



## Variation of Electrical Activity of Bovine Cerebrum and Cerebellum Tissue with Temperature

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### ABSTRACT

The variation of the electrical activity of Bovine cerebrum and cerebellum tissues within the physiological temperature range of 5°C to 40°C was investigated. Fresh cerebrum and cerebellum samples were excised from a healthy cow and measurements were carried out on the tissues within six hours with a Jenway 4010 conductivity meter and Jenway 2030 pH/bulk electric Potential meter. Data was obtained and graphs of variation of pH, bulk electric potential and conductivity with temperature were plotted. The graph of the pH and bulk electric potential showed an exponential decay and exponential rise with temperature respectively. The conductivity graph showed a two-phase behaviour as an Ohmic conductor from 5°C to 25°C and as a semiconductor from 25°C to 40°C displaying a transition temperature. The measurement for conductivity was carried out in the presence of a static magnetic field of 1.92 mT. The graph showed that the conductivity significantly changed in the presence of the field with general increase in values and with distort comparatively. The key implication of this finding is that the brain tissue appears to behave like a conductor and a semiconductor with a sharp transition temperature at (25±1) °C. The brain tissue appears to be magnetosensitive to magnetic field in its vicinity.

## 1. Introduction

The electrical activity in biological tissues may be investigated by using electric conductivity, bulk electric potential and pH which varies with temperature [1]. The variation of the above electrical activity parameters with temperature reflects the existence of such properties as energy band, ionic transport, polarization etc. which are known to depend on the material. Electrical switching effect found in elemental semiconductors, have been observed in the biologically important pigments melanin; known to play essential role in the retina, brain or ear [2,3]. Piezoelectric effects have been observed directly in bone [4], pyroelectricity observed in nerve tissue [5, 6, 7].

Bovine cerebrum and cerebellum tissue consist of grey and white matter which are basically complex matrix of nerve cells – neurons. The tissue may be classified as a heterogeneous, jelly with relatively high concentration of such ions as  $Na^+$ ,  $K^+$ ,  $Ca^{2+}$  etc. These ions are not evenly distributed, therefore membrane potential is observed to exist between the inside of a cell and the outside. The tendency of an ionic species to diffuse across a plasma membrane is directly proportional to the ratio of concentrations inside and outside nerve cell. The tendency of an ionic species to move across cell membrane under an electrostatic potential is a function of the difference in charge concentration between intra cellular and extra cellular fluids, which is normally expressed as Nernst equation which takes the form [8, 9]

$$E_k = 58 \log \frac{K_o}{K_i} \quad (1)$$

Where  $k_o$  is the extracellular concentration of Potassium,  $k_i$  is the intracellular concentration and  $E_k$  is the equilibrium potential.

Equation (1) is the Nernst equation for  $K^+$ . The equation however, holds for other ions. The brain tissue is characteristically mild alkaline probably because of the  $Na^+$ ,  $K^+$ ,  $Ca^{2+}$  ions. The nerve cells or neurons when at fixed peak voltage, are propagated along the axon. These nerve impulses or action potential are generated in the presence of stimulus such as temperature change and sound etc., which brings the neurons to a threshold [10, 11, 12]. The effect of temperature change on the electrical activity of bovine cerebrum and cerebellum tissue considered in this study, seeks to investigate changes in the normal function of the brain tissue at temperatures from  $5^\circ\text{C}$  to  $40^\circ\text{C}$ . This could serve as a source of information to understand the electrical nature of Brain tissues which is central to its function as the central processor of signals and information in the nervous systems.

## 2. Materials and Method

Three samples of Bovine brain were obtained from freshly slaughtered healthy cow in an abattoir in Benin City. The brains were dissected to obtain samples of cerebrum and cerebellum. Each sample was introduced into large enough boiling tube that could contain the probes of the conductivity meter and pH/bulk electric potential meter. As a result of the jelly-like nature of samples, it was carefully fed into the probes before placing them in the boiling tube with more of the sample. The boiling tube was partially immersed inside a grant temperature controlling water bath [13,14] permitting temperature variation between  $5^\circ\text{C}$  to  $40^\circ\text{C}$ .

The sample was cooled to  $0^\circ\text{C}$  by chilling the water into the bath using a refrigerator output ring. Distilled water with conductivity of  $0.011\mu\text{mho/m}$  (or  $\mu\text{Sm}^{-1}$ ) and pH 7.00 was used to calibrate the conductivity meter and pH/Bulk electric potential meter respectively. Eight temperatures from  $0^\circ\text{C}$  to  $40^\circ\text{C}$  at interval of  $5^\circ\text{C}$  with corresponding conductivity, pH and Bulk electric potentials for all samples were measured as the temperature of the water bath rise.

## 3. Results and Discussion

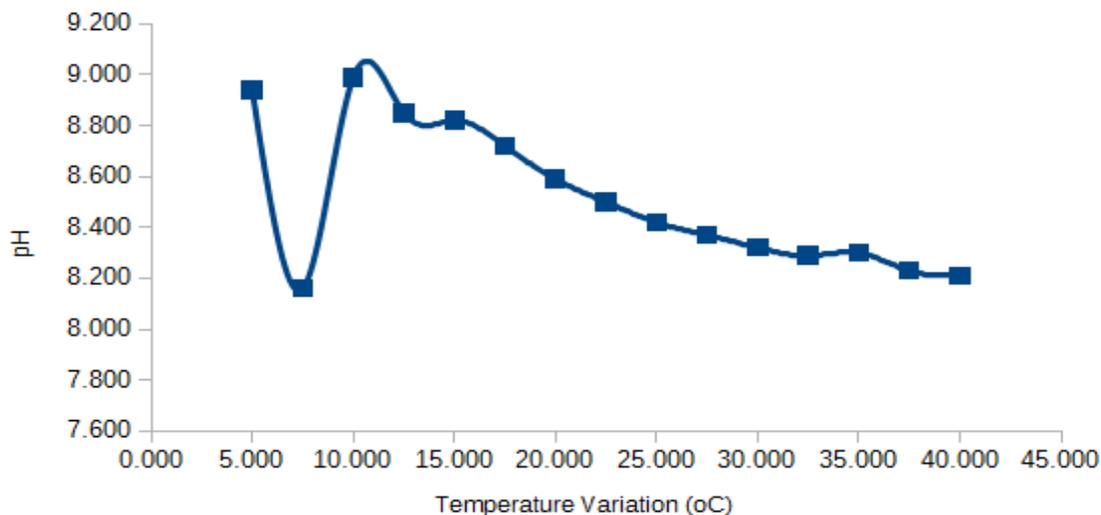


Fig. 1: Variation of pH with Temperature for Bovine Cerebrum Tissue.

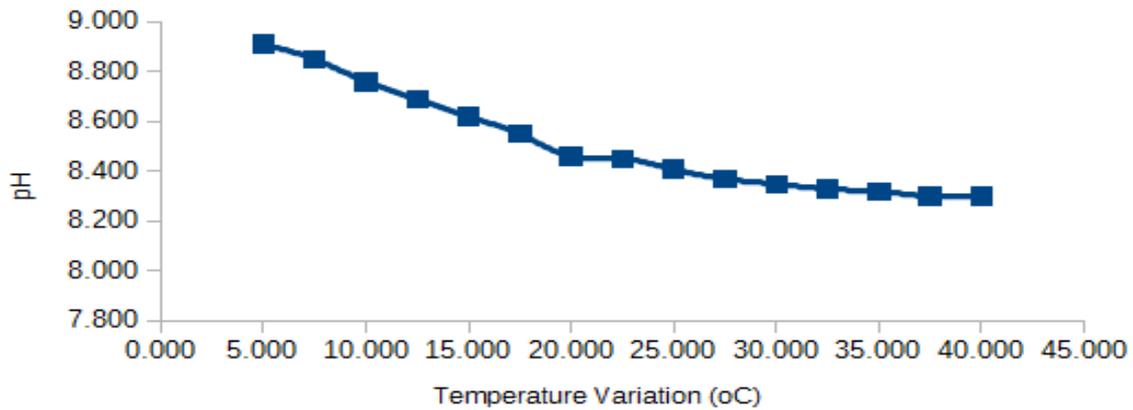


Fig. 2: Variation of pH with Temperature for Bovine Cerebellum Tissue.

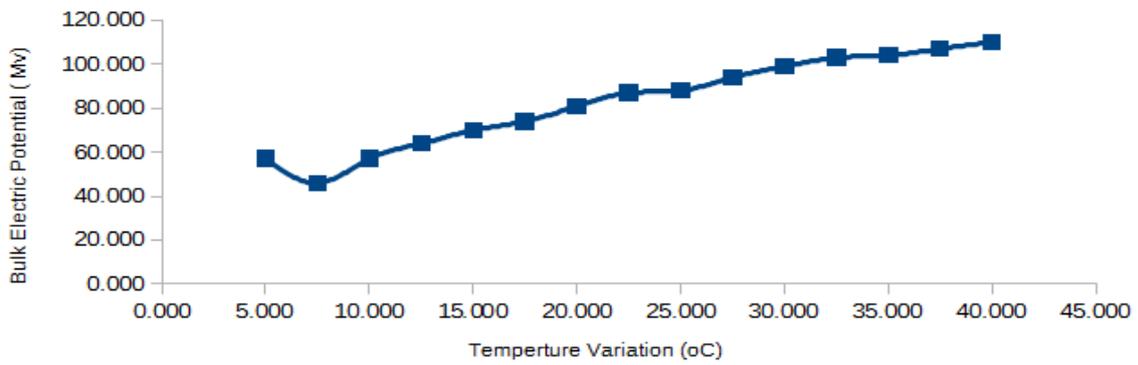


Fig. 3: Variation of Bulk Electric Potential with Temperature for Bovine Cerebrum Tissue.

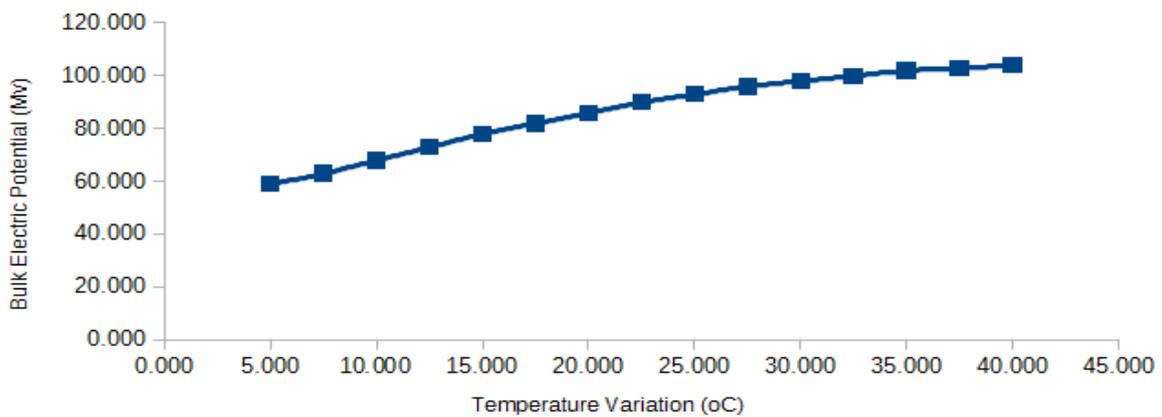


Fig. 4: Variation of Bulk Electric Potential with Temperature for Bovine Cerebellum Tissue

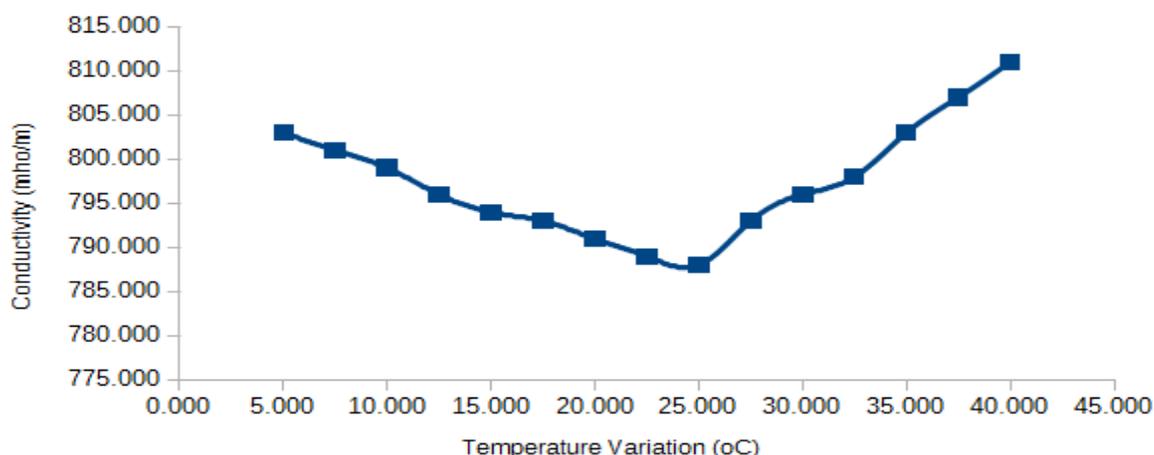


Fig. 5: Variation of Conductivity with Temperature for Bovine Cerebrum Tissue

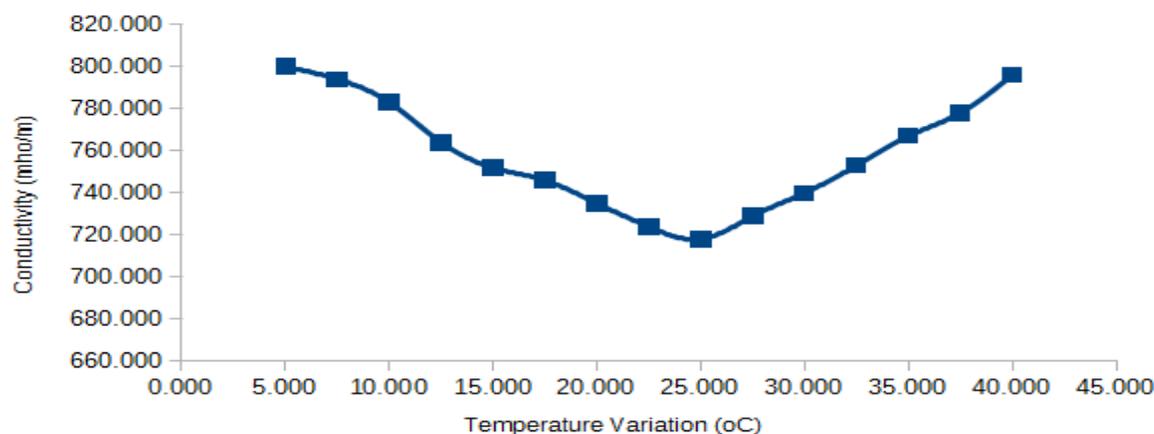


Fig. 6: Variation of Conductivity with Temperature for Bovine Cerebellum Tissue

Fig.1 and 2 shows the pH curves for cerebrum and cerebellum in the temperature range of 5°C to 40°C respectively. The results show noticeable variational decrease in the alkalinity of the brain tissue within the physiological temperature range.

Fig.3 and 4 shows the Bulk electric potential for the cerebrum and cerebellum.

Fig.5 and 6, shows the conductivity of the cerebrum and cerebellum respectively. The conductivity for both cerebrum and cerebellum shows a characteristic fall between (5±1)°C to (25±1)°C followed by a rise from (25±1)°C to (40±1)°C.

The transition temperature of about 25°C is clearly seen on the graphs (Fig.5 and Fig.6), and it is the same for the cerebrum and cerebellum tissue. The characteristic fall from (5±1)°C to (25±1)°C fits well with the behaviour of electronic conduction in metals and electrolytes, in other words referred to as the standard semiconduction equation [15].

$$\sigma = \sigma_0 e^{(-E/kT)} \quad (2)$$

Eq. (2) is standard semiconduction equation, where E is the activation energy and k is the Boltzmann constant,  $\sigma_0$  is the initial condition fixed conductivity.

#### 4 Conclusion

The result obtained in this study shows that the pH of the brain tissue is mild alkaline with value between 8.2±0.1 and 9.2±0.1. This may be due to the presence of Na<sup>+</sup>, K<sup>+</sup> and Ca<sup>2+</sup> ions in the brain tissues.

Through the physiological temperature range, the pH shows a curve which fit well with an exponential decay curve.

The bulk electric potential rises exponentially with temperature. The conductivity plot in Fig.5 and 6, shows a transition at about 25°C.

Firstly, a fall from (5±1) °C to (25±1) °C, fits well with the expression for Ohmic conduction. This is probably due to the available ions and electrons in the tissue. Conductivity falls with temperature in metallic conductors and electrolytes. Secondly, a rise from (25±1) °C to (40±1) °C fits well with the standard semiconduction equation. This behaviour is probably due to the increase in the density of charge carriers with temperature exceeding the effect of scattering, due to thermal agitation of macro-molecules of the brain tissues. The characteristic behaviour of the brain tissue conductivity with temperature change suggest that transmission of impulses is stabilised at room temperature of about 25°C. The increase in conductivity at either below or above 25°C, reflects the likely increase in the electrical activity of the brain.

For instance, during high fever, the temperature of the brain is higher than 25°C, reflecting marked increase in the conductivity of the brain tissues and probably high frequency firing of the brain neurons.

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