## HORANG PENGESAHAN STATUS TESIS

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<thead>
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<th>JUDUL: Determination of Vitamin C (ascorbic acid) Content in Vitamin C supplements by redox titration</th>
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<tr>
<td>Ijazah: Bachelor of Science (Hons) - Industrial Chemistry</td>
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DETERMINATION OF VITAMIN C (ASCORBIC ACID) CONTENT IN VITAMIN C SUPPLEMENTS BY REDOX TITRATION

PIRADEEPA JEYARAJU

DESSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE WITH HONOURS

INDUSTRIAL CHEMISTRY PROGRAMME
SCHOOL OF SCIENCE AND TECHNOLOGY
UNIVERSITY MALAYSIA SABAH

APRIL, 2007
DECLARATION

I hereby declare that this dissertation is based on my original work, except for quotations and summaries each of which have been fully acknowledged.

PIRADEEPA JEYARAJU
HS2004-2293

APRIL, 2007
NAME: Piradeepa Jeyaraju

TITLE: Determination of Vitamin C (ascorbic acid) Content in Vitamin C Supplements by Redox Titration

APRIL, 2007
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Thank you.
ABSTRACT

Two redox titration methods namely, iodometric titration and DCP/DCPIP titration, were used for the analysis of vitamin C in three brands of vitamin C supplements, namely Flavettes, Redoxon and Ceelin. The results showed that the vitamin C content of Flavettes, Redoxon and Ceelin brands was 493.3±6.7 mg/tablet, 992.1±7.9 mg/tablet and 99.8±0.2 mg/5 mL syrup, respectively according to iodometric analysis and 495.6±4.4 mg/tablet, 945.8±54.2 mg/tablet and 96.8±3.2 mg/5 mL syrup, respectively for DCP/DCPIP analysis. The values are in good agreement (% relative error <5%) to the reported values, which are 500 mg/tablet, 1000 mg/tablet and 100 mg/5 mL syrup respectively.
PENENTUAN KANDUNGAN VITAMIN C (ASID ASKORBIK) DI DALAM TABLET VITAMIN C MELALUI TITRATAN REDOKS

ABSTRAK

Dua kaedah titratan redoks, iaitu, kaedah iodometric dan kaedah DCP/DCPIP telah digunakan dalam analisis kandungan vitamin C dalam tiga produk vitamin C. Hasil kajian menunjukkan kandungan vitamin C dalam jenama Flavettes, Redoxon dan Ceelin adalah masing-masing 493.3±6.7 mg/pil, 992.1±7.9 mg/pil dan 99.8±0.2 mg/5 mL sirap bagi analisis titratan iodometric dan masing-masing 495.6±4.4 mg/pil, 945.8±54.2 mg/pil dan 96.8±3.2 mg/5 mL sirap bagi analisis titratan DCP/DCPIP. Nilai yang diperolehi adalah hampir sama (% ralat relatif <5%) dengan nilai yang dilaporkan iaitu masing-masing 500 mg/pil, 1000 mg/pil dan 100 mg/5 mL sirap.
CONTENTS

COVER PAGE i
DECLARATION ii
VERIFICATION iii
ACKNOWLEDGEMENT iv
ABSTRACT v
ABSTRAK vi
CONTENTS vii
LIST OF TABLES x
LIST OF FIGURES xi
LIST OF SYMBOLS AND ABBREVIATIONS xii

CHAPTER 1 INTRODUCTION 1
1.1 Context and Relevance of Study 1
1.2 Objectives 3
1.3 Scope of Study 3

CHAPTER 2 LITERATURE REVIEW 4
2.1 Vitamins 4
2.2 Vitamin C 6
   2.2.1 Characteristic of Vitamin C 7
   2.2.2 Importance of Vitamin C 9
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2.2.1 Antioxidant</td>
<td>10</td>
</tr>
<tr>
<td>2.2.2.2 Collagen Formation</td>
<td>10</td>
</tr>
<tr>
<td>2.2.2.3 Common Cold and Vitamin C</td>
<td>11</td>
</tr>
<tr>
<td>2.2.2.4 Diabetes and Vitamin C</td>
<td>11</td>
</tr>
<tr>
<td>2.2.2.5 Cancer and Vitamin C</td>
<td>12</td>
</tr>
<tr>
<td>2.2.2.6 Other Functions</td>
<td>13</td>
</tr>
<tr>
<td>2.2.3 Content of Vitamin C in Foods</td>
<td>14</td>
</tr>
<tr>
<td>2.2.4 Chemical Reactions of Vitamin C</td>
<td>15</td>
</tr>
<tr>
<td>2.3 Dietary Intakes and Dosage</td>
<td>16</td>
</tr>
<tr>
<td>2.4 Vitamin C Supplements</td>
<td>18</td>
</tr>
<tr>
<td>2.5 Analysis of Vitamin C</td>
<td>19</td>
</tr>
<tr>
<td>2.6 Redox Titration</td>
<td>20</td>
</tr>
<tr>
<td>2.6.1 Iodometric Analysis</td>
<td>20</td>
</tr>
<tr>
<td>2.6.2 DCP/DCPIP Analysis</td>
<td>21</td>
</tr>
<tr>
<td><strong>CHAPTER 3 METHODOLOGY</strong></td>
<td>22</td>
</tr>
<tr>
<td>3.1 Vitamin C Samples</td>
<td>22</td>
</tr>
<tr>
<td>3.2 Iodometric Analysis</td>
<td>23</td>
</tr>
<tr>
<td>3.2.1 Preparation of Sodium Thiosulfate Solution</td>
<td>23</td>
</tr>
<tr>
<td>3.2.2 Preparation of 0.01 M of Potassium Iodate Solution</td>
<td>24</td>
</tr>
<tr>
<td>3.2.3 Preparation of Starch Solution</td>
<td>24</td>
</tr>
<tr>
<td>3.2.4 Preparation of 0.5 M Sulfuric Acid Solution</td>
<td>24</td>
</tr>
<tr>
<td>3.2.5 Standardization of Sodium Thiosulfate Solution</td>
<td>25</td>
</tr>
<tr>
<td>3.2.6 Preparation of Vitamin C Solution</td>
<td>26</td>
</tr>
<tr>
<td>3.2.7 Analysis of vitamin C</td>
<td>26</td>
</tr>
</tbody>
</table>
3.3 DCP/DCPIP Analysis

3.3.1 Preparation of the 2,6-Dichlorophenolindophenol Solution

3.3.2 Preparation of Standard Ascorbic Acid Solution

3.3.3 Standardization of the 2,6-Dichlorophenolindophenol Solution

3.3.4 Preparation of Vitamin C Solution

3.3.5 Determination of Vitamin C in Samples

3.3.5.1 Calculation of Vitamin C Content

CHAPTER 4 RESULT AND DISCUSSION

4.1 Iodometric Analysis of Vitamin C

4.2 DCP/DCPIP Analysis of Vitamin C

4.3 Standardization of Sodium Thiosulfate

4.4 Vitamin C Content According To Iodometric Method

4.5 Vitamin C Content According to DCP/DCPIP Method

4.6 Comparison Between Iodometric and DCP/DCPIP Analysis

CHAPTER 5 CONCLUSION

REFERENCES

APPENDIX
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table 2.1</th>
<th>Fat Soluble Vitamins and Its Importance</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2.2</td>
<td>Water Soluble Vitamins and Its Importance</td>
<td>6</td>
</tr>
<tr>
<td>Table 2.3</td>
<td>Food Sources and Its Vitamin C Content</td>
<td>14</td>
</tr>
<tr>
<td>Table 2.4</td>
<td>Examples of Vitamin C Supplements Sold in Malaysian Pharmacies</td>
<td>18</td>
</tr>
<tr>
<td>Table 3.1</td>
<td>Samples of Vitamin C Supplements</td>
<td>22</td>
</tr>
<tr>
<td>Table 4.1</td>
<td>Vitamin C Contents in Samples</td>
<td>60</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

| Figure 2.1 | L-ascorbic Acid | 8 |
| Figure 2.2 | L-dehydroascorbic Acid | 8 |
| Figure 3.1 | Iodometric Titration Set Up | 23 |
| Figure 3.2 | DCP/DCPIP Titration Set Up | 28 |
| Figure 4.1 | Color of Solution Prior to Titration | 33 |
| Figure 4.2 | Color of the Solution after Addition of Sulfuric Acid | 33 |
| Figure 4.3 | Color of the Solution after Titrating with Sodium Thiosulfate | 33 |
| Figure 4.4 | Color of the solution when Starch Added | 34 |
| Figure 4.5 | Color of the solution at the Endpoint | 34 |
| Figure 4.6 | Blue colored DCPIP solution | 35 |
| Figure 4.7 | Color of Solution after Titration with DCPIP | 35 |
| Figure 4.8 | The colorless DCPIPH₂ Solution at Endpoint | 35 |
| Figure 4.9 | Color of the Solution at Endpoint | 36 |
| Figure 4.10 | Content of Vitamin C in Selected Vitamin C Supplements Brands via Iodometric Analysis | 37 |
| Figure 4.11 | Content of Vitamin C in Selected Vitamin C Supplements Brands via DCP/DCPIP Analysis | 38 |
| Figure 4.12 | Contents of Vitamin C in Three Different Samples | 38 |
LIST OF SYMBOLS AND ABBREVIATIONS

CV  Coefficient of Variation
DCP  Dichlorophenol
DCPIP  2,6-dichlorophenolindophenol
DRI  Dietary Reference Intake
d  Standard Deviation from the Mean
E_r  Percentage of Relative Error
M  Molarity/concentration
RDA  Recommended Dietary Allowance
SD  Standard Deviation
UL  Tolerable Upper Intake Levels
V  Volume
molL^{-1}  mol per liter
x_i  Volume of titrant
\mu  Average volume of titrant
N  Amount of replicate
s  Sample standard deviation
x  Reported value of sample
CHAPTER 1

INTRODUCTION

1.1 Context and Relevance of Study

Vitamins comprises of diverse group of organic compounds that are nutritionally essential micronutrients in human health. The term vitamin is actually derived from the word ‘vital’ and ‘amine’, because vitamins are required for life and were originally taught to be amines. Vitamins can be considered minor but necessary constituents of food than the essential amino acids (Campbell et al., 2003). They are required for normal growth, protection and functioning of our body. A deficiency of vitamins can result in hypovitaminosis and if more severe, in avitaminos. It happens because of insufficient supply of vitamin containing foods, disturbance in resorption, stress and diseases (Belitz & Grosch, 1999; Shils et al., 1999).

Most vitamins serves as coenzymes or part of coenzymes, they have catalytic functions and are used over and over in metabolic reactions. There are 13 vital vitamins in human diets, which can be divided into two states, that is, water-soluble, which comprises vitamin B1 (thiamine), vitamin B2 (riboflavin), niacin, vitamin B6 (pyridoxine), panthothenic acid, folic acid (folsac), vitamin B12, biotin and vitamin
C (ascorbic acid) and fat-soluble, that is vitamin A, vitamin D, vitamin E and vitamin K (Campbell et al., 2003).

Human body needs the vitamins that have been mentioned earlier in certain doses. So, we need to consume foods that contain vitamins which the body needs. But nowadays, people prefer to take vitamins as supplements. These supplements are now manufactured in various brands and compositions according to peoples need (i.e. 500 mg/tablet, 250 mg/tablet, 100 mg/tablet and so on). Specifically, vitamin C supplements are one of the most famous and profitable product these days. Vitamin C supplements can be consumed in few ways such as, liquids, powders, tablets or chewable tablets in daily basis (Boyle & Anderson, 2004).

Apart from the other vitamins that have been mentioned, vitamin C or ascorbic acid is the most wanted vitamin in human body. Vitamin C is a water-soluble vitamin which is essential for normal functioning of the body. Unlike most mammals, human do not have the ability to make their own vitamin C. We must therefore obtain vitamin C through our diet. Ideally one would take the natural form of vitamin C which is in vegetables and fruits. Vitamin C present in many fruits and vegetables, the best source being broccoli, cabbages, sweet pepper, parsley, papaya, oranges, kiwi fruit and so on (Bushway et al., 1989).

The content of vitamin C can be determined in foods, may it be vegetables or fruits, and other products in a number of ways. The methods include redox titration (Shils et al., 1999), high performance liquid chromatography or HPLC technique (Shakya et al., 2006), voltametric analysis (Shakya et al., 2006), potentiometric
analysis, acid-base titration (Lenghor *et al.*, 2002), capillary electropherosis (Versari *et al.*, 2004), colorimetric method (McGown *et al.*, 1982), dinitrophenylhydrazine method (McGown *et al.*, 1982), spectrophotometric (Shils *et al.*, 1999), and lastly florometric method (Shils *et al.*, 1999). Comparatively, redox titration is the most common and preferred classical technique for vitamin C analysis. This technique includes the iodometric and DCP/DCPIP methods (Silva *et al.*, 1999).

1.2 Objectives

The objectives of this study are:

a) To determine the vitamin C (ascorbic acid) content of selected vitamin C supplements using iodometric method.

b) To determine the vitamin C (ascorbic acid) content of selected vitamin C supplements using DCP/DCPIP method.

c) To compare the results obtained for DCP/DCPIP method and iodometric method.

d) To compare the results obtained with the reported values.

1.3 Scope of Study

In this study, the vitamin C content of selected vitamin C supplements will be determined using redox titration methods, namely the iodometric method and DCP/DCPIP method. The value obtained will be compared with each other as well as with the reported values.
2.1 Vitamins

About a century ago, scientists ushered in a new era in the science of nutrition: the discovery of vitamins. They quickly realized that these substances which are found in minute amount in food were just as important to health as fats, carbohydrates, and proteins. A diet lacking in one could cause barrage of symptoms and ultimately, death (Belitz & Grosch, 1999; Shils et al., 1999). Vitamins are powerful, indispensable compound that perform various bodily functions that promote growth, reproduction and maintain health. They are organic compounds, meaning that they contain or are related to carbon compounds. Contrary to popular belief, vitamins do not supply calories or energy (Boyle & Anderson, 2004).

Tropical greenies especially fruits are a major food source that supply vitamins and minerals to our body (Guerrero et al., 1998). Human body conducts the routine activities in it and protects from diseases via vitamins and minerals since this nutrients have a specified functions towards protecting our body (Hardisson et al., 2001; Whitney & Rolffes, 2005; Grosvenor & Smolin, 2006).
To date, scientists have identified 13 vitamins, each with its own special roles to play. There are 9 water soluble vitamins: 8 B vitamins and vitamin C. These water soluble vitamins can be found in the watery compartments of foods and travels freely in blood. In contrast, the 4 fat soluble vitamins: A, D, E and K are generally found in the fats and oils of foods (Whitney & Rollfes, 2005). Since they are stored in the liver and in body fat, it is possible for mega doses of the fat-soluble vitamins to build up the toxic levels in the body and cause undesirable side effects (Boyle & Anderson, 2004). Table 2.1 and Table 2.2 show the fat soluble and water soluble vitamins and their sources, roles and deficiency symptoms respectively.

Table 2.1 Fat Soluble Vitamins and Its Importance

<table>
<thead>
<tr>
<th>Fat Soluble Vitamins</th>
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<tr>
<td><strong>Vitamins</strong> (chemical name)</td>
</tr>
<tr>
<td>Vitamin A</td>
</tr>
<tr>
<td>Vitamin D (cholecalciferol)</td>
</tr>
<tr>
<td>Vitamin E</td>
</tr>
<tr>
<td>Vitamin K</td>
</tr>
</tbody>
</table>

(Sources: Shils et al., 1999; Campbell et al., 2003; Boyle & Anderson, 2004)
<table>
<thead>
<tr>
<th>Vitamins (chemical name)</th>
<th>Sources</th>
<th>Chief Roles</th>
<th>Deficiency Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamine</td>
<td>Meat, pork, liver, fish, poultry, whole-grain and enriched cereals and grain products, nuts and legumes</td>
<td>Helps enzymes release energy from carbohydrates ; supports normal appetite and nervous system function</td>
<td>Beriberi : edema, heart irregularity, mental confusion, muscle weakness, apathy, impaired growth</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>Milk, leafy green vegetables, yogurt, cottage cheese, liver, meat, whole-grain or enriched breads, cereals and grain products</td>
<td>Helps enzymes release energy from carbohydrates, fat and proteins ; promote healthy skin and normal vision</td>
<td>Eye problems, skin disorders around nose and mouth, magenta tongue, hypersensitivity to light</td>
</tr>
<tr>
<td>Niacin</td>
<td>Meat, egg, poultry, fish, whole-grain and enriched breads, cereals and grain products, nuts, legumes, peanuts</td>
<td>Helps enzymes release energy from energy nutrients ; promotes health of skin, nerves, and digestive system</td>
<td>Pellagra : flaky skin rash on parts exposed to sun, loss of appetite, dizziness, weakness, irritability, fatigue, mental confusion, indigestion, delirium</td>
</tr>
<tr>
<td>Vitamin B₆ (pyridoxine)</td>
<td>Meat, egg, poultry, fish, legumes, fruits, soy products, whole-grains products, green leafy vegetables</td>
<td>Protein and fat metabolism ; formation of antibodies and blood cells ; helps convert tryptophan to niacin</td>
<td>Nervous disorders, skin rash, muscle weakness, anemia, convulsions, kidney stones</td>
</tr>
<tr>
<td>Folate (folacin, folic acid)</td>
<td>Green leafy vegetables, legumes, seeds, citrus fruits, melons, enriched breads and grains products</td>
<td>Red blood cell formation ; protein metabolism ; new cell division</td>
<td>Anemia, heartburn, diarrhea, smooth red tongue, depression, poor growth, neural tube defects, increased risk of heart disease, stroke and certain cancers</td>
</tr>
<tr>
<td>Vitamin B₁₂ (cobalamin)</td>
<td>Animal products, meats, fish, poultry, shellfish, milk, cheese eggs, fortified cereals</td>
<td>Help maintain nerve cells; red blood cell formation, synthesis of genetic materials</td>
<td>Anemia, smooth red tongue, fatigue, nerve degradation progressing to paralysis</td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>Widespread in foods</td>
<td>Coenzyme in energy metabolism</td>
<td>Rare ; sleep disturbances, nausea, fatigue</td>
</tr>
<tr>
<td>Biotin</td>
<td>Widespread in foods</td>
<td>Coenzyme in energy metabolism ; fat synthesis ; glycogen formation</td>
<td>Loss of appetite, nausea, depression, muscle pain, weakness, fatigue, rash</td>
</tr>
<tr>
<td>Vitamin C (ascorbic acid)</td>
<td>Citrus fruits, cabbage-types vegetables, tomatoes, potatoes, dark green vegetables, peppers, lettuce, cantaloupe, strawberries, mangoes, papaya</td>
<td>Synthesis of collagen(help heal wounds, maintain bone and teeth, strengthens blood vessel walls) ; antioxidant, strengthens resistance to infections ; helps body absorb iron</td>
<td>Scurvy : anemia depression, frequent infections, bleeding gums, loosened teeth, pinpoint hemorrhages, muscle degeneration, rough skin, bone fragility, poor wound healing, hysteria</td>
</tr>
</tbody>
</table>

(Sources: Shils et al., 1999; Campbell et al., 2003; Boyle & Anderson, 2004)

## 2.2 Vitamin C

Vitamin C is “the most famous of vitamins” and it is the first one school children learn. Most people can rhyme off at least a few foods that contain vitamin C.
Examples of vitamin C sources include oranges, pineapple, banana, grapes, kiwi, parsley, passion fruit, cabbages, cauliflowers, broccoli, papaya, mango, guava, lemon, sweet pepper and so on (Suntornsub et al., 2002; Hernández et al., 2006). In 1930s, Albert Szent-Gyorgyi was awarded the Nobel Prize for his discovery and isolation of ascorbic acid when the nutrient was in demand for the prevention and treatment of scurvy (Richards, 1991). Humans and other primates, guinea pigs, an Indian fruit-eating bat, and the red-vented barbul and some related species of Passeriformes birds unable to synthesis the ascorbate (Davey et al., 2000; Gropper, 2002). An accurate and specific determination of vitamin C content of fruits and vegetables are extremely important to understand the relationship of dietary intake and human health (Lee & Kader, 2000).

### 2.2.1 Characteristics of Vitamin C

Vitamin C (L-3-keto-threo-hexuronic-asid-γ-lactone) also famously known as ascorbic acid, is a white, crystalline solid with melting point of 192°C and molecular formula of C₆H₈O₆. It is soluble in water, moderately soluble in alcohol, and insoluble in ether, chloroform, benzene, xylene and petroleum ether (Shils et al., 1999). In aqueous solution, ascorbic acid behaves as a monobasic acid, forming salts containing monovalent metal atom or equivalent. Its main chemical property is that it oxidizes extremely easily in solution, thus reducing anything that can accept electrons (Richards, 1991; Gropper, 2002).

Vitamin C is hexose derivative, similar in structure to the six-carbon sugar glucose that is acidic and its reducing properties are contributed by the 2, 3-enediol
moiety. This compound is highly polar, thus, it is readily soluble in aqueous and insoluble in less polar solvent (Fennema, 1996). Acidic character of this compound is a result of ionization where the molecular structure contains two ionizable enolic hydrogen atoms ($pK_{a2}$ at carbon-3 = 4.17; $pK_{a2}$ at carbon-2 = 11.57) (Shils et al., 1999). Two-electron oxidation and hydrogen dissociation converts L-ascorbic acid (Figure 1.1) to L-dehydroascorbic acid (Figure 1.2) (Fennema, 1996; Metzler, 2003). L-isoascorbic acid, the C-5 optical isomer and the D-ascorbic acid, the C-4 optical isomer, behave in a chemical similar manner to L-ascorbic acid but these compounds have essentially no vitamin C activities. L-isoascorbic acid and L-ascorbic are widely use as food ingredients for their reducing and antioxidative activity (e.g. in the curing of meats and for inhibiting enzymatic browning in fruits and vegetables) but D-ascorbic acid has no nutritional value (Fennema, 1996).

In addition to being known as ascorbic acid and L- ascorbic acid, vitamin C is also known as 2, 3-didehydro-L-threo-hexano-1, 4-lactone, 3-oxo-L-
gulofuranolactone, L-threo-hex-2-enonic acid gamma-lactone, L-3-keto-threo-hexuronic acid lactone, L-xylo-ascorbic acid and antiscorbutic vitamin (Shils et al., 1999). All vitamin C requiring animals lack the enzyme L-gulano-gamma-lactone oxidase, the final step in the synthesis of ascorbic acid from glucose that is why they can not produce ascorbic acid by themselves (Wilson et al., 1979).

In human’s body vitamin C is absorbed from the intestine by energy-depending active transport; it is found primarily in the adrenal and pituitary glands with small amounts distributed among other organs. Vitamin C and its metabolites (e.g. diketogulonic acid, oxalic acid and ascorbate 2-sulfate) will be exerted primarily in the urine (Shils et al., 1999; Gropper, 2002). Vitamin C is also weak acid which also has metal complexing properties (Metzler, 2003). When dry, vitamin C crystals will undergo inactivation when exposed to air, heat, light or metals such as copper and iron. The vitamin is unstable in alkali medium but relatively stable in an acid one (Wilson et al., 1979).

### 2.2.2 Importance of Vitamin C

The functions of ascorbic acid or vitamin C are based primarily on its properties as a reversible biologic reductant. As such, it provides reducing equivalents for a variety of biochemical reactions, is essential as a cofactor for reactions requiring a reduced metal ions (Fe$^{2+}$ and Cu$^+$), and serves as a protective antioxidant that operates in the aqueous phase and can be regenerated in vivo when oxidized. Few of the roles of ascorbic acid have been established on a definitive molecular basis (Shils et al., 1999).
2.2.2.1 Antioxidant

A major role of vitamin C is its function as antioxidant, which is important in food additive. This happens when vitamin C oxidizes itself and then regenerates already-oxidized substances such as iron and copper to their original form. In this process, the damaging oxidizing agent is removed. Oxidation of iron in the intestine is protected by vitamin C (Kirschmann & Kirschmann, 1996).

Adults with Graves’ disease (increased thyroid function) who take antioxidants (vitamins C) in addition to prescription medication may help normalized thyroid function faster than with medication alone (Ingels, 2004). Macular degeneration is a disease caused by progressive deterioration of the central part of the retina (the surface of the back of the eye) known as the macula. A number of studies have found that antioxidants supplements can prevent and slow the progression of macular degeneration (Williams, 2006). Chemically, the high level of ascorbic acid in the eyes provides antioxidant protection against photolytically generated free radicals in various ocular fluids and tissues, including lens, cornea, vitreous humor and retina (Shills et al., 1999).

2.2.2.2 Collagen Formation

Another primarily functions of vitamin C is maintaining collagen, a protein necessary for the formation of connective tissues in skin, ligaments and bones. Collagen in one of the most abundant proteins in the body and it is the foundation of bones, cartilage and connective tissues. Collagen contains the usual amino acids like other proteins
and is synthesized like other proteins, except vitamin C is necessary for two chemical steps on its formation (Wilson et al., 1979; Shils et al., 1999; Boyle & Anderson, 2004).

Vitamin C aids in the addition of an –OH group (hydroxylation) to the amino acids praline and lysine to form hydroxyproline and hydroxylysine. When vitamin C is missing, an under hydroxylated form of collagen is produced that has abnormal physical properties. This finding could be explained by the unsatisfactory wound healing (Wilson et al., 1979; Shils et al., 1999). Cells in the arterial walls need collagen to help them expand and contract with the beats of the heart (Wilson et al., 1979; Shils et al., 1999).

2.2.2.3 Common Cold and Vitamin C

Supplementing with vitamin C may decrease the frequency of the common cold, but does not appear to affect the duration or severity of the infection. Vitamin C is necessary for proper immune function (Beauchamp, 2005). Any effect of ascorbic acid in preventing colds may be a result of increased hydroxylation of procollagen secretion (Metzler, 2003).

2.2.2.4 Diabetes and Vitamin C

Supplementing with vitamin C may help prevent some of the complications of diabetes by lowering blood pressure and reducing the stiffness of arteries. Diabetics have higher requirements for vitamin C than healthy people. Vitamin C, which has a
REFERENCES


Anastos, N., Barnett, N. W., Hindson, B. J., Lenehan, C. E. and Lewis, S. W., 2004. Comparison of soluble Manganese (IV) and acidic potassium permanganate chemiluminescence detection using flow injection and sequential injection analysis for the determination of ascorbic acid in vitamin C tablets. Talanta 64(1), 130-134.


vitamin C content in fruits, vegetables and fruit juices. *European Food Research and Technology* 217, 269-273.


