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Bruceshield: Internet of things integrated biometric and food detection system to eradicate brucellosis milk contamination

Jasa Dwi Tirtono[1]*, Lupita Prashanti[1], Raphael Abel Saputra[2], I Gede Wahyudi Saputra[1], Dian Ayu Permatasari[1]

[1] *Veterinary Medicine Study Program, Faculty of Veterinary Medicine, Universitas Airlangga, Surabaya, East Java, 60115, Indonesia;*

[2] *Robotics and Artificial Intelligence Engineering, Faculty of Advanced Technology and Multidiscipline, Universitas Airlangga, Surabaya, East Java, 60115, Indonesia.*

*Correspondence: jasatirtono92@gmail.com

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ABSTRACT

Background: Brucellosis is a zoonotic infectious disease caused by the bacteria of the genus *Brucella* spp. that causes abortion and chronic disease in animals and humans, resulting in economic losses worldwide. **Methods:** The methodology used in this article is a literature review. Literature review is a method of synthesizing by performing qualitative and does not require quantitative analysis. **Findings:** Brucellosis remains endemic in ruminant livestock in Indonesia, with a prevalence rate of 40% in ruminants and the highest incidence of cases is in Java Island. Vaccination, livestock movement monitoring, and diagnostic methods such as PCR can prevent this disease but those methods are challenged by cost and a lack of trained personnel. **Conclusion:** With this in mind, innovative solutions including Bruceshield have been formulated to help the vision of "Brucellosis Free Indonesia 2025". Bruceshield is a complete entity combining animal retinal biometrics, food detection using MCDA-LFB technology, and IoT for accurate identification, rapid detection, and effective data collection of IoT-ready devices. This system ties into Sustainable Development Goal (SDG) number 3 to ensure healthy lives and promote well-being for all, as well as the One Health paradigm linking human, animal, and environmental health. **Novelty/Originality of this article:** Some of these methods include MCDA-LFB for DNA analysis, retinal biometric systems for animal identification (as a livestock identification method), and static QR codes that report parasite detection and enable traceability to the consumer in dairy products. Bruceshield wishes to lower *Brucella* harassment into milk, break the chain of infection transmission, and pursue transparency and safety of the dairy and livestock industry.

KEYWORDS: biometric system; brucellosis; IoT; MCDA-LFB; one health.

1. Introduction

Brucellosis is the most common zoonosis in the world, but it should not be underestimated as its effects are not only infectious in animals, but can also infect humans. Brucellosis in humans can be considered a life-threatening disease. Brucellosis is caused by facultative intracellular bacteria caused by *Brucella* spp. bacterial strains (De et al., 2008). The bacteria can be transmitted to humans through exposure to tissues or fluids from infected animals or milk contaminated with *Brucella* spp. From a medical perspective, Brucellosis is a zoonosis that can cause fetal death and spontaneous abortion in animals,

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chronic disease, focal complications, and severe flu-like symptoms in humans (Glanville et al., 2017). Brucellosis affecting humans also has other common clinical findings such as fever, myalgia, nocturnal hyperhidrosis, weight loss, nausea and vomiting. In addition, in severe conditions, uncommon clinical symptoms may occur. It was reported in the incidence of patients in the country of Turkey with 484 cases of Brucellosis. Cases were reported with symptoms of anemia in 21.5% of patients, thrombocytopenia in 18.8% of patients, and leukopenia in 14.6% of patients. Pansitopenia can occur in up to 2-14% of infected individuals (Ulug et al., 2011). In fact, some cases of Brucellosis have been confused with Malaria and Typhoid, leading to inappropriate treatment for patients (Laine et al., 2023). Thus, Brucellosis disease can cause serious health problems for animals and humans, so a prevention innovation is needed through breaking the chain of spread.

Indonesia as a country with the livestock sector as a contributor to national income is still not free from Brucellosis. Brucellosis is a zoonotic disease caused by infection with *Brucella* genus bacteria that can affect both ruminants and humans. The prevalence rate of Brucellosis of 40% in ruminants throughout Indonesia allows for the transmission of Brucellosis to humans (Ahzan et al., 2022). The prevalence of Brucellosis cases in animals varies. In the DKI Jakarta region, an average of 4.5% was recorded. West Java Province with an average percentage of 3.6% with West Bandung Regency having a prevalence of 5.1%. Research conducted by Setianingrum (2020), stated that the prevalence in Batu City, East Java had a prevalence of Brucellosis of 0.7%. Several other areas with high prevalence in Indonesia were followed by Boyolali City and Kulon Progo. Thus, the highest prevalence of Brucellosis cases in livestock occurs in Java. In 2018, tests were conducted using the Rose Bengal Test (RBT) and Complement Fixation Test (CFT) methods and the results showed that 231 out of 285 (81%) livestock were positive for Brucellosis in East Java (Kusuma, 2020).

Accurately recording the prevalence of human Brucellosis cases remains a challenge (Alloghani et al., 2019). This is because Brucellosis is often confused with other diseases and the incidence of Brucellosis cases in humans will not be accurate only through data reported to health institutions due to incomplete data and lack of geographical representation (Laine et al., 2022). According to a study conducted by Laine et al. (2023), Asia and Africa are one of the high-risk areas, including Southeast Asia as an endemic area of Brucellosis. Estimated global estimates of Brucellosis data show that around 500,000 cases occur each year, even using statistical modeling research, it is estimated that the global incidence of Brucellosis cases reaches 1.6 to 2.1 million cases each year.

Brucellosis can cause serious impacts on the livestock sector, namely a decrease in livestock productivity such as decreased milk production, high abortion rates, and infertility in individual livestock. The impact of Brucellosis will be very large in several endemic areas such as Asia and Africa. Brucellosis cases alone are known to cause losses of up to 10% of the total lactation yield. In a study conducted by Setiawan (2020), abortion cases due to Brucellosis accounted for a percentage of 8.5% of the 29.2% of abortion cases that occurred in livestock. Farmers with animals that experience Brucellosis will be faced with two choices, namely taking treatment steps or slaughtering animals. The treatment option will certainly make farmers incur medical expenses. On the other hand, slaughtering Brucellosis-infected livestock directly will also cause huge losses for farmers. Brucellosis cases that continue to occur in Indonesia alone are estimated to have brought economic losses of up to 315 billion rupiah per year. Another study by Basri and Sumiarto (2017) stated that economic losses in livestock due to Brucellosis can reach 3.6 trillion rupiah per year, which is equivalent to 1.8% of the total value of assets in Indonesia.

Prevention and control of Brucellosis in Indonesia in the form of slaughtering infected livestock, vaccination, and regulation of livestock traffic have been carried out by the government to achieve the target of Brucellosis-Free Indonesia 2025 (Noor et al., 2016). Brucellosis vaccination program as a prevention effort. Brucellosis in Indonesia uses the *Brucella* abortus RB51 vaccine in dairy cows on the island of Java. Vaccination is carried out mainly in infected areas with a prevalence of more than 2% and in beef cattle for areas with a prevalence of less than 2% (Kusuma, 2021). However, in its application, this effort is still not enough to eradicate Brucellosis in Indonesia. In general, diagnostic prevention of Brucellosis cases has now been developed, including microbiological isolation of organisms, bacterial identification, and nucleic acid amplification-based methods have been used and developed to detect Brucellosis in various samples (Kattar et al., 2007). However, these developments are still not enough. The methods are time-consuming and require skilled technical personnel to handle cultures of the bacteria (Sagi et al., 2017). Brucellosis treatment in the United States uses the "agent of choice" method due to its infectiousness and laboratory personnel are often infected when manipulating cultures. Molecular methods such as Polymerase Chain Reaction (PCR) have been used because they are fast, sensitive and specific techniques. However, PCR-based testing is constrained by the high cost of specialized equipment and testing must be done in a specialized setting, limiting the scope of identification (Bounaadja et al., 2009; Law et al., 2014; Kaden et al., 2017).

One alternative to break the chain of *Brucella* infection from animals to humans can be done by monitoring the transmission media, one of which is through animal products. The animal product that most often acts as an intermediary for transmission is milk. Contaminated milk is generally the result of improper and unhygienic pasteurization or comes from cattle affected by brucellosis. Bruceshield innovation is one of the efforts in realizing Brucellosis-Free Indonesia 2025 by utilizing a *Brucella* -vaccinated cow recording system and monitoring biometric-based dairy products and food detectors integrated with the Internet of Things (IoT) connected to applications that are easily accessible to all people. In addition to easy application access, this integrated system consisting of vascular retinal biometric system, food detector using Multiple Cross Displacement Amplification - Lateral Flow Biosensor (MCDA-LFB), and Internet of Things (IoT) has potential advantages. Vascular retinal biometric with the concept of retinal pattern biometrics provides the right results to identify animals, because each animal has a unique and different retinal pattern. MCDA-LFB test has the advantages of fast processing, high sensitivity and specificity, and cost efficiency. While IoT as a fast data collection, storage and sharing system that will be used in Bruceshield applications. Thus, the Bruceshield innovation was created with the aim of fulfilling SDGs number 3, namely a healthy and prosperous life and elaborating the concept of One Health for the sake of survival for humans, animals, and the environment.

2. Methods

The methodology used in this article is a literature review. Literature review is a method of synthesizing by performing qualitative and does not require quantitative analysis (Armstrong et al., 2011). Design ideas were identified from various international and national journal literature with the main focus on test methods consisting of Multiple Cross displacement Amplification-Lateral Flow Biosensor (MCDA-LFB) test, Retinal Biometric system, Static QR-Code system, and IoT Internet of Things (IoT). Multiple cross displacement amplification lateral flow biosensor (MCDA-LFB). Analysis is carried out through techniques or methods carried out in the research of Li et al. (2019). The analysis applied includes.

Primer design: Preparation of a set of 10 primers targeted at the Bscp31 gene of *Brucella* spp. Specifically, the Bscp31 gene encodes a protein present in all *Brucella* species and biovars (Ohtsuki et al., 2008). Targeting of a set of 10 primers was performed with PRIMER PREMIER 5.0 software. Bacterial strains and genomic DNA: A total of 97 *Brucella* bacterial strains and 18 non-*Brucella* strains were involved. The vaccine strain B. Suis vaccine strain as target method optimization. Genomic templates were extracted using a DNA extraction kit. Then, the extracted DNA was measured for concentration using an ultraviolet spectrophotometer at a ratio of A260/280. Preparation of lateral flow biosensor (LFB): The Lateral Flow Biosensor (LFB) was operated and used to demonstrate MCDA results according to a previous research report by (Wang et al., 2017). Streptavidin-coated polymer particles were placed in the conjugate pad. Anti-FITC and biotin-BSA were fixed on the test line (TL) and control line (CL), respectively.

MCDA reaction: The MCDA process was performed in a single step using a 25 μL mixture consisting of 2.5 μL of the provided 10X buffer, 0.4 μM each of F1 and F2 displacement primers, 0.8 μM each of amplification primers C1*, C2, R1, R2, D1, and D2, 1.6 μM each of cross primers CP1 and CP2, 0.8 M betaine, 1.4 mM dCTP, 0.4 mM biotin-14-dCTP, 1.4 mM dGTP, 1.4 mM dUTP, 1 μL of Bst 2. 0 polymerase, 0.3 μL AUDG, and 1 μL DNA template. Visualization of LFB amplification products was adapted from a previous publication (Wang et al., 18b). After that, the temperature assay ranged from 60°C - 67°C with an interval of 1°C. Negative controls used 1 μL of Salmonella (isolate strain) and Bacillus cereus (isolate strain) while double distilled water (DW) 1 μL as blank control. Sensitivity of MCDA-LFB test analysis: Using dilutions of type B. Suis (GZ-CDC-S2) with concentrations covering the range of 10 ng/μL to 100 ag/μL (10 ng, 10 pg, 1 pg, 100 fg, 10 fg, 1 fg, and 100 ag/μL). A total of 1 μL of genomic template was added to the MCDA reaction mixture. Simulation of congenital contamination: MCDA amplicons generated from 10 pg/μl in the absence of AUDG enzyme were identified using an ultraviolet spectrophotometer, which was used to make dilutions of $1\, x\ 10-13\ to\ 1 \times 10-20\ g\ \mu L-1$. One microliter of each dilution was used as a template for the MCDA reaction, which was used as a simulated source of innate contaminants. Analytical specificity of MCDA-LFB assay: The analytical specificity test of the MCDA-LFB used DNA templates (at least 10 ng per microliter) from 79 *Brucella* strains and 18 non-*Brucella* strains. All MCDA results utilized a lateral flow biosensor and all assays were repeated three times.

2.2 Retinal biometric system

The Retinal Biometric System application is utilized as a method of identifying individual farm animals in the recording process. The Retinal Biometric System works by utilizing the unique retinal vascular pattern of the eye in each individual animal which will then be processed through several stages of preprocessing, segmentation, feature extraction and classification. This will make it easier for medical personnel and farmers to monitor animal health and productivity.

2.3 Static QR-code system, application, and internet of things (IoT)

The QR-Code used is a static QR-Code where the information cannot be changed after the data is inputted and converted into a QR-Code. Static QR-Code is included in milk packaging by entering some data that aims to ensure consumer safety. Static QR-Code in this innovation will contain data in the form of a unique code that is generated according to the batch of milk production data entered into the Cloud database, this unique code functions as a key that will be used by Bruceshield application users to access data from the main database (Perriam et al., 2019). The data accessed from the database are milk production batch code, milk production date, expiration date, milk test date, test results, and serving suggestions. The method of making Static QR-Code requires a combination of several systems such as a data encoding system, a hardware system in the form of a smartphone, and an encoding system (Priyambodo et al., 2020).

In implementing the Bruceshield application system, a Cloud database is required to store cow data, including unique codes, names, dates of birth, vaccination history, and milk quality. Furthermore, we will use a backend API that has been developed using a framework that supports the creation of Representational State Transfer Application Programming Interface (REST) endpoints, so that data retrieval based on unique codes and increased scalability of data in the database can be done properly (Lomotey & Deters, 2013). This backend is then hosted on a platform that supports global accessibility so that it can be accessed by future users.

In the system workflow, the unique code of each cow and the data from the food detector analysis are converted into a QR code that is printed on the dairy packaging. When the user scans the QR code using the app, the unique code is extracted and sent to the backend API to retrieve the cow data from the database. The retrieved data is then displayed to the user through the app, providing complete and transparent information regarding the dairy.

The use of Cloud databases can pose a risk of data leakage and data manipulation by unintended parties if not accompanied by a qualified security system. Separating access rights and roles in a system is very important to maintain security and control over data and resources. With this separation, we can ensure that only users or applications that have proper authorization can access or modify certain data (Mehra, 2024). This prevents unauthorized access and reduces the risk of data leakage or manipulation. To do so, we can assign various roles such as “admin”, “user”, or “guest”, each with different access rights, such as read, write, or both access. At the database level, this can be set up through security rules that limit the type of access granted to each role, while in the application, these access rights are implemented through authentication and authorization systems, such as using tokens or API keys, to verify that only authorized users can perform certain actions.

The unified data that has been obtained through the MCDA-LFB test and Retinal Biometric System will then be compiled in an application that can be accessed by health workers, breeders, and the public. The working system of the MCDA-LFB test, Retinal Biometric System, Static QR-Code system, and IoT in the Bruceshield application is described in the schematic below.

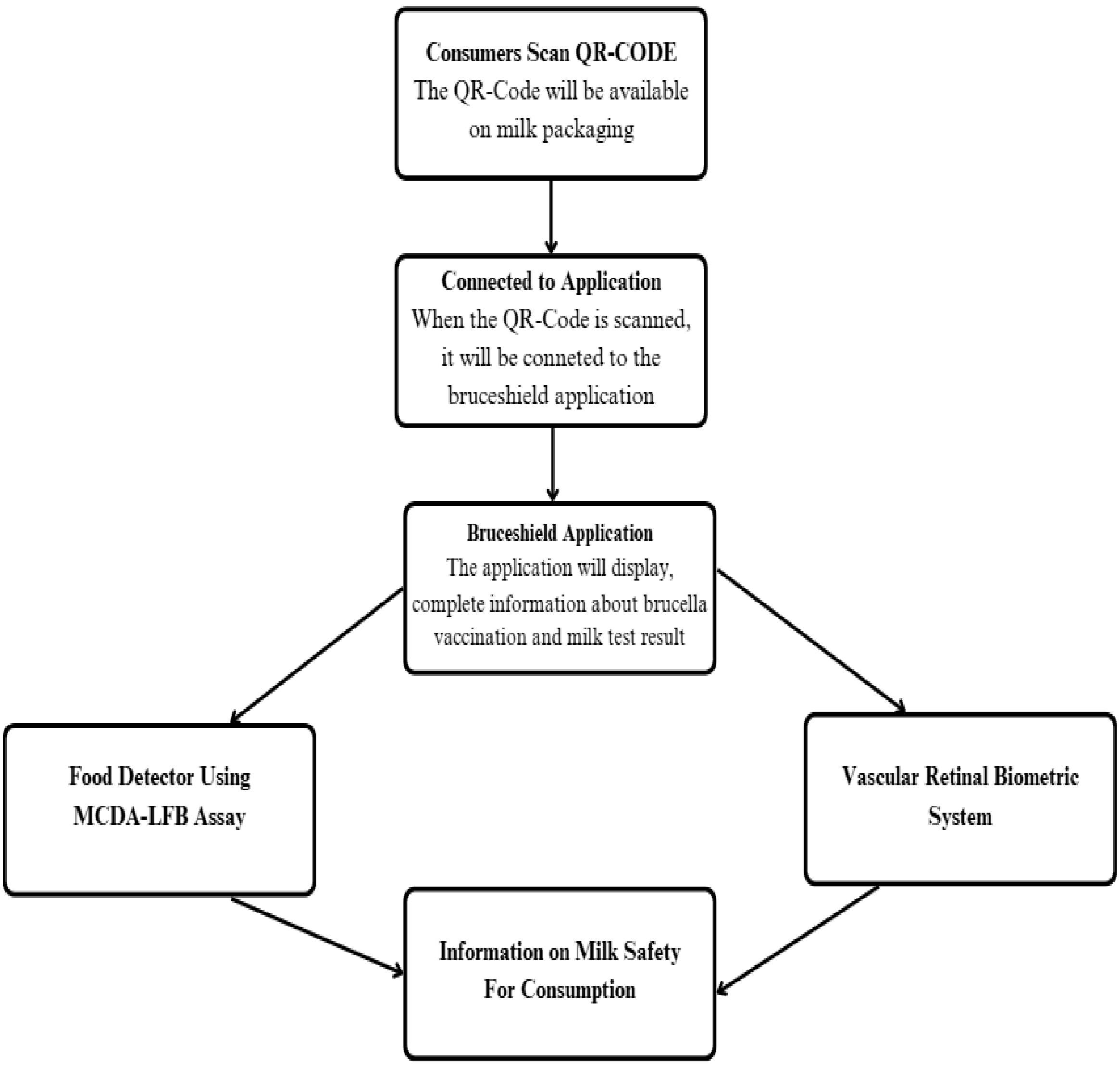

Figure 1. Workflow of the system for MCDA-LFB, retinal biometric system, and IoT in bruceshield application

3. Result and Discussion

One Health is essentially a collaborative approach that brings together multiple disciplines to achieve the best health outcomes for people, animals and the environment (Kaplan, 2021). This perspective is particularly important in addressing the control and eradication of brucellosis, a serious zoonotic disease that impacts both animals and humans (Kahn et al., 2007). Brucellosis can cause significant health problems in humans, and in some cases, can be life-threatening (Irvem et al., 2015). Given the urgency of this issue, there is a critical need to develop innovative prevention strategies aligned with the One Health concept to effectively address the spread of brucellosis. These strategies should be easy to use, rapid, sensitive and specific enough to be utilized by veterinarians, researchers, farmers and other stakeholders involved in animal health management.

To achieve this goal, the proposed collaborative innovation includes three critical systems: a vascular retinal biometric system for accurate animal identification, a food detection system that uses Multiple Cross Displacement Amplification-Lateral Flow Biosensor (MCDA-LFB) to ensure food safety, and an Internet of Things (IoT) framework for smooth application development. By integrating these systems, we can create an effective monitoring and reporting mechanism that can enhance disease prevention efforts while driving improved health outcomes across species. This comprehensive approach not only addresses the immediate challenges posed by brucellosis, but also improves our understanding of the health connections between humans, animals and the environment. Through these innovations, we can strive for a sustainable future where the impact of zoonotic diseases is significantly reduced.

3.1 Vascular retinal biometric system

Biometric systems have become powerful tools for identifying individuals, providing notable benefits compared to traditional methods like passwords and ID cards. These systems utilize unique physical or behavioral traits, such as fingerprints, facial recognition, iris patterns, and voice recognition, to verify identities. A study by Jain et al. (2016) found that biometric systems in human achieve impressive accuracy rates, with fingerprint recognition exceeding 99% accuracy in controlled settings. This level of reliability is crucial in high-security areas, such as banking and border control. Additionally, biometric systems improve user convenience by removing the need to remember passwords or carry physical IDs. A survey by Ratha et al. (2017) revealed that 82% of users favored biometric authentication for its simplicity and speed. The incorporation of biometric technology into mobile devices has also made it easier for users to unlock their phones or make payments with just a fingerprint scan or facial recognition (De et al., 2008).

Biometrics with retinal patterns utilize the uniqueness of the retinal blood vessel patterns found in each individual (Mazumdar & Nirmala, 2018). Using vascular retina as a biometric system for identifying animals has proven to be quite effective, taking advantage of the distinct retinal patterns found in individual animals for reliable identification. Unlike traditional methods that often depend on physical tags or microchips, which can be lost or damaged, vascular retinal biometrics provides a non-invasive and highly precise identification approach. Research by Kadir et al. (2022) indicates that the vascular patterns in the retina are unique to each animal, much like human fingerprints, making them an excellent choice for biometric identification. The study showed that the accuracy of recognizing retinal patterns could surpass 95%, greatly minimizing the risk of misidentification. A study conducted by Rahman et al. (2023) emphasized that the use of retinal biometrics could enhance efficiency in veterinary practices and livestock management, offering farmers prompt insights into their animals' identities and health conditions. In the process, the retinal pattern-based biometric system will be divided into several processes, namely preprocessing, segmentation, feature extraction and classification.

Pre-processing: Sample data in the form of retinal blood vessel pattern images that have been obtained are then pre-processed. At this stage, image quality is improved by removing artifacts or irrelevant segments. With pre-processing, the quality of the data to be processed will increase so that it shows the best results in the segmentation and feature extraction process (Perumal & Thambusamy, 2018). The preprocessing stage of color image data will be converted to black and white and continued with denoise. Images that have passed the denoise process are then subjected to contrast enhancement and histogram adjustment. The next stage is the image will be calculated on the average red, green, blue (Szymkowski et al., 2020). Segmentation: The segmentation stage will basically be responsible for recognizing and delimiting the part that is the focus of the input image. In the segmentation stage, the method used is thresholding. In this method, the image will be divided into foreground and background based on the threshold value (Sannasi et al., 2019).

Feature extraction: At this stage is a stage that will extract important parts of the raw data. This extraction will improve image quality by reducing image dimensions, extracting important parts and converting raw data into a set that will be used for classification. This extraction includes color, texture and shape of the data (Kumar et al., 2020). Classification: This process will determine the output of the data that will determine the classification by label (Lai & Deng, 2018). So, at this stage the retinal pattern is already in the form of a database containing retinal owner data. This data includes the identity of the cow and the history of brucellosis vaccination. Additionally, the integration of this biometric system with modern technologies like the Internet of Things (IoT) significantly improves its use for real-time monitoring and data collection. This feature enables effective tracking of livestock health and movement, which is essential for managing animal populations and ensuring food safety.

3.2 Food detector with MCDA-FLB test

The food detector is designed using a biosensor system. The food detector will analyze the feasibility of milk with the main objective of detecting *Brucella* bacteria in dairy products. In principle, the food detector designed uses a biosensor with Multiple Cross displacement Amplification - Lateral Flow Biosensor (MCDA-LFB) which is considered more accurate and faster. This is in accordance with research conducted by Wang et al. (2015) MCDA-LFB test has high sensitivity, specificity, easy operation, fast analysis results, and time and cost efficiency. The MCDA-LFB biosensor test uses bacterial DNA amplification where this test has components consisting of biological components, transducers, and biosensor readers (Patel et al., 2020). The biological component functions as an electroactive that reacts in a half-cell reaction. Meanwhile, the reader component is an electronic signal processor that is useful for displaying the results of the test (Wulandari et al., 2021). The MCDA-LFB test consists of biological components in the form of DNA and enzymes, a transducer in the form of an LFB converts the detection results (DNA-probe complex) into a visual signal in the form of a color line on the lateral flow strip, and a reader component as a reader of the analysis process performed.

The MCDA-LFB test also allows as an assay to refine current isothermal amplification techniques, such as rolling circle amplification, helicase-dependent amplification, strand displacement amplification, cross priming amplification (Yan et al., 2014). Thus, MCDA-LFB test is the right choice of innovation in detecting *Brucella* bacteria in milk. Specifically, the MCDA-LFB analysis process in previous publications conducted by Li et al. (2019) and Wang et al. (2015) was carried out on different bacterial strains. The research conducted by Li et al. (2019) used the *Brucella* bacterial strain while the research conducted by Wang et al. (2015) used the L. monocytogenes strain. Both studies have almost similar process stages with the same goal, namely to detect the presence of bacteria. In the publication of Li et al. (2019) there are three detection methods used to configure and verify *Brucella* products including real-time turbidity, colorimetric indicators (Malachite Green, MG), and lateral flow biosensor (LFB) detection. In the research of Wang et al. (2015) used two methods carried out in the research of Zhang et al. (2014) to prove the validation of the MCDA test, namely colorimetric indicators with FD reagents and agarose gel electrophoresis as MCDA detection.

The development of MCDA-LFB to detect *Brucella* bacteria is indeed an innovation that has great potential for future use. In a research study conducted by Lie et al. (2019), the results of the Lateral Flow Biosensor demonstration occurred color changes in positive and negative samples that could be seen directly. Positive samples change from blue to green while negative samples from blue to colorless. In further confirmation, it is displayed in the form of a line where the positive sample will have two lines namely Control Line and Test Line, while the negative will have a “Control Line” line.

The results of the specificity test performed by targeting the Bscp 31 gene were successfully developed for the detection of *Brucella* spp. A set of MCDA primers, recognizing 10 regions in the Bscp 31 gene, provided a high level of specificity for the detection of *Brucella* spp. For further confirmation, it was based again on the specificity analysis test of the MCDA-LFB test analysis. Positive results were obtained from all tests for *Brucella* strains, but negative results were obtained for non-*Brucella* strains. This data shows that the MCDA-LFB test targeting the Bscp 31 gene identified *Brucella* spp strains with 100% specificity (Li et al., 2019). The same thing was also said in the research study of Wang et al. (2015) MCDA test on bacterial strain L. monocytogenes a set of primers hybridized correctly according to the target sequence. This provides a high level of specificity and the specificity of detection is verified. The amplification system was carried out in the presence of genomic DNA template at the optimum milk temperature of 63˚C (Zhang et al., 2014). The temperature is also in accordance with the research report of Li et al. (2019) where 63˚C was chosen as the optimal temperature used in carrying out the MCDA procedure.

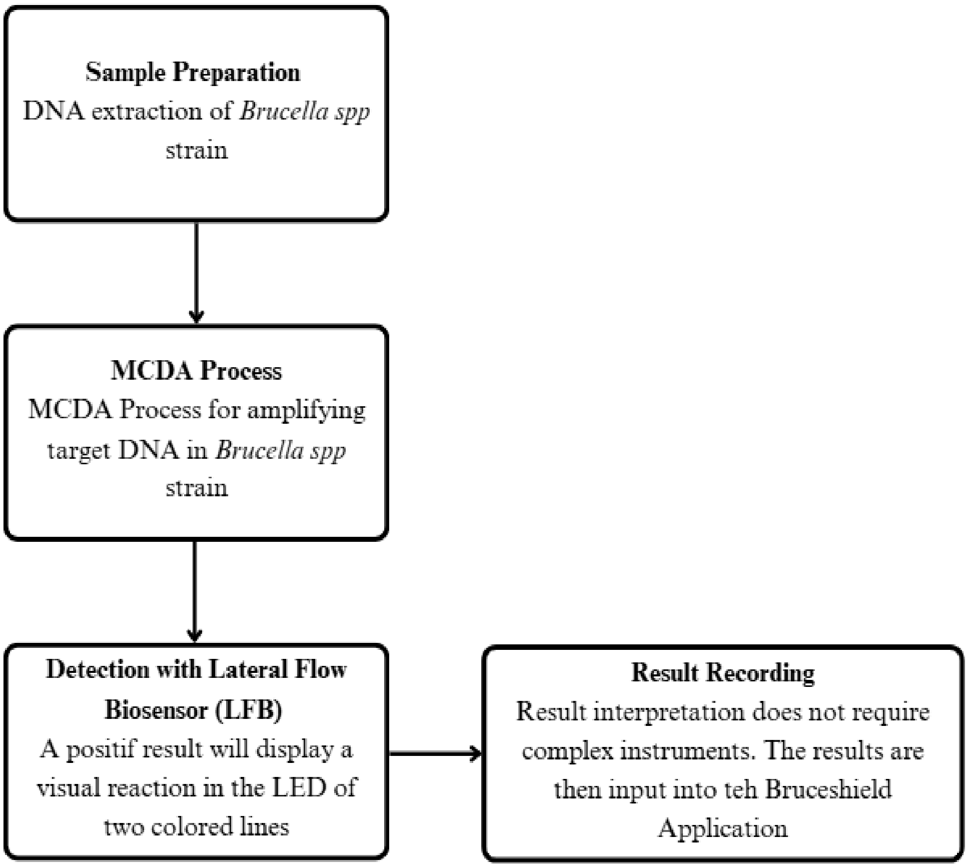

Figure 10. Brief workflow for food detector using MCDA-LFB assay

The MCDA-LFB test to detect *Brucella* strain disease has been successfully developed. Apart from the high specificity test, the study results from Lie et al. (2019) also provide analytical sensitivity test results of 10 fg of reagent using pure culture (the lowest limit of target DNA that can still be detected by the system) which is 10 femtograms of target DNA in a certain volume (usually 1 μl) of solution used for reaction or testing. This indicates the low concentration of target DNA that can still be detected, reflecting the high sensitivity of the method. With biosensors, amplification products are visually analyzed, easy to use, disposable and objective. Amplification arising from inherent contamination can be eliminated by using dUTP and AUDG enzymes. Thus the food detector using the MCDA-FLB biosensor system provides fast results, simple process, sensitive, real time, and can potentially be used as a monitoring food detector on *Brucella* spp. The MCDA-FLB test also eliminates the thermal cycling step (isothermal amplification at a single temperature), incubation in a short time (40 minutes for MCDA) using a simple block heater or water bath, without the need for complex tools such as thermal cycler PCR (Wang et al., 2015).

The remarkable properties and advantages of the food detector process with the MCDA-FLB biosensor system are attractive and have the potential to be applied in the innovation idea we developed. To complete the convenience, the results obtained in this test will be inputted into the Bruceshield application which is connected to the QR-Code on the milk packaging. Information from the results of this food detector test as information on the health aspects of milk that has been circulated. All data will be connected using deep learning to send information to the application (Wulandari et al., 2021). We also plan in the future to package the food detector test process into one unit in the form of a box so that it can be carried everywhere (Ekka et al., 2015). Schematically the food detector process will be shown as follows.

3.3 Integration with the internet of thing (IoT)

The Internet of Things (IoT) is a system that involves connecting physical devices to an internet network to collect, store, and share data. The ever-evolving IoT provides unparalleled opportunities to develop new solutions for complex challenges (Harshitha et al., 2023). IoT utilizes the Cloud to store data online, allowing data that has been captured and stored by devices that have been integrated with the IoT system to be accessed anywhere. The combination of IoT and Cloud not only provides efficiency in data management but also facilitates collaboration and cost savings for developers. By utilizing Cloud and IoT technology, the system creates an efficient, transparent, and reliable ecosystem for cow identification, milk data management, and provides confidence to consumers through direct accessibility of information. It also enables scalability and flexibility (Bello et al., 2021) that helps farmers increase productivity and add value to their dairy products.

Storing data on the cloud: Cloud is a key component in integrating IoT in Bruceshield. Using the Cloud, we can easily store and manage data that has been inputted by officers anywhere and anytime. Cloud technology provides affordable computing facilities and scalable computing facilities using a "pay as you go" pricing model (Bello et al., 2021), so developers can focus more on managing and organizing data and improving convenience in the user experience. Unique code generation: Unique code generation is done when there is data from the latest batch inputted by the clerk. This unique code will later be converted into a QR-Code and used by application users to access data from the database. Accessing product data: Users can access product data using the Bruceshield application by scanning the QR Code located on the product packaging. After scanning the QR Code, the application will make a request to the Cloud server via the Application Programming Interface (API) and provide product data that matches the QR Code that has been scanned (Perriam et al., 2019).

3.4 QR-code and system output through bruceshield application

The effectiveness of QR codes in disclosing food and beverage product information has been increasingly recognized over the years, as consumers are putting more pressure for increased transparency about their consumed products. The codes act as the interface between the physical product and digital information to which a consumer requires instant access by scanning the product with a smartphone. One can access such data via the QR code scan, including all the necessary nutrition facts, ingredient list, sourcing information, and allergen warnings. In Zhang et al. (2021), the authors identified that QR codes contribute significantly to consumer engagement through instantaneous access to product information, which could facilitate informed purchase decisions.

More than that, QR codes help traceability in terms of food safety. They allow consumers to trace the origin of food products in the event of foodborne illness and recalls. A product-based survey on consumers conducted by Lee and colleagues (2020) revealed that 78% of them prefer those products traceable through QR codes, indicating a positive shift towards accountability in the food supply chain. Such capability does not only enable consumers, but it also encourages manufacturers to uphold much higher standards of quality and safety. MCDA-LFB test result data on milk contamination detection and recording of farm animal health supported through the Vascular Retinal Biometric System method will be connected using the IoT method and displayed on the Bruceshield application. In supporting food safety, dairy products that have passed the MCDA-LFB test will be presented in a Quick Response Code (QR-Code) and included in the milk packaging. Static QR-code: Static QR-Code creation will be carried out for each batch of production. According to research by Priyambodo et al. (2020), the QR-Code creation process is carried out through several stages as follows.

Encoder system: The encoder system plays an important role in converting data to be stored into QR-Code. In this study, the data to be entered into the QR-Code is a unique code that is generated according to the batch of milk production data entered into the Cloud database, this unique code serves as a key that will be used by Bruceshield application users to access data from the main database such as milk production code, milk production date, milk test date, test results, and relevant milk serving suggestions for the milk in the package. QR-Code reading accuracy is improved using the Error-Correcting Code method through the use of Bose, Chaudhuri, Hocquenghem (BCH) codes. Hardware system: In the application of this study, the use of smartphones plays one of the roles as a scanning tool when the QR-Code detection process is carried out. Milk packaging plays a role in the media in the QR-Code detection process. The QR-Code will be placed on the side of the milk product packaging. Decoder system: QR-Codes printed on milk packaging can be scanned by consumers using the Bruceshield application. The application will scan the QR-Code and decode the information contained in it in the form of a unique code which will later be used as a key to access cow data from the database. QR-Code will be detected using the Android Studio system contained in the application. When the application scans the QR-Code, the camera will detect it as a sequence of "0" and "1" bits. The system will then identify the QR-Code configuration with the results in the form of information format and QR-Code version. The information format will then be extracted with the aim of obtaining error correction and masking patterns. If an error is identified, the system will correct the error. The result obtained when QR-Code detection is information data.

3.4.2 Bruceshield application

The Bruceshield application using smartphones has two main features, namely the login feature as a veterinarian, breeder, and the general public. Veterinarians, breeders, and the general public must first enter account information to access features in the Bruceshield application. After logging in the general public feature will provide several options such as "scan QR-Code", "Brucellosis window", and "Helpdesk". Scan QR-Code will display detailed milk history data starting from milk production history, verification results of dairy products free from bacterial contamination, good dairy product storage advice. The Brucellosis Window feature will display information related to Brucellosis in humans. Additional features include a helpdesk connected to the nearest health agency if the public experiences symptoms related to Brucellosis. While the veterinarian feature after login, features that can be selected can be in the form of recording vaccines using the Vascular Retinal Biometric system, Recording milk which is used as a data input feature for test examination results on milk, and the Database Recording feature in the form of a database related to recording on cows and milk test results. Features available to breeders can be in the form of a choice of features, namely “My Livestock” which contains recording data on the health of livestock owned by breeders that have been uploaded by veterinarians and animal health medical personnel. Another additional feature on the farmer account is a helpdesk that can be used when livestock experience emergency conditions. The helpdesk feature on the farmer account will also be connected to the nearest veterinarian or animal health medical personnel (Li et al., 2019).

Brucellosis eradication can be achieved with the help of various parties ranging from researchers, government both field of human and animal health, farmers, milk producers, government, human health agencies, and the general public (Mazumbar & Nirmala, 2018). This collaboration is important for the creation of one health for the success of the innovations we offer. In addition, Bruceshield will certainly continue to have sustainable innovations along with the development of increasingly advanced technology. The innovation we offer is expected in the future to be able to detect the health of food and beverages, especially products other than milk. The next application of Bruceshield is expected to not only be used by producers of animal products from within the country, but can also be used by producers who import animal products. In addition, the Bruceshield innovation can be developed into a special tool or kit that can be applied by the public directly aimed at increasing safety for the general public.

4. Conclusion

Bruceshield is a system designed to minimize the contamination of *Brucella* sp. bacteria in milk. Bruceshield is an integrated system for monitoring so that it can break the chain of the spread of Brucellosis infection in milk that combines biometric detection and food detector integrated with the Internet of Things (IoT) and connected to the application. In this system, biometric detection is aimed at recording individual *Brucella* vaccinated livestock by animal health workers and food detectors that apply the Multiple Cross displacement Amplification - Lateral Flow Biosensor (MCDA-LFB) biosensor as a form of feasibility test for dairy products. These two systems are then integrated with IoT which is displayed in the application. On the other hand, consumers also get a guarantee of dairy product safety by scanning the QR-code dairy products that have been previously recorded as having passed the test. The application also has features such as product storage suggestions and consumer services to facilitate understanding of the dairy products that have been obtained. Bruceshield is one of the system innovations that involves directly from various sectors, namely animal health workers, human health agencies, farmers or milk producers, to the general public to form an ideal One Health concept.

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Author Contribution

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Biographies of Authors

Jasa Dwi Tirtono, Veterinary Medicine Study Program, Faculty of Veterinary Medicine, Universitas Airlangga.

- Email: jasatirtono92@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Lupita Prashanti, Veterinary Medicine Study Program, Faculty of Veterinary Medicine, Universitas Airlangga.

- Email: lupita.prashanti-2021@fkh.unair.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Raphael Abel Saputra, Robotics and Artificial Intelligence Engineering, Faculty of Advanced Technology and Multidiscipline, Universitas Airlangga.

- Email: raphabel70@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

I Gede Wahyudi Saputra, Veterinary Medicine Study Program, Faculty of Veterinary Medicine, Universitas Airlangga.

- Email: suputradew@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Dian Ayu Permatasari, Veterinary Medicine Study Program, Faculty of Veterinary Medicine, Universitas Airlangga.

- Email: dian.ayu.permatasari@fkh.unair.ac.id
- ORCID: 0000-0001-7423-3075
- Web of Science ResearcherID: N/A
- Scopus Author ID: 57217108986
- Homepage: https://unair.ac.id/daftar-fakultas/daftar-dosen/dian-ayu-permatasari/