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MORALITY BEFORE KNOWLEDGE

Glucose Monitoring Device by BioSENS Digital Innovation Based on Organic Thin-Film Transistors to Prevent Early Diabetes

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ABSTRACT
Diabetes is now one of the most serious chronic diseases in the world, with a growing prevalence globally, including among adolescents. The goal of this research, to develop a non-invasive diagnostic method, is an urgent need. The invasive nature of traditional finger-prick blood glucose tests can discourage patients from regularly monitoring their glucose levels, leading to inadequate disease management and increasing the risk of diabetes complications.
The method used is a non-invasive method that measures glucose levels in saliva through a smartphone app. This technology works using Organic Thin-Film Transistors (OTFTs) that integrate glucose oxidase, which reacts with saliva to produce hydrogen peroxide (H_2O_2), which then decomposes into proton ions, triggering an electrical signal. This signal is then processed by a smart device.
The result is the availability of non-invasive, needle-free blood sugar testing through the innovative BioSENS device.

KEYWORDS: Diabetes, Health Technology, Non-Invasive, OTFT, BioSENS

1. Introduction

Diabetes mellitus (DM), also known as diabetes, is a condition in which blood glucose or sugar levels rise above normal limits, preventing the body from producing or using insulin, which can lead to various complications (Ulya et al., 2023).

Diabetes is now one of the most serious chronic diseases in the world, with rates continuing to rise globally, including among adolescents. According to a report by the Indonesian Pediatrician Association (IDAI) (2023), the prevalence of type 1 diabetes increased 70-fold in children under 18 from 2010 to 2023.

Along with the rapid development of technology, lifestyle changes among young people, especially adolescents, have undergone significant changes. Adolescents, with their penchant for fast food and sugary drinks, lack of physical activity, and a digital lifestyle that is predominantly indoor, are among the triggers for the increased risk of diabetes mellitus.

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Lack of monitoring and prevention efforts means many adolescents are unaware that they have diabetes, which ultimately puts them at risk of developing serious complications in adulthood. The International Diabetes Federation (IDF) (2025) reported that 589 million adults (20-79 years old) have diabetes, with more than 40% of them unaware they have the condition. This number is projected to increase to 853 million by 2050.

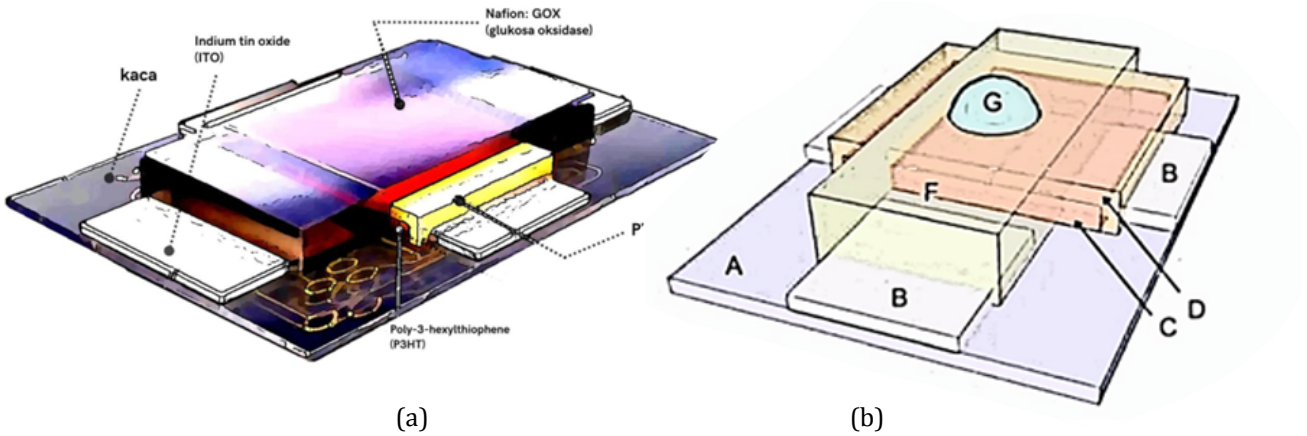
Meanwhile, Indonesia ranks fifth in the world for the number of diabetes sufferers (IDF, 2021). According to data from the Ministry of Health (Kemenkes) (2023), approximately 35 million Indonesians have diabetes. This figure represents approximately 13% of Indonesia's total population of approximately 270 million.

Diabetes has now become a global epidemic, affecting many countries, including Indonesia. Previously considered an adult problem, diabetes is now also affecting adolescents at an alarming rate. The 2023 Indonesian Health Survey (SKI) revealed an increase in the prevalence of diabetes mellitus (DM) among people aged 15 and over, as measured by blood sugar levels. The SKI showed that the prevalence of DM, based on blood sugar levels, in those aged 15 and above reached 11.7% in 2023, up from 10.9% in the 2018 Basic Health Research (Riskesdas). A 15-year-old today represents a valuable asset for the next ten or twenty years.

Diabetes mellitus is an incurable disease that requires lifelong management to control blood sugar levels to improve the quality of life of sufferers (Sumakul et al., 2022). Emergency cases of diabetes mellitus have the potential to affect adolescents because they are a group that enjoys consuming various types of food without balancing it with a healthy lifestyle and behavior. Studies show that 87% of adolescents consume junk food on a relatively frequent basis (Silalahi, 2019).

Therefore, early detection of DM and pre-DM in adolescents is a crucial first step to improve the health and productivity of the younger generation in the future.

2. Methods



(a) (b)

Fig. 1. Device configuration of two types of OTFTs (a) BioSENS device; (b) Illustration of a sensor device equipped with the enzyme GOX to detect the presence of glucose

2.1 Tools and Materials

a) Glass

As a substrate or base on which all sensor layers are built so that all components can be properly attached (see Fig. 1).

b) ITO (Indium Tin Oxide)

Acts as the source and drain electrodes for electrical current. Because ITO is conductive and transparent, it helps control the electric current in the transistor.

c) P3HT (Poly-3-hexylthiophene)

Acts as a semiconductor layer through which electrons move, carrying current.

d) PVP (Polyvinylphenol)

An insulator or dielectric layer, PVP acts as a regulator of charge flow to ensure a stable flow and a separator between the electrode and the semiconductor layer, allowing the device to respond only to changes in the detected glucose, without interference from other charges in the surrounding environment.

e) PEDOT-PSS

The conductive polymer for the electrode was replaced by Nafion, which contains the enzyme GOX, to enable the electrode to detect glucose.

f) Nafion-GOX

The nafion layer contains the enzyme glucose oxidase (GOX), which reacts with glucose to produce hydrogen peroxide (H_2O_2). Protons from the H_2O_2 change the transistor's electrical properties, allowing it to recognize and respond to the presence of glucose.

g) Analyte (Glucose in Saliva)

The substance detected is a droplet of glucose-containing solution.

2.2. Ways of Working.

BioSENS, or Bio-Surveillance and Early Notification System, is a digital innovation based on Organic Thin Film Field-Effect Transistors (OTFTs) with a non-invasive method that can measure glucose levels in saliva via a smartphone app. This technology works by using OTFTs that integrate glucose oxidase, which reacts with saliva to produce H_2O_2, which then decomposes into proton ions, triggering the formation of an electrical signal. This signal is then processed by a smart device (see Fig. 2).

Fig. 2. The BioSENS device sends a signal to the app

When saliva containing glucose touches the Nafion-GOX layer, a reaction occurs that produces hydrogen peroxide (H_2O_2) and releases protons. These protons then affect a conductive material called P3HT, changing its conductivity to conduct electricity. This change is then detected by the ITO electrode, which converts it into an electrical signal.

3. Results and Discussion

From this signal, the system can detect glucose levels in saliva, which are then displayed via an app. The app not only provides glucose levels but also offers various other features, such as an "Education" feature on diabetes and a "Statistics" feature for daily glucose measurements. Through this breakthrough, BioSENS is expected to optimize diabetes prevention efforts to be more effective and sustainable (see Fig 3).

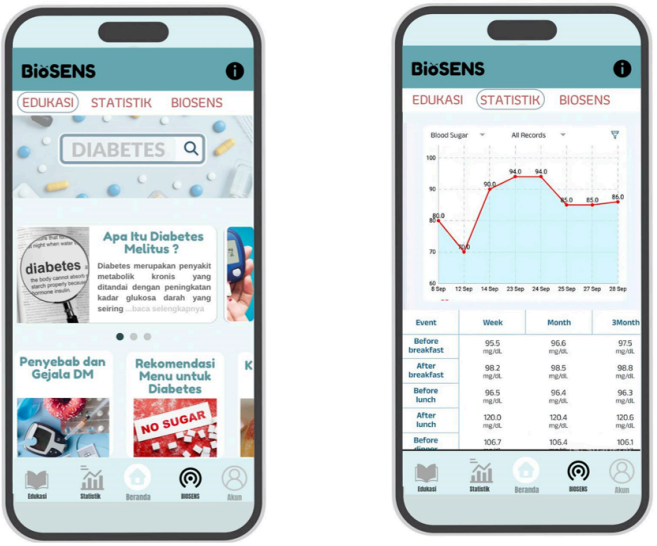


Fig. 3. (a) Education Feature (Provides Information about DM); (b) Statistics Feature (Records the Results of Each Measurement)

3.1 Urgensi dan Solusi Pencegahan Angka Diabetes di Indonesia

Indonesia is facing a rising trend of diabetes, creating an urgent need for sustainable prevention strategies. Sugary food consumption carries a variety of serious health risks. The Ministry of Health notes that uncontrolled type 1 diabetes can lead to various health problems, such as nerve damage, impaired vision, kidney failure, and the risk of heart disease. If left untreated, type 1 diabetes can be life-threatening and even fatal.

The significant increase in the number of diabetes sufferers in Indonesia deserves serious attention from the government. However, the relatively high cost of diabetes treatment and testing, along with the invasive methods using needles, are widely feared. This can be a particular challenge for patients who require regular blood sugar monitoring, such as those with type 1 diabetes, who may need to test their blood glucose levels several times a day. The need for frequent blood sampling can also lead to infections, especially if patients do not follow proper hygiene protocols (American Diabetes Association, as cited in Ko & Liao, 2023).

Therefore, the development of non-invasive diagnostic methods is an urgent need, because the invasive nature of traditional blood glucose tests with blood sampling through finger pricks can discourage patients from monitoring their glucose levels regularly, leading to inadequate disease management and increasing the risk of diabetes complications.

3. 2 Potentials that can be utilized

In today's era, technological developments have penetrated the healthcare sector, facilitating access to more practical and affordable healthcare. Therefore, saliva analysis offers a convenient, non-invasive alternative that can be used anywhere and anytime.

Many researchers have demonstrated a correlation between saliva detection and increased blood glucose levels, leading to the development of diabetes. Saliva is a fluid containing various substances, such as hormones, enzymes, antibodies, and several other growth factors, similar to blood. These substances are expressed in saliva from the blood, passing through the intercellular space through active and passive methods. Therefore, many blood components are found in saliva, making it highly potential for early detection of systemic diseases such as diabetes (Tiara in Sumintarti, 2015).

One of the main advantages of saliva glucose monitoring is its non-invasiveness, ease, low cost, and painlessness, as it does not require the use of needles or lancets. This makes it a convenient option for individuals who are reluctant to monitor their blood glucose levels regularly.

3.3. SWOT Analysis

The strengths and weaknesses of BioSENS were identified through a SWOT analysis as follows:

1) Strengths

a. Convenient and practical: BioSENS is designed with a non-invasive method that utilizes saliva as a detection medium without blood draws, making it much more practical and painless.

b. Efficient Recovery and Examination Time: With an OTFT-based detection system, BioSENS enables fast and efficient glucose level monitoring, accelerating early diagnosis without requiring recovery time because it does not cause scars.

c. Wide accessibility: This device is designed for independent use at home using only a smartphone. Therefore, BioSENS is highly suitable for the wider community, including those in areas with limited access to healthcare facilities.

d. Cost-effectiveness: Prevention and treatment of diabetes mellitus are often expensive. BioSENS offers a more economical health monitoring solution because it does not require consumables such as needles or test strips, and reduces reliance on hospital care.

2) Weaknesses

a. Contamination risk for medical personnel: The safety of medical practitioners handling samples can be compromised by bacterial or viral infections from saliva.

b. Requires a digital device such as a smartphone and an internet connection, requiring network and battery power to obtain test results.

3) Opportunities

a. High number of diabetes sufferers: The incidence of diabetes is increasing annually and is predicted to become more severe, thus increasing the need for innovations in diabetes prevention.

b. Technological advancements: With increasingly advanced developments and advances in technology, there are significant opportunities for BioSENS to develop as a modern solution aligned with the trend of digitalization of healthcare services.

c. Support from government and healthcare institutions: Support for health innovations from agencies such as the Ministry of Health and healthcare digitalization programs.

4) Threats

a. Competition from similar technologies: The emergence of advanced technology in the form of non-invasive glucose monitoring devices from global companies could become strong competitors.

b. Public perception that is not yet fully convinced and trusting of the accuracy of new innovations.

3.4 Strategic Steps for Implementing BioSENS

The following are the steps for implementing BioSENS:

a. Collaboration with Health Institutions

This collaboration involves community health centers (Puskesmas) or hospitals to ensure the device meets medical and bioethical standards regarding accuracy, safety, and

effectiveness in real-world settings so that it can be implemented in the wider community, especially adolescents.

b. Socialization of Device Use

Socialization plays a crucial role in building public awareness about early glucose monitoring. For example, using schools as an appropriate platform for collaboration with students can serve as the basis for policies for preventing diabetes at a young age.

c. Evaluation and Development Phase

After BioSENS is implemented, periodic evaluations of its effectiveness as a preventative measure in detecting diabetes risk early are necessary. Evaluations are conducted by observing changes and the impact of BioSENS use on users' lifestyle habits. The results of these evaluations are then used for development and refinement so that BioSENS can provide glucose monitoring tailored to the community's needs in the future.

3.5 Parties Involved in Implementing BioSENS

For BioSENS to be successfully implemented, collaboration from various parties is required, namely:

a. The public, especially health-conscious adolescents

The target users of BioSENS are health-conscious individuals, including those who want to independently monitor their blood glucose levels, so that early symptoms of diabetes or blood sugar fluctuations can be detected early.

b. Health Support Workers

Strong collaboration between doctors, nurses, PTM health posts (posbindu), and other health support workers is required. Their role is crucial in bridging health knowledge for patients, providing diagnoses, and determining necessary medical procedures.

c. Academics

Academics play a role in conducting research studies or identifying the performance of BioSENS, thus providing monitoring and evaluation for the device's progress.

d. Ministry of Health (Kemenkes)

Supports the integration of BioSENS into national health programs, such as community health centers (Puskesmas) or schools. They also play a role in overseeing the safety and effectiveness of the device to ensure that the medical devices produced meet established standards.

e. Technology and Telecommunications Sector

The technology and telecommunications sector plays a crucial role in developing and maintaining the BioSENS digital platform. They also serve as providers of digital networks and infrastructure to ensure the system runs smoothly across all regions, including remote areas.

f. Government

The government provides support by providing facilities and can conduct monitoring and evaluation to improve the performance of BioSENS.

This cross-sector collaboration is crucial to ensure that BioSENS is not only a sophisticated medical technology, but also operationally effective and has a real impact on improving national health.

4. Conclusions

Based on the above discussion, it can be concluded that diabetes in Indonesia requires attention, especially among young people. Several screening efforts have been carried out, but the relatively high cost of treatment and DM testing, along with the invasive method using syringes, are widely feared and carry the risk of infection, especially if patients do

not follow proper hygiene protocols. Therefore, by leveraging current technological advances, the BioSENS device innovation is present as an effort to prevent diabetes early. BioSENS, or Bio-Surveillance and Early Notification System, is a digital innovation based on OTFT with a non-invasive method that can measure glucose levels in saliva through a smartphone application. The main advantages of this innovation are its non-invasive nature, ease, affordability, and painlessness because it does not require the use of needles or lancets, making it a convenient option. The success of this initiative relies on the involvement of various parties, especially healthcare workers who have officially partnered. Consequently, the BioSENS innovation is expected to receive full support from the government, healthcare workers, and related sectors, to support early detection and prevention of diabetes, thereby improving the nation's health and becoming a step forward in realizing Indonesia's golden generation.

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Author Contribution

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