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Determination of ascorbic acid in bulk and vitamin-C tablets using manganese (III) in aqueous acidic perchlorate media

Abstract

A redox titration with an oxidising agent is a straightforward method for assessing the molecular weight and quantity of ascorbic acid in commercially available vitamin tablets. The iodometric titration of unreacted Mn (III) in aqueous perchlorate medium is used in this study to measure the molecular weight and amount of ascorbic acid in tablets. Ascorbic acid, often known as vitamin C is essential for human health and plays an important part in a variety of physiological processes in the human body. It is a vital vitamin with antioxidant properties that supports the immune system and helps the body fight infections and diseases. Vitamin C supplements are widely accessible and are used to prevent or treat deficiencies. Ascorbic acid determination is multifaceted and serves important roles in assessing nutritional health, ensuring the quality of food and pharmaceutical products, supporting clinical diagnoses, and advancing scientific understanding.

Keywords: ascorbic acid, iodometry, Mn (III), molecular weight, perchloric acid, vitamin C tablets

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Introduction

Ascorbic acid is a strong electron donor and water-soluble antioxidant[1,2] with a structure as in Figure 1. It supports the proper configuration of proteins, lipids, enzymes, DNA, and other antioxidants, thereby contributing to health benefits (Chart 1). Unlike the majority of vertebrates guinea pigs, bats, passeriform birds, and primates, including humans, do not have L-gulono-1,4-lactone oxidase, which prevents them from synthesising vitamin C. As a result, they are entirely reliant on dietary vitamin C consumption.[3-5] Hence, vitamin C is an essential dietary component.[6] Vitamin C levels in the body range from 300 mg to roughly 2 g.[7] Vitamin C levels are maintained at high levels in cells and tissues, with the largest concentrations seen in leukocytes (white blood cells), eyes, adrenal glands, pituitary gland, and brain. Extracellular fluids, such as plasma, red blood cells, and saliva, have relatively modest quantities of vitamin C.[7] Vitamin C is essential for the manufacture of collagen, L-carnitine, and some neurotransmitters, as well as for protein metabolism.[6] Fruits and vegetables are the best sources of vitamin C. Other good food sources include red and green peppers, kiwifruit, broccoli, strawberries, brussels sprouts, and cantaloupe.[8,9] Determining the amount of ascorbic acid in a tablet is essential for ensuring accurate dosing, safety, efficacy, and compliance with regulatory standards. It contributes to the overall quality control of the product and helps both consumers and healthcare professionals to make informed decisions regarding vitamin C supplementation.[10]

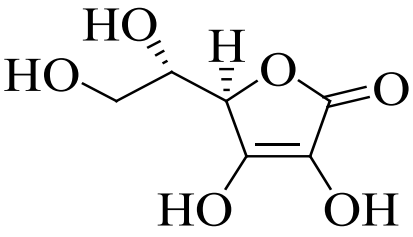

Figure 1 Molecular structure of ascorbic acid.

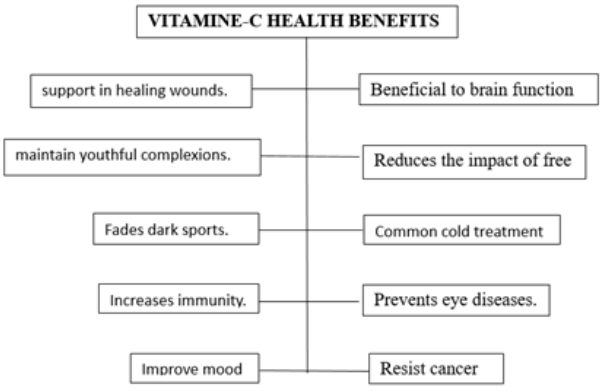

Chart 1 Health benefits of vitamin C

Reagents and procedure

The experimental setup employed commercially available reagents, with distilled water serving as the solvent. As part of the study, ascorbic acid and vitamin C tablets within the 100-500 mg range were utilized. Analytical grade reagents, specifically manganese (II) carbonate, perchloric acid, and ascorbic acid (E. Merck), were employed in the investigation.

Manganese (II) perchlorate was prepared by dissolving $MnCO_3$ in aqueous perchloric acid. On subjecting manganese (II) perchlorate for anodic oxidation, manganese (III) was prepared. After analysing Mn (III) by iodometry, 0.01 M solution of Mn (III) was prepared. Ascorbic acid solutions were prepared shortly before usage. Perchloric acid was used to maintain pH of the solution.

Determination of molecular weight of ascorbic acid

In a laboratory setting, a precise quantity of 20-60 mg of ascorbic acid was accurately measured and dissolved in 10 mL of distilled water within an Erlenmeyer flask. Subsequently, a solution of 40 mL of 0.01 mol Mn (III) and 1 mL of perchloric acid was introduced into

the flask. The reaction mixture was well agitated and left undisturbed at room temperature for approximately 30 minutes. To determine the remaining unreacted Mn (III), a titration was carried out using a 0.01 mol sodium thiosulphate solution. This titration was performed after incorporating 1 mL of 2N sulfuric acid, 1 mL of 10% potassium iodide, and using starch as an indicator. To establish a baseline, a blank titration was conducted without the inclusion of ascorbic acid in the initial mixture.[9] The molecular weight (m) of ascorbic acid was subsequently computed based on the variance in the volume of sodium thiosulphate solution consumed during the titration process described in reaction 1.

The stoichiometric measurements[10] indicates that the overall reaction can be represented as in the reaction 1.

$$2Mn^{3+} + H_2A \rightarrow 2Mn^{2+} + A + 2H^+ \quad (1)$$

The reaction mechanism for the reaction 1 is shown in the scheme 1.

Scheme 1

$$Mn^{3+}{}_{aq} \rightleftharpoons \left[Mn(OH)\right]^{2+}{}_{aq} + H^+$$

$$H_2A \rightleftharpoons HA^- + H^+$$

$$Mn^{3+}{}_{aq} + H_2A \rightarrow Mn^{2+}{}_{aq} + Radical$$

$$\left[Mn(OH)\right]^{2+}{}_{aq} + H_2A \rightarrow Mn^{2+}{}_{aq} + Radical$$

$$Mn^{3+}{}_{aq} + HA^- \rightarrow Mn^{2+}{}_{aq} + Radical$$

$$\left[Mn(OH)\right]^{2+}{}_{aq} + HA^- \rightarrow Mn^{2+}{}_{aq} + Radical$$

$$Mn^{3+} + Radical \rightarrow Mn^{2+}{}_{aq} + A$$

Hence,

One mole of ascorbic acid ≡ Two mole of Mn (III) ≡ Two mole of iodine ≡ 4000 mL of 1M sodium thiosulphate

i.e. m gm. of ascorbic acid ≡ 4000 mL of 1M sodium thiosulphate.

"w" gm. of ascorbic acid ≡ (V_2-V_1) mL of M sodium thiosulpate.

$$\frac{m}{4000} = \frac{w}{(V_2 - V_1)\mathrm{M}}$$

$$\text{or } M = \frac{4000w}{(V_2 - V_1)\mathrm{m}} \quad (1)$$

m = molecular weight of ascorbic acid where w = weight of ascorbic acid/tablet, M= molarity of sodium thiosulphate, V_1 and V_2 = volume of sodium thiosulphate consumed for experimental and blank titration respectively.

Estimation of ascorbic acid in pharmaceutical vitamin tablets

In the experimental procedure, a specified quantity of finely powdered vitamin C tablets, ranging from 10 to 60 mg, containing ascorbic acid within the range of 100 to 500 mg, was meticulously dissolved in 10 mL of distilled water within the confines of an Erlenmeyer flask. Subsequently, a mixture consisting of 40 mL of 0.01 mol Mn (III) and 1 mL of perchloric acid was introduced into the flask. After ensuring thorough agitation, the reaction mixture was allowed to stand at room temperature for approximately 30 minutes. The released iodine was then titrated against a 0.01M sodium thiosulphate solution, facilitated by the addition of 1 mL of 2N sulfuric acid, 1 mL of 10% potassium iodide, and utilizing starch as an indicator. To establish a baseline, a blank titration was conducted in the absence of vitamin C tablets.[9] The quantity of ascorbic acid denoted as 'W' present in the vitamin C tablets was subsequently determined by computing the difference in the volume of sodium thiosulphate solution consumed during the experimental and blank titration, as outlined by equation 2.

$$W = \frac{\mathrm{m}(V_2 - V_1)\mathrm{M}}{4000} \quad (2)$$

Results and discussion

The approach discusses how to calculate the molecular weight of ascorbic acid and estimate the amount of ascorbic acid present in vitamin-C tablet by using this redox titrimetric method with an oxidizing agent is simpler in comparison to that of literature method. It is observed that by this strategy, the standard deviation for the theoretical and experimental values was less than 1 with respect to the molecular weight of the ascorbic acid as shown in table 1. The relative percentage errors for ascorbic acid in vitamin-C tablets were determined to be less than 2% as in table 2. The chemicals used in this experimental part were used as such without any further purification. The method showed here can be utilized in even PG/UG academic labs for direct assessment of ascorbic acid content in tablets as well as to demonstrate its molecular weight.

Table 1 Experimentally determined molecular weight of ascorbic acid in 30 minutes (Theoretical molecular weight of ascorbic acid is 176.13)

Trial	1	2	3	4	5	6	Average	Standard deviation
Amount of ascorbic acid	35.76	51.33	47.9	29.74	38.62	41.35	176.18	0.25
Experimentally determined Molecular weight	176.35	175.96	176.26	175.79	176.31	176.4		
Trial	**7**	**8**	**9**	**10**	**11**	**12**		
Amount of ascorbic acid	56.49	22.89	43.68	25.67	31.83	33.69	176.1	0.24
Experimentally determined Molecular weight	175.91	176.42	175.88	176.29	175.85	176.22		

Table 2 The quantity of ascorbic acid present in ascorbic acid containing prescribed tablets

Name of the tablet	Limcee					Becosule				
Trials	1	2	3	4	5	1	2	3	4	5
Amount taken (mg)	23.67	46.86	36.12	27.9	59.03	19.67	56.45	35.26	43.64	28.45
Amount Found (mg)	23.91	47.32	36.54	28.21	59.34	19.42	56.61	35.59	43.15	28.19
Relative error (%)	1.01	0.98	1.16	1.11	0.53	1.27	0.28	0.94	1.12	0.91

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Table 2 Continued...

Name of the tablet	**Celin**					**Ester-C**				
Trials	1	2	3	4	5	1	2	3	4	5
Amount taken (mg)	57.25	14.89	35.89	32.78	49.03	53.94	22.96	34.65	41.84	29.89
Amount Found (mg)	57.36	14.74	35.63	32.93	48.92	54.21	23.14	34.29	42.01	30.11
Relative error (%)	0.19	1.01	0.72	0.46	0.22	0.5	0.78	1.04	0.41	0.74
Name of the tablet	**Limcor**					**Brixcee**				
Trials	1	2	3	4	5	1	2	3	4	5
Amount taken (mg)	38.29	47.18	41.03	28.05	59.01	48.66	39.21	51.63	24.93	15.99
Amount Found (mg)	38.72	47.45	40.75	28.53	58.89	48.23	39.67	51.43	25.09	16.12
Relative error (%)	1.12	0.57	0.68	1.71	0.2	0.88	1.17	0.39	0.64	0.81
Name of the tablet	**Eucee**					**Frutcee**				
Trials	1	2	3	4	5	1	2	3	4	5
Amount taken (mg)	32.03	42.99	54.36	37.05	19.11	52.04	40.96	38.72	27.93	46.04
Amount Found (mg)	32.15	43.28	54.66	37.71	19.43	52.66	41.14	38.54	27.63	46.51
Relative error (%)	0.38	0.67	0.55	1.78	1.67	1.19	0.44	0.46	1.07	1.02

Conclusion

It is important to get an adequate amount of ascorbic acid through a well-balanced diet or, through supplements if necessary. Since various Ascorbic acid supplements are available, estimating the ascorbic acid in tablets is crucial to pharmaceutical quality control, guaranteeing correct dosing, regulatory compliance, and overall product quality. Based on the outcomes of this study, we conclude that this titrimetric approach of instantaneous ascorbic acid determination is adaptable and has applications spanning from nutrition and healthcare to agriculture and industry. It is vital in understanding physiological processes and enabling research across several disciplines.

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None.

Conflicts of interest

Authors declare that there is no conflict of interest.

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