</td>
<td>32</td>
</tr>
<tr>
<td>Iron (mg/100 g)</td>
<td>33</td>
<td>3.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Thiamin (mg/100 g)</td>
<td>200</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Riboflavin (mg/100 g)</td>
<td>60</td>
<td>220</td>
<td>110</td>
</tr>
<tr>
<td>Niacin (mg/100 g)</td>
<td>0.6</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Ascorbic Acid (mg/100 g)</td>
<td>51</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td>Vitamin A (I.U./100 g)</td>
<td>8100</td>
<td>6100</td>
<td>600</td>
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3:1 (Clydesdale and Francis, 1970). Chlorophylls are the pigments specifically investigated in this study.

Texture

The texture of vegetables is related to the turgor of the cells, the presence of supporting tissues and the cohesiveness of the cells. Turgor, pressure of the cell contents on the partially elastic cell wall, produces a rigidity. This is produced by a balance of forces which allows for an exchange of substances while maintaining the cell at its normal volume. When the cell volume decreases, however, the cell becomes limp and flaccid. Rigidity will also be lost if the cell volume increases to such a point that the cell ruptures and its contents flow out. Water is mainly responsible for the changes in volume of a cell (Meyer, 1960).

Osmosis is a common force affecting cell volume. Due to the semipermeability of the protoplasm and cell wall, water and some other small molecules can pass into and out of the cell. Water moves in larger amounts from an area in which it is high in concentration to one in which water is low in concentration (Meyer, 1960).

Elasticity of the cell walls is also an important factor in cell turgor. If high elasticity occurs the cell volume can increase greatly without the cell rupturing. However, a high elastic cell wall will cause a rapid loss of turgor even as it adapts itself if the cell volume decreases. A stronger but more rigid wall would maintain a firm texture (Meyer, 1960).

The structure of the plant is also an important factor in the texture of the vegetable. The cell walls and the intercellular bonding
material responsible for cell adhesion (protopectin) give strength to plant tissues. A review discussing this aspect of texture has been written by Sterling (1963).

Most vegetables become less tender and more fibrous as they mature. Cell walls thicken and lignin accumulates which gives vegetable tissues a woodiness. Stringiness found in the leaves of spinach is due to large quantities of lignin (Charley, 1972).

Flavor

Flavor is a composite of taste, aroma and mouthfeel (Charley, 1972). Volatile components make up the major flavor characteristics of a food, while non-volatiles play a role in taste sensations like sweet, sour, salt and bitter. The degree to which volatile compounds contribute to flavor depends upon their potency, expressed in threshold value, and on their concentration (Schutte, 1974).

Volatile compounds involved in the flavor of a food can be formed during growth of the plant or during the process required to make the food edible. During the latter the compounds may be formed enzymically, such as during the chopping of vegetables which allows flavor enzymes and precursors to come in close contact, or non-enzymically during the heating of the food. The volatile flavor compounds are formed from carbohydrates, proteins and triglycerides (Schutte, 1974).

Sulfur compounds usually make a large contribution to flavor because of their strong odor and low threshold values. These compounds play a major role in the flavor of vegetables. Examples of the sulfur compounds present in vegetables include dimethyl monosulfide, dimethyl
disulfide, methanethiol and hydrogen sulfide. Sulfur-containing flavor compounds identified in specific vegetables are listed in a review by Schutte (1974).

**Effects of Cooking on the Chemical Composition and Physical Characteristics of Green Vegetables**

**Structural Components**

Cellulose and most hemicelluloses are relatively resistant to the heat effects of normal cooking. Therefore, the cell walls usually retain their integrity. The pectic substances, however, can swell and solubilize due to hydrogen bond breakage. This in turn can produce some of the softness that occurs on cooking of vegetables (Sterling, 1963).

**Plant Acids**

Organic plant acids can be divided into volatile and non-volatile acids. During cooking, the volatile acids escape as a vapor while non-volatile acids escape into the cooking water. Monocarboxylic acids such as acetic and butyric are volatile. Different plants vary as to the amount of volatile acids present. The major portion of the acids released during cooking does not volatilize, but rather escapes into the cooking water. These acids can alter the pH of the cooking water (Charley, 1972).

**Nutritive Values**

It has been found that nutrient losses vary according to the type of food, the stability of the nutrient, the amount of cooking water, the time of cooking and the cooking method used (Ang and
During vegetable cooking, nutrients can be lost in the cooking water or in some cases by destruction (Charley, 1970). Cook and Sundaran (1963) reported significantly smaller amounts of phosphorus, iron, thiamin, riboflavin, niacin, pantothenic acid, vitamin B₆ and ascorbic acid in boiled artichokes as compared to the raw vegetable.

Because ascorbic acid is both water-soluble and susceptible to oxidation it is often used as an index of the effect of cooking on other nutrients in vegetables (Charley, 1970).

The leaching of ascorbic acid into the cooking liquid appears to be the chief factor responsible for losses. Sweeney et al. (1959) investigated ascorbic acid retention in cooked broccoli using thirteen cooking methods. They found significant losses of ascorbic acid during cooking regardless of the method used. Retention was 60-85 percent of its original ascorbic acid content in all methods except when excessive amounts of cooking liquid was used.

Mulay, Dhopeshwarwarkar and Magar (1952) found that if cooking water was used much more ascorbic acid is retained. When the cooking water was not thrown out, 5-12 percent of the ascorbic acid was lost during open-air cooking. When the water was discarded, the loss of ascorbic acid increases 35-58 percent. Other studies dealing with nutritive loss during cooking of vegetables include Eheart and Gott (1964), Kamalanathan et al. (1974), Kamalanathan, Saraswathi and Devadas (1972), Noble (1967), and Pasricha (1967).

When ascorbic acid is subjected to a suitable catalyst and in the presence of oxygen, it will oxidize to dehydroascorbic acid. Dehydroascorbic acid still has approximately 75-80 percent of the
vitamin activity of ascorbic acid, but the exact activity has not been satisfactorily determined. Dehydroascorbic acid will become biologically inactive when the pH level is above 4.0 (Schanderl, 1970).

**Plant Pigments**

The carotenoids present in vegetables have been considered stable to ordinary cooking procedures. Martin et al. (1960) found 100 percent retention of carotene in cooked broccoli.

The chlorophylls in green vegetables can be altered in many ways. The changes within the molecule that may affect the color include loss of magnesium, removal of phytol and methyl ester groups, and oxidation of the ring. Chlorophylls can be degraded by acid, especially carboxylic acids which are naturally present in fruits and vegetables. In fresh, raw fruits and vegetables the acids and chlorophylls are separated in the cell. The acids are in the sap of the vacuoles and chlorophylls are in the chloroplasts. However, cooking can alter the cell membranes and permit contact of the acid and pigment. Hydrogen atoms can replace the magnesium in the tetrapyrrole structure and the chlorophyll molecules are then changed to pheophytins. Pheophytin \( a \) is grayish green in color while pheophytin \( b \) is a dull yellowish green (Charley, 1972).

Sweeney and Martin (1958) found that the loss in green color of broccoli during cooking is due chiefly to the conversion of chlorophyll \( a \) to pheophytin \( a \). Since chlorophyll \( a \) is an intense blue-green color, it undergoes a pronounced change in appearance when converted to pheophytin \( a \), a grayish green. Conversion of chlorophyll \( b \), a yellow-green, to pheophytin \( b \), a dull yellowish green, would not effect a
striking change in appearance. Eheart and Gott (1965) reported that the initial rate of conversion of chlorophyll a appeared to be about six times as fast as that of chlorophyll b upon cooking.

The length of the heating period and its effect on chlorophyll in broccoli was also investigated by Sweeney and Martin (1958). As the time of cooking increased the chlorophyll retention decreased. At the end of 20 minutes cooking time, less than one-third of the total chlorophyll remained. Similar results were reported by Gilpin et al. (1959). Sweeney and Martin (1961) found the pH range 6-7 to be critical in retention of chlorophyll in cooking frozen vegetables.

To minimize the effects of acids on chlorophyll, Charley (1970) suggests that cooking a vegetable in an uncovered pan will help eliminate volatile acids and by using enough water to cover the vegetable those acids which are non-volatile will be diluted.

Texture

Changes in crispness and tenderness will affect the texture of vegetables. Changes in crispness caused by heat are due to the denaturation of the vegetable's cell cytoplasm and the membranes (Charley, 1970). Destruction of the selective permeability of the cell membranes occurs at about 150° F. The internal pressure is permanently reduced once the selective permeability is lost. The cells no longer retain water but lose it through diffusion. This loss causes limpness in cooked vegetables (Matz, 1962). Changes in tenderness during cooking involve the lessening of cell adhesion caused by the cementing material protopectin. Insoluble pectic substances are converted into soluble
materials and dispersible in hot water. Too much alteration of the protoplasm may result in a mushy product (Charley, 1970).

Gilpin et al. (1959) studied the effect of length of cooking times on the texture of broccoli. When broccoli was cooked for increasing lengths of time by any of the atmospheric pressure procedures, texture improved up to about 10 minutes but was impaired by 15 minutes or more. About five minutes of cooking time was needed to obtain tender broccoli using five pounds of pressure, but only two minutes were needed when the broccoli was cooked at fifteen pounds pressure.

Texture of cooked vegetables can also be changed by acids or alkalies. Acid, such as vinegar, may prolong the time necessary to tenderize plant tissue while alkali, such as sodium bicarbonate, will shorten cooking time and produce a mushy product (Lowe, 1955).

Schrumpf and Charley (1975) studied the effects of microwave cooking on texture of broccoli and carrots. Cooking by microwave versus boiling produced less acceptable products. Vegetables cooked by microwave had greater water loss, more shrunken contour and more pronounced collapse of cells in tissues. This suggested that dehydration of the cell wall may account for the greater toughness observed.

Flavor

Cooking can decrease or enhance the flavor, or develop undesirable flavors in vegetables.

Loss of flavor can occur with large amounts of water and long cooking time. It is generally due to a decrease in sweetness caused by sugar dispersing into the cooking water (Charley, 1970).
Some vegetable flavors are heat-induced. Dimethyl sulfide, present in almost all types of vegetables, is formed during heating of methionine and pectin. Methionine and pectin react to produce S-methylmethionine which decomposes to dimethyl sulfide, dimethyl disulfide, methanethiol, acrolein and methanol (Schutte, 1974).

Sulfur-containing vegetables can cause undesirable flavors. When (+)-S-methyl-L-cysteine sulfoxide found in cabbage is heated in the presence of acid, volatile sulfur compounds, which contribute to the aroma of overcooked cabbage, are formed. This compound can also be found in vegetables such as kale, mustard, turnips, cauliflower and broccoli (Charley, 1970).

Charley (1970) recommends cooking in an uncovered pan in enough water to almost cover the vegetable. The water should help dilute the acids while the uncovered pan should permit the escape of volatile sulfides and disulfides.

Gilpin et al. (1959) investigated lengths of cooking times of various methods and their effect on flavor. They found that generally flavor was best developed when the texture was nearest optimum.

**Effects of Specific Cooking Methods on the Composition and Characteristics of Green Vegetables**

Much research done on the effects of cooking on nutritive content, color retention, texture and flavor view two or more of these aspects because one method resulting in excellent color retention may cause great ascorbic acid loss. Palatability should also be considered. If a vegetable will not be acceptable due to poor texture or flavor, excellent color or ascorbic acid retention will be of no avail.
Conventional Methods

Fisher and Dodds (1952) compared the effects of three different levels of water in cooking twelve vegetables in stainless steel utensils with tight fitting lids. The drained vegetables lost reduced ascorbic acid as the amount of water was increased but this was only significant for peas and shredded cabbage. They determined that vegetables cooked in a medium amount of water produced a desirable product in relation to color and consistency and also a nutritious product.

In 1956 Noble and Gordon investigated four common household methods of cooking on the ascorbic acid content and color of various varieties of green beans. The four cooking methods were as follows: (1) boiling in an open saucepan in enough water to cover during the entire cooking period; (2) cooking in a tightly covered saucepan in just enough water to prevent scorching; (3) cooking in a pressure saucepan at 15 pounds pressure; and (4) steaming. They determined that the samples cooked in boiling water retained significantly less ascorbic acid than did those cooked by the other three methods, none of which were significantly different from one another. An average of 60 percent of ascorbic acid was retained in samples cooked in boiling water while an average of 74 percent of ascorbic acid was retained in samples prepared by the other methods. The green beans prepared in boiling water or in the pressure saucepan had superior green color to samples cooked in the tightly covered pan or steamer.

In another study done by the same researchers (Gordon and Noble, 1959b) ascorbic acid retention and color differences in 11 different vegetables using the same four cooking methods were studied. The percentage retention of ascorbic acid in the boiling water method
for vegetables as a whole was 45 percent of the original content while 69 percent of the ascorbic acid was retained with the steaming methods. No significant difference was found within the steaming methods. With the exception of asparagus, the color of all of the green vegetables, again, was greener when cooked in boiling water or pressure saucepan than in tightly covered saucepan or steamer.

Noble (1967) did a further study to determine the effect of overcooking vegetables in boiling water and in a pressure saucepan at 15 pounds pressure on the ascorbic acid content and color. Cooking periods were "until tender" with an additional 5, 10, 50 minutes for the boiling water method or 1, 2, 3, 5 minutes in the pressure saucepan. Mean ascorbic acid retention of both cooking methods decreased significantly as the cooking periods increased. The mean percentage of ascorbic acid dissolved in the cooking waters did not change with longer cooking times, however. It was presumed that this ascorbic acid had been changed to biologically inactive substances during cooking. Increased cooking time also affected the green vegetables. The color progressed from green-yellow to yellow as cooking time increased with either method.

Waterless Methods

Waterless cooking, using only water that clings to the vegetable, has also been investigated. Krehl and Winters (1950) studied the effects of waterless cooking along with three other cooking methods with water on the retention of both minerals and vitamins. The waterless cooking method resulted in the greatest retention of nutrients
while boiling with sufficient water to cover produced the greatest nutrient loss.

Charles and Van Duyne (1954) and Gordon and Noble (1964) also investigated the waterless cooking method. Charles and Van Duyne compared the waterless method with a boiling method in which the vegetables were cooked in half their weight of water in a tightly covered saucepan. Neither method of cooking resulted in significantly higher retention of ascorbic acid. However, vegetables boiled in the tightly covered saucepan were generally rated superior in appearance, color and flavor to the vegetables prepared by the waterless method. Gordon and Noble reported greater ascorbic acid retention of vegetables when the waterless method was used than when the boiling method was used but less with the pressure saucepan method. Vegetables cooked by the waterless method were not as mild in flavor or as green in color as those prepared in boiling water. The difference in the results of these investigators may be due to the fact that the boiling method used by Gordon and Noble is an open air method while Charles and Van Duyne used a tightly covered saucepan.

Microwave Methods

In recent years microwave ovens have become important as domestic cooking appliances. The effects of this type of cooking on the nutritive value, color, texture and flavor have been studied to some extent.

Campbell, Lin and Proctor (1958) compared microwave cooking to conventional cooking of fresh cabbage and broccoli and frozen broccoli and peas. Generally microwave cooking allowed more retention of
ascorbic acid in fresh and frozen broccoli whether the vegetable was cooked just to palatable tenderness or overcooked for twice the optimum time for each method. When solidly frozen vegetables were heated for the length of time required for defrosting and cooking to pleasing tenderness, retention of ascorbic acid was practically equivalent during both conventional and microwave cooking. Microwave heating, however, gave greater retention of ascorbic acid when the use of partially defrosted peas permitted shorter heating periods for both cooking methods.

Gordon and Noble (1959a) investigated flavor and color as well as ascorbic acid retention in vegetables of the cabbage family prepared by boiling water, pressure saucepan, and microwave methods of cooking. They reported that vegetables cooked in boiling water were milder in flavor and greener in color than those cooked by the other two methods. Ascorbic acid retention was greatest in the electronic range followed by the pressure saucepan. The vegetables cooked in boiling water retained the least ascorbic acid.

A similar study by Chapman, Putz, Gilpin, Sweeney, and Eisen (1960) studied the effects of microwave and boiling methods on fresh and frozen broccoli. They reported differing results in relation to flavor and color. They found that the flavor of broccoli cooked to optimum texture of stems electronically and by boiling was estimated about the same. Color retention of the fresh vegetable was better when cooked electronically while the differences in color of the two methods using frozen broccoli were inconclusive. They also found ascorbic acid retentions in both fresh and frozen broccoli cooked to optimum texture higher using the microwave method.
Differing from the previous studies mentioned Kylen et. al. (1961) reported no significant differences in the ascorbic acid retention in seven fresh and three frozen vegetables cooked by a conventional and a microwave method. Mean total palatability scores were significantly lower after microwave cooking than conventional cooking for fresh broccoli, cauliflower and soybeans. However, fresh and frozen green beans and frozen broccoli received significantly higher ratings when prepared electronically.

Eheart and Gott (1964) compared ascorbic acid and carotene retention of frozen green vegetables and potatoes when cooked by the microwave method without water and the microwave and conventional methods with the same amount of water. They reported no significant difference in ascorbic acid retention when frozen broccoli, peas, spinach and fresh potatoes were cooked with and without water by the microwave method. Significantly more ascorbic acid was retained in frozen spinach when cooked in the microwave oven than when prepared conventionally. No significant differences in ascorbic acid retention occurred in peas, broccoli, and potatoes when prepared in water in either microwave or conventional methods. Only peas were analyzed for carotene which was completely retained by both microwave and conventional methods.

The effects of microwave cooking on the texture of broccoli and carrots were studied by Schrumpf and Charley (1975). They reported cooking by microwave produced less acceptable products than boiling. Greater water loss, more shrunken contour and more pronounced collapse of cells in tissues of the vegetables occurred during microwave cooking than boiling.
Frying Methods

There are relatively few reports in the literature studying the effects of frying on green vegetables. Two different investigations have studied potatoes however. Choudhuri et al. (1963) compared the nutritive value of fresh potatoes after boiling, frying, baking and canning. The fried potatoes were 2-ml wafers cooked in hydrogenated peanut oil at 180°C. They reported a decrease of ascorbic acid in all cases. On an actual basis the fried potatoes retained greater ascorbic acid than after baking but less than after either canning or boiling. On a fat-free, moisture-free basis, the fried potatoes' retention of ascorbic acid was greater than baked or canned but less than boiled.

Domah, Davidek and Velisek (1974) reported that frying 3-6-ml slices of potatoes in 140°C sunflower seed oil for 10, 20 and 30 minutes resulted in a small decrease in total ascorbic acid. Only 18 percent of the ascorbic acid content was destroyed during 30 minutes of frying at 140°C.

Caldwell and Gim-Sai (1973) studied the effects of cooking on the ascorbic acid content of cassava and Ceylon spinach. Frying, boiling in water, and cooking in coconut milk were the methods employed. Fried vegetables retained the greatest amount of ascorbic acid, followed by cooking in coconut milk and boiling in water.

Panning, a form of frying, was compared to boiling, steaming and pressure cooking by Kamalanathan et al. (1974). The effects of these cooking methods on the nutrient content of three Indian vegetables were studied. Pressure cooking was found to be superior in retention of iron, calcium, phosphorus, ascorbic acid and riboflavin.
Stir-frying, an Oriental method of cooking, has been studied by Eheart and Gott (1965). They compared the effects of an adapted stir-fry method, a microwave method and conventional methods on ascorbic acid, chlorophyll and pH in broccoli and green beans. Ascorbic acid retention was highest in both vegetables when they were prepared in a small amount of water. However, broccoli retained as much ascorbic acid when stir-fried as when cooked in a small amount of water. The microwave method caused less ascorbic acid retention than stir-frying for broccoli but was about the same as stir-frying for green beans. The stir-fry method gave superior color compared to the microwave and conventional cooking methods, causing less conversion of chlorophyll to pheophytin. Stir-fried broccoli also rated highest in sensory panel scores. However, the stir-fried green beans rated highest only for color.

Pasricha (1967) also investigated the stir-fry method of cooking and reported that pressure cooking resulted in better retention of ascorbic acid than stir-frying.
CHAPTER III

MATERIALS AND METHODS

Vegetable Samples

Preparation of Vegetables

Spinach, broccoli and green beans were purchased from a local retail store. Sufficient amounts of a vegetable for a specific analytical test to be run in triplicate were purchased at one time.

The vegetables were cleaned as follows:

Spinach leaves were separated, stems removed, washed under running water, drained, and patted dry with paper towels.

Approximately one-third of the broccoli stalk was cut off and leaves were removed. The broccoli was then washed under running water, drained, and cut into one inch by one-eighth inch pieces.

Green beans were washed in tubs of water and drained. The ends were snapped off and the beans were cut into two inch pieces.

The vegetables were then randomly divided into portions required for the specific test and refrigerated in tightly closed plastic bags until used within six days. Approximately 20 g of vegetable were removed for moisture determinations.
Cooking of Vegetables

The cooking methods used were microwave oven, steaming, boiling, waterless and stir-frying. Detailed procedures are described in Appendix 1.

Chemicals and Equipment

All chemicals used were of reagent grade. The reagents prepared for ascorbic acid and chlorophyll determinations are described in Appendix 2.

The cooking apparatus and equipment used are listed in Appendix 3.

Analytical Tests

Moisture Determination

Moisture content was determined for each batch of spinach, broccoli and green beans. Three runs were completed for each batch. The method used was that of the Association of the Official Analytical Chemists (1970). Samples in triplicate weighing approximately 2 g each were dried in an electric air drying oven at 135 ± 2°C for 2 hours. Loss in weight was calculated as moisture content. Average values were reported.

Ascorbic Acid Determination

Ascorbic acid was determined in raw and cooked spinach, broccoli and green beans in triplicate. Ascorbic acid content was determined by the 2,6-dichlorophenolindophenol visual titration method according to the Association of Vitamin Chemists (1966). The method is based upon the reduction of the dye, 2,6-dichlorophenolindophenol
by an acid solution of ascorbic acid. The ascorbic acid is extracted in an acid medium to maintain proper acidity for the reaction and to avoid autoxidation of the acid (Schanderl, 1970). Once the ascorbic acid is used the unreduced dye will be pink in the acid medium. The detailed procedure is presented in Appendix 4.

**Chlorophyll Determination**

The procedure used in the chlorophyll determinations was a spectrophotometric method. Radiant energy striking a food is reflected, absorbed or transmitted. A spectrophotometer measures transmission through, absorption by, or emission from a sample as well as reflectance (Jacobsen, 1972).

The particular method used in this study determines chlorophyll retention by measuring absorbance at wavelengths of 536 nm and 558 nm. This method, developed by Vernon (1960), can determine quantitatively chlorophyll a, chlorophyll b, pheophytin a, pheophytin b, total chlorophyll, total pheophytin and percentage retention of chlorophylls using a Beckman DU spectrophotometer or an equivalent model. Since one was not available for this study, only the percentage of total chlorophyll could be determined with the Beckman Model B spectrophotometer available, using equation 13 cited in Vernon's method. This modified method was used by Eheart and Gott (1965) in a study comparing chlorophyll determination methods as an adequate method for a quick and satisfactory determination. The detailed procedure is described in Appendix 5.

**Sensory Evaluation**

In order to compare acceptability of the vegetables prepared by various cooking methods, a sensory evaluation was conducted. A taste
panel consisting of students enrolled in food science classes, and faculty trained in sensory evaluation was used. Nineteen, seventeen and sixteen panelists participated in the spinach, broccoli and green beans evaluations, respectively.

Attempts were made to control as many influencing factors as possible according to Larmond (1970). Testing took place in a quiet, well-lighted room approximately two hours after a meal and continued until approximately one hour before the next meal.

The vegetables were prepared the day before the evaluation and refrigerated in covered containers due to time limitations of the researcher. The vegetables were removed from the refrigerator approximately four hours before the evaluation was to begin so they could attain a uniform room temperature. The vegetable samples were coded and served on clean, odorless and tasteless paper plates. Stainless steel utensils were used.

Panelists were asked to wash their mouths with water between samples. In each tasting session, the panelists were presented with a vegetable, prepared in various manners. They were asked to rank the samples for texture, color, flavor and overall acceptance on a scale of one to four or five. One was rated as most acceptable while four for the spinach samples and five for the broccoli and green beans samples were ranked as least acceptable. Samples of the questionnaires are in Appendix 6.

Statistical Treatments

Data on ascorbic acid and chlorophyll retention and sensory evaluation were statistically analyzed using analysis of variance and
Duncan's multiple-range test (Larmond, 1970; and Duncan, 1955). Scatter diagrams and correlation coefficients, r, were determined to correlate chlorophyll retention percentages and ranked color data (Ferguson, 1966; and Joslyn, 1970).
CHAPTER IV

RESULTS AND DISCUSSION

Moisture Content of the Vegetables Used

The moisture content of the spinach, broccoli and green beans used for ascorbic acid and chlorophyll analyses are presented in Table 2.

These results are similar to those in the U.S.D.A.'s Composition of Foods (Watt and Merrill, 1963). The handbook reports the following percentages: broccoli, raw spears, 89.1; beans, snap, green, raw, 90.1; and spinach, raw, 90.7.

Effect of Cooking Method on Ascorbic Acid Retention

Ascorbic acid retention of spinach, broccoli and green beans cooked by various methods are presented in Table 3. The mean percentage retention in spinach samples ranged from 67 to 28 percent. The stir-fried method of cooking allowed the most retention of ascorbic acid while the microwave method caused greatest ascorbic acid loss.

The mean percentage ascorbic acid retentions in broccoli samples ranged from 98 to 52 percent. The steaming method of cooking caused greatest vitamin retention while the method of boiling in large amounts of water without a lid caused the least ascorbic acid.
TABLE 2

MOISTURE CONTENT (%) OF VEGETABLES

<table>
<thead>
<tr>
<th>Run</th>
<th>Spinach</th>
<th>Broccoli</th>
<th>Green Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93.5</td>
<td>88.8</td>
<td>93.0</td>
</tr>
<tr>
<td>2</td>
<td>93.2</td>
<td>90.7</td>
<td>93.4</td>
</tr>
<tr>
<td>3</td>
<td>93.0</td>
<td>89.6</td>
<td>93.4</td>
</tr>
<tr>
<td>Average</td>
<td>93.2</td>
<td>89.7</td>
<td>93.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Run</th>
<th>Spinach</th>
<th>Broccoli</th>
<th>Green Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>92.9</td>
<td>91.9</td>
<td>93.0</td>
</tr>
<tr>
<td>2</td>
<td>92.7</td>
<td>91.7</td>
<td>93.1</td>
</tr>
<tr>
<td>3</td>
<td>93.7</td>
<td>91.9</td>
<td>93.6</td>
</tr>
<tr>
<td>Average</td>
<td>93.1</td>
<td>91.8</td>
<td>93.2</td>
</tr>
</tbody>
</table>
TABLE 3
ASCORBIC ACID RETENTION OF SPINACH, BROCCOLI AND GREEN BEANS COOKED BY VARIOUS METHODS

<table>
<thead>
<tr>
<th>Method of Cooking</th>
<th>Fresh Basis (mg/100g)</th>
<th>Moisture-free Basis (mg/100g)</th>
<th>Mean Retention (%)</th>
<th>F Values&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spinach</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw</td>
<td>17</td>
<td>246</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Microwave Oven</td>
<td>5</td>
<td>70</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Steamed</td>
<td>8</td>
<td>122</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Waterless</td>
<td>7</td>
<td>106</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Stir-fried</td>
<td>11</td>
<td>164</td>
<td>67</td>
<td>30.98**</td>
</tr>
<tr>
<td><strong>Broccoli</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw</td>
<td>109</td>
<td>1055</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Microwave Oven</td>
<td>88</td>
<td>855</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Steamed</td>
<td>106</td>
<td>1030</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>Boiled, 1:0.5 (Veg.:H₂O)</td>
<td>93</td>
<td>902</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Boiled, 1:4 (Veg.:H₂O)</td>
<td>57</td>
<td>553</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Stir-fried</td>
<td>95</td>
<td>922</td>
<td>87</td>
<td>16.52**</td>
</tr>
<tr>
<td><strong>Green Beans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw</td>
<td>12</td>
<td>185</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Microwave Oven</td>
<td>8</td>
<td>112</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Steamed</td>
<td>9</td>
<td>129</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Boiled, 1:0.5 (Veg.:H₂O)</td>
<td>8</td>
<td>120</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Boiled, 1:4 (Veg.:H₂O)</td>
<td>7</td>
<td>103</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Stir-fried</td>
<td>10</td>
<td>141</td>
<td>76</td>
<td>13.39*</td>
</tr>
</tbody>
</table>

<sup>1</sup>Obtained by analysis of variance.

* p < 0.005
** p < 0.001
The F values obtained through analyses of variance for both spinach and broccoli samples indicate that difference in ascorbic acid retention between samples is significant \((p < 0.001)\).

Mean percentage ascorbic acid retentions in green beans ranged from 76 to 56 percent. The stir-fried sample retained the greatest ascorbic acid and the sample boiled in large amounts of water lost the most ascorbic acid. The difference between the various cooking methods is significant \((p < 0.005)\).

Duncan's multiple-range test was applied to the data for the spinach, broccoli and green beans samples. Results from the test, indicating where the significant differences exist, are presented in Table 4. The stir-fried spinach sample retained significantly more ascorbic acid than spinach prepared by the other three methods of cooking. The broccoli sample boiled in large amounts of water without a lid retained significantly less ascorbic acid than the broccoli cooked by the other four methods. The stir-fried green beans sample, though not significantly better than the steamed sample, did retain significantly more ascorbic acid than the two boiling methods and the microwave method.

These results indicate that the stir-fry method of cooking allows significantly greater retention of ascorbic acid than other methods. The stir-fry method is best for retention of ascorbic acid for leafy vegetables and is equally as good as steaming for stem and flower vegetables and green beans.

These results also indicate that contact with water and length of cooking period may be a factor in nutrient loss. The stir-fried and steamed samples consistently retained greater amounts of ascorbic
**TABLE 4**

**DUNCAN'S MULTIPLE-RANGE TEST FOR DIFFERENCES IN ASCORBIC ACID RETENTION IN SPINACH, BROCCOLI AND GREEN BEANS COOKED BY VARIOUS METHODS**

<table>
<thead>
<tr>
<th>Samples:</th>
<th>Stir-fried</th>
<th>Steamed</th>
<th>Waterless</th>
<th>Microwave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinach*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Means:</td>
<td>164.01</td>
<td>122.27</td>
<td>106.11</td>
<td>69.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Samples:</th>
<th>Steamed</th>
<th>Stir-fried</th>
<th>Boiled (1:0.5)</th>
<th>Microwave</th>
<th>Boiled (1:4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Means:</td>
<td>1029.77</td>
<td>922.34</td>
<td>902.36</td>
<td>855.48</td>
<td>553.06</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Samples:</th>
<th>Stir-fried</th>
<th>Steamed</th>
<th>Boiled (1:0.5)</th>
<th>Microwave</th>
<th>Boiled (1:4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Beans*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Means:</td>
<td>141.49</td>
<td>128.72</td>
<td>119.84</td>
<td>112.29</td>
<td>103.41</td>
</tr>
</tbody>
</table>

* p < 0.01

Note: Any two means not underscored by the same line are significantly different.
acid; and of the samples, only the stir-fried green beans were cooked in a small amount of water. Both broccoli and green beans samples boiled in large amounts of water without a lid lost more ascorbic acid than those cooked by the other four methods. Also both the stir-fried and steamed samples required less cooking time than the other samples with the exception of the spinach samples prepared by the waterless method. Though additional water was not added to samples prepared by the waterless method, the spinach did have water droplets clinging to its leaves which may have been a contributing factor in the lower retention of the ascorbic acid.

Noble and Gordon (1956) reported similar findings in green beans samples. Though they reported overall higher mean retentions of ascorbic acid in green beans than found in this study, samples prepared in large amounts of boiling water without a lid retained less ascorbic acid than those cooked by the other three methods. Also, steamed vegetables retained more ascorbic acid than vegetables boiled in small amounts of water with a lid. Previous reports by Gordon and Noble (1959b) and Noble (1967) also confirm these findings.

Research done by Campbell, Lin and Proctor (1958), Gordon and Noble (1959a) and Chapman et al. (1960) indicated greater retention of ascorbic acid in vegetables prepared by microwave than conventional boiling methods. Though both samples of broccoli and green beans cooked by microwave retained more ascorbic acid than the samples boiled in large amounts of water, only the broccoli sample retained significantly more than the boiled sample in this study. The sample prepared by microwave did not retain more ascorbic acid than the samples boiled in small amounts of water with lids. Also this sample retained the
least amount of ascorbic acid of the spinach samples. These differences can possibly be attributed to different cooking times, sizes of cooking containers, and amounts of water used.

Eheart and Gott (1965) reported similar results for broccoli samples but differing results for green beans. They reported that boiling vegetables in small amount of water with a lid caused more ascorbic acid retention than the other methods tested. Samples that were prepared by stir-frying, microwave cooking and boiling in large amounts of water did not differ significantly in retention of ascorbic acid. The difference between results could be attributed to the different cooking times and, specifically, the different stir-frying method employed. Eheart and Gott used a modified stir-fry method with an electric skillet. After the vegetable pieces were stir-fried at 350°F with 10 ml of cooking oil, the heat was reduced to 250°F, a small amount of water was added, and the skillet was covered for the remainder of the cooking period. The total cooking time was greater for both green beans and broccoli samples than used in this study.

**Effect of Cooking Method on Chlorophyll Retention**

Data on chlorophyll retention in spinach, broccoli and green beans cooked by various methods are presented in Table 5. Since a formula (Appendix 5) was used to determine the mean percentage retention of chlorophyll from spectrophotometric data, values above 100 percent were obtained for two raw vegetable samples and one cooked sample.

The stir-fried method of cooking caused the greatest retention of chlorophyll in the spinach and broccoli samples. The microwave
TABLE 5
CHLOROPHYLL RETENTION OF SPINACH, BROCCOLI AND GREEN BEANS
COOKED BY VARIOUS METHODS

<table>
<thead>
<tr>
<th>Method of Cooking</th>
<th>Spinach</th>
<th>Broccoli</th>
<th>Green Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>106</td>
<td>105</td>
<td>100</td>
</tr>
<tr>
<td>Microwave Oven</td>
<td>80</td>
<td>70</td>
<td>37</td>
</tr>
<tr>
<td>Steamed</td>
<td>84</td>
<td>77</td>
<td>38</td>
</tr>
<tr>
<td>Waterless</td>
<td>92</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Stir-fried</td>
<td>105</td>
<td></td>
<td>19</td>
</tr>
</tbody>
</table>

Mean Retention (%)

<table>
<thead>
<tr>
<th>Method of Cooking</th>
<th>Spinach</th>
<th>Broccoli</th>
<th>Green Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>106</td>
<td>105</td>
<td>100</td>
</tr>
<tr>
<td>Microwave Oven</td>
<td>80</td>
<td>70</td>
<td>37</td>
</tr>
<tr>
<td>Steamed</td>
<td>84</td>
<td>77</td>
<td>38</td>
</tr>
<tr>
<td>Waterless</td>
<td>92</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Stir-fried</td>
<td>105</td>
<td></td>
<td>19</td>
</tr>
</tbody>
</table>

Mean Retention (%)

F Values

<table>
<thead>
<tr>
<th>Method of Cooking</th>
<th>Spinach</th>
<th>Broccoli</th>
<th>Green Beans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microwave Oven</td>
<td>100.61*</td>
<td></td>
<td>34.90*</td>
</tr>
<tr>
<td>Steamed</td>
<td></td>
<td></td>
<td>35.12*</td>
</tr>
<tr>
<td>Boiled, 1:0.5 (Vegetable:H₂O)</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiled, 1:4 (Vegetable:H₂O)</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stir-fried</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Obtained through analysis of variance.
2 *p < 0.001
method caused the greatest loss of chlorophyll in both. As with the
spinach and broccoli samples, the stir-fried green beans sample
retained the highest percentage of chlorophyll. The sample boiled in
small amounts of water with lid had the greatest loss of the pigment,
however.

As shown in Table 5, F values obtained through analyses of
variance have shown that the differences in chlorophyll retention
between the methods are significant ($p < 0.001$) for all three vege-
tables. Results of the Duncan's multiple-range test, indicating where
the significant differences exist, are presented in Table 6. These
data indicate that stir-frying is an excellent cooking method for the
retention of chlorophyll. However, steaming, microwave cooking and
boiling in small amounts of water are not good cooking methods for
chlorophyll retention. The stir-frying and boiling (large amounts of
water) methods did not differ significantly in chlorophyll retention
in broccoli but did so in green beans. This possibly is due to the
length of cooking time since green beans samples were boiled for a
longer period of time than broccoli samples to achieve tenderness.

The vegetables cooked in containers with lids as in the
steamed, microwave and boiled (small amounts of water) methods lost
significantly more chlorophyll than those cooked in open containers,
stir-fried and boiled (large amounts of water) methods, or in con-
tainers that were uncovered frequently during the cooking period as
with the waterless method. The only exception to this was in the
broccoli samples, where there was no significant difference found
between the two boiling methods. This trend supports the suggestions
by Charley (1970) that large amounts of boiling water to dilute acid
TABLE 6

DUNCAN'S MULTIPLE-RANGE TEST FOR DIFFERENCES IN CHLOROPHYLL RETENTION IN SPINACH, BROCCOLI AND GREEN BEANS COOKED BY VARIOUS METHODS

<table>
<thead>
<tr>
<th></th>
<th>Spinach*</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Samples:</strong></td>
<td>Stir-fried</td>
<td>Waterless</td>
<td>Steamed</td>
<td>Microwave</td>
<td></td>
</tr>
<tr>
<td><strong>Means:</strong></td>
<td>105.16</td>
<td>91.98</td>
<td>83.60</td>
<td>79.71</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Broccoli*</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Samples:</strong></td>
<td>Stir-fried</td>
<td>Boiled (1:4)</td>
<td>Boiled (1:0.5)</td>
<td>Steamed</td>
<td>Microwave</td>
</tr>
<tr>
<td><strong>Means:</strong></td>
<td>98.78</td>
<td>93.09</td>
<td>84.14</td>
<td>76.52</td>
<td>69.89</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Green Beans*</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Samples:</strong></td>
<td>Stir-fried</td>
<td>Boiled (1:4)</td>
<td>Steamed</td>
<td>Microwave</td>
<td>Boiled (1:0.5)</td>
</tr>
<tr>
<td><strong>Means:</strong></td>
<td>73.68</td>
<td>43.69</td>
<td>37.78</td>
<td>36.73</td>
<td>18.78</td>
</tr>
</tbody>
</table>

* p < 0.01

Note: Any two means not underscored by the same line are significantly different.
and an uncovered pan to eliminate volatile acids help minimize the effects of acid on the color of cooked green vegetables. However, little or no water was used in the stir-fry method. This indicates that possibly the use of oil as a cooking medium as well as a short cooking period and an open cooking vessel may be factors in chlorophyll retention in stir-fried samples.

Eheart and Gott (1965) reported greater chlorophyll retention in stir-fried broccoli and green beans samples also. The green beans sample cooked by microwave did retain more chlorophyll than those boiled in large amounts of water however. They suggested that the high chlorophyll retention in stir-fried samples could be due to the presence of oil. Less contact with water made the transport of $H^+$ ions in solution more difficult or may have caused less rupture of the chloroplasts.

These results are also similar to previous research by Gordon and Noble (1959a and 1959b) and Noble and Gordon (1956) in which the Nickerson whirling disc method was used to compare color retention. Color in boiling methods was better than in steaming, microwave cooking or boiling in a tightly covered container in most cases.

Chapman et al. (1960), however, reported the microwave method to be better than the boiling method in color retention. Smaller amounts of boiling water were used by the researchers which may be the cause for differing results.

**Effect of Cooking Method on Palatability**

Sensory evaluation mean rank scores of spinach, broccoli and green beans cooked by various methods are presented in Table 7. The
<table>
<thead>
<tr>
<th>Spinach</th>
<th>Microwave</th>
<th>Steamed</th>
<th>Waterless</th>
<th>Stir-fried</th>
<th>F Values&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td>1.95</td>
<td>2.21</td>
<td>2.58</td>
<td>3.26</td>
<td>3.60*</td>
</tr>
<tr>
<td>Color</td>
<td>2.84</td>
<td>3.16</td>
<td>2.53</td>
<td>1.47</td>
<td>8.87****</td>
</tr>
<tr>
<td>Flavor</td>
<td>2.10</td>
<td>2.26</td>
<td>2.89</td>
<td>2.74</td>
<td>1.59</td>
</tr>
<tr>
<td>Overall Acceptance</td>
<td>2.10</td>
<td>2.42</td>
<td>2.58</td>
<td>2.89</td>
<td>1.26</td>
</tr>
<tr>
<td>Total Score</td>
<td>8.99</td>
<td>10.05</td>
<td>10.58</td>
<td>10.36</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Broccoli</th>
<th>Microwave</th>
<th>Steamed</th>
<th>Boiled (1:0.5)</th>
<th>Boiled (1:4)</th>
<th>Stir-fried</th>
<th>F Values&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td>2.94</td>
<td>2.53</td>
<td>3.06</td>
<td>2.41</td>
<td>4.06</td>
<td>3.37*</td>
</tr>
<tr>
<td>Color</td>
<td>4.59</td>
<td>3.53</td>
<td>3.00</td>
<td>1.53</td>
<td>2.35</td>
<td>19.37****</td>
</tr>
<tr>
<td>Flavor</td>
<td>2.82</td>
<td>2.29</td>
<td>2.88</td>
<td>3.35</td>
<td>3.65</td>
<td>1.78</td>
</tr>
<tr>
<td>Overall Acceptance</td>
<td>2.94</td>
<td>2.35</td>
<td>3.00</td>
<td>2.76</td>
<td>3.94</td>
<td>2.65*</td>
</tr>
<tr>
<td>Total Score</td>
<td>13.29</td>
<td>10.70</td>
<td>11.94</td>
<td>10.05</td>
<td>14.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Green Beans</th>
<th>Microwave</th>
<th>Steamed</th>
<th>Boiled (1:0.5)</th>
<th>Boiled (1:4)</th>
<th>Stir-fried</th>
<th>F Values&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td>2.31</td>
<td>2.31</td>
<td>3.31</td>
<td>3.31</td>
<td>3.75</td>
<td>2.97*</td>
</tr>
<tr>
<td>Color</td>
<td>2.75</td>
<td>3.00</td>
<td>4.50</td>
<td>2.94</td>
<td>1.81</td>
<td>9.46****</td>
</tr>
<tr>
<td>Flavor</td>
<td>2.00</td>
<td>2.69</td>
<td>3.19</td>
<td>3.94</td>
<td>3.19</td>
<td>3.91**</td>
</tr>
<tr>
<td>Overall Acceptance</td>
<td>2.25</td>
<td>2.31</td>
<td>3.69</td>
<td>3.56</td>
<td>3.19</td>
<td>3.17*</td>
</tr>
<tr>
<td>Total Score</td>
<td>9.31</td>
<td>10.31</td>
<td>14.69</td>
<td>13.75</td>
<td>11.94</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Obtained through analysis of variance

* p < 0.05
** p < 0.01
*** p < 0.005
**** p < 0.001
scores are based on a scale of one to four or five with one rated as most acceptable.

The spinach sample cooked by microwave was rated most acceptable in texture, flavor and overall acceptance while the stir-fried spinach sample was rated most acceptable in color. Though the stir-fried sample was ranked lowest in overall acceptance, when considering total scores the waterless cooked sample was least acceptable.

F values determined by analyses of variance showed significant differences for texture (p < 0.05) and color (p < 0.001) in the cooking methods. Duncan's multiple-range test confirmed that the texture of the stir-fried method is significantly less acceptable than the microwave or steamed method (Table 8). It also showed that the color of the stir-fried sample was significantly (p < 0.01) more acceptable than the samples prepared by the waterless, microwave and steamed methods.

Broccoli boiled in large amounts of water was rated most acceptable in texture and color while steamed broccoli was rated most acceptable in flavor and overall acceptance. Stir-fried broccoli was least acceptable in texture, flavor and overall acceptance and microwave cooking of the vegetable was least acceptable in color.

Statistically, there was no significant difference in flavor between broccoli samples. F values determined by analyses of variance showed significant differences in cooking methods rated for texture (p < 0.05), overall acceptance (p < 0.05) and color (p < 0.001). Duncan's multiple-range test (Table 9) shows where the significant differences occur. The stir-fried broccoli was significantly less acceptable in texture than samples steamed and boiled in large amounts
TABLE 8
DUNCAN'S MULTIPLE-RANGE TEST FOR DIFFERENCES IN PALATABILITY OF SPINACH COOKED BY VARIOUS METHODS

<table>
<thead>
<tr>
<th></th>
<th>Texture*</th>
<th>Color**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samples</td>
<td>Microwave</td>
<td>Steamed</td>
</tr>
<tr>
<td>Means:</td>
<td>1.95</td>
<td>2.21</td>
</tr>
</tbody>
</table>

*p < 0.05

**p < 0.01

Note: Any two means not underscored by the same line are significantly different.
### TABLE 9

DUNCAN'S MULTIPLE-RANGE TEST FOR DIFFERENCES IN PALATABILITY OF BROCCOLI COOKED BY VARIOUS METHODS

<table>
<thead>
<tr>
<th>Texture*</th>
<th>Samples:</th>
<th>Boiled (1:4)</th>
<th>Steamed</th>
<th>Microwave</th>
<th>Boiled (1:0.5)</th>
<th>Stir-fried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means:</td>
<td></td>
<td>2.41</td>
<td>2.53</td>
<td>2.94</td>
<td>3.06</td>
<td>4.06</td>
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<table>
<thead>
<tr>
<th>Color**</th>
<th>Samples:</th>
<th>Boiled (1:4)</th>
<th>Stir-fried</th>
<th>Boiled (1:0.5)</th>
<th>Steamed</th>
<th>Microwave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means:</td>
<td></td>
<td>1.53</td>
<td>2.35</td>
<td>3.00</td>
<td>3.53</td>
<td>4.59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Acceptance*</th>
<th>Samples:</th>
<th>Steamed</th>
<th>Boiled (1:4)</th>
<th>Microwave</th>
<th>Boiled (1:0.5)</th>
<th>Stir-fried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means:</td>
<td></td>
<td>2.35</td>
<td>2.76</td>
<td>2.94</td>
<td>3.00</td>
<td>3.94</td>
</tr>
</tbody>
</table>

*\(p < 0.05\)

**\(p < 0.01\)

Note: Any two means not underscored by the same line are significantly different.
of water. The steamed and microwave samples were significantly less acceptable in color than the other three methods. In overall acceptance stir-frying ranked lowest.

Chapman et al. (1960) also found no difference in flavor of broccoli boiled or electronically cooked. They did find better color in electronically cooked broccoli than boiled broccoli, however. This difference in results is probably due to differing amounts of water used in the boiling methods. Only one cup of water was used for one pound of fresh broccoli in their study.

The microwave method of cooking green beans was rated most acceptable in flavor and overall acceptance and rated equally most acceptable with steaming in texture. Stir-fried green beans were most acceptable in color. Total scores showed boiling in small amounts of water least acceptable.

F values determined by analyses of variance showed significant differences among cooking methods rated for all four characteristics. Texture and overall acceptance showed significant differences (p < 0.005). Flavor and color data were significant (p < 0.01 and p < 0.001, respectively). Duncan's multiple-range test (Table 10) shows that the stir-fried vegetable was significantly less acceptable in texture than the microwave and steamed methods. The sample boiled in small amounts of water was significantly less acceptable than the other four methods in color. The microwave sample was significantly more acceptable in flavor than the sample boiled in large amounts of water. In overall acceptance the microwave and steamed methods were more acceptable than either boiling method.
TABLE 10
DUNCAN'S MULTIPLE-RANGE TEST FOR DIFFERENCES IN PALATABILITY
OF GREEN BEANS COOKED BY VARIOUS METHODS

<table>
<thead>
<tr>
<th>Texture*</th>
<th>Samples:</th>
<th>Microwave</th>
<th>Steamed</th>
<th>Boiled (1:4)</th>
<th>Boiled (1:0.5)</th>
<th>Stir-fried</th>
<th>Means:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2.31</td>
<td>2.31</td>
<td>3.31</td>
<td>3.31</td>
<td>3.75</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Color**</th>
<th>Samples:</th>
<th>Stir-fried</th>
<th>Microwave</th>
<th>Boiled (1:4)</th>
<th>Steamed</th>
<th>Boiled (1:0.5)</th>
<th>Means:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1.81</td>
<td>2.75</td>
<td>2.94</td>
<td>3.00</td>
<td>4.50</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flavor**</th>
<th>Samples:</th>
<th>Microwave</th>
<th>Steamed</th>
<th>Boiled (1:0.5)</th>
<th>Stir-fried</th>
<th>Boiled (1:4)</th>
<th>Means:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2.00</td>
<td>2.69</td>
<td>3.19</td>
<td>3.19</td>
<td>3.94</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Acceptance*</th>
<th>Samples:</th>
<th>Microwave</th>
<th>Steamed</th>
<th>Stir-fried</th>
<th>Boiled (1:4)</th>
<th>Boiled (1:0.5)</th>
<th>Means:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2.25</td>
<td>2.31</td>
<td>3.19</td>
<td>3.56</td>
<td>3.69</td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05
**p < 0.01

Note: Any two means not underscored by the same line are significantly different.
Considering total scores of the three vegetables, the microwave method of cooking gave the most acceptable spinach and green beans. Boiling in large amounts of water was rated most acceptable with broccoli samples. A different method for each vegetable was ranked least acceptable. Spinach prepared by the waterless method, broccoli stir-fried, and green beans boiled in small amounts of water ranked least acceptable in total scores.

Eheart and Gott (1965), however, found different results in their panel scores. Stir-fried broccoli was most acceptable while broccoli boiled in small amounts of water was least acceptable. Green beans prepared by microwave were least acceptable while green beans boiled in large amounts of water were most acceptable. These differences between results may be partially due to the difference in stir-fried methods used as well as the length of cooking times.

Kylen et al. (1961) showed better mean palatability scores for a conventional boiling method when compared to an electronic cooking method for broccoli, cauliflower and soybeans. This is in agreement to the total scores for broccoli though not with green beans samples in this study.

Gordon and Noble (1959a) also found vegetables cooked in boiling water were more acceptable in flavor and color than those cooked by pressure saucepan or electronic range. This is in agreement with the broccoli color scores in this study but not with the broccoli flavor scores or green beans color and flavor scores. This again could be due to the different lengths of cooking time employed by the researchers.
An important factor influencing the sensory scores in this study may have been the sample preparation. Possibly results would have been different and/or more consistent if the vegetable samples had been evaluated by the taste panel when they were freshly prepared and at a warmer temperature.

In summary it appears that acceptance of a method of cooking varies with the vegetable used. Only a few consistencies between the vegetables occurred. Microwave cooking, steaming and boiling in large amounts of water produced a more acceptable product in texture, while stir-frying was not acceptable. Apparently, the crispness of the stir-fried samples was not pleasing to the American palate and they were possibly considered undercooked.

Stir-fried, however, and boiled (large amounts of water) vegetables were generally rated acceptable in color while microwave cooked, steamed and boiled (small amounts of water) vegetables were not well accepted.

A correlation test was not done between total mean rank scores and ascorbic acid retention, though it appears that acceptance of a vegetable does not correlate with high ascorbic acid retention. Spinach and green beans prepared in a microwave oven and broccoli boiled in large amounts of water were rated most acceptable according to the total mean rank scores. However, these methods of preparation caused large amounts of ascorbic acid loss in the vegetables studied.

In view of the total mean rank scores stir-frying is the least acceptable method of cooking in relation to texture, color, flavor and overall acceptance. However, spinach and green beans prepared in a
microwave oven and broccoli boiled in large amounts of water are acceptable.

**Correlation Between Chlorophyll Retention and Color Ranking Scores**

Scatter diagrams were plotted for the percentage of chlorophyll retention and color ranking scores of the three vegetables and are presented in Figure 1. High correlation coefficients ranging from 0.93 to 0.78 were found in the three vegetables. Analyses were limited to average values since the samples used for chlorophyll analyses were not the same as those used for the sensory evaluation.

Though the color scores do correlate well with the chlorophyll retention data, those samples prepared uncovered were not consistently rated more acceptable. Eheart and Gott (1965) found similar high correlation between panel color scores and chlorophyll retention.
Figure 1. Scatter diagrams illustrating correlation of percentage of chlorophyll retention and mean rank color scores of spinach, broccoli and green beans cooked by various methods.

Spinach

\[ r = 0.93 \]
\[ Y = -0.06X + 7.91 \]

Broccoli

\[ r = 0.90 \]
\[ Y = -0.09X + 10.60 \]

Green Beans

\[ r = 0.78 \]
\[ Y = -0.045X + 4.896 \]
CHAPTER V

SUMMARY AND CONCLUSIONS

The effects of the Chinese stir-fry method of cooking on three green vegetables were compared with microwave cooking, steaming, waterless cooking, and two boiling methods. Ascorbic acid and chlorophyll retention and palatability were determined in spinach, broccoli and green beans.

The stir-fry method of cooking was found to be an excellent method of cooking for ascorbic acid and chlorophyll retention in the three vegetables studied. Stir-fried spinach retained significantly more ascorbic acid than spinach prepared by the other three methods of cooking; and stir-fried green beans, though not significantly better than the steamed sample did retain significantly more ascorbic acid than the two boiling methods and the microwave method. The stir-fried broccoli samples retained a high percentage of ascorbic acid though it was not significantly greater than in broccoli prepared by three of the other four cooking methods. Contact with water and length of cooking time appear to be a factor in ascorbic acid loss. Cooking methods that employed little or no water and short heating periods generally retained more ascorbic acid than other methods.

Stir-fried spinach, broccoli and green beans retained greater amounts of chlorophyll than samples prepared by the other cooking methods. Data for both stir-fried spinach and green beans were
significantly different, while data for stir-fried broccoli did not differ significantly with samples boiled in large amounts of water. Vegetable samples prepared in open cooking vessels and/or large amounts of water generally retained more chlorophyll than those samples prepared in small amounts of water in closed containers. Interestingly, cooking methods that permit retention of chlorophyll were not necessarily the best methods for retention of ascorbic acid. An exception to this was the stir-fry method which caused retention of both ascorbic acid and chlorophyll to a large extent.

A high correlation was found between chlorophyll retention and color scores obtained through sensory tests in all three vegetables. Considering total palatability scores of three vegetables, stir-frying is a less acceptable cooking method than the other methods, however. Acceptance of a method varied with the vegetable used. The microwave method of cooking was rated most acceptable for spinach and green beans samples while boiling in large amounts of water was rated most acceptable for broccoli samples. Interestingly, these methods were poor in retention of ascorbic acid. A different method for each vegetable was ranked least acceptable. Spinach prepared by the waterless method, broccoli stir-fried and green beans boiled in small amounts of water ranked least acceptable in total scores.

In summary, the Chinese stir-frying method of cooking is a good method for retention of ascorbic acid and chlorophyll in spinach, broccoli and green beans. However, it produces a less overall acceptable cooked product to the American palate.
BIBLIOGRAPHY


Joseph, M. L. 1972. Professor, California State University, Northridge.


APPENDICES
APPENDIX 1

COOKING METHODS

Spinach

All spinach samples were placed in a colander and rinsed briefly under running water before cooking.

Microwave Cooking: Spinach, weighing 300 g, was placed in a 2 1/2-qt covered glass casserole with only the water left clinging to its leaves. The spinach was cooked in the microwave oven for 4 minutes. After removal from the oven the casserole was kept covered for 5 minutes at room temperature to allow for additional cooking.

Steaming: Spinach, weighing 300 g, was divided and put into two identical steamers which were placed in identical stainless steel saucepans containing levels of water that did not touch the steamers. The water was brought to a boil on an electric range. The saucepans were then covered and the heat setting reduced to medium. The spinach continued to cook for 8 minutes.

Waterless Cooking: With only the water that was clinging to its leaves, 300 g of spinach were placed in a stainless steel saucepan with heat from an electric range set on high. When steam formed the saucepan was covered and the heat setting was reduced to medium-low. The sample was cooked for 5 minutes. Every one-minute interval the spinach was stirred with a fork.
Stir-frying: The wok was heated for 30 seconds over high heat on a direct flame from a gas range. Fifteen ml of peanut oil was added and swirled in the wok. After allowing 30 seconds more to heat the oil, 300 g of spinach was added and stirred vigorously for 3.5 minutes.

Broccoli

Equal amounts of stalk and floweret were used when cooking the broccoli.

Microwave Cooking: Broccoli, weighing 300 g, was put in a 1 1/2-qt covered glass casserole with 118.5 ml of water. The casserole was placed in the microwave oven and cooked for 7 minutes. After removal from the oven the casserole was kept covered for 5 minutes at room temperature.

Steaming: A stainless steel steamer containing 300 g of broccoli was put into a saucepan containing a quantity of water that did not touch the bottom of the steamer. The water was brought to a boil on an electric range. The saucepan was then covered and the heat setting reduced to medium. The broccoli continued to cook for 9 minutes.

Boiling (Vegetable:water ratio, 1:0.5): One hundred and fifty grams of broccoli stalks were added to 150 ml of boiling water on an electric range. After the water began a second boil, the heat setting was reduced to low and the saucepan was covered. After 6 minutes 150 g of flowerets were added, the saucepan covered again, and cooking continued for 6 more minutes.

Boiling (Vegetable:water ratio, 1:4): One hundred and fifty grams of broccoli stalks were added to 1200 ml of boiling water on an electric range. After the water began a second boil, the heat setting was
reduced to medium-low and the broccoli cooked uncovered. After 6 minutes 150 g of flowerets were added. Cooking continued for another 6 minutes.

**Stir-frying:** The wok was heated for 30 seconds over high heat on a direct gas flame. Fifteen ml of peanut oil was added and swirled in the wok. After heating the oil for 30 seconds, 150 g of broccoli stalks were added and stirred vigorously for 1.5 minutes. Then, 150 g of flowerets were added and stirred for another 3.5 minutes.

**Green Beans**

**Microwave Cooking:** Three hundred grams of green beans were put in a 1 1/2-qt covered glass casserole with 118.5 ml of water. The casserole was placed in the microwave oven and the green beans were cooked for 8 minutes. After removal from the oven the casserole was kept covered for 5 minutes at room temperature.

**Steaming:** A stainless steel steamer basket containing 300 g of green beans was put into a saucepan containing a quantity of water that did not touch the bottom of the steamer basket. The water was brought to a boil on an electric range. The saucepan was then covered and the heat setting reduced to medium. The green beans continued to cook for 13 minutes.

**Boiling (Vegetable:water ratio, 1:0.5):** Three hundred grams of green beans were added to 150 ml of boiling water on an electric range. After the water began a second boil, the heat setting was reduced to low and the saucepan was covered. The green beans continued cooking for 20 minutes.

**Boiling (Vegetable:water ratio, 1:4):** Three hundred grams of green
beans were added to 1200 ml of boiling water on an electric range. After the water began a second boil, the heat setting was reduced to medium-low, and the green beans cooked uncovered for 20 minutes.

**Stir-frying:** The wok was heated for 30 seconds over medium heat on a direct gas flame. Fifteen ml of peanut oil was added and swirled in the wok. After heating the oil for 30 seconds, 300 g of green beans were added and stirred vigorously. After 3 minutes, 60 ml of water was added and the sample cooked without stirring for two minutes. The green beans were then stirred briefly and allowed to continue cooking for 5.5 minutes. During this period the green beans were stirred quickly at 1 minute intervals.

The above methods of preparation for spinach, broccoli and green beans were used for analysis of ascorbic acid. Methods varied slightly for chlorophyll analysis. Only 200 g of the vegetable were cooked for each method. The amount of cooking water only varied in the boiling methods of broccoli and green beans. The different quantities were as follows:

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<tr>
<th></th>
<th>Boiling (1:0.5)</th>
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<tr>
<td>Broccoli</td>
<td>100 ml</td>
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<tr>
<td>Green Beans</td>
<td>100 ml</td>
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APPENDIX 2

CHEMICALS

Chemical reagents used for ascorbic acid determinations are as follows:

6 percent Metaphosphoric Acid Solution (0.005 M EDTA)
Without heating 60 g of reagent grade HPO₃ pellets and 1.8 g disodium ethylenediaminetetraacetate were dissolved in 900 ml of distilled water. It was then diluted to 1 liter and filtered through 2 fluted filter paper. It was stored in the refrigerator. A fresh solution was prepared weekly.

3 percent Metaphosphoric Acid Solution (0.0025 M EDTA)
Five hundred milliliters of the above 6 percent solution was diluted to 1 liter with distilled water.

0.025 percent 2,6-Dichlorophenolindophenol Solution
Approximately 62.5 mg of the sodium salt of 2,6-dichlorophenolindophenol was dissolved in approximately 187.5 ml of hot distilled water containing 52.5 mg NaHCO₃. After cooling it was diluted with water to 250 ml. It was placed in a brown bottle and refrigerated. A fresh solution was prepared weekly.

Ascorbic Acid Standard
One hundred milligrams of ascorbic acid was dissolved in the 3 percent
HPO$_3$ solution and diluted to 500 ml with the same solvent. Since this solution is unstable it was prepared fresh for use.

Caprylic Alcohol

Chemical reagents used for chlorophyll determinations are as follows:

Acetone

80 percent Acetone

Eight hundred milliliters of acetone were diluted to 1 liter with distilled water.

Diatomaceous earth
APPENDIX 3

COOKING APPARATUS AND EQUIPMENT

Stainless steel saucepans, 8" wide and 4" deep
Stainless steel steamers which fit inside the saucepans
Glass casserole dishes, 1 1/2- and 2 1/2-qt sizes
Common steel alloy wok, 14" wide and 4 1/2" deep at center, purchased from a Los Angeles Chinese grocery store
Colander
Miscellaneous stainless steel utensils
Electric and gas ranges
Tappan electronic range, Model R-4A
Refrigerator
Drying oven
Beckman Model B spectrophotometer
Balances and weighing pans
Waring blender and transformer
Glass burets and stands
Miscellaneous laboratory glassware
Filter paper, Whatman #1, 2v, 31 and 42
Aluminum dishes with lids ≥ 50 ml in diameter and ≤ 1 ml deep
Dessicator
APPENDIX 4

PROCEDURE FOR ASCORBIC ACID DETERMINATION

The procedure used for the ascorbic acid analysis is as follows:

a. The vegetable sample was cooked according to the specific method. After cooking it was refrigerated for 10 minutes.

b. Two hundred grams of the cooled sample was blended with 200 ml of 6 percent HPO₃ on high speed. Since the spinach samples were bulky a small amount was put in the blender at first. The rest was added slowly. All of the 200 g were in the blender within the first 2 minutes.

c. Ten grams of this slurry was transferred to a 100-ml volumetric flask and diluted to volume with 3 percent HPO₃. One drop of caprylic alcohol was added to reduce foam.

d. The diluted sample was filtered through Whatman #31 fluted filter paper. The first few milliliters of filtrate was discarded. The filtration was completed in the refrigerator.

e. A ten-ml aliquot of the filtrate was pipetted into a 125-ml Erlenmeyer flask. Three aliquots were used.

f. The aliquots were titrated immediately with 2,6-dichlorophenolindophenol to a faint pink end point which persisted for 15 seconds.

g. Three blanks containing 10 ml of 3 percent HPO₃ each were also run.
It was necessary to standardize the 2,6-dichlorophenolindo-
phenol daily. This was done as follows:
a. Three 5-ml aliquots of the standard ascorbic acid solution (each
containing 1 mg ascorbic acid) were diluted with 5 ml of 3 percent
\( \text{HPO}_3 \).
b. The aliquots were titrated with the dye solution to a pink color
which persisted for 15 seconds.
The volume of dye needed represented 1 mg of ascorbic acid. Thus, the
ascorbic acid equivalent of 1 ml of dye solution was equal to 1 divided
by the volume in milliliters of the dye solution used in the titration.
APPENDIX 5

PROCEDURE FOR CHLOROPHYLL DETERMINATION

The procedure used in the chlorophyll analysis is as follows:

a. The sample, weighing 70 g, was placed in a blender with enough acetone to produce an 80 percent acetone solution considering the moisture content of the particular vegetable.

b. The sample was blended for 3 minutes.

c. The sides of the blender cup were scraped and this residue was added back to the liquid. Three grams of diatomaceous earth was added to aid in filtering.

d. The sample was filtered through a fine-fritted glass filter with light suction using Whatman #1 filter paper.

e. The blender cup was rinsed with 80 percent acetone and added to the residue and run through the filter.

f. The filter residue was rinsed with approximately 25 ml of 80 percent acetone.

g. The filtrate was placed in a volumetric flask and brought to volume. A 500-ml flask was used for the green beans and broccoli filtrates while a 1-liter flask was used for the spinach filtrate. It was necessary to dilute the spinach sample to get an accurate reading on the spectrophotometer.
h. The filtrate was further filtered through Whatman #42 fluted filter paper for clarity.

i. Three milliliters of 80 percent acetone was added to a 100-ml volumetric flask. This was diluted to volume with the filtered extract.

j. The sample was stoppered and stored in the dark at room temperature for 3 hours.

k. The absorbancy was then read at 536, 558, and 700 nm on a Beckman Model B Spectrophotometer. Readings at 700 nm were used to check for clarity of samples. A blank containing 80 percent acetone was used.

l. Percentage of total chlorophyll retention was determined using the following equation:

\[
\frac{2.10 - \frac{A_{536}}{A_{558}}}{1.26} \times 100
\]
APPENDIX 6

FORMS USED IN SENSORY EVALUATION
Sample A
SENSORY EVALUATION

Name: __________________________
Date: __________________________
Product: ________________________

Please rank these samples for texture, color, flavor and overall acceptance according to your preference.

1 = most acceptable to you
4 = least acceptable to you

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Thank you for participating.
Sample B
SENSEORY EVALUATION

Name: _______________________
Date: _______________________
Product: ____________________

Please rank these samples for texture, color, flavor and overall acceptance according to your preference.

1 = most acceptable to you
5 = least acceptable to you

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Thank you for participating.