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BIOCHEMISTRY, BIOPHYSICS, AND MOLECULAR BIOLOGY

Fatty Acid Composition of Odonate's Eyes

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Abstract—We have studied the fatty acid composition of eyes of amphibiotic insects, namely, the odonate *Sympetrum flaveolum*. The main polyunsaturated fatty acid of odonate's eyes has been found to be 20:5n-3 (eicosapentaenoic fatty acid, EPA) rather than 18:2n-6 and 18:3n-3, which usually dominate in eyes of terrestrial insects, or 22:6n-3, which dominates in eyes of vertebrates. The prevalence of EPA in odonate's eyes probably provides a more effective transmission of light signal in this animal compared to terrestrial insects. It is important for odonates because vision plays a decisive role in finding and catching prey.

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Polyunsaturated fatty acids (PUFAs) are known to play an important role in many physiological and biochemical processes in animals. For example, docosahexaenoic acid (DHA, 22:6n-3) is the main component of phospholipids of cell membranes of the human retinal photoreceptors, in which its content reaches 30% of the total content of fatty acids, which is the highest value among tissues [1, 2]. Due to 22-atom carbon chain and six double bonds, the DHA molecule in fact has a spiral shape and probably provides the curvature, elasticity, and fluidity of specialized cell membranes optimal for effective rhodopsin conformation during light absorption [1, 3, 4]. However, it is known that some invertebrates, e.g., *Drosophila*, dispense with long-chain (≥20 carbon atoms) polyunsaturated fatty acids, instead of which they apparently use 18-atom PUFAs to transmit the light signal [1, 5]. Indeed, the compound eyes of terrestrial insects practically do not contain DHA, although the compound eyes of aquatic representatives of the same type Arthropoda, higher crustaceans, contain approximately 13% DHA [6]. The above data are based on the comparison of aquatic invertebrates with terrestrial insects. However, it is known that terrestrial insects usually do not have access to food sources containing significant amounts of EPA and DHA [7–9].

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Table 1. Content of FAs as a percentage of the total amount (mg/g wet weight) in the eyes and bodies of the odonate *Sympetrum flaveolum* from the Baraba forest–steppe, June–August 2015

FA	Eyes	Bodies
12:0	0.34 ± 0.03	0.41 ± 0.02
14:0	1.74 ± 0.47	2.71 ± 0.42*
16:0	12.46 ± 0.52	13.73 ± 0.19
16:1n-9	0.33 ± 0.05	0.47 ± 0.04*
16:1n-7	2.69 ± 0.31	5.15 ± 0.23*
16:1n-6	0.16 ± 0.01	0.26 ± 0.03*
15-17BFA[1]	1.78 ± 0.32	1.85 ± 0.39
18:0	9.72 ± 0.79	6.57 ± 0.58*
18:1n-9	18.94 ± 3.43	29.37 ± 4.78*
18:1n-7	7.18 ± 0.93	3.73 ± 0.57*
18:2n-6	10.55 ± 0.12	14.56 ± 0.69*
18:3n-6	0.19 ± 0.03	0.23 ± 0.05
18:3n-3	5.48 ± 0.47	6.08 ± 0.82
18:4n-3	0.20 ± 0.05	0.26 ± 0.08
20:0	2.15 ± 0.48	0.84 ± 0.12*
20:1[2]	0.53 ± 0.05	0.20 ± 0.02*
20:2n-6	2.35 ± 0.30	0.20 ± 0.03*
20:3n-6	0.27 ± 0.03	0.17 ± 0.03*
20:4n-6	3.76 ± 0.36	4.03 ± 0.46
20:3n-3	0.95 ± 0.08	0.08 ± 0.02*
20:4n-3	0.23 ± 0.03	0.14 ± 0.03*
20:5n-3	15.87 ± 1.08	6.78 ± 1.16*
22:0	0.95 ± 0.26	0.78 ± 0.10
22:6n-3	0.01 ± 0.01	0.06 ± 0.01*
Total amount of FAs, mg/g	18.5 ± 1.87	29.8 ± 4.29*

$M \pm m$, $n = 5$ (the number of determinations for each type of samples). * $p < 0.05$, Student's t test. [1]Total amount of FAs with branched chain consisting of 15 and 17 carbon atoms; [2]total amount of FA isomers with 20 carbon atoms and one double bond.

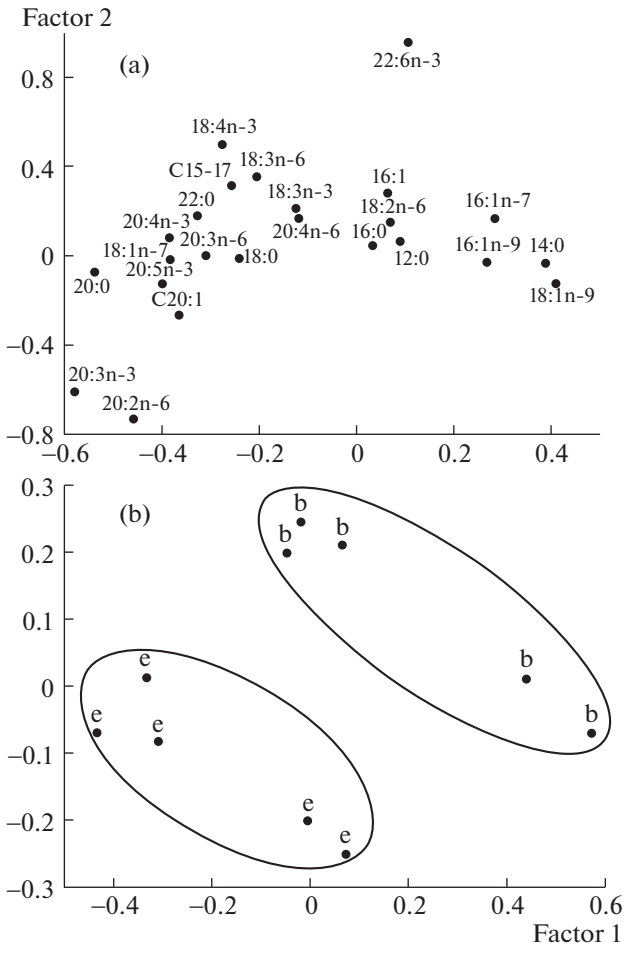

Fig. 1. The results of multivariate canonical correspondence analysis of the fatty acid composition in the eyes and bodies of adult odonate *Sympetrum flaveolum*, collected in June–August 2015 in the Baraba forest–steppe. (a) Distribution of FAs in 2D factor space. (b) Distribution of eye (e) and bodies (b) in 2D factor space. Factor 1—72.7% inertia, factor 2—20.6% inertia, $\chi^2 = 126.3$ at 207 degrees of freedom.

Thus, the aim of our work was to study the fatty acid (FA) composition in the compound eyes of amphibiotic insects, whose larvae grow and develop in water, i.e., have access to PUFA-rich food and are able to store these acids in their biomass, including the adult stage [10].

Adult odonates *Sympetrum flaveolum* L., 1758, caught in the Baraba area of the West Siberian forest–steppe, were used as a model species of amphibiotic insects. The study area and the methods of collecting and processing samples, including gas chromatography–mass spectrometry analysis of FAs, were described in detail in [10]. In total, we analyzed five samples of eyes and bodies of *S. flaveolum*, each of which included biomaterial obtained from several individuals.

In compound odonate's eyes, we detected significantly higher levels of 18:0, 18:1n-7, 20:0, Σ20:1, 20:2n-6, 20:3n-6, 20:3n-3, 20:4n-3, and 20:5n-3 FAs and lower levels of 14:0, 16:1n-9, 16:1n-7, 16:1n-6, 18:1n-9, 18:2n-6, and 22:6n-3 FAs as compared with those in the bodies (table). The total content of FAs in the compound eyes was significantly lower than in the bodies. Multivariate canonical analysis revealed that the greatest contribution to the differences in the total composition of FAs between the eyes and the bodies was made by 20:3n-3 and 18:1n-9, 20:2n-6 and 22:6n-3 FAs (Fig. 1). It should be noted that, unlike vertebrates, the DHA content in compound odonate's eyes was significantly lower than in the body tissues (table). Thus, the main PUFA in the compound eyes of the amphibiotic insect, odonate, is EPA instead of 18:2n-6 and 18:3n-3 FAs, as in the terrestrial insect species [5, 6]. We confirmed the differences between the FA composition of the eyes of vertebrates and the eyes of insects, consisting in the virtual absence of DHA in the latter. Perhaps, these differences in the composition of phospholipids of photoreceptor membranes are determined by different pathways of activation of rhodopsin regeneration in invertebrates and vertebrates [11].

Thus, this is the first study to show that the compound eyes of adult amphibiotic insects (odonates) do not contain higher amounts of DHA compared to the body tissues. However, in contrast to the terrestrial insects, the main PUFA in odonate's eye is EPA. Possibly, the presence of the 20-atom EPA with a large number of double bonds in odonate's eyes compared to the dominant 18-atom PUFA in *Drosophila* eyes provides a more efficient transmission of the light signal, which is required for odonates as air hunters, for which vision plays a crucial role in finding and catching prey.

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