Open Journal of Animal Sciences, 2026, 16(4), 353-368
https://www.scirp.org/journal/ojas
ISSN Online: 2161-7627
ISSN Print: 2161-7597

Using Video Cameras to Examine the Vitality of Broilers for Facilitating Precision Livestock Farming Technology Adoption in the Poultry Industries

Uri Marchaim[1], Moshe Meron[1], Rami R. Hagege[1], Dan Levanon[1,2]

[1]MIGAL - Galilee Research Institute, Kiryat Shmona, Israel
[2]Tel-Hai University of Kiryat Shmona in the Galilee, Upper Galilee, Israel
Email: uri@migal.org.il

How to cite this paper: Marchaim, U., Meron, M., Hagege, R.R. and Levanon, D. (2026) Using Video Cameras to Examine the Vitality of Broilers for Facilitating Precision Livestock Farming Technology Adoption in the Poultry Industries. *Open Journal of Animal Sciences*, **16**, 353-368.
https://doi.org/10.4236/ojas.2026.164024

Received: August 20, 2026
Accepted: September 26, 2026
Published: September 29, 2026

Abstract

At MIGAL - Galilee Research Institute in collaboration with Lulei-Of-HaGalil poultry production integration, we developed a novel video analysis system that is combined with an Enviro-Detect (ED) systems to detect better vitality, growth and welfare indicators of poultry flocks and enhance on-farm decision making. The developed technology and methodology, that was validated and implemented in two broiler-houses in each farm, is a holistic Precision Livestock Farming (PLF) system for broiler-houses. It integrates innovative environmental monitoring and AI-driven analysis of broilers vitality to improve broilers health, maintain productivity, save costs and reduce environmental footprint. It was demonstrated that by using environmental intelligence in farms that a solution can be reached to these customers' problems, by integrating environmental monitoring with smart interventions while cooperating with the farmers and their representatives. The Lulei-Of-HaGalil Integration represents a regional poultry-production integration in the Upper Galilee, based on a cooperative network of local broiler farms that supply poultry to the Of-HaGalil processing system. The integration coordinates production planning, flock management, feed supply, professional guidance, veterinary oversight, data collection, and marketing/processing interfaces, thereby functioning as a structured farm-to-processing value chain embedded in the regional agricultural ecosystem to enhance on-farm decision making. Poultry farmers spend a great deal of time checking the health and welfare of their chickens. This can mean walking through the flock several times a day monitoring for signs of poor health. This PLF system links continual on-board image analysis, with a low-cost camera mounted in the broiler house to provide regular updates on flock movement throughout the day, representing their validity and, in case of reduced movement, send an alarm to the farmer. The algorithm developed recognises subtle changes in patterns of behaviour and the information is provided to the farmer throughout the day as a brief report.

Keywords

PLF/Smart Technologies, ICT Tools, Vitality, Implementation, Technology Barriers

1. Introduction

Poultry farming is one of the most efficient animal husbandry methods, and it provides nutritional security to a significant portion of the world population. Using modern intensive farming techniques, global production has reached 133.4 mil. tonnes in 2020, with a steady growth each year [1]. Such intensive growth methods however lead to a significant environmental footprint, therefore proper management that will minimize its adverse effects is proposed. Since a broiler-house may house tens of thousands of broilers, livestock farmers face a huge challenge to combine a need for production efficiency with animal health/welfare requirements along with environmental sustainability and impact mitigation. The developed technology and methodology, validated and implemented in two broiler-houses in the Galilee, Israel, is a holistic Precision Livestock Farming (PLF) system for broiler-houses that integrates innovative environmental monitoring (developed by an Australian company, PLF Agritech Pty Ltd. [2]) and AI-driven analysis of broilers vitality to improve broilers health, maintain productivity, save costs and reduce environmental footprint. It was demonstrated that by using environmental intelligence in farms/co-ops solutions to customers' problems are achieved, by integrating environmental monitoring with smart interventions.

The importance of Precision Livestock Farming (PLF) technologies in agricultural practices is widely recognised, yet the actual adoption rate remains low. To address this issue, research with several interconnected sub-studies was initiated across seven countries to encourage PLF technology utilisation [3]. Despite successful deployment, challenges such as animal behaviour, sensor positioning, and internet connectivity affected operational efficiency. Concurrently, surveys were conducted to assess livestock producers' attitudes and identify adoption barriers [4] [5]. Subsequently, a sophisticated cloud-based ICT tool was developed to integrate research outcomes [3]. The findings have highlighted concerns regarding the cost, complexity, maintenance, and perceived benefits of PLF technologies, exacerbated by internet connectivity issues in rural areas [6]. Machine learning analysis identified the technological readiness levels of farmers, providing information for the development of the new PLF Compass tool [7]. This integrated application facilitates technology adoption by offering personalised recommendations and benefit assessments [3].

Over decades of agricultural industrialization, technology has enabled farmers to raise thousands of broilers together, increasing scale and profitability. Even as global demand for broiler products increases (by as much as 40 percent in the next 15 years!), the number of farmers raising animals continues to fall [1] [8]. And with expected increased mouths to feed by 2050, industrial ag is here to stay, along with the cameras that will serve as a farmer's eyes and ears. It aims to keep animals healthy in high-volume broiler's operations. Overcrowding and unsanitary conditions increase the chances that animals get sick or injured. Today's tech can help farmers intervene earlier, provide more targeted care, and even encourage healthier behaviour from the outset.

The need for a combined system that is beyond the state of art is needed as a holistic PLF system for broiler houses integrating the following innovative elements:

- Innovative environmental monitoring sensors [9] combining vitality of broilers by video cameras with sensors of gases, water and feed consumption that can control ventilation and send immediate data to farmers.
- The first-time use of AI-driven analysis of video to identify the vitality of broilers using unique analytical approach to image analysis.
- The first integration of those parameters that can support reduction of footprints at broiler-houses.

Today the market offers a few detectors of gases which provide the farmer data, but the data has very little connection to the environmental stress of the broilers and does not send immediate alarm when incident occurs. Furthermore, the Enviro-Detect system used in this study does integrate the various environmental sensors into a self-contained system [9].

The camera-based system that was installed in broiler house combined with AI was well suited to quantify broiler vitality continuously and to detect early behavioral changes caused by environmental stress such as ammonia (NH_3). It is a step forward on the earlier reported article [10] that emphasized the importance of AI and computer vision for early heat-stress detection. The key was not to monitor individual birds, but to analyze the behavior of the flock as a biological sensor that reacts to the flock response to the situation. Rather than simply measuring movement, the AI developed gave an indication, by "seeing" the birds as dots that are moving, how the flock behave [11] as the methodological foundation and [12] as evidence of its practical application to poultry health monitoring.

Combining the continuous video AI analysis with environmental sensors (gas, humidity, dust), the AI does something a human cannot: it calculates the relationship between the sudden rise of ammonia in the broiler house and flock behavior and examine thew overlapping of events in order to alert the farmer. The AI looks for deviations from the baseline of the usual flock behaviour at this age. This allows the farm manager to fix the ventilation system immediately, preventing an outbreak of disease or mass mortality. Based on the recent reduction in movement, increased clustering, and environmental trends, there is a high probability that broilers are stressed and there is a need for immediate response.

2. Methodology

Sites of examining the methodology

Lulei-Of-HaGalil Integration is a cooperative regional broiler-production network in the Upper Galilee that links local poultry farms with professional management, feed supply, monitoring, and processing infrastructure, creating a practical platform for applied poultry innovation and precision livestock farming. The Lulei-Of-HaGalil Integration is a regional vertically coordinated poultry production system in the Upper Galilee, linking multiple 28 farms, broiler growers, the poultry slaughterhouse/processing facility, feed supply, veterinary/professional guidance, and production planning into one organized agricultural value chain. It serves as a living, regionally embedded poultry value-chain platform, connecting poultry houses across kibbutzim and agricultural communities with feed, veterinary, management, monitoring, and slaughterhouse/processing operations. This structure enables coordinated implementation of innovations at farm scale, including precision livestock monitoring, environmental sensing, animal-welfare assessment, production-efficiency improvements, and data-driven decision support.

3. Stage of Development and Technology Readiness Level

The proposed technology is a 'game changer' for improving welfare, productivity and forecasting for the supply chain. Practically on farm, this technology will allow growers to monitor flocks around the clock. Farmers will be notified when the vitality show irregularities. Camera analysis would allow immediate intervention by the farmer [13]. The module will help optimize the broilers' performance by reacting faster than the farmer to intake deviations. The system continuously monitors climate data and the broilers' feed and water intake. We used PLF's Enviro-Detect™ system which sent data to the farmers but were at this stage not providing online communication (**Figure 1**). The apparatus provides a practical instrumentation kit for monitoring airborne pollutants. The development needed during the project is directed at sending the information from the sensors online to the farmers (**Figure 2** and **Figure 3**), providing information of the inside conditions of a building, compared to the outside.

The system uses video technology in the four commercial broiler houses, two in each farm, to examine stress and vitality of the birds. Units (several cameras mounted on the roof, spread in diverse locations) and two Enviro-Detect™ system were installed in each building, continuously monitor the flock below. AI analysis translates these images into an index for animal migration and activity, both of which are valuable indicators of animal vitality. We wired up video cameras to take continuous photos of the birds at the broilers' houses, transferred each broiler to a dot, and examined their moves around their site. Then we were looking for patterns in their behaviour. This enables the AI to analyse how long they stay at site or move, and analyse their activity, to give a pattern compared to an "usual" expected activity according to their age. The combined system of gas and dust analysis and the video AI analysis enables detecting effect of the environmental conditions (and maybe early disease effects) on the behaviour of a flock of broilers, to be followed from minute to minute, so that any abnormal behaviour is signalled quickly to limit negative consequences to a minimum.

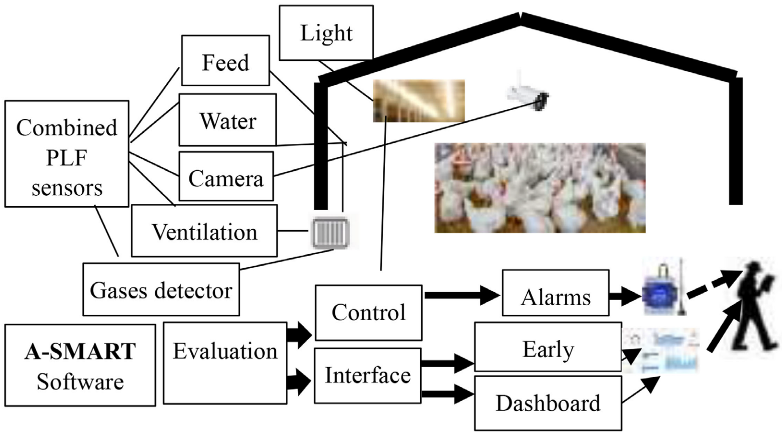

Figure 1. Schematic overview of broiler house management optimisation through the implementation of PLF tools.

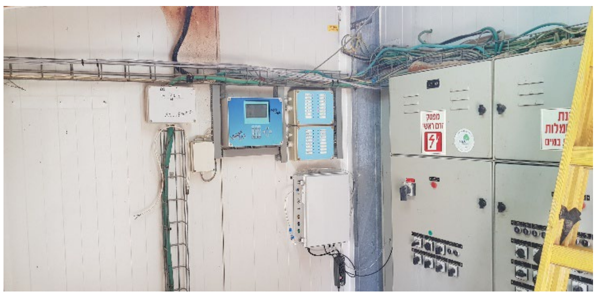

Figure 2. Enviro-Detect™ system were installed in the control room of the broiler-house.

Figure 3. Video cameras mounted on broiler-house roof.

4. Project's Preliminary Results - Experience with Farmers in 2 Poultry Farms

The systems (both cameras and gas detectors) were installed in two farms in the upper Galilee, Israel, in collaboration with "Lulei Of-HaGalil". It was examined and discussed several times with the farmers, the experts from this integration and their veterinarian. The broiler-houses of the Lulei-Of-HaGalil Integration operate around 42 days per cycle and around 5 or 6 cycles a year, with very careful cleaning between cycles. We were examining the farms for the entire year, and in one farm we had some problems of internet at one of the broiler-house that enabled only observing 3 cycles.

Early detection of broiler flock stress using real time video

Early warning for prevention of disease outbreak in broiler production has considerable economic value. At present only very experienced human observation can detect stress signs before decline of food and water intake and visible disease signs. Video recordings from cameras installed in the broiler house are processed using a computer-vision algorithm. In each video frame, individual chickens are detected and represented digitally by a point, usually corresponding to the centre of the bird's detected body area. The algorithm then links the same point across consecutive frames, creating a movement trajectory for each chicken. Each tracked point is assigned spatial and movement-related properties, including its two-dimensional location, movement speed, and direction of travel. Speed is calculated from the distance travelled between consecutive frames divided by the elapsed time, while direction is calculated from the change in the point's coordinates. This transformation converts the original video into structured numerical data that can be used to analyse bird movement, activity levels, spatial distribution, behavioural changes, and possible welfare or health abnormalities. It follows the research regarding transformation of original video into structured numerical data that can be used to analyse bird movement, activity levels, spatial distribution, behavioural changes, and possible welfare or health abnormalities [11] [14] [15].

Video monitoring has the potential to detect flock vitality changes and stress signs, however quantification of those signs and warning system for the grower is yet to be development (**Figure 4** and **Figure 5**).

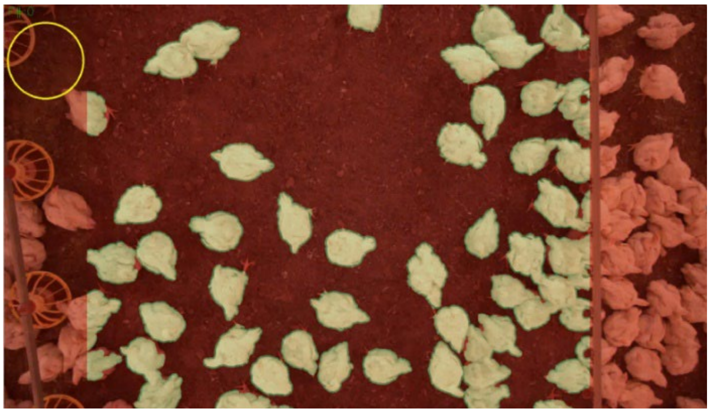

Figure 4. Chicken segmentation algorithm for segmenting each chicken to a subset. These subsets can be used to extract various quantities of the chicken such as area parameter shape, color, etc.

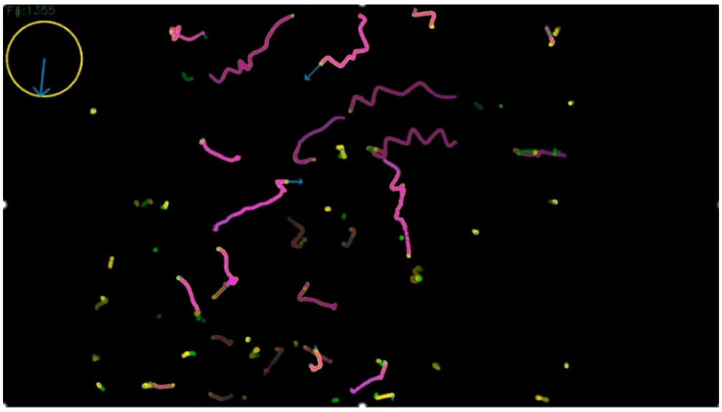

Figure 5. Data Reduction reduce the raw data to data structure, which is more manageable, demonstrating chicken becomes a point with properties such as location speed and direction, etc.

Video survey: In the broiler rearing house at kibbutz Kfar Giladi and kibbutz Kfar-Hanasi, Israel, three security cameras (Avcom, Hod Hasharon Israel) were mounted under the roof, looking vertically down by FOV of 110 degree, covering 8 square meters of floor area. An additional camera was mounted under the roof looking along the house to observe overall view of the flock, total 4 cameras for each broiler-house. Video was recorded by 4K resolution 24 fps continuously 24/7, with remote connection.

Air quality monitoring: Two air quality monitoring devices (Enviro-Detect™, (ED) PLF Agritech Pty Ltd), developed by PLF, consisting of CO_2, NH_3, and dust detectors, inside and outside temperature and relative humidity sensors. Measurements are taken by the system continuously. Systems were mounted one at the middle of the building and one at the outlet fans end. Data was collected at the PLF server and mailed weekly analysed to the grower in hard copy, and in digital data base format to the MIGAL laboratory. When a change in the BVI was noticed by the Enviro-Detect system they send an immediate notice to MIGAL. They are developing now an automatic response to the farmer.

5. Results

Proof of concept validation in 2 poultry farms

The systems (both cameras and gas detectors) were installed in two kibbutzim in upper Galilee, Israel, in collaboration with "Lulei Of-HaGalil" Broilers' Integration of 29 kibbutzim in the region. It was examined and discussed several times with the experts from this integration and their veterinarian. Results from the combined system of air monitoring and video of the broilers are shown in Figure 6.

The purple lines represent vitality indexes from healthy cycles, sampled from 4 different fields of view. The Broiler Vitality Index (BVI) was defined as a video-derived indicator of flock activity, calculated using AI-based analysis of bird movement. The index was used to monitor temporal changes in behavioural activity and identify deviations from expected activity patterns. By associating detections across successive frames, the algorithm maintains a consistent identifier for each bird as it moves, enabling the reconstruction of individual movement trajectories and calculation of activity-based indicators.

The vitality index is a quantity we measure which averages the speed of individual birds. As can be seen from the green line (Figure 6) which is the average across all healthy cycles we have, it is decreasing as a function of time because of increasing stock density and bird weight.

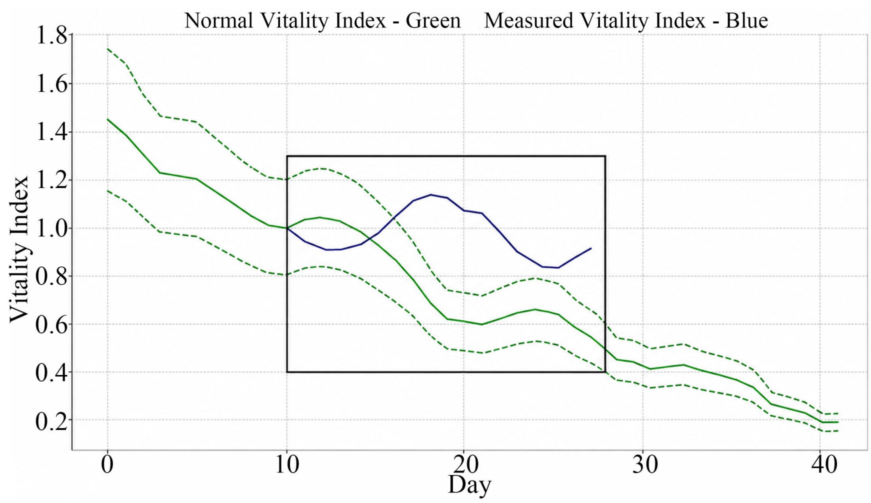

Figure 6. Developed vitality index during 42 days of growth, with actual results when ammonia incident happened.

The dashed green envelope shows the limit of variations we encountered in all healthy cycles such as the purple lines. The blue line clearly gets outside that envelope which shows unusual behaviour 2 days before our sensor detected the presence of unwanted levels of ammonia in the growing zone.

Technological Innovation and current results: a real scenario

We have developed mechanisms that enable the extraction of broiler tracks in high accuracy. The algorithm is a hybrid of deep learning systems and expert systems, and we are unique in the capability of building such algorithms. The results shown in Figure 7 and Figure 8 are the vitality index when an event happens. In order to decide how to optimize performance by using several of those vitality indexes, we plan to collect more cycles.

The main benefit of the developed AI is the extreme reduction of observed data to only big motions in the field of view, which enables very detailed analysis of the flock's vitality. This average speed is changing as the growth cycle goes on. We call this normal vitality index. We found that this graphic presentation is behaving in a very similar way in all the healthy production cycles.

In one of our records of full growth cycles, an elevated ammonia event happened. It was recorded by the ED gas monitor, creating real damage to the flock and was not detected by the grower, while water and food intake records were inspected only after looking into the ammonia records and an unnormal vitality change at the broiler house. Our approach led to an earlier detection of the event and quick alarm to the farmer. The maximum deviations we observed from the averages of all these graphic presentations are around 20% (dotted lines in Figure 7). When tested on unhealthy or irregular cycles, the deviations were much higher, therefore enabling early detection of stress (Figure 6). The dashed green line represents the largest deviation we observed from the healthy averages. As shown in Figure 7 and Figure 8, Vitality Index responded to the ammonia pollution, foreseeing 2 - 3 days the peak pollution and the subsequent intake stagnation. It demonstrates the potential of the tested interpretation of a broiler video monitoring.

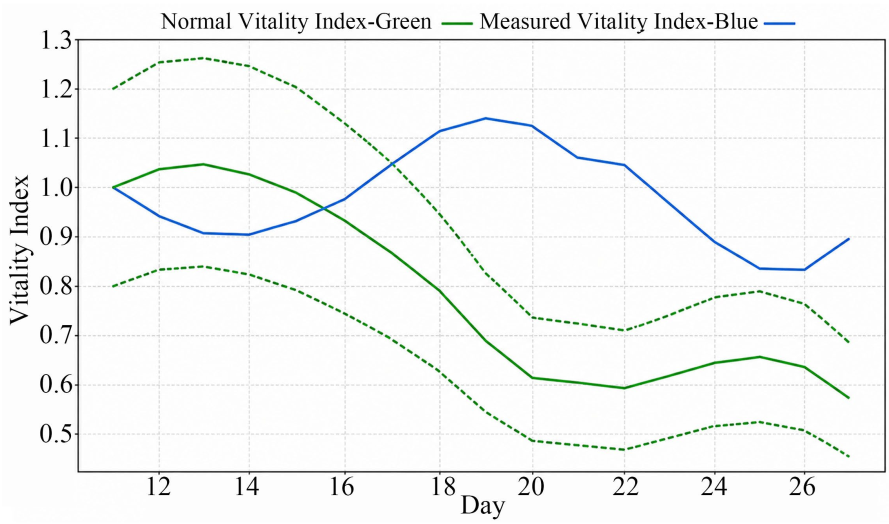

Figure 7. Ammonia pollution event at Kfar Giladi broiler house, January 2023. Marked insert indicate stagnant feed and water intake period. Blue line indicates early detection by the vitality index; red rectangle indicates stagnation period.

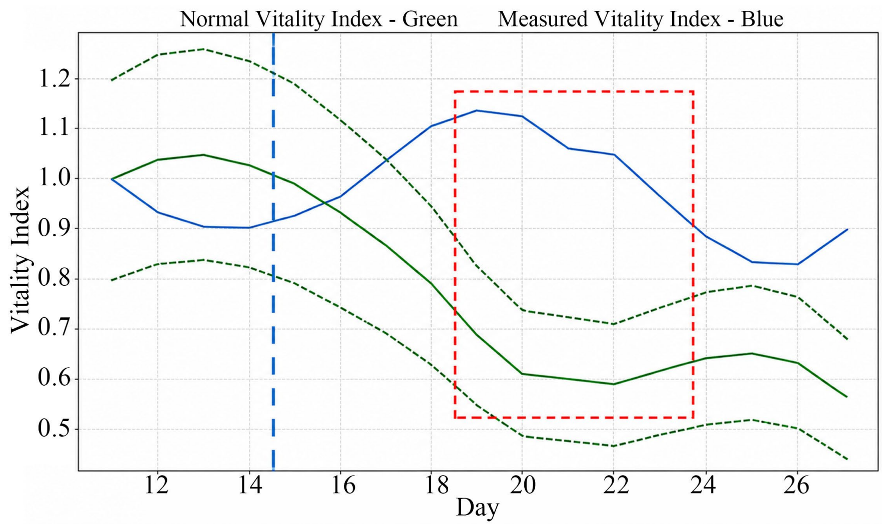

Figure 8. Vitality index during 18 days at Kfar Giladi broiler house, January 2023. Solid green line indicates average behaviour of the vitality index in healthy cycles, while blue line indicates early detection by the vitality index.

6. Discussions

Our results from the two broilers-houses (where the systems were installed) showed advantage to the farmer (who received an alarm during the night on NH_3 concentration that affected broilers). The research funded by the Israeli Innovation Authority under the ICT-Agri project, got the interest of the "Lulei Of Ha-Galil" broilers' integration. It involved the experts in AI, the researchers in the poultry sector at MIGAL and researchers in PLF (part of the EU LivestockSense project), using the equipment of PLF Agritech Pty Ltd company (Brisbane, Australia), that produced the Enviro-Detect sensor systems and analysed the data from the broiler-houses, providing it directly to the farmers. According to the results and benefits that were identified from the development of the methodology, the companies and farmers involved declared that having the results and benefits from the collaboration of researchers and industrialists, led to improvement of the technology.

We have done a patent survey, as well as examined the literature published, and we are sure that the proposed system that integrates both the AI examination of the broilers vitality by videos, the ammonia and carbon dioxide gases emissions, and the sensors that monitor water & feed uptake, temperature and humidity as a combined system, is not on the market and has the potential to be commercially viable. The economic analysis provided herein shows that it will pay back the farmers within 1 - 2 years.

The technology and methodology we developed, validated and implemented in two broiler-houses in the Galilee, is a holistic PLF system for broiler-houses that integrates innovative environmental monitoring and AI-driven analysis of broilers vitality to improve health of broilers, maintain productivity, save costs and reduce environmental footprint. We demonstrated that by using environmental intelligence in farms we can reach a solution to these customers' problems, by integrating environmental monitoring with smart interventions.

In promoting for a competitive advantage in animal welfare, we plan to actively implement camera technologies combined with environmental analysis to monitor broiler flocks, using different approaches to the PLF technology. Monitoring of broilers' behaviour will also supplement existing environmental control systems that maintain temperature and humidity to ensure control systems are providing a representative indication of temperatures across the shed. Camera analysis would allow immediate intervention by the farmer.

Credibility of the impacts

The results of the development combine vertical impact on innovative solutions on the broiler production management related to the environmental aspects and welfare of livestock and workers, through creating new integrated knowledge based on pilots' results and new integrated solutions, combining them with horizontal impact on stakeholders' involvement (farmers' organizations), socio-economical aspects, policy and potential business. The project developed an updated economic analysis that provides the economic pathways to adapting transformative approaches and strategies to include new tools and best practices to the broilers' sector, as well as develop policy plans to maximize environmental efficiency.

Environmental aspects

This methodology serves intensive poultry farming and has a significant environmental footprint effect. In intensive broilers' houses waste materials such as poultry litter and manure can pose a serious threat to environmental and human health and need to be managed properly. Poultry production and waste by-products are linked to NH_3, N_2O and CH_4 emissions, and have an impact on animal and human health. Dust emitted from intensive poultry production operations can adversely impact poultry and farm workers health, enhancing the infection of birds with Newcastle and the bronchitis virus [16]. Effect of increase CO_2 concentration during heating the broiler-houses, typical to cold winter, has an immediate effect on broilers' health and welfare. It is reported that at a concentration of 11800 ppm, symptoms of gasping and shortness of breath were observed, while the birds began to die at 17400 ppm [17]. The methodology developed had a positive effect (shortening by day or two) on the length of the production and account for much of the variation in environmental burdens by broilers. Farms' gas emission and dust created by the broilers were noted. Controlling humidity and manure, the main component of generating ammonia, will be a great benefit.

Implementing the methodology will enable workers controlling the gas emissions and avoid problematic situation that effect the growth rate. In addition, the methodology presents a clearer focus on higher business potential, presented in the following economic analysis and based on discussions with the farmers' broilers' Integration. It is a financial model for the combination of different technological procedures, because farmers understand that these factors are directly impacting on the viability and profitability of their enterprises.

Regarding the Environmental Challenges

Environmental, Social and Governance (ESG) aspects of the proposed PLF activities are rapidly gaining the interest of the farmers' organizations and stakeholders. Environmental challenges in broiler houses Including heat stress, excessive humidity, poor air quality, high ammonia and carbon-dioxide concentrations, wet litter, uneven ventilation and inefficient energy use directly affect the profitability of poultry production. Improving these conditions can therefore create substantial economic value for farmers. Improved air quality can also increase production efficiency. High ammonia concentrations are associated with respiratory irritation, reduced feed intake, poorer growth, impaired feed utilisation, increased susceptibility to disease and higher mortality. Reducing ammonia and maintaining dry litter may consequently decrease foot pad and hock burn, veterinary costs, mortality, carcass condemnations and production losses.

We were able to align with global ESG-related principles and guidelines, and adopt and implement various technologies, sensors and AI practices to address these emerging challenges, to cope with the specific objectives set out in this specific Transition Challenge meaning a major systemic obstacle that must be overcome to move from the current economic and societal model toward an environmentally sustainable one.

We foresee the expected outcome as a commercial emergence of new class of environmental technologies that radically improve several of the issues mentioned in the EU 8th Environment Action Program for 2030 [18]. A business model, its initial validation and a business plan, is presented as an outcome of the project. The expected outcomes and impacts of the project relevant to the Transition Challenge are:

- Reduction of environmental pollution through integration of technologies demonstrated by means of sustainable pilot-scale prototypes, performing environmental monitoring and improving welfare of birds and human;
- Enabling an evidence-based environmental policy for the livestock industry as well as improving and simplifying the environmental policy making through environmental intelligence;
- Promotion of the development of an EU "environmental monitoring/remediation-based" economy;
- Develop an exploitation strategy (including formal IP protection) and a credible business model for the deployment and use of the novel combined device, in the relevant environment. We estimate it can generate high impact in terms of regional economic returns (e.g. innovative companies created, increased market share, competitive advantage) and environmental benefits (e.g. earlier and more efficient detection and decontamination).
- We present to farmers and farmers' organizations how they can integrate the ESG criteria into their strategy, business and culture goals in order to make tangible societal and environmental impact. As such, the implementation of the methodology support organisations in their journey to harness the power of ESG transparency and implementation to achieve competitive advantage, and to attract and retain investors, employees and other stakeholders.
- The methodology can identify changes in the environment, measure flock's vitality as well as the emission of gases, and report social and environmental impact (s). It is based on stakeholder engagement strategies and assessments of their contribution (and experience), in order to facilitate the implementation stage, and aims to take special care after the end of the project to implement the results and be responsible for attracting investments.

7. Estimated Economic Benefits of Early Detection of Broiler Stress

Improved environmental and health management in broiler houses may generate economic value through higher saleable live weight, lower mortality, fewer downgraded birds, reduced medication requirements, and fewer production disruptions. Camera-based artificial-intelligence monitoring may contribute to these outcomes by detecting changes in bird movement, activity, and spatial distribution before stress becomes evident to farm personnel (**Table 1**).

A hypothetical partial-budget analysis was therefore used to estimate the economic effect of avoiding a one-day delay in the detection of a health or environmental stress event. The calculation considered a 1000 m^2 broiler house stocked with 13,700 birds and six production cycles per year. In the delayed-detection scenario, market weight declined from 2.70 to 2.58 kg·bird^{-1}, mortality increased from 5% to 9%, and the feed conversion ratio increased from 1.52 to 1.66. Feed was valued at €540 t^{-1}. Other operating costs were assumed to remain unchanged. Input values were based on information supplied by the farmers' organization and should be updated for the production system and price year examined.

Table 1. Illustrative economic effect of a one-day delay in detecting broiler stress.

Indicator	Timely detection	One-day delay	Effect of delay
Market weight (kg·bird^{-1})	2.70	2.58	−0.12
Mortality (%)	5	9	+4 percentage points
Feed conversion ratio	1.52	1.66	+0.14
Annual production (t·per 1000 m^2)	176	161	−15
Total direct expenses (€·kg^{-1})	1.34	1.46	+0.12
EBITDA after capital return (€·kg^{-1})	0.19	0.07	−0.13*

*Difference reflects unrounded source values. EBITDA, earnings before interest, taxes, depreciation and amortization.

Under these assumptions, a one-day delay reduced annual saleable production by approximately 15 t·per 1000 m^2 and lowered EBITDA after capital return by approximately €0.13 kg^{-1}. Assuming six production cycles per year and that early warning is economically effective in two cycles, the avoidable loss is approximately €76,000 ha^{-1}·year^{-1} (about 585 t affected production × €0.13 kg^{-1}). A more conservative benefit of €50,000 ha^{-1}·year^{-1} may therefore be used for preliminary evaluation.

An illustrative extrapolation based on 15.5 million tonnes of EU broiler production in 2021 and an estimated production area of 8900 ha gives a theoretical benefit of up to €445 million year^{-1} when the conservative hectare-level estimate is applied. This figure should not be interpreted as a forecast: realized benefits will depend on disease and environmental-stress incidence, system sensitivity and specificity, farmer response time, production intensity, local prices, and the capital and operating costs of the monitoring system. These costs should be incorporated in a full cost-benefit or net-present-value analysis before commercial conclusions are drawn.

Based on some economic estimation that were published earlier [19] [20] aiming to detect behavioral changes associated with heat stress, elevated ammonia, or ventilation failure 30 - 120 minutes before they become apparent to farm personnel, they estimated the cost to the U.S. poultry industry US$128 - 165 million annually. Those calculations are not cited as an established AI-derived saving. It represents the total potential gross value of the flock, which can then be used as the baseline for calculating avoided losses.

Similar estimation on the importance of AI to the handling of the broiler industry that presents combining published biological effects (mortality, feed conversion, weight gain) with typical commercial flock values were presented by Lara and Rostango [21] several years ago concerning heat stress that causes economic losses. This review reports that heat stress causes: reduced feeding intake, lower body weight gain, poorer feed conversion, increased mortality. It cites annual losses to the U.S. poultry industry of US$128 - 165 million due to heat stress.

The poultry sector, which has an extremely important place in terms of food safety and nutrition, is the fastest growing agricultural sub-sector. The market is expected to hit $ 422.97 billion in 2025 with a CAGR of 7% (tonyelumelufoundation.org). This information and data, on market opportunities for the proposed platform and the methodology, gives an estimation on market uptake but must be approached locally. It is important to add the non-tangible social benefits and welfare of workers and livestock.

The approach to commercialise the integrated technology is presented in **Figure 9** and is planned to be implemented in the stages "Initiation" and "Development" during the first 2 years, and "Exploitation" mainly in the 3rd year and during the establishment of the company that will commercialize the integrated technology.

Those broilers integration in different countries are the main market for the system. Every day that the broiler does not reach the determined level of production efficiency on the farm will reduce the expected feed conversion ratio (FCR) (kg/kg). FCR is a key indicator of farm profitability in poultry production.

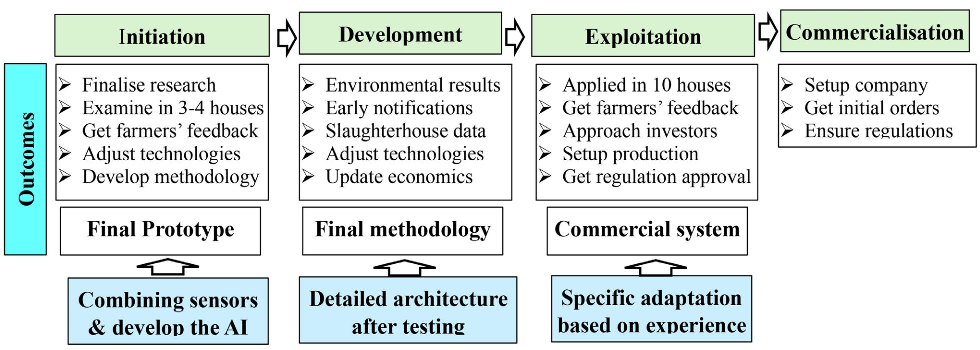

Figure 9. Design of the exploitation stage for further develop and implement the methodology.

We are aiming to develop in the near future a multimodal AI framework that fuses camera vision with environmental sensing to generate a real-time Broiler Vitality Index (BVI). The proposed system would identify subtle behavioral changes that precede heat stress or ammonia exposure, enabling proactive management. Such a framework aligns well with precision livestock farming and explainable AI by providing both predictions and interpretable behavioral indicators that explain why an alert was issued (**Figure 9**). This predictive capability could improve animal welfare, reduce mortality, and optimize ventilation and climate control.

Acknowledgements

We want to thank the Israeli Innovation Authority, who funded the project as part of the European project LivestockSence of the ICT-AGRI ERA-NET Cofund.

Author Contributions

Both researchers were involved in developing the research conceptualization. U. Marchaim was the researcher, and D. Levanon supported the review of the implications for agriculture and horticulture & editing.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] FAO (2021) Meat Market Review: Overview of Global Meat Market Developments in 2020. Food and Agriculture Organization of the United Nations.

[2] PLF Agritech Pty Ltd. (2023) Air Quality Measuring Apparatus Used in Animal Husbandry. AU 2020256312 B2.

[3] Banhazi, T.M., Banhazi, A., Tikasz, I.E., Palotay, S., Mallinger, K., Neubauer, T., *et al.* (2024) Facilitating PLF Technology Adoption in the Pig and Poultry Industries. *Studies in Agricultural Economics*, **126**, 43-49.

[4] Tikász, I.E., Király, G., Bálint, C., Opalinsky, S., Sorensen, C.A.G., Gunnarsson, S., Marchim, U., Kokin, E., Mallinger, K. and Banhazi, T. (2023) Conditions of Applying Advanced Information Technologies in Livestock Farming. *XL CIOSTA & CIGR Section V International Conference*, Évora, 10-13 September 2023, 101-110.

[5] Mallinger, K., Corpaci, L., Neubauer, T., Tikász, I.E., Goldenits, G. and Banhazi, T. (2024) Breaking the Barriers of Technology Adoption: Explainable AI for Requirement Analysis and Technology Design in Smart Farming. *Smart Agricultural Technology*, **9**, Article 100658. https://doi.org/10.1016/j.atech.2024.100658

[6] Kopler, I., Marchaim, U., Tikász, I.E., Opaliński, S., Kokin, E., Mallinger, K., *et al.* (2023) Farmers' Perspectives of the Benefits and Risks in Precision Livestock Farming in the EU Pig and Poultry Sectors. *Animals*, **13**, Article 2868. https://doi.org/10.3390/ani13182868

[7] Mallinger, K., Corpaci, L., Neubauer, T., Tikász, I.E. and Banhazi, T. (2023) Unsupervised and Supervised Machine Learning Approach to Assess User Readiness Levels for Precision Livestock Farming Technology Adoption in the Pig and Poultry Industries. *Computers and Electronics in Agriculture*, **213**, Article 108239. https://doi.org/10.1016/j.compag.2023.108239

[8] Guarino, M., Norton, T., Berckmans, D., Vranken, E. and Berckmans, D. (2017) A Blueprint for Developing and Applying Precision Livestock Farming Tools: A Key Output of the EU-PLF Project. *Animal Frontiers*, **7**, 12-17. https://doi.org/10.2527/af.2017.0103

[9] Banhazi, T.M. (2009) User Friendly Air Quality Monitoring System. *Applied Engi-*

neering in Agriculture, **25**, 281-290. https://doi.org/10.13031/2013.26331

[10] Oso, O.M., Mejia-Abaunza, N., Bodempudi, V.U.C., Chen, X., Chen, C., Aggrey, S.E., *et al.* (2025) Automatic Analysis of High, Medium, and Low Activities of Broilers with Heat Stress Operations via Image Processing and Machine Learning. *Poultry Science*, **104**, Article 104954. https://doi.org/10.1016/j.psj.2025.104954

[11] Roberts, S.J., Cain, R. and Dawkins, M.S. (2012) Prediction of Welfare Outcomes for Broiler Chickens Using Bayesian Regression on Continuous Optical Flow Data. *Journal of The Royal Society Interface*, **9**, 3436-3443. https://doi.org/10.1098/rsif.2012.0594

[12] Colles, F.M., Cain, R.J., Nickson, T., Smith, A.L., Roberts, S.J., Maiden, M.C.J., *et al.* (2016) Monitoring Chicken Flock Behaviour Provides Early Warning of Infection by Human Pathogen *Campylobacter*. *Proceedings of the Royal Society B*: *Biological Sciences*, **283**, Article 20152323. https://doi.org/10.1098/rspb.2015.2323

[13] García, R., Aguilar, J., Toro, M., Pinto, A. and Rodríguez, P. (2020) A Systematic Literature Review on the Use of Machine Learning in Precision Livestock Farming. *Computers and Electronics in Agriculture*, **179**, Article 105826. https://doi.org/10.1016/j.compag.2020.105826

[14] Guo, Y., Chai, L., Aggrey, S.E., Oladeinde, A., Johnson, J. and Zock, G. (2020) A Machine Vision-Based Method for Monitoring Broiler Chicken Floor Distribution. *Sensors*, **20**, Article 3179. https://doi.org/10.3390/s20113179

[15] Okinda, C., Nyalala, I., Korohou, T., Okinda, C., Wang, J., Achieng, T., *et al.* (2020) A Review on Computer Vision Systems in Monitoring of Poultry: A Welfare Perspective. *Artificial Intelligence in Agriculture*, **4**, 184-208. https://doi.org/10.1016/j.aiia.2020.09.002

[16] Mohammad Al-Kerwi, M.S., Mardenli, O., Mahdi Jasim, M.R. and Al-Majeed, M.A. (2022) Effects of Harmful Gases Emitted from Poultry Houses on Productive and Health Performance. *IOP Conference Series*: *Earth and Environmental Science*, **1060**, Article 012082. https://doi.org/10.1088/1755-1315/1060/1/012082

[17] Pedersen, S., Blanes-Vidal, V., Jørgensen, H., Chwalibog, A., Haeussermann, A., Heetkamp, M.J.W. and Aarnink. A.J.A. (2008) Carbon Dioxide Production in Animal Houses: A Literature Review. *CIGR Ejournal*, **10**, 1-19.

[18] European Commission (2026) Environment Action Programme (EAP) to 2030. https://environment.ec.europa.eu/strategy/environment-action-programme-eap-2030_en

[19] Aviagen Group (2025) Ross Broiler Pocket Guide.

[20] Guðjónsdóttir, S.B., Vásquez-Mejía, C.M., Shrivastava, S. and Ögmundarson, Ó. (2025) A Life Cycle Assessment of Broiler Chicken Meat and Egg Production in Iceland. *Poultry Science*, **104**, Article 105072. https://doi.org/10.1016/j.psj.2025.105072

[21] Lara, L. and Rostagno, M. (2013) Impact of Heat Stress on Poultry Production. *Animals*, **3**, 356-369. https://doi.org/10.3390/ani3020356.