Short communication

The Influence of KCl on the Resting Potential of *Tenebrio molitor* Larva and Imago Muscle

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The study of mechanisms underlying the production of resting potential in insect muscle fibers has revealed some differences as compared with other excitable cells. In some systems the resting membranes of the insect muscle fibers are potassium electrodes according to the Nernst equation (Janiszewski and Skubalanka 1967; Wareham et al. 1974; Ashcroft 1981). On the other hand, many authors have found that membrane potentials of many invertebrate muscle fibers vary with $[K^+]_0$ with a considerable divergence from the slope of 58 mV, and that E_m is very different from E_k, usually exceeding it. Belton and Grundfest (1962) showed that muscle fibers of the larva of *Tenebrio molitor* which are normally surrounded by the haemolymph with a high concentration of potassium ions, are insensitive to changes in $[K^+]_0$ over a wide range between 0 and 120 mmol/l. It has been shown that in these systems in the resting state, the permeability of the muscle membrane to other ions allows to introduce the concept of a so-called "multiionic electrode" (Usherwood 1969; Janiszewski 1981).

Detailed studies have tried to evaluate the contribution of various ions to the resting potential in the *Tenebrio larva* muscle. The results obtained have suggested that since complete substitution of choline or Tris for 70 mmol/l Na^+ does not modify the resting potential significantly, the contribution of Na^+ to this potential would be rather small. Also it has been shown that the resting potential seems not to be sensitive to changes in divalent cations, such as Mg^{2+}, Ca^{2+} and Ba^{2+}. When 70 mmol/l Cl^- ions were replaced with various anions, the membrane hyperpolarized. The effectiveness of hyperpolarization was of the following order: $Cl^- = Br^- < NO_3^- \ll$ acetate$^-$ = propionate$^-$ (Belton and Grundfest 1962; Grundfest and Kusano 1970; Janiszewski and Olszewska 1984; Kusano and Janiszewski 1984).

Data obtained on muscle fibers from larval stages have posed the question whether ionic requirements underlying the resting potential may change during

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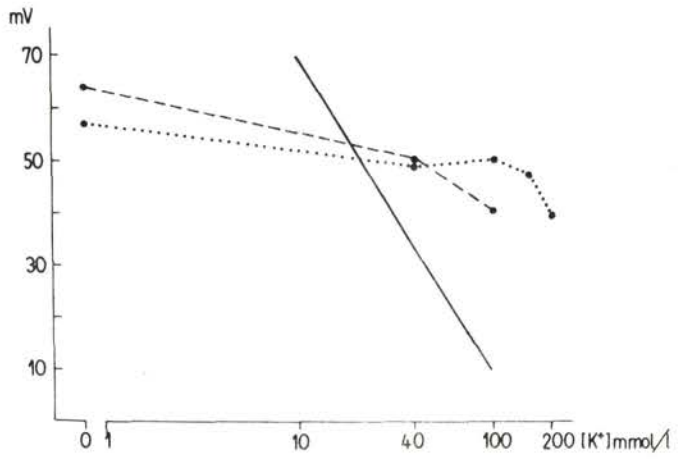

Fig. 1. The effect of variation of $[K^+]_o$ on the muscle resting potential in *Tenebrio molitor* larva (...) and imago (– – –). The points represent mean values. The solid line shows the slope for 58 mV according to the Nernst equation.

ontogenesis (Janiszewski and Grajpel 1983). Electrophysiological experiments on cultured tissues provide some insight into the problem. Spitzer and Lamborghini (1976) showed that the action potential inward current in amphibian neurons in culture may be carried by Ca^{2+} or Na^+ depending on the stage of the development. In experiments carried out in larval stages VI to XIII, Olszewska (1972) could show that the permeability of the muscle membrane for ions involved in electrogenesis undergoes some changes.

In the present paper the influence of KCl on the muscle membrane resting potential in the *Tenebrio molitor* larva and imago was analysed.

The experiments were performed using the conventional microelectrode technique. In the larva the resting potential was recorded from the ventral muscles and in the imago from dorsoventral muscles. The standard saline contained (in mmol/l): NaCl 80; KCl 40; $CaCl_2$ 5; $MgCl_2$ 10; glucose 435 (Belton and Grundfest 1962; Kusano and Janiszewski 1976). The KCl content in the saline used for the experiments was 0; 40; 100; or 200 mmol/l. The number of measurements in a given experimental situation (KCl concentration) varied between 77 and 80 in the larva, and between 117 and 155 in the imago.

Figure 1 summarizes the results obtained. The resting muscle potential in the saline containing 40 mmol/l KCl was 50.4 ± 0.52 mV (mean $\pm$ SE) and 49.1 ± 0.54 mV for imago and larva, respectively. In 100 mmol/l KCl the respective values were 40.9 ± 0.9 mV and 50.6 ± 0.5 mV. In larva the resting potential was also measured in 150 mmol/l and 200 mmol/l KCl; values of 47.8 ± 0.5 mV and

39.8 ± 0.6 mV were measured respectively. As may be seen from the figure, there is a marked difference in the curve slopes for the larva and imago respectively. A curve for 58 mV resulting from Nernst equation is given for comparison.

The results obtained in the present work indicate that during the development of *Tenebrio molitor* from the larva stage to imago, some changes of the ionic requirements for the muscle membrane potential may occur. Similar results obtained on other material have been reported by Hotta et al. (1983). These authors observed on cultured chick embryo muscle cells that Ca^{2+} channels may be formed on the cell membrane in very early stages of myogenesis, and Na^+ and K^+ channels develop sometimes later.

Recently Kusano and Janiszewski (1984) have shown that the relative contribution of K^+ ions to the muscle resting potential in *Tenebrio molitor* larva increases with increasing pH. This may be one of the possible explanations of the results obtained in the present work.

The mechanism underlying the different ionic processes found in our present work require further, detailed investigation.

References

Ashcroft F. M. (1981): Calcium dependent action potentials in the skeletal muscle fibres of stick insect *Carausius morosus*. J. Exp. Biol. **93,** 257—267

Belton P., Grundfest H. (1962): Potasium activation and K spikes in muscle fibers of mealworm larva (*Tenebrio molitor*). Am. J. Physiol. **203,** 588—594

Grundfest H., Kusano K. (1970): Role of various cations in the depolarizing electrogenesis of mealworm muscle fiber. J. Gen. Physiol. **55,** 139

Hotta K., Oba T., Yamamoto Y. (1983): Development of ionic channels in early stage of genesis in skeletal muscle. Proc. Int. Union Physiol. Sci. Sydney, **15,** 153

Janiszewski L. (1981): Ionic mechanisms in excitable membranes. Proceeding of Sixth School on Biophysics of Membrane Transport, Poland, 151—162

Janiszewski L., Grajpel B. (1983): The influence of KCl on the muscle resting potential in the larva and imago of *Tenebrio molitor*. Proc. Int. Union Physiol. Sci. Sydney, **15,** 44

Janiszewski L., Skubalanka E. (1967): Influence of potassium ions concentration on resting potential in the skeletal muscle fibers of the stick insect (*Carausius morosus BR*). Acta Physiol. Pol. **18,** 295—303

Janiszewski L., Olszewska E. (1984): The effect of some anions on the muscle resting potential in *Tenebrio molitor*. Acta Physiol. Pol. (in press)

Kusano K., Janiszewski L. (1976): Neuromuscular transmission in mealworm larvae (*Tenebrio molitor*). In: Electrobiology of Nerve, Muscle and Synapse. (Ed. Reuben J. P., Purpura D. P., Bennett M. V. L., Kandel E. R.), pp. 93—103, Raven Press, New York

Kusano K., Janiszewski L. (1984): Electrophysiological properties of mealworm (*Tenebrio molitor*) muscle fibers. (in preparation)

Olszewska E. (1972): The nature of muscle electrical phenomena in larval development of *Tenebrio molitor*. Studia Soc. Sci. Tor. **3,** 1—32

Spitzer N. C., Lamborghini J. (1976): The development of the action potential mechanism of amphibian neurons isolated in culture. Proc. Nat. Acad. Sci. USA **73,** 1641—1645

Usherwood P. N. R. (1969): Electrochemistry of insect muscle. Adv. Insect Physiol. **6,** 205—276
Wareham A. C., Duncan C. J., Bowler K. (1974): The resting potential of cockroach muscle membrane. Comp. Biochem. Physiol. **48 A,** 765—797

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