THE INTERPRETATION OF THE NMR SPECTRA OF FLAVONE C-MONOGLYCOSIDES

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It is extremely difficult to establish the position of attachment of the carbohydrate residue to the aglycone in flavone C-monoglycosides in view of their existence in nature in the form of two isomers in each case [1, 2]. Originally [2, 3], the criterion for this consisted of the physicochemical properties of the substances and, in particular, the results of paper chromatography. Later, NMR spectroscopy came into predominant use [4-7]. Other methods have also been proposed [8, 9].

In the present paper we give the results of a determination by the NMR method of the position of attachment of the carbohydrate residues to the aglycone in two representatives of the C-monoglycosides, orientin and homoorientin, that we isolated some time ago [8, 10].

Analysis of the spectra with integration of the areas of the signals showed the presence in each compound of five aromatic and seven aliphatic protons (Table 1). The interpretation of the signals of the hydrogen protons was performed in accordance with the literature [4-7, 11-13]. In orientin, the hydrogen protons are present in the 2',3,5',6,6' positions, and in homoorientin in the 2',3,5',6',8 positions. The same arrangement of the hydrogens in vitexin and saponaretin has been given previously [12]. According to available information, the aliphatic protons belong to the carbohydrate substituent – glucose [4, 5]. From a comparison with the aglycone luteolin [4, 11, 13], orientin has no hydrogen proton in position 8 and homoorientin none in position 6, which shows their probable replacement by carbohydrate residues. However, in our opinion, it is difficult to agree with this. In the first place, up to the present time the assignment of the signals of the hydrogen protons has been performed provisionally. In luteolin, for example, the signal of the proton at δ 6.50 ppm has been ascribed to the hydrogen in position 8 of ring A and the signal at 6.30 ppm to the hydrogen in position 3 of ring C [4]. In another paper, the assignment of the signals of these protons was made differently, and theoretical bases for this interpretation were given [13]. In the literature, an assignment of the signals of the hydrogen protons in the regions of the spectrum considered is found both in the new and in the previous treatment [6, 11]. In the second place, according to the theory of the recyclization of C-glycosides in nature, there should be two isomeric C-monoglycosides of one and the same aglycone formed according to the Wessely–Moser transformation [14]. But if the existence of two C-monoglycosides can in fact be explained by this transformation, there is no place in this hypothesis for the four isomers appearing after the mild hydrolysis of the C-diglycosides [15]. Abroad, the structure of only one of the four isomers for each of the C-diglycosides of two aglycones has been determined by NMR spectroscopy [5, 13], which also shows some arbitrariness in the interpretation of the spectra. There

TABLE 1. NMR Characteristics of Orientin and Homoorientin

Substance	Aromatic protons						Aliphatic protons	
	B			C	A		glucose	
	H-2'	H-6'	H-5'	H-3	H-8	H-6	H-1	6 protons
Orientin	7,49	7,37 d (J=3 Hz	6,88 d (J=4 Hz	6,50	—	6,24	4,75	3,30 m
Homoorientin	7,28 m		6,89 d (J=5 Hz	6,45 d (J=3 Hz		—	4,79	3,45 (1)+3,29 (5)

Note. d – doublet; m – multiplet.

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is information in the literature [16, 17] which indicates the existence in nature of more than two C-monoglycosides of one and the same aglycone, and this once again confirms the inconsistency of the theory of recyclization. And, in the third place, in the spectrum of homoorientin, in comparison with that of orientin, without taking into account the chemical shifts assigned to the 6- and 8-isomers, a diamagnetic shift of the signal of the H-2' proton by 0.21 ppm is observed.

In actual fact, if the loss of the H-6 proton and its appearance at H-8 (as follows from the recyclization theory) is considered as a paramagnetic shift of the H-6 proton, it is equal in our case to 0.21 ppm (see Table 1). Foreign scientists have also shown that the transition from one isomer to another characterized by the loss of the proton at H-6 and its appearance at H-8, or conversely, is necessarily accompanied by a shift in the signal of the H-2' proton [5]. Consequently, the transition of a proton from one position to another (according to the recyclization theory) causes a change in the magnetic screening of several protons. In such a case, the whole molecule is responsible for any proton transition and then the assignment of the C-glycosides to the 6- and 8-isomers from the presence or absence of the signals of protons of only these positions is extremely questionable.

In determining the structures of orientin and homoorientin, as a working hypothesis we adopted V. I. Litvinenko's rotation theory of the structure of flavone C-glycosides [1]. According to this hypothesis, the appearance of isomers is due to the rotation of the carbohydrate substituent around the C—C bond and the subsequent assumption of a hindered conformation with the fixation of its hydrogen bonds: the syn position arises when the oxygen of the carbohydrate ring is turned to the hydroxy group in position 7 and is remote from the heteroatom of the aglycone, and the anti carbohydrate ring is turned in the opposite direction. For the 6-C-glycosides the syn and anti arrangements relate to the hydroxy group in position 5. In the syn position, a greater number of hydroxy groups participate in the formation of hydrogen bonds, which is expressed in a decrease in the polarity of the flavonoid on paper chromatography. For the anti position the opposite conclusion is logical. Rotation isomers will have a single magnetic center of the molecule.

In orientin and homoorientin, the transition from one isomer to the other takes place through the rotation of the carbohydrate substituent, which is shown by dia- and paramagnetic shifts of the signals of the H-2' and H-6 protons as the most remote from it. The shifts of the signals of the other protons (H-3, H-6') are weaker (see Table 1).

On the basis of the results of a physicochemical analysis [8, 10] and the present investigations, orientin can be characterized as luteolin 8-C-syn-β-D-glucopyranoside and homoorientin as the 8-C-anti-β-D-glucopyranoside.* Orientin and homoorientin are rotation isomers. The difference between the chemical shifts of the last and first signals of aromatic protons in orientin is 1.25 ppm (see Table 1), and in homoorientin, it is 0.83 ppm. Thus, the 8-C-syn isomer has a greater spread of the aromatic part of the NMR spectrum than the 8-C-anti isomer. The range of distinction of the isomers is 0.42 ppm.

EXPERIMENTAL

The NMR spectra were taken on a Varian HA-100D instrument in completely deuterated methanol. The chemical shifts of the protons are given in the δ scale. TMS was used as internal standard.

The characteristics of the NMR spectroscopy of orientin and homoorientin are given in Table 1. For convenience in analyzing the results obtained, the assignments of the signals of the protons have been made by analogy with literature data.

SUMMARY

1. A satisfactory explanation of the structures of orientin and homoorientin has been obtained in an evaluation of the results of NMR spectroscopy from the point of view of the rotation theory of the structure of flavone C-glycosides.

2. On the basis of the investigations performed, orientin has been characterized as luteolin 8-C-syn-β-D-glucopyranoside and homoorientin as luteolin 8-C-anti-β-D-glucopyranoside. Orientin and homoorientin are rotation isomers.

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*In the modern foreign literature, the terms "syn" and "anti" to denote the conformations of saturated compounds have been replaced by the terms "cisoid" and "transoid" to distinguish them from isomers at C = N. (E. Eliel, Principles of Stereochemistry [Russian translation], Moscow (1971), pp. 6, 40.)

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