Pakistan J. Sci. Ind. Res., Vol. 31, No. 10, October 1988

TEMPERATURE DEPENDENCE STUDIES OF BIO-EMF-DEVICES

K.M. Jain and Anuj Hundet

Government Science College, Rewa-486 011, India

(Received June 5, 1988; revised October 18, 1988)

BEDs, the low power sources, have recently been developed using plant leaves. A study based on temperature as a probe shows that the biological activities play dominant role and the energy producing reactions in BEDs seem to be enzyme catalysed bio-chemical reactions. The results are compared with the cell-free system.

Key words: Temperature, Bio-emf-devices.

INTRODUCTION

A plant leaf is a well defined bio-chemical system which has a great potential with material technology point of view [1]. The bio-electrical properties of plant leaves also make them useful source for electrical energy tapping [2]. The Bio-emf-devices (BEDs) recently developed using *Sansevieria trifasciata* (ST) leaf have been found useful in energizing practically all electronic circuits consuming upto hundreds of micro-watts of power [3]. The mechanism of power generation from BEDs is not yet clear, though the involvement of biological activities has been speculated [3]. It seems that the biological activities, like, physiological processes and the injury and healing of tissues may be important in this context because of their electrical origin [4-7].

The bio-chemical reactions are highly temperature sensitive [8]. Thus the study based on temperature variations of BEDs is expected to throw light on the type of energy producing reactions involved. In this paper, we present our results.

EXPERIMENTAL

Thin mettalic plate of zinc having a surface area of 4 sq.cms. is taken and a 2 mm. thick supporting plate of teflon with a central hole for electrical connection is affixed on one side of it to construct the electrode [3]. In order to facilitate temperature dependence studies, a 1.2 cm. thick brass electrode having 6 sq.cm. surface area approximately and 3 mm. deep side-ways slots for clips is constructed (Fig. 1a). The ST-BED [3] obtained using these electrodes is quite suitable for temperature variation studies. The brass electrode of the BED is now placed on a thermal bar platform in a suitably designed conductivity chamber (Fig. 1b). The inlet and outlet were also provided for air passage. This also allows the humidity to vary freely in the chamber. The temperature of the BED is controlled from outside. The temperature measurements were made using a copper-constantan thermocouple attached at the top of the brass electrode and HIL digital panel meter 2301. The heating rate during the experiment was 0.75° per minute and the continuous variations in voltage and power values were recorded with increasing temperature.

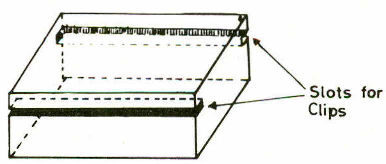

Fig. 1a. Brass electrode.

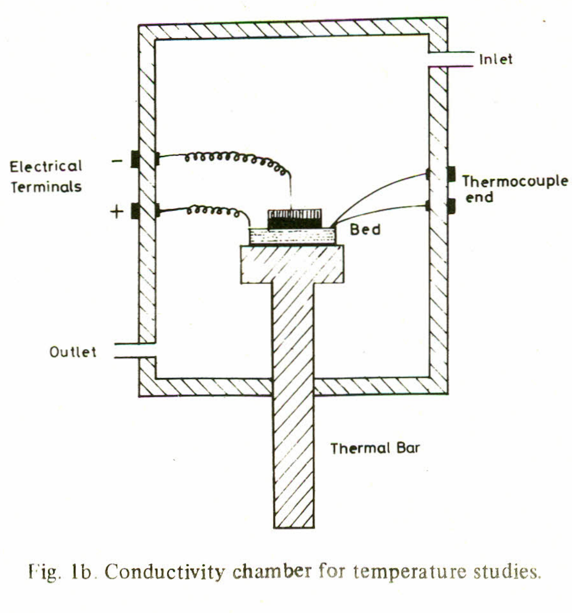

Fig. 1b. Conductivity chamber for temperature studies.

RESULTS AND DISCUSSION

Leaf system: Open circuit volage. The open circuit voltage (V_{oc}) is 'no load voltage' of the BED. Its variation with rising temperature is shown in Fig. 2. The value of V_{oc}) is about 850 mV at room temperature (26°) which decreases continuously upto about 38° with increasing temperature. It is well known that the open circuit voltage is very important battery parameter and is related to the free energy (△H) of the reaction. Assuming that two electrons are involved in the reaction and entropy contributions are negligible, the Gibbs-Halmholtz equation gives the value of △H as 39.11 k-cal/mole at room temperature which becomes 34.97 k-cal/mole at about 38°. In a bio-system, where enzymes play dominant role, the decreasing value of △H with rising temperature may result possibly from the varying nature of energy producing reactions.

From ~38 to ~60°, a varying V_{oc} value is observed. This may be attributed to the thermal injury of living cells and also to the growing inactivation of enzymes. A further rise in temperature caused a rapid fall in V_{oc} value accompanied by vigorous fluctuations. The fluctuating values are marked by arrows (Fig. 2). The length of the arrow indicates the amplitude of variation in the value. The fluctuating values of V_{oc} are possibly due to the breaking of the weak hydrogen bonds of enzyme structure.

Power through 1000 ohms. The effect of temperature variation on the power output from the BED has been studied when the power is drained through a load of 1000 ohms.

The results are plotted in Fig. 3. The power values rise significantly up to 38°. The fluctuations in power originate in the vicinity of 36 – 38.5° temperature region. They persist up to about 60 ± 1° and then there is rapid drop in power value.

It is well known that the temperature coefficient is lower for physical reactions in comparison to the enzyme catalysed bio-chemical reactions. Over a limited range of temperature, the velocity of the enzyme catalysed reactions increases as temperature rises. The velocity of many biological reaction roughly doubles with a 10° rise [9]. The power value is expected to depend on the velocity of the reaction. From the Fig. 3, we see that in the initial temperature region, a 10° rise in temperature always results in an enhancement of power value by more than twice. This observation suggests about the possibility of involvement of enzymatic activities. Further the enzyme catalysed reaction rate rises more nearly exponentially with temperature in the temperature region of physiological interest [10]. We have plotted log (power) versus T^{-1} in Fig. 4. A good straight line obtained in this plot further supports the possible role of bio-activities which embody enzymatic components in the energy producing reactions in BEDs.

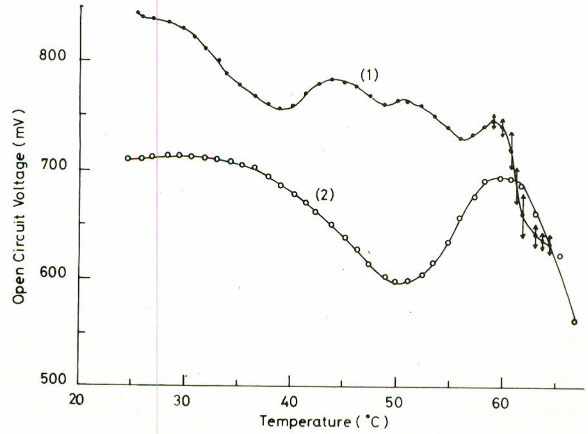

Fig. 2. Variation of open circuit voltage with temperature (1) ST-BED; (2) Cell-free system.

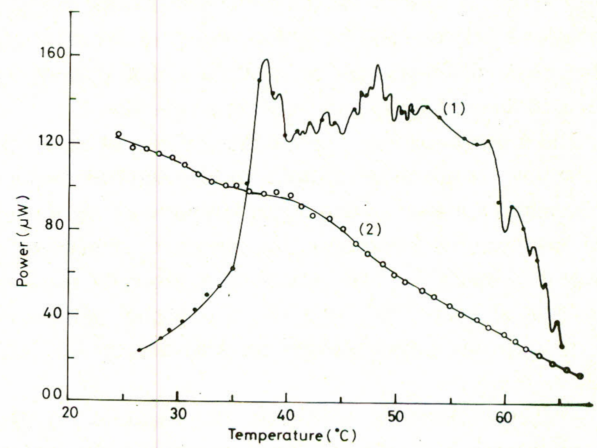

Fig. 3. Variation of power through a load of 1000 ohms with temperature (effective BED area 4 sq.cm.). (1) ST-BED; (2) Cell-free sytem.

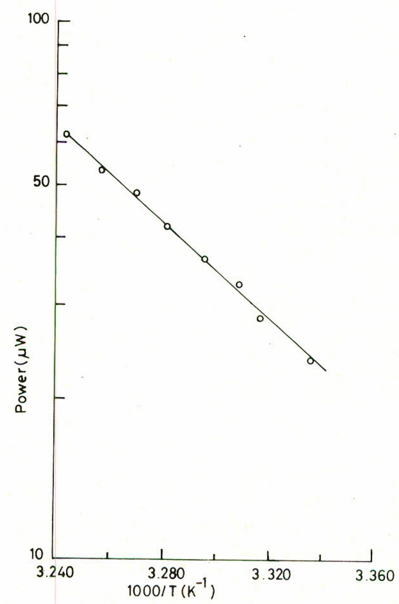

Fig. 4. Plot of log (power) versus T^{-1} in the low temperature region.

Cell-free system. In order to compare the results obtained on temperature studies of ST-BED, we have carried out one experiment in which a filter paper soaked in the cell-free extract from ST-leaf was used instead of ST-leaf. The results on the temperature dependence of V_{oc} and power are included in the Fig. 2 and 3. From the figures, we observe that the results obtained in the two cases are remarkably different.

The cell-free extract contains various inorganic salts, carbohydrates, proteins, enzymes and other organic and inorganic species. This cell-free system seem to work like a physical system. This is apparent from the absence of fluctuations in the plots (Fig. 2 and 3). As the living cells are not present in cell-free extract, the enzymes remain no longer active. A monotonic fall in the power value in Fig. 3 is obtained for the cell-free system which is distinctly different from the behaviour of ST-BED which showed the effects of thermal injury and enzymatic activities.

The behaviour of V_{oc} is also much different especially in the low temperature region. In the cell-free system, V_{oc} remains constant in the initial temperature region and then decreases with increasing temperature. Interestingly, slowly decreasing V_{oc} value starts rising after 50^{o} reaching maximum at about 60^{o}. This rise is expected because of the presence of enzymes which get denatured in this temperature range.

Acknowledgements. Authors are thankful to Mr. Navin Chandra, RRL, Bhopal for many fruitful discussions. The financial support from MAPCOST, Bhopal is gratefully acknowledged.

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