AI-Enabled Precision Reproductive Management Platform to Reduce Repeat Breeding and Infertility in Dairy Cattle

CisGEN Biotech Discoveries Private Limited is a pioneering animal health biotechnology start-up in India, committed to the development of novel and technology-driven solutions addressing critical challenges in livestock health and reproduction. Established eight years ago and incubated at the Bio-Incubator, IIT Madras Research Park, Chennai, CisGEN represents a successful model of translational research evolving into field-deployable innovations. The company is founded and led by techno-entrepreneurs with Doctoral qualifications in Veterinary Science and supported by strong expertise in reproductive biotechnology, diagnostics, and applied veterinary sciences. CisGEN originated as an offshoot of research outcomes from some of India's most competitive innovation grant programs, including the Biotechnology Ignition Grant (BIG) and the Small Business Innovation Research Initiative (SBIRI), both awarded by BIRAC under the Department of Biotechnology (DBT), Government of India. In addition to these flagship grants, CisGEN has received funding from national and international bodies, including support from the TATA Trust–funded Centre for Advanced Translational Health Foundation (CHATF). Over the years, the company has successfully commercialized multiple novel and patented animal health products, many derived directly from internal research initiatives. Within the first four years of incorporation, CisGEN published several peer-reviewed scientific articles in reputed international journals, including high–impact factor publications, demonstrating scientific rigor and research credibility comparable to established academic institutions. The company has been granted two patents and has filed three additional patents from its in-house R&D programs, reflecting its sustained commitment to innovation and intellectual property generation.

Despite India being one of the world's largest milk-producing nations with a vast bovine population, reproductive inefficiency remains a major constraint affecting productivity, extending calving intervals, and resulting in less than optimal farm economics. Suboptimal estrus detection is a principal cause of low conception rates and repeat breeding. In most field settings, estrus identification depends heavily on behavioural observation, external physical signs, and inseminator experience. These methods are inherently subjective and often lead to missed heats or mistimed insemination. While progesterone assays and ultrasonography provide greater diagnostic accuracy, their routine application across Smallholder rural dairy systems is limited due to high cost, infrastructure requirements, and lack of skilled service providers. This creates variability in reproductive outcomes, particularly in resource-

constrained environments. Recognizing this gap, CisGEN developed CowVuw, a patented video-assisted artificial insemination device designed specifically for dairy animals. CowVuw integrates a high-resolution waterproof imaging module with LED illumination, enabling real-time visualization of the external cervical os during insemination. By eliminating blind semen deposition, the device improves procedural accuracy, reduces cervical trauma, and enhances inseminator confidence. Additionally, CowVuw integrates with a mobile application that captures and stores images, thereby transforming a traditionally manual process into a digitally documented intervention.

CowVuw improves the accuracy of insemination, but the visual information it provides is still judged subjectively by the inseminator. The external cervical os shows hormonally regulated morphological and vascular changes across the Estrus cycle stages including Proestrus, Estrus, Metestrus, and Diestrus. These changes, including variations in dilation, tissue tone, vascular prominence, and mucus characteristics, are visually identifiable but lack standardized classification. The lack of a structured analytical framework prevents these observations from being used for objective estrus staging. Artificial Intelligence (AI) and Machine Learning (ML) technologies can help convert these visual signs into objective, data based estrus staging tool. We at CisGEN are trying to integrate the ML technology and AI into CowVuw device to help the inseminator identifying the appropriate timing of insemination using the cervix image.

We are also leveraging high-resolution imaging of the external cervical os to determine the pregnancy status of the animal at the earliest possible stage. Following successful conception, the bovine cervix undergoes distinct physiological and morphological changes driven by progesterone dominance, including alterations in cervical tone, surface texture, mucus characteristics, vascular patterning, and coloration. While these changes are subtle and often not reliably detectable through routine visual examination during early gestation, they can be systematically captured through standardized imaging and analysed using advanced computer vision techniques. By longitudinally monitoring cervical images from the time of insemination and correlating them with confirmed pregnancy outcomes, deep learning models can be trained to identify early visual biomarkers associated with pregnancy establishment. This approach enables differentiation between pregnant, non-pregnant, and early embryonic loss cases significantly earlier than conventional diagnostic methods such as rectal palpation or ultrasonography. Early identification of non-pregnant animals allows timely re-insemination, improved reproductive efficiency, and reduction in inter-calving intervals. The integration of

AI-based pregnancy prediction into the imaging platform offers a non-invasive, scalable, and field-deployable solution that complements existing reproductive management practices and supports precision livestock farming.

Computer vision algorithms, particularly deep convolutional neural networks, can identify subtle morphological, vascular and textural features beyond routine human interpretation. By systematically collecting and annotating a large-scale, high-resolution dataset of external cervical os images across natural estrus cycles, controlled estrus synchronization models, and post insemination periods, it becomes possible to train supervised learning models capable of accurately classifying Estrus stages, pregnancy establishment, and identifying indicators of early embryonic mortality.

The primary objective of this research initiative is to enhance early and accurate estrus identification to optimize insemination timing, enable early confirmation of pregnancy, and facilitate rapid identification of non-pregnant or embryonic loss cases, thereby reducing repeat breeding events and prolonged inter-calving periods. Generating a minimum of 10,000 outcome validated images per Estrus and reproductive status category will support the development of a robust, balanced dataset for algorithm training, validation and longitudinal predictive modelling.

AI integration will significantly reduce inter-operator variability, standardize reproductive status assessment across diverse geographic and management conditions, and empower veterinarians and field technicians with real-time, evidence-based decision support. For estrus detection, insemination planning and post breeding reproductive monitoring. From a commercial standpoint, embedding AI analytics into CowVuw will transform it from a visualization-assisted device into a scalable, intelligent reproductive management platform.

Scientifically, this initiative will establish one of the first structured repositories of external cervical os imaging linked to confirmed Estrus physiology, pregnancy outcomes, embryonic viability in cattle. The convergence of CisGEN's biotechnology foundation, patented imaging capability, and AI-driven analytics addresses a critical productivity challenge in bovine reproduction and aligns strongly with national priorities in dairy productivity enhancement, digital agriculture, and precision livestock farming.