Acta Scientific Biotechnology

Volume 1 Issue 12 December 2020

Mini Review

Enantiomorphism of Tartaric Acid as a Property of Five-Dimensional Polytopes

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Received: November 26, 2020

Published: November 30, 2020

Abstract

It is shown that the optical activity of tartaric acid, discovered by Louis Pasteur, is associated with the different shapes of D-tartaric acid and L-tartaric acid molecules, which are polytopes in dimension 5. This differs significantly from Louis Pasteur's assumption about the relationship between optical activity and the shape of tartaric acid crystals in the three-dimension space.

Keywords: Molecule; Tartaric Acid; Optical Activity; Polarized Light; Dimension; Polytope; Symmetry

Introduction

The phenomenon of optical activity (i.e. the ability of substances to rotate the plane of polarization of polarized light) is widespread among organic compounds. Optically active substances include many important natural substances, such as proteins, carbohydrates. This phenomenon has deep biological significance, as it is associated with the asymmetry of living matter and the phenomenon of life. In 1848, Louis Pasteur discovered the optical activity of liquid tartaric acid and proposed to explain this phenomenon by the different form of crystals of D and L tartaric acid in three-dimensional space. In this work, spatial images of D and L forms of tartaric acid molecules are construct and it is proved that the dimension of these molecules is five. Thus, the stereoisomerism of tartaric acid should be considered not in three-dimensional, but in five-dimensional space.

The dimension of aldose monosaccharide

The combination of carbon atoms to form a chain of a certain length is a distinctive feature of biomolecules and organic chemistry compounds. Carbohydrates are the main source of energy for the body. All carbohydrates are made up of units that are saccharides. The simplest saccharide is an aldose monosaccharide, which contains three carbon atoms (Figure 1).

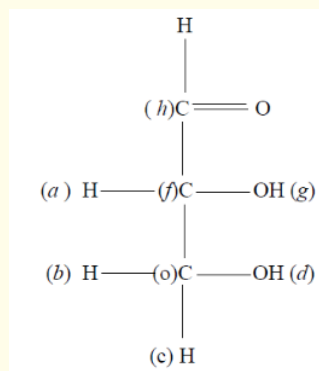

Figure 1: Shema of the molecule aldose monosaccharide.

Spatial structure of the molecule aldose monosaccharide is shown in figure 2 [1].

The dimension of a polyhedrons can be determined by the Euler-Poincaré equation [2]:

$$\sum_{i=0}^{n-1}(-1)^i f_i(P) = 1 + (-1)^{n-1}. \quad (1)$$

There n is dimension of a polytope *P*, f_i is the number of elements with dimension i in the polytope P.

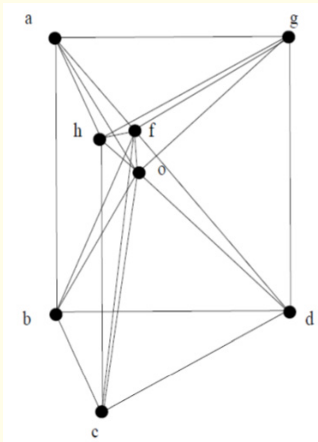

Figure 2: Spatial structure of the molecule aldose monosaccharide.

In figure 2 there is a tetrahedron *bcdf* with center *o* and a tetrahedron *oahg* with center *f*. Equation (1) implies that each tetrahedron with center has dimension 4 [3]. The vertex *f* of the first tetrahedron is the center of the second tetrahedron, and the vertex *o* of the second tetrahedron is the center of the first tetrahedron. Hydrogen (H) atoms are located at the vertices *a, b, c*, hydroxyl groups (OH) are located at the vertices *g, d*, carbon atoms (C) are located at the vertices *o, f, h*. The oxygen and hydrogen atoms following the carbon atom at the vertex *h* are not shown in figure 2 for simplification. It is necessary to determine the dimension of the polytope *bcdfahgo*. The polytope in figure 2 has 8 vertices (f_0 = 8), 22 edges (*ab, ag, af, ao, ah, gh, gf, go, gd, bf, bo, bd, bc, df, do, dc, hc, hf, ho, cf, co, fo)*. Therefore, f_1 = 22. The polytope in figure 2 has 29 planar faces, of which 26 are the triangles (*aho, afo, ahf, afg, ahg, aog, aob, afb, bfo, bco, bod, bfd, bfc, bcd, ghf, gho, gfo, god, gfd, dfo, dco, dfc, cof, chf, cho, hfo*) and 3 quadrangles (*abdg, hcgd, abhc*). Therefore, f_2 = 29. The polytope in figure 2 has 20 three - dimensional figures, of which 13 are tetrahedrons (*bcfd, ahog, dcfo, bcdo, bfdo, cfdo, ahof, ahgf, hogf, aogf, fgod, fohc, foab*), 6 pyramids (*agbdo, ahbcf, ahbco, agbdf, Chgdf, chgdo*) and one (*ahgbcd)* prism. Therefore, f_3 = 20. It follows from the construction of the polytope in figure 2 that it includes two tetrahedrons with the center *bcdfo* and *oahgf*. In addition to these two polytopes with dimension 4, five 4 - polytopes also appear in the polytope in figure 2. Three of these polytopes have as their base three rectangular faces of the prism *ahgbcd*, whose vertices are connected with the vertices *f, o* located inside the prism. To prove their 4 - dimensionality, consider one of these polytopes *abhcfo*, since the proofs for the other two polytopes are similar. This polytope has 6 vertices (f_0 = 6); 13 edges (*ab, ah, hc, bc, af, hf, bf, cf, ho, ao, bo, co, fo)*, f_1 = 13; 13 two - dimensional faces (*ahf, aho, abo, abf, afo, bfo, boc, ahbc*), f_2 = 13; 6 three -dimensional faces (*hfoc, abof, bfoc, afho, ahcbf, ahcbo*), f_3 = 13. Substituting the obtained values of the numbers of faces of different dimensions into equation (1), can find that equation (1) is satisfied for *n* = 4

6 - 13 + 13 - 6 = 0.

It is proved by the 4 - dimensionality of the polytope *abhcfo*.

The two polytopes of dimension 4 there are formed by the *ahgbcd* prism with the vertex *f* or *o* inside its. Consider the prism *ahgbcd* with the vertex *f* (the proof for the prism with vertex *o* is similar). The polytope *ahgbcdf* has 7 vertices, f_0 = 7; 15 edges (*ah, hg, ag, bd, bc, cd, ab, hc, gd, af, fh, fg, bf, fc, fd*), f_1 = 15; 14 two - dimensional faces (*ahg, bdc, ahf, hfg, afg, bfc, fcd, bfd, fhc, afb, fgd, ahbc, hcgd, agbd*), f_2 = 14; 6 three - dimensional faces (*ahgbcd, ahgf, bcdf, abdgf, hgcdf, ahbcf*), f_3 = 6. Substituting the values of the numbers of faces of various dimensions obtained for the polytope *ahgbcdf* into equation (1) can find that it is satisfied for *n* = 4

7 - 15 + 14 - 6 = 0.

This proves that the polytope *ahgbcdf* has a dimension of 4.

Thus, for the polytope in figure 2 are f_0 = 8, f_1 = 22, f_2 = 29, f_3 = 20, f_4 = 7. Substituting these values into equation (1) can find that it is satisfied for *n* = 5

8 - 22 + 29 - 20 + 7 = 2.

This proves that the polytope in figure 2 has dimension 5.

The dimension of tartaric acid molecules

The aldose monosaccharide has two an enantiomorphism configuration of D and *L*. The aldose monosaccharide molecules in both of these configurations have a dimension of 5 [1]. We will consider the difference in these configurations by the example of a closely related tartaric acid, which played a major role in the development of biology, starting with Pasteur's well - known works [4]. However, instead of the known images of these molecules in the form of Fisher's projections (Figure 3 and 4), we will use images of space of higher dimension for their images.

Comparing Fisher images of aldose monosaccharide (Figure 1) and tartaric acid (Figure 3 and 4) [5,6] can see that these compounds have the same main part of the design. It has the form of two tetrahedrons with a center, and the center of each of them is simultaneously the vertex of another tetrahedron. There is some difference in functional groups of compounds. Enantiomorphism forms of tartaric acid differ in the mirror image of hydrogen ions and hydroxyl groups in the main part of the molecule's structure. The dimension of this construction how it is shown earlier equal 5. Thus, the dimension of the molecules tartaric acid in both forms is 5. Images of polytopes corresponding to a molecule of tartaric acid in the form D and form L are presented in figure 5 and 6.

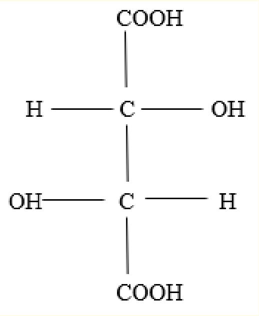

Figure 3: Shema of the molecules D-tartaric acid.

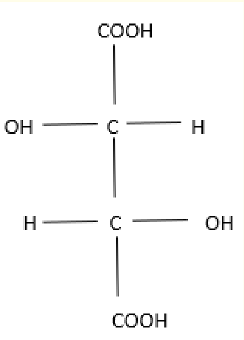

Figure 4: Shema of the molecules L-tartaric acid.

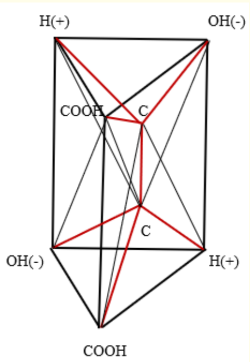

Figure 5: Spatial structure of the D-tartaric acid.

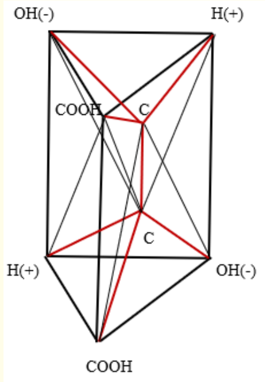

Figure 6: Spatial structure of the L-tartaric acid.

The brown color in figure 5 and 6 denotes the edges corresponding to the chemical bonds between the atoms. The black color in these figures denotes the edges that have values only as the edges of the convex body. The outer contour of both molecules in three-dimensional space is a triangular prism. There are two carbon atoms within these prisms. These two carbon atoms and lead to an increase in the dimension of the molecule to five. On the outer contour, two enantiomorphism forms have the opposite arrangement of hydrogen ions and a hydroxyl group. The images obtained make it possible to explain the main property of tartaric acid - rotation of the plane of polarization of the incident light in different directions: in the case of the *D* form to the right, in the case of the *L* form to the left. It is known devices for rotating the plane of polarization of light, having the appearance of two folded triangular prisms, the boundary between which serves to reflect light [7]. Can say that the molecule of tartaric acid is a natural device for rotating the plane of light polarization. Two carbon atoms play the role of the reflecting partition in the molecule. The rotation occurs in the forms *D* and *L* in different directions because of the opposite arrangement of the charges of the hydrogen ions (+) and the hydroxyl group (-) in these forms. Thus, the reason for the different rotation of the plane of polarization of light lies not in the different forms of the crystals of *D* - tartaric acid and *L*-tartaric acid, as Pasteur suggested, but in different forms of molecules, clearly visible in the image in the space 5*D*.

Conclusion

Analysis of the geometry of the tartaric acid molecule using the Euler-Poincaré equation showed that the dimension of this molecule is five. A polytope of dimension five corresponding to the structure of the tartaric acid molecule was constructed. It was found that this polytope has two enantiomorphic forms, differing only in the opposite arrangement of the hydrogen ions and the hydroxyl group with opposite charges. In the middle of the molecule are two bonded carbon atoms that reflect the incident paralyzed light in opposite directions, depending on the location of the charges. Thus, a molecule of tartaric acid, and not a crystal of tartaric acid, as suggested by Louis Pasteur, possesses optical activity. Especially since there are no crystals of tartaric acid in the solution where the rotation of the plane of polarization was observed. Moreover, the rotation of the plane of polarization occurs in a space of dimension five, and not in a space of dimension three.

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