Proc. Indian Acad. Sci. (Anim. Sci.), Vol. 89, Number 2, April 1980, pp. 109–112.


# Utilisation of carbohydrates in the heart of the scorpion *Heterometrus fulvipes* (C L Koch)

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MS received 2 March 1979

**Abstract.** The changes in the levels of total anthrone positive substances glycogen and glucose and the activities of phosphorylase, lactate dehydrogenase and succinate dehydrogenase were studied in the *in situ* heart of the scorpion *H. fulvipes*, based on the theme of acceleration and inhibition. TAPS and glucose showed appreciable depletion in the accelerated hearts and conservation in the inhibited hearts. Glycogen depletion in the accelerated hearts is not significant while conservation in the inhibited hearts is significant. Both active and total phosphorylases as well as the combined ratio showed increasing trend with increase in heart rate and *vice versa*. The role of carbohydrates as metabolic fuel to sustain the heart beat is also discussed.

**Keywords.** *Heterometrus fulvipes*; heart rate; acceleration; inhibition; carbohydrates.

## 1. Introduction

Information on the physiology and pharmacology of the arthropod heart in general (Krijgsman 1952) and of scorpion heart in particular (Kanungo 1957; Zwicky and Hodgson 1965; Devarajulu Naidu 1973) is available. It was shown by Devarajulu Naidu (1973) that $1 \times 10^{-5}$ M acetylcholine (Ach) and $1 \times 10^{-5}$ M 5-hydroxy tryptamine (5-HT) accelerate and inhibit the heart rate respectively to the maximum extent in this species. The rate of heart beat is significantly different between the sexes in this scorpion (Padmanabha Naidu 1966; Jayaram and Padmanabha Naidu 1979). But the metabolic profile underlying the differential heart rate did not receive much attention. In view of this, the study of carbohydrate utility with reference to differential heart rate appears to be ideal, towards forming a base for further studies on energetics of the cardiac muscle, the literature on which is scanty at present. The levels of phosphorylase, lactate dehydrogenase (LDH) and succinate dehydrogenase (SDH) which have an intimate involvement in carbohydrate metabolism are also reported.

## 2. Materials and methods

Details of collection and maintenance of scorpions were described earlier (Devarajulu Naidu and Padmanabha Naidu 1975). Only adult male scorpions of similar size were used since size and sex are known to alter the rate of heart beat (Padmanabha Naidu 1966).

Five *in situ* heart preparations (Devarajulu Naidu and Padmanabha Naidu 1975); were simultaneously maintained in scorpion perfusion fluid (Padmanabha Naidu 1967) and the rate of heart beat (beats/min) was recorded for each *in situ* heart as the mean value of 3 observations. These hearts were removed and pooled in cold (4° C) to designate as one normal heart sample.

$1 \times 10^{-5}$ M solutions of Ach and 5-HT prepared separately in perfusion fluid were used to accelerate and inhibit the *in situ* heart rate respectively. A series of 5 *in situ* hearts maintained for 30 min in accelerated state and another series of 5 hearts in inhibited state are removed in parallel and pooled as above after recording the rate of heart beat and these denote one accelerated heart sample and one inhibited heart sample respectively. The heart samples were prepared between 10 and 12 hr of the day since this scorpion is known for notable diel variations in heart rate and some of the associated enzymes (Devarajulu Naidu and Padmanabha Naidu 1976; Chandrasekhara Reddy and Padmanabha Naidu 1977; Jayaram *et al* 1978).

Total anthrone positive substances (TAPS) representing total carbohydrates were estimated by using anthrone reagent (Carroll *et al* 1956), glycogen and glucose by the method of Kemp *et al* (1954) and proteins according to Lowry *et al* (1951). Phosphorylase (EC 2.4.1.1) was assayed by the method of Cori *et al* (1955) and the liberated inorganic phosphorus according to Fiske and Subba Row as given by Oser (1965). SDH (EC 1.3.99.1) and LDH (EC 1.1.1.27) activities were assayed by the method of Nachlas *et al* (1960).

## 3. Results and discussion

The heart rates were determined in normal, accelerated and inhibited *in situ* hearts to know the percentage acceleration and inhibition. The increase in the heart rate upon acceleration was 29·71% and the decrease upon inhibition was 28·70% which are statistically significant (table 1). TAPS level dropped significantly (13·22%) with elevated heart rate and increased (16·26%) with lowered heart rate, the percentage depletion being less than preservation indicating the importance of carbohydrate as metabolic fuel to sustain the heart beat.

Glycogen, though depleted by 8·99% in the accelerated hearts is not significant, a 15·84% conservation in the inhibited hearts is significant. The insignificant depletion of glycogen in the accelerated scorpion heart, as in isolated rat heart (Gartner and Vahouney 1973), indicates the myocardial capacity for glycogen retention even during higher activity. The disproportionate conservation of glycogen in the inhibited hearts is notable (table 1). The glycogen depletion with elevated heart rate, though not statistically significant, reflects the triggering of glycogenolysis as evidenced by elevated phosphorylase activity (table 1). A significant increase was observed in the activity of active (59·3%) and total (24·2%) phosphorylases in the accelerated hearts. The ratio of active-to-total phosphorylase (*a*/*ab*) which is taken as a more reliable means of assessing the phosphorylysis of glycogen increased to 29·33% upon acceleration. This ratio in the inhibited hearts is not significantly different from the normal value denoting the nonutility of glycogen

**Table 1.** Heart rate (beats/min) levels of TAPs, glycogen and glucose (mg/gm wet wt), activities of phosphorylase (μ mol pi/mg protein/hr), SDH and LDH (μ mol formazan/mg protein/hr) in normal, accelerated and inhibited heart samples of *H. fulvipes* : Figures in the parentheses are number of observations.

| Constituents | Normal Hearts | Accelerated Hearts | % Change over normal Hearts | Inhibited Hearts | % Change over normal Hearts |
|---|---|---|---|---|---|
| Heart rate (10) | 62·60±1·17 | 80·9 ±1·49[a] | +29·71 | 44·0 ±1·18[a] | −28·70 |
| TAPS (10) | 5·249±0·321 | 4·556±0·637[e] | −13·22 | 6·104±0·627[b] | +16·26 |
| Glycogen (10) | 2·916±0·342 | 2·654±0·613[NS] | − 8·99 | 3·378±0·487[e] | +15·84 |
| Glucose (10) | 1·379±0·499 | 0·773±0·137[b] | −43·99 | 1·912±0·322[d] | +38·53 |
| Active Phosphorylase *a* (6) | 24·04 ±2·059 | 38·4 ±3·106[a] | +59·80 | 18·39 ±2·195[a] | −24·31 |
| Total Phosphorylase *ab* (6) | 48·31 ±3·88 | 60·0 ±4·81[a] | +24·20 | 38·08 ±4·33[a] | −21·20 |
| *a*/*ab* ratio | 49·74 ±2·62 | 64·28 ±6·00[a] | +29·33 | 48·59 ±8·94[NS] | − 2·31 |
| SDH (6) | 3·506±0·434 | 6·335±0·319[a] | +80·69 | 3·069±0·225[c] | −12·47 |
| LDH (6) | 1·054±0·201 | 2·071±0·339[e] | +96·40 | 1·014±0·081[NS] | − 3·90 |

*P* Value: [a] $< 0·001$; [b] $< 0·002$; [c] $< 0·005$; [d] $< 0·001$; [e] $< 0·02$.

NS: Not Significant

in the inhibited myocardium. Thus, it appears that the cardiac muscle of the scorpion, like vertebrate muscles, retains a fair amount of glycogen even upon 30 min acceleration, probably to protect the enzymes associated with glycogen from disruption (Heilmeyer *et al* 1970) and to ensure future heart metabolism.

There is a 43·29% drop in glucose level upon 30 min acceleration and a 38·53% increase with 30 min inhibition and both are highly significant. It is significant that utilisation of glucose in the accelerated hearts is higher than conservation in inhibited hearts. Hence, the situation with respect to glucose is reverse of TAPS and glycogen where utilisation is less than conservation (table 1). This higher depletion of glucose content in the heart upon acceleration might provide the necessary high energy for elevated heart activity. This perhaps is responsible for the maintenance of myocardial contractility, heart metabolism and ultrastructure, as indicated by Dhalle *et al* (1973) for rat isolated heart. The increase in the glucose content in the inhibited hearts could be due to lowered substrate demand and also counter-supports the importance of glucose as energy yielding fuel to keep up higher heart rate. In tune with the changes in the levels of carbohydrates, there has been a 96·4% raise in LDH and 80·69% raise in SDH activities in the accelerated hearts (table 1). LDH activity overpowering the SDH activity upon acceleration reveals the probable propensity of the scorpion heart towards lactate metabolism. The increase in SDH activity in accelerated hearts may be correlated to higher glucose utilisation to step up oxidative path ways and to initiate the availability of energy in larger quantities. The decrease in LDH and SDH activities in the inhibited hearts, obviously be the consequence of lowered cardiac activity with subnormal requirements of energy. Thus, the carbohydrate fuel mixture, in varying proportions appear to meet partially the energy needs of the differential heart rate. Studies to decide the role of amino acids and fatty acids as metabolic fuels underlying the heart beat in this species are in progress.

## Acknowledgements

The authors thank Prof. K S Swami for providing facilities. Award of teacher fellowship to V Jayaram by University Grants Commission, New Delhi, is gratefully acknowledged.

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