INTERNATIONAL BACCALAUREATE

Chemistry Extended Essay

Ascorbic Acid Levels in Vitamin Pills

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D1129-039

Session: May 2010

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Word Count: 3303

TED Ankara Collage Foundation High School, 2010

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ABSTRACT

Although it is generally accepted that a balanced diet without supplementation contains enough vitamin C, it is still the most widely taken nutritional supplement world-wide. The present study aims to answer the question *"Does the amount of Vitamin-C is equal to the level shown on the box?"*

After a brief research I found that there were nineteen different tablets containing vitamin C in Vademecum (which is the Turkish National Formulary of drugs), and only two of them were in the form of pure Vitamin C tablets made by *Roche* and *Polifarma* in Turkey. On the other hand I was able to find Vitamin C tablets in over ten different brand names over-the-counter which were all being sold without a prescription, six of them were randomly selected for evaluation. Six different brand name of vitamin C sold as *over-the-counter* and two sold in pharmacy with prescription were analyzed using iodometric titration method based on an oxidation-reduction reaction between vitamin C and iodine. Results were compared to the amounts shown on the box and deviation was shown as mg and percentage.

Vitamin C from *Healthy America, Natural Wealth, Walgreens and CVS* were found to include less than the amount shown on the box. Remaining four, including *GNC* and *Mason Nature*, over-the counter pills, and *Polifarma C* and *Roche Redoxan,* pills with prescription, were found to include more than the amounts shown on the box. The most reliable pills were from *GNC* and *Polifarma* respectively. The deviation was most in pills from *Natural Wealth* which was followed by *Healthy America* and *CVS* respectively.

The content of vitamin C in the tablets was found to be different than the manufacturer's specification in the prospectus with the mean deviation of 3.7%.Vitamin C from *GNC* and *Polifarma* with the deviation of 0.5% were most reliable ones.

Keywords: Vitamin C, ascorbic acid, iodometric titration, tablets

Word count: 300 words

Research Question: *"Does the amount of Vitamin-C is equal to the level shown on the box?"*

INTRODUCTION

Vitamin C or ascorbic acid is essential for human life and is required for a range of physiological functions in human body. It can be found either in fresh fruits and vegetables naturally or in medical forms such as normal tablets, effervescent tablets and liquid vials. It is the most widely taken supplement. Though daily requirements of vitamin C are changeable according to the age, sex and conditions, it is around 75 to 90 mg per day for healthy adults and no more than 2000mg per day is recommended[1]. Other related species for which the vitamin C is also essential, consume around 60 times more than daily amount for healty adults[2]. There is continuing debate over the best dose schedule of vitamin C (the amount and frequency of intake) for maintaining optimal health in humans. It is known that Mediterranean diet contains enough vitamin C without supplementation for an average healthy adult, while those who are pregnant, smoker, have some stress and/or diseases require slightly more[1]. If it is consumed more than its required it may cause some side effects including nausea, vomiting, diarrhea etc.[3,4].

Medical forms can either be in pure vitamin C form or in part of multivitamin complexes. Instead of pure vitamin C forms, tablets are coming out as multivitamin complexes due to some commercial benefits at most. After a brief research I found that there were nineteen different tablets containing vitamin C in Vademecum (which is the Turkish National Formulary

[1] Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids: consensus report. Institute of Medicine of the National Academies. (www.iom.edu. Retrieved: 30th November 2009)

[2] Milton K. Micronutrient intakes of wild primates: are humans different?" *Comp Biochem Physiol a Mol Integr Physiol* 2003; **136(1)**: 47–59.

[3] Levine M, Conry-Cantilena C, Wang Y, et al. Vitamin C pharmacokinetics in healthy volunteers: Evidence for a recommended dietary allowance. *Proc Natl Acad Sci USA* 1996; **93**: 3704–3709

[4] Pauling L. Evolution and the need for ascorbic acid. *Proc Natl Acad Sci USA* 1970; **67(4)**: 1643–1648

of drugs), and only two of them were in the form of pure Vitamin C tablets made by *Roche* and *Polifarma* in Turkey[5]. On the other hand I was able to find Vitamin C tablets in over ten different brand names in the market which were all being sold as *over-the-counter* medication without a prescription. As most people buy the vitamins from the pharmacy without a prescription, I decided to ask the question whether the tablets include the equal amount of vitamin C shown on the box. In order to find the answer, the amount of vitamin C was evaluated in both tablets sold with or without prescription using iodometric titration method. In this method the reaction between iodine and starch suspension, will indicate the endpoint by producing the blue-black product. The triiodide ions are quickly converted into iodide ions when ascorbic acid is present. However when all of the ascorbic acid is oxidized, the excess iodide will react with starch and will cause the blue-black color.

The Chemistry of Vitamin C

Vitamin C or with its well known name, ascorbic acid might be found in the fruits and vegetables naturally. It is quite sensitive to the light, to heating, and to the action of some oxidizing agents. Therefore it is oxidized quickly in aqueous solutions by reacting with atmospheric oxygen[6].

[5]Ommaty R. Vademecum-Modern İlaç Rehberi. Medical Tribune Yayıncılık, 32nd Editions, Istanbul- 2009
[6]Chemical and Biological Properties of Vitamin C.<http://www.netsci-journal.com/97v4/97014/ vitc2.html > retrieved: 19 November 2009

Ascorbic acid is formulated as $C_6H_8O_6$ and illustrated as:

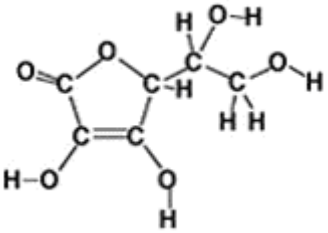


Figure 1: The ascorbic acid, $C_6H_8O_6$ [7]

Ascorbic acid is a water soluble vitamin with molecular weight of 176.12 g/mol and melting point of 193˚C. World-wide accepted daily requirement of ascorbic acid is about 60–95 mg[1]. The organic name for ascorbic acid is 2-oxo-L-threo-hexono-1,4-lactone-2,3-enediol[8]. The last outstanding property of ascorbic acid seems to be its antioxidant characteristic. Ascorbic acid is a reducing agent which reverses the oxidation in aqueous solution. Increased amounts of free radicals triggers the condition called oxidative stress which is kept under control by antioxidants. If there is not enough antioxidants some stress related diseases including hypertension, atherosclerosis, chronic inflammatory diseases and diabetes might occur. Therefore daily supplement of ascorbic acid is very important for disease prevention and even for the treatment.

[7] <http://www.chemistry.wustl.edu/~edudev/LabTutorials/Vitamins/images/Ascorbate.jpg> retrieved: 19 November 2009

[1] Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids: consensus report. Institute of Medicine of the National Academies. (www.iom.edu. Retrieved: 30th November 2009)

[8] Ascorbic Acid, Wikipedia <http://en.wikipedia.org/wiki/Ascorbic_acid> retrieved: 19 November 2009

METHODS

Research Question: *"Does the amount of Vitamin-C is equal to the level shown on the box?"*

Equipment and Supplies

Beaker 50.00 ml (± 0.01 ml), 100.00 ml (± 0.01 ml) and 500.00 ml (± 0.01 ml)

Graduated cylinder 50.00 ml (± 0.01 ml), 100.00 ml (± 0.01 ml) and 500.00 ml (± 0.01 ml)

Volumetric flask 250.00 ml (± 0.01 ml)

Erlenmeyer flask 25.00 ml (± 0.01 ml), 50 ml (± 0.01 ml)

Burette 50.00 ml (± 0.01 ml)

Potassium iodide (KI) 20.00g (± 0.001 g)

Potassium iodate (KIO_3) 5.00g (± 0.001 g)

3 M sulfuric acid 100.00 ml (± 0.01 ml)

Vitamin C (pure powdered ascorbic acid) 0.750g (± 0.001 g)

Corn starch 100.00g (± 0.001 g)

Distilled water

Scale (± 0.001 g)

Microwave

Press

Magnetic Stirrers

Vitamin C sold as over the counter (*Healthy America, Mason Nature, Natural Wealth, Walgreens, GNC, and CVS*)

Vitamin C sold with prescription (*Roche, Polifarma*)

Variables and Constants

- **Constants**

Temperature: 25-26^{o}C (measured with electronic thermometer)

Sun light (direct sunlight damages the structure of vitamin C)

- **Independent Variable**

Unknown amount of vitamin C in solution.

- **Dependent Variable**

The amount of iodate solution used to reach the end point of reaction between vitamin C and iodate.

Experimental Procedures

Ascorbic acid is determined by using an oxidation-reduction reaction. I preferred the redox reaction rather than the acid-base titration as other substances in pills can act as acids and change the titrated amount, whereas the change occur only in very small quantities with the oxidation by iodine. The solubility of iodine is increased with iodide and triiodide is occured:

$$I_{2\,(aq)} + I \leftrightarrow I_3^-$$

I_3^- then oxidizes vitamin C to dehydroascorbic acid:

$$C_6H_8O_6 + I_3 + H_2O \rightarrow C_6H_6O_6 + 3I^- + 2H^+$$

Vitamin C *dehydroascorbic acid*

The endpoint is production of a blue-black color which occurs as a result of the reaction of iodine with starch suspension. When ascorbic acid is present, I_3^- is converted to iodide and no

color change is observed. However, when all ascorbic acid were utilized, expected blue-black color occurs due to the reaction between starch and excess triiodide[9].

This titration procedure is widely accepted and is appropriate for testing the amount of vitamin C in the tablets, liquids and fruits and vegetables.

1. Preparation of iodine solution

I have used 400ml beaker in order to dissolve 5.0 g of potassium iodide (KI) and 0.268 g of potassium iodate (KIO_3) in 200 ml of distilled water. Then I added 30 ml of 3 M sulfuric acid into this solution which were all poured into a 500 ml graduated cylinder. I diluted the solution to the final volume of 500 ml with distilled water again. After mixing the solution thoroughly I transferred the solution into a 600 ml beaker.

2. Preparation of vitamin C standard solution and 1% starch solution

After dissolving 0.250 g of vitamin C in 100 ml water, I diluted it in a 250 ml volumetric flask. Then, I have started the preparation of 1% starch solution. In order to prepare this solution, 1g of corn starch was added to every 99ml of cold water. As the starch is insoluble in cold water and needs to be boiled to stay in solution, I boiled the mixture and left alone for a while to get it cold again.

3. Standardization of the iodine solution with the vitamin C standard solution

25.00 ml of ascorbic acid solution was inserted into a 125 ml Erlenmeyer flask and then I added 10 drops of 1% starch solution on top of it. I rinsed he burette twice with 5-10 ml of iodine solution first and then filled. I recorded initial burette volume and then titrated the

[9] Helmenstine AM. Vitamin C determination by iodine titration. About.com Guide. (Retrieved: 3.12. 2009, http://chemistry.about.com/od/demonstrationsexperiments/ss/vitctitration.htm)

solution until the endpoint was reached (*the first sign of blue color that remains after at least 20s of swirling*). I recorded the final volume and then repeated each titration three times. As its widely accepted the intraassay variation has to be less than 5%.

4. Stabilizing the Constants

The stabilization of the temperature was not hard. The laboratory where I worked had a continuously running air circulation system. This air circulation system stabilizes the temperature at 21-22^{0}C. The tough part was preventing the sunlight from falling on the solutions directly. The structure of vitamin C is very suitable to be damaged by sunlight or any other kind of light similar to sunlight (fluorescence or any bright light). I used thick and dark colored curtains to prevent sun light from falling on the experiment directly.

5. Titration of samples

I selected six boxes randomly from all the samples bought from the free-market and two boxes from the pharmacy then I took one tablet from each box after controlling the expiry dates. As the difference on shelf-life might affect the result of titration, I chose the tablets with same expiry dates. Tablets were weighed using the scale and then crushed using a press. I dissolved the powder in 100 ml of distilled water then completed solution to 250 ml with water. I took 25 ml into 125 ml Erlenmeyer flask after filtration using filter-paper. 10 drops of 1% starch solution were added and titration was started. Titration was performed according to the procedure followed for standard vitamin C solution and each measurement was performed in triplicate. Then the mean level of used iodine solution was taken for calculations.

Calculations

To calculate the amount of vitamin C in one pill, I prepared a standard vitamin C solution which contains 0.250 g (250 mg) ascorbic acid. Then I titrated it with iodine solution and recorded the value for this standard solution which is 17.73 ml. So I ended up with the equation below.

$$\textit{The amount of ascorbic acid in one pill} = \textit{Used amount of iodine solution} \times \frac{\textit{Amount of ascorbic acid in standard solution (0.250g)}}{\textit{Amount of iodine solution used for oxidizing standard ascorbic acid solution (17.73ml)}}$$

Vitamin C from Walgreens:

17.43 ml solution is needed to oxidize one pill of vitamin C (the value 17.43 ml is the mean of three trials). So the equation should be;

$$\textit{Amount of ascorbic acid in one Walgreens tablet} = 17.43\ ml\ I_3^- \times \frac{0.250\ g\ ascorbic\ acid}{17.73\ ml\ I_3^-}$$

$$\textit{Amount of ascorbic acid in one Walgreens tablet} = 0.24570\ g\ ascorbic\ acid = \underline{245.70\ mg}\ ascorbic\ acid$$

Rest of the calculations are shown in Appendix 1.

RESULTS

Six different brand name of vitamin C sold in the market as *over-the-counter* and two brand name sold in pharmacy with prescription were analyzed. Table 1 shows the brand names and mass of pills (g) measured. Amount of vitamin C shown on the box also given in table 1.

Sample	**Including vitamin C amount shown on the box (g)**	**Mass of pill (g) (± 0.001g)**
I. Over-the-Counter		
Healthy America	0.500	1.157
Mason Nature	0.500	0.600
Natural Wealth	1.000	1.248
Walgreens	0.250	0.317
GNC	0.500	0.927
CVS	0.500	0.640
II. With prescription only		
Roche Redoxan Chewing	0.500	0.589
Polifarma Plan C	0.500	0.564

Table 1: ***Name of the company, mass of pill (g) and amount of vitamin C (g) shown on the box***

Amount of vitamin C in each pills analyzed using iodometric titration method as explained in methods section. The results of each measurements and intraassay variation of the experiments were shown in table 2. Every analysis was performed in triplicate and intraassay variation was 3.37 % (less than 5%) which means all the measurements and test results are reliable.

Sample	***1. trial (ml) (±0.01ml)***	***2.trial (ml) (±0.01ml)***	***3.trial (ml) (±0.01ml)***	***Average (ml) (±0.01ml)***	***Intraassay Variation (%)***
Polifarma C	34.57	35.72	36.13	35.64	3.92
Roche Redoxan	35.67	36.24	36.88	36.42	2.49
Healthy America	30.80	31.10	32.70	31.53	3.90
Mason Nature	37.30	36.10	35.90	36.43	3.55
Natural Wealth	69.00	67.60	63.40	66.66	5.75
Walgreens	17.70	17.90	17.60	17.43	0.80
GNC	34.80	35.90	36.20	35.63	3.59
CVS	33.60	34.00	34.20	33.93	1.48
Average Variation					3.37

Table 2: ***Amount of KIO_3 titrated (ml) and intraassay variations (%)***

Table 3 shows the calculated and given ascorbic acid amounts in vitamin C products with respect to amounts of titrated KIO_3 solution (ml) and mass of vitamin C products. Four of them were found to include less vitamin C than the amount shown on the box (*Healthy America, Natural Wealth, Walgreens, and CVS*). Remaining four including *GNC* and *Mason Nature* from over-the-counter drugs and *Polifarma C* and *Roche Redoxan,* pills with prescription, were found to include more than the amounts shown on the box. However reason of these values can be the additional materials used in the tablets or the materials I used for the experiment are not precise enough for the exact values.

Brand of Vitamin C	**Trial no.**	**Average Mass of pill (g)**	**KIO_3 Amount Titrated (ml) (±0.01)**	**Calculated Ascorbic Acid ($C_6H_8O_6$) (mg)**	**Ascorbic Acid in Prospectus (mg)**
Standard Vit. C	3	0.250	17.73	250.00	250
Polifarma C Plan	3	0.564	35.64	502.53	500
Roche Redoxan	3	0.589	36.42	513.53	500
Healthy America	3	1.157	31.53	444.58	500
Mason Nature	3	0.600	36.43	513.67	500
Natural Wealth	3	1.248	66.66	939.93	1000
Walgreens	3	0.317	17.43	245.70	250
GNC	3	0.927	35.63	502.39	500
CVS	3	0.640	33.93	478.42	500

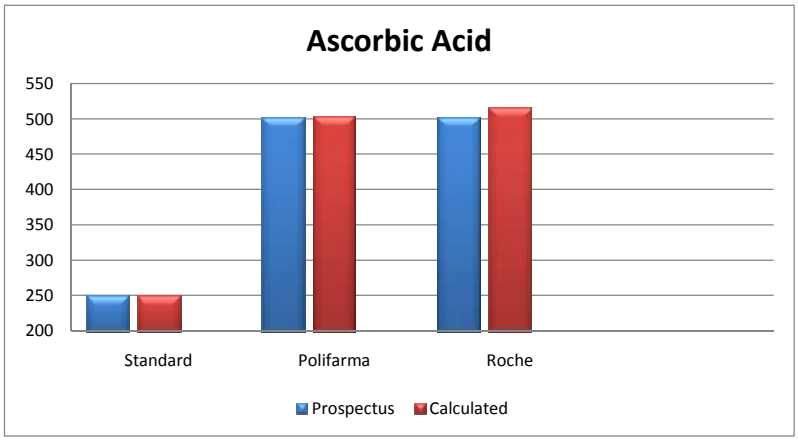
Table 3: ***Calculated and given ascorbic acid amounts in vitamin C products with respect to amounts of titrated solution and mass of Vitamin C products***

Table 4 shows the deviation from prospectus for each pill as milligram (mg) and as percentage (%). According to the table, there was no pill without deviation. The most reliable pills were from *GNC* and *Polifarma* respectively (with the deviation from prospectus being 2.39 mg, 0.478% and 2.53mg, 0.506%). The deviation was most in vitamin C from Natural Wealth (-60.07mg and -6.007%) which was followed by Healthy America (-55.42mg and -11.084%) and CVS (-21.58mg and -4.316%) respectively.

Brand of Vitamin C	**Calculated Ascorbic Acid ($C_6H_8O_6$) (mg)**	**Ascorbic Acid in Prospectus (mg)**	**Deviation from prospectus(mg)**	**Deviation from Prospectus (%)**
Standard Vitamin C	250.00	250	-	-
Polifarma C Plan	502.53	500	2.53	0.506
Roche Redoxan	513.53	500	13.53	2.706
Healthy America	444.58	500	-55.42	-11.084
Mason Nature	513.67	500	13.67	2.734
Natural Wealth	939.93	1000	-60.07	-6.007
Walgreens	245.70	250	-4.30	-1.72
GNC	502.39	500	2.39	0.478
CVS	478.42	500	-21.58	-4.316
			Average Deviation (%)	**3.694**

Table 4: ***Amount of Vitamin C (mg) and deviation from the prospectus (mg) and (%)***

A.



B.

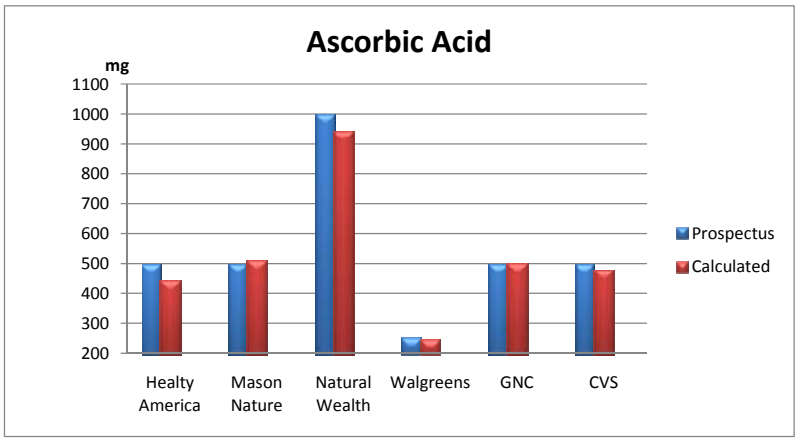
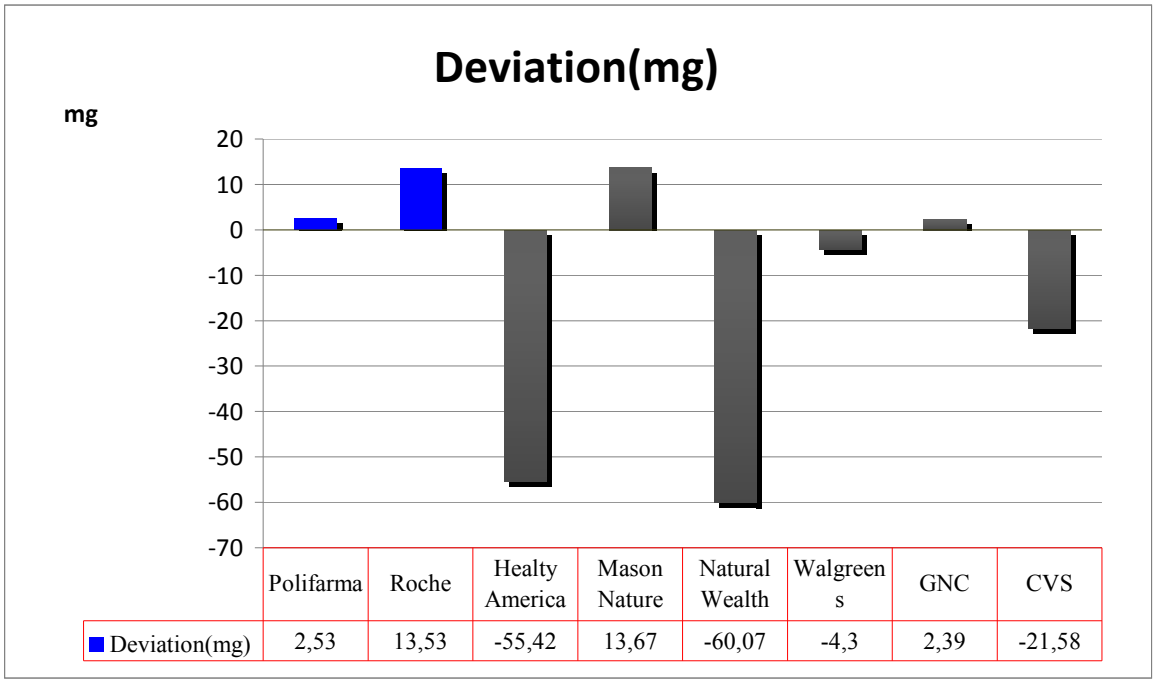


Figure 1: Amount of Vitamin C (mg) and deviation from the prospectus (mg).

A: Vitamin C with prescription**, B:** Vitamin C without prescription.



	Polifarma	Roche	Healty America	Mason Nature	Natural Wealth	Walgreens	GNC	CVS
Deviation(mg)	2,53	13,53	-55,42	13,67	-60,07	-4,3	2,39	-21,58

Figure 2: Value of deviation from the prospectus shown as "mg".

DISCUSSION AND CONCLUSIONS

Ascorbic acid is an important vitamin for human health and also act as co-factor for many enzymes therefore is needed for physiological functions in the body especially for the synthesis of important substances including collagen, and some neurotransmitters[10]. Ascorbic acid accelerates hydroxylation reactions by increasing the activity of enzymes hydroxylase and oxygenase.

The ascorbic acid requirement of the body might be supplemented from daily nutrients and also the supplemental tablets. However, stress, smoking, any disease conditions and especially infections deplete the ascorbic acid reserves in the body and demands higher doses of ascorbic acid supplementation[11]. It was suggested that ingestion of high doses(1–2 g) of ascorbic acid effectively prevents/ameliorate common cold[12]. It is beneficial for common cold and in some other conditions including wound healing, atherosclerosis and even cancers[13, 14]. It has also been shown that the usage of 100–120 mg/daily ascorbic acid achieves optimum risk reduction of heart diseases, stroke and cancer in healthy individuals[14].

Present study tries to answer the question of whether the amount of vitamin C shown on the box was equal to the real amount in the tablets. In order to answer this question two different brand names of vitamin C sold with prescription (*Roche and Polifarma*) and six well known brand names sold in the market without prescription (*Healthy America, Mason Nature, Natural*

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[10] Levin M. New concepts in the biology and biochemistry of ascorbic acid. *New Engl J Med* 1986; **31:**892-902

[11] Naidu KA. Vitamin C in human health and disease is still a mystery. *Nutrition Journal* 2003; **2**:7 (The electronic version of this article is the complete one and can be found online at: http://www.nutritionj.com/content/2/1/7)

[12] Douglas RM, Hemila H, D'Souza R, Chalker EB, Treacy B. Vitamin C for preventing and treating the common cold. *Cochrane Database Syst Rev* 2004 ;**18(4)**: CD000980

[13] Collins N. The facts about vitamin C and wound healing. *Ostomy Wound Manage* 2009; **55(3)**: 8-9

[14] Ohno S, Ohno Y, Suzuki N, Soma G, Inoue M. High-dose vitamin C (ascorbic acid) therapy in the treatment of patients with advanced cancer. *Anticancer Res*. 2009; **29(3)**: 809-815

Wealth, Walgreens, GNC and CVS) were evaluated. Ascorbic acid levels in the pills were measured using iodometric titration method.

From the results obtained, it was less than the manufacturer's specification in four tablets (*Natural Wealth, Healthy America, CVS and Walgreens*, respectively) and it was more than manufacturer's specification in two tablets including *GNC* and *Mason Nature* respectively. It was also found that the amount in the tablets sold with prescription was more than the manufacturer's specifications. So from this point it might be said that local company, *Polifarma*'s vitamin C tablets are more coherent with the prospectus than imported *Roche* Redoxan tablets are.

In redox titration, the reducing and oxidizing properties of ascorbic acid was used. The investigation succeeded and deviations remained under 5%. From this perspective, it can be said that determining concentration of tablets by using redox titration method is reliable. There was another method to calculate the amount of ascorbic acid in one pill which is a titration with 1,2-dichloroindophenol. However it is hard to find this material and the method includes the usage of highly concentrated sulfuric acid which makes it dangerous. I chose iodometric titration method because the materials were not hard to find and it is more precise than the titration with dichloroindophenol. The other reason of me choosing the redox titration method was that of a number of other substances in the tablets might act as acids, but relatively few interfere with the oxidation of ascorbic acid by iodine.

Though my test results are reliable with the intra-assay variation being less than 5%, one should still remember that the difference between the dictated and measured levels of vitamin C may be due to the poor technique of titration, self-oxidation of vitamin C, and the other materials used in pills such as cellulose. The additional materials can help the ascorbic acid's oxidization which causes a deviation between the values of iodine solution used for oxidization

because of that, a deviation will appear between the values of ascorbic acid amounts. The reacted ascorbic acid and iodine mixture should immediately be titrated in order to reduce the vaporization of iodine. However, even with these shortcomings redox titration is still better than acidic titration method as explained previously.

I have to admit that there were number of precautions during the experiments, ascorbic acid is unstable and can easily be oxidized. Oxidation can be highly speeded up when it is heated or dissolved in the water. To obtain a better result from the experiment, when storing the solution direct sunlight should be avoided; it should be kept in a cool place and in an air-tight bottle. Also an aluminum folio should be used to cover the bottle of solution because indoor lightings can also oxidize the ascorbic acid. Besides, the timing of the addition of starch solution is also very important and it should be added when the solution changes its color to pale yellow.

I selected the most commonly consumed *over-the-counter* vitamin C tablets in Turkey, all of which are imported mostly from USA. When I analyzed the ascorbic acid levels in the pills and compared them to the amounts shown on the box, I found that the most reliable tablets were from GNC with the deviation of 0.478%. It was followed by *Walgreens, Mason Nature and CVS*. The tablets from *Natural Wealth* and *Healthy America* were the worst and less reliable. Amount in *GNC*'s vitamin C tablet was even more coherent with the prospectus than the amount in vitamin C sold with prescription namely *Polifarma* and *Roche*.

The content of vitamin C in commercial tablets was found to be different than the manufacturer's specification in the prospectus. Some had more others had less than the manufacturer's specifications with the mean deviation of 3.7%.Vitamin C from *GNC* and *Polifarma* with the deviation of 0.5% were most reliable ones. The deviations might result from many different conditions which require further investigations.

I have taken all that precautions during the experiment. All the tablets had been kept in air-tight bottles. They were taken out only when they are used. I never kept them in the direct sunlight or in a warm place. Therefore, the difference between the dictated and measured levels cannot be the result of poor technique or self oxidations.

To improve the results of this experiment more precise equipment can be used. A more isolated laboratory can help to reduce the effects of environment. Additionally the effects of the sun light falling directly on the pills can be evaluated as a further investigation.

Acknowledgements

I specially would like to thank Mrs. Serenay Tarhan GÜLER for supporting me throughout this project. This experiment is performed in the laboratories of Hacettepe University Institute of Oncology. Therefore I also would like to thank Prof Dr Dicle GÜÇ for their kind permission.

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13. Collins N. The facts about vitamin C and wound healing. *Ostomy Wound Manage* 2009; **55(3)**: 8-9.

14. Ohno S, Ohno Y, Suzuki N, Soma G, Inoue M. High-dose vitamin C (ascorbic acid) therapy in the treatment of patients with advanced cancer. *Anticancer Res*. 2009; **29(3)**: 809-815

APPENDICES

Appendix 1(Calculations)

To calculate the amount of vitamin C in one pill, I prepared a standard vitamin C solution which contains 0.250 g (250 mg) ascorbic acid. Then I titrated it with iodine solution and recorded the value for this standard solution which is 17.73 ml. So I ended up with the equation below.

$$\textit{The amount of ascorbic acid in one pill} = \textit{Used amount of iodine solution} \times \frac{\textit{Amount of ascorbic acid in standard solution (0.250g)}}{\textit{Amount of iodine solution used for oxidizing standard ascorbic acid solution (17.73ml)}}$$

Walgreens:

17.43 ml solution is needed to oxidize one pill of vitamin C (the value 17.43 ml is the mean of three trials). So the equation should be;

$$\textit{Amount of ascorbic acid in one Walgreens tablet} = 17.43\ ml\ I_3^- \times \frac{0.250\ g\ ascorbic\ acid}{17.73\ ml\ I_3^-}$$

$$\textit{Amount of ascorbic acid in one Walgreens tablet} = 0.24570\ g\ ascorbic\ acid = \underline{245.70\ mg}\ ascorbic\ acid$$

GNC:

35.63 ml of iodine solution is needed to oxidize one pill of GNC tablets.

$$\textit{Amount of ascorbic acid in one GNC tablet} = 35.63 \text{ ml } I_3^- \times \frac{0.250 \text{ g ascorbic acid}}{17.73 \text{ ml } I_3^-}$$

$$\textit{Amount of ascorbic acid in one GNC tablet} = 0.50239 \text{ g ascorbic acid} = 502.39 \text{ mg ascorbic acid}$$

CVS:

33.93 ml of iodine solution is needed to oxidize one pill.

$$\textit{Amount of ascorbic acid in one CVS tablet} = 33.93 \text{ ml } I_3^- \times \frac{0.250 \text{ g ascorbic acid}}{17.73 \text{ ml } I_3^-}$$

$$\textit{Amount of ascorbic acid in one CVS tablet} = 0.47842 \text{ g ascorbic acid} = 478.42 \text{ mg ascorbic acid}$$

Healthy America:

31.53 ml of iodine solution is needed to oxidize one pill.

$$\textit{Amount of ascorbic acid in one Healthy America tablet} = 31.53 \text{ ml } I_3^- \times \frac{0.250 \text{ g ascorbic acid}}{17.73 \text{ ml } I_3^-}$$

$$\textit{Amount of ascorbic acid in one Healthy America tablet} = 0.44458 \text{ g ascorbic acid} = 444.58 \text{ mg ascorbic acid}$$

Mason Nature:

36.43 ml of iodine solution is needed to oxidize one pill.

$$\textit{Amount of ascorbic acid in one Mason Nature tablet} = 36.43 \text{ ml } I_3^- \; x \; \frac{0.250 \text{ g ascorbic acid}}{17.73 \text{ ml } I_3^-}$$

$$\textit{Amount of ascorbic acid in one Mason Nature tablet} = 0.51367 \text{ g ascorbic acid} = 513.67 \text{ mg ascorbic acid}$$

Natural Wealth:

The solution of Natural Wealth pill couldn't be titrated with 50 ml burette because the amount of vitamin C in one pill is too much, so I doubled the volume of solution. Molarity of solution is halved. Now used amount of iodine solution should be close to the 500 mg pill titrations. After recording the data I doubled the amount of iodine solution to require the real amount of solution needed to titrate the initial ascorbic acid solution.

33.33 ml iodine solution needed to oxidize 1000 mg pill in 500 ml water so 66.66 ml is needed to oxidize 1000 mg pill in 250 ml water.

$$\textit{Amount of ascorbic acid in one Natural Wealth tablet} = 66.66 \text{ ml } I_3^- \; x \; \frac{0.250 \text{ g ascorbic acid}}{17.73 \text{ ml } I_3^-}$$

$$\textit{Amount of ascorbic acid in one Natural Wealth tablet} = 0.93993 \text{ g ascorbic acid} = 939.93 \text{ mg ascorbic acid}$$

Polifarma C Plan:

35.64 ml of iodine solution is needed to oxidize one pill.

$$\textit{Amount of ascorbic acid in one Polifarma C Plan tablet} = 35.64 \text{ ml } I_3^- \times \frac{0.250 \text{ g ascorbic acid}}{17.73 \text{ ml } I_3^-}$$

$$\textit{Amount of ascorbic acid in one Polifarma C Plan tablet} = 0.50253\text{g ascorbic acid} = 502.53 \text{ mg ascorbic acid}$$

Roche Redoxan :

36.42 ml of iodine solution is needed to oxidize one pill.

$$\textit{Amount of ascorbic acid in one Roche Redoxan tablet} = 36.42 \text{ ml } I_3^- \times \frac{0.250 \text{ g ascorbic acid}}{17.73 \text{ ml } I_3^-}$$

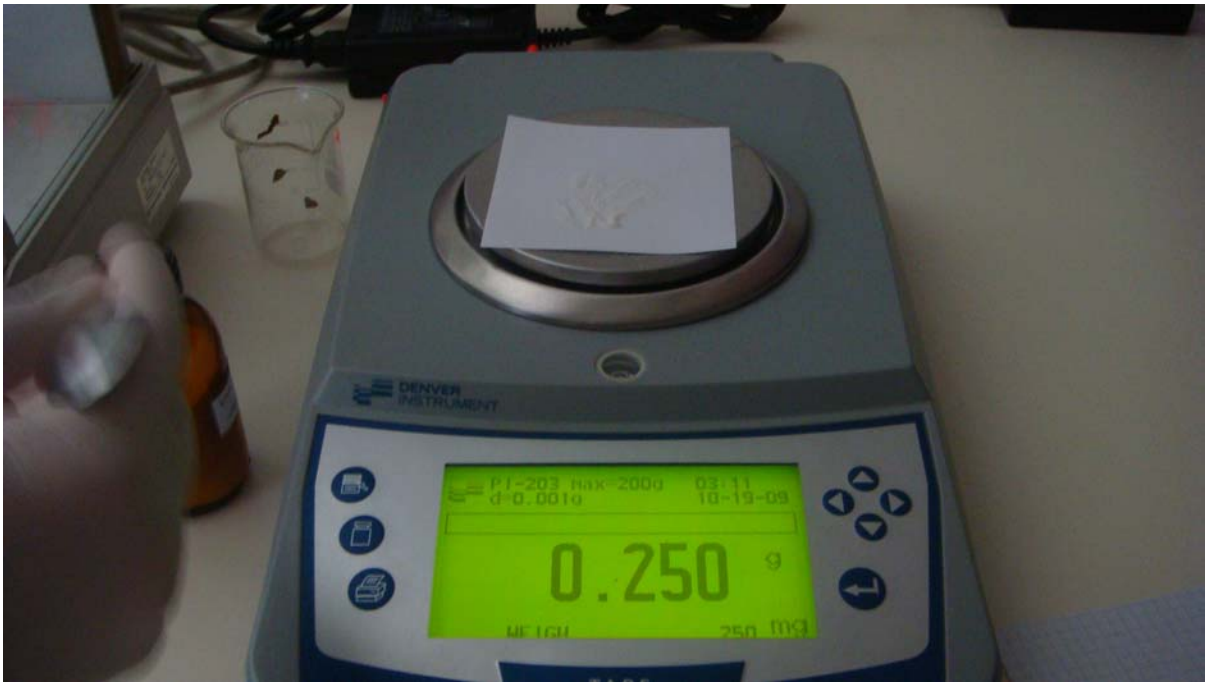
$$\textit{Amount of ascorbic acid in one Roche Redoxan tablet} = 0.51353 \text{ g ascorbic acid} = 513.53 \text{ mg ascorbic acid}$$

Appendix 2: (Photographs)

List of Pictures

Picture 1:Boxes of Vitamin C Pills

Picture2: Crushing Process of Pills



Picture 3: Vitamin C Amount in Standard Ascorbic Acid Solution

Picture 4: Magnetic Stirrer for a better dissolving

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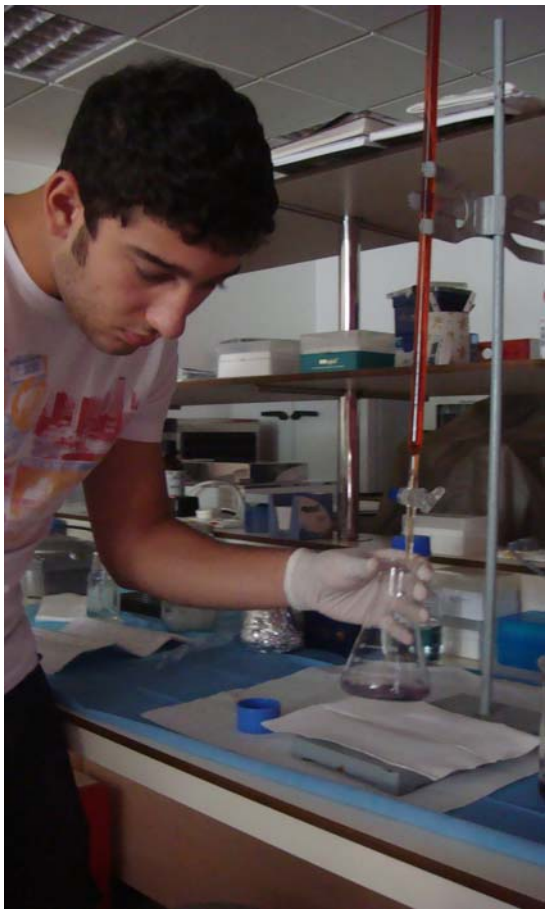
Picture 5: Measuring the Amount of Solution which will be titrated

Picture 6: Titration Process



Picture 7: Titration Process

Picture 8: Blue-Black Product which indicates End Point of the Reaction