Commentary

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A Bird's Eye View of Lactate Biosensors

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Commentary

Lactic acid (2-Hydroxypropanoic acid) or lactate (ionic form of lactic acid) is generated from pyruvic acid under anaerobic condition in all tissues like skeletal muscle, brain, RBC and kidney. The normal level of lactic acid in serum is in the range of 0.5-2.2 mM. During exercise and extensive work, its level in blood increases upto 12 mM and 25 mM. Lactate level is measured in dairy products to monitor the freshness, stability and quality of foods. It is also measured in alcoholic beverages to examine their acidity and tartness. Blood lactate level provides valuable information of stress in marine products/fish culture industry. Determination of serum lactate is required in the differential diagnosis and medical management of hyperlactemia, cardiac arrest and resuscitation sepsis, reduced renal excretion, hypoxia induced cancer, decrease extra hepatic metabolism, intestinal infarction and lactic acidosis. Among the various methods available for determination of lactate, biosensing method is comparatively simple, sensitive, selective, rapid and economical. A biosensor is an analytic device, employing a biological recognition element, which is in the direct spatial contact with the transducer element. The review article describes the classification of various lactate biosensors, their principle, merits and demerits [1]. As per this classification, lactate biosensors have been divided into 5 major classes: (i) Electrochemical, (ii) Electrochemiluminescence, (iii) Fluorescence, (iv) Microband and (v) Reagent-less biosensors.

The electrochemical biosensors have been classified further into (a) potentiometric and (b) amperometric lactate biosensors. The potentiometric lactate biosensors measure the accumulation of charge potential at the working electrode compared to the reference electrode in an electrochemical cell, when zero or no significant current flows between them. Though, these biosensors have the advantage of relative simplicity, yet suffer from interference by endogenous ammonium ion in the blood or urine, low limit of detection and poor stability of enzyme electrode. Amperometric lactate biosensors measure the current which is directly proportional to the concentration of lactic acid. These biosensors have the advantages of high sensitivity, rapidity, inexpensive and disposable compared to potentiometric and conductometric biosensors. Amperometric lactate biosensors can be classified further as lactate oxidase (LOx) and lactate dehydrogenase (LDH) based biosensors. In LOx based biosensors, H_2O_2 is generated from lactate by LOx, which is oxidized at the electrode surface giving a current proportional to the concentration of lactate. In LDH based amperometric biosensors, the electrons are generated from pyruvate to form lactate and back by the LDH followed by conversion of NADH into NAD+ and back. The current flow is measured, which is directly proportional to lactate concentration.

Electrochemiluminescence lactate biosensors are based on generation of H_2O_2 from lactate by LDH and pyruvate oxidase, which enhances the electrochemiluminescence of luminol, which sense the lactate concentration. These biosensors offer the advantage of simple instrumentation, low detection limit (LOD) and wide dynamic working range but lack selectivity, specificity and depend on pH and temperature.

Fluorescence based lactate biosensor employ a quantum dot hydrogel based fluorescence probe for biosensing and bioimaging the extracellular lactate. By surface engineering, the destabilized Nile-Blue functionalized quantum dot sol monitor the lactate in presence of NAD and LDH through florescence resonance energy transfer. This specifically detects and images the extracellular lactate metabolism. These biosensors are highly specific, sensitive and image the extracellular lactate metabolism but have disadvantages of photo-bleaching of fluorescent organic dyes conjugated to the lactic acid and potential loss of biological activity of biomolecules upon chemical conjugation of fluorescent dye.

Microband lactate biosensors are based on screen printed carbon microband electrodes fabricated from water based ink, which readily detect H_2O_2. The same ink with the addition of LOx has been used to construct microband biosensors to determine lactate.

The reagentless lactate biosensors are based on electropolymerized co-polymer film of poly (5-hydroxy-1,4-naphthoquinone-co-5-hydroxy-3-acetic acid-1,4-napthoquinone). The quinine group of this polymer is electroactive and act as the immobilized mediator for the enzyme recycling at a working potential much lower than for other mediators. These biosensors do not require any reagent but has certain interference due to molecular oxygen.

A wide variety of nanomaterials have been used in lactate biosensors to improve their analytical performance. The use of enzyme nanoparticles in place of native enzyme in fabrication of biosensors not only improves its analytic efficiency but also simplify its construction The laboratory model of these biosensors could also be miniaturized by chip designing to develop a portable/commercial device for its use at the bedside of patient like commercially available glucose biosensor "Glucometer" for quick measurement of glucose in whole blood.

References

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