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São Paulo School of Advanced Science on Precision Livestock Farming
October 15th to 24th, 2024
Jaboticabal - Brazil

SÃO PAULO SCHOOL OF ADVANCED SCIENCE ON PRECISION LIVESTOCK FARMING

In the pursuit of sustainable solutions for livestock production, new systems and technologies have been developed and proposed in recent years, and the emergence of Precision Livestock Farming (PLF) has been a game-changer. PLF aims to optimize production management by continuously and automatically monitoring and controlling aspects such as animal productivity, environmental impacts, and animal health and welfare. While cutting-edge equipment drives PLF forward, the biggest challenge lies in processing the vast amounts of collected data. This is where multidisciplinary teams play an essential role, as correctly interpreting biological responses is critical to harnessing the full potential of PLF. To make a qualitative leap in PLF research, the Organizing Committee planned the São Paulo School of Advanced Science on Precision Livestock Farming (SPSAS-PLF). With support and funding from the São Paulo Research Foundation (FAPESP, Process 2023/05506-1), we organized a 10-day immersive experience at the School of Agricultural and Veterinary Sciences of São Paulo State University (Unesp Jaboticabal). By bringing together globally renowned scientists advancing PLF science, we aimed to inspire graduate students and young scientists to explore various aspects of PLF research in depth. The goal of this program was to foster significant interest in PLF research, empowering young scientists to play a global role in advancing science and bridging the gap between fundamental and applied research in PLF. In this document, we have compiled the contributions of young scientists who presented their PLF research projects and findings during the SPSAS-PLF, held at Unesp Jaboticabal from October 15 to 24, 2024. We hope everyone enjoys reading this collection of fresh ideas, which we believe will contribute to the advancement of Precision Livestock Farming research!

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São Paulo School of Advanced Science on
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PROCEEDINGS OF SÃO PAULO SCHOOL OF ADVANCED SCIENCE ON PRECISION LIVESTOCK FARMING

EFFECTS OF CRATE SIZE ON MORTALITY AND POSTURAL BEHAVIOR IN POST-FARROWING SOWS

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Preweaning mortality (PWM) is a economic and animal well-being issue for swine producers in the US. On average, producers face about a 16% pre-weaning mortality. A significant portion of this, around 6%, is because sows accidentally overlay their piglets in farrowing crates. The posture behavior of sow plays a vital role in overlaying piglets and this behavior has a significant effect on farrowing crate dimensions. This study aims to explore the interplay between farrowing crate size, mortality rates, and postural behavior in post-farrowing sows. This study employed three farrowing stalls: Traditional (T), Expanded creep area (C), and Expanded sow area (S). Expanded creep area extended the piglet area (2.44 m × 1.83 m) while retaining the sow area identical to Traditional, while Expanded sow area included an extended piglet area (2.44 m × 1.83 m) with a sow area of 2.13 m × 0.71 m. Postural data were collected from 18 post-farrowing sows over three consecutive days, each comprising a 24-hour period. A computer vision system employing top-down Kinect V2 depth sensors captured images at a rate of 10 frames per minute throughout the duration of the study. Depth images were utilized exclusively due to their ability to convey relative height differences of the animals, while RGB images were disregarded due to variations in light intensity. A pre trained YOLO v8_cls model that trained with six different postural categories (standing (STAND), kneeling (KNEEL), sitting (SIT), sternal lying (LOB), lying on the right side (LOR), and lying on the left side (LOL)) was utilized for inferencing all the depth images to posture database. The mortality class high and low was determined from the piglet survival rate. The results showed that the SIT posture has a significant effect on the mortality rate (p-value = 0.004) and the sows from expanded sow area crates (S type) shown more time spent in SIT (average 38 min/day) in this posture compared to traditional one (average 29.89 min/day). This study provides valuable insights for farmers to make decisions about crate size.

Keywords: farrowing crate size, computer vision, YOLO, postures, pre-weaning, mortality.

A DAILY ADJUSTMENT OF FEED FOR GROWING-FINISHING PIGS CAN REDUCE ENVIRONMENTAL IMPACT

Yann Malini Ferreira[*1,2], Rayna Souza Vieira do Amaral[2], Blandina Gonçalves Valério Silva[2], Leila Cristina Salles Moura[2], Diana Assis de Oliveira[2], Tadeu Eder da Silva[4], Luciano Hauschild[5], Inês Andretta[6] Luan Sousa Santos[2,3]

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Developing pig production in Brazil has raised concerns regarding its environmental impact. Sustainable practices, particularly in waste management and feed production, are imperative to reduce the industry's ecological footprint. This study delves into the environmental ramifications of two feeding strategies in pig farming, focusing on three feed formulation scenarios: Brazilian tables (BT-2017), NRC (NRC-2012), and AGPIC (AGPIC-2021). The comparison encompasses conventional phase-feeding (CON) and daily fit (DFM) models. The CON model uses a 5-phase system providing the same diet to all pigs within a group during each proposed phase. In contrast, the DFM adjusted the diet based on the nutritional requirements of aging pigs, anticipating subsequent diets through daily adjustments using the DFM. The study aims to evaluate the impact of these proposed feeding scenarios' life cycle assessment (LCA). The functional unit is defined as one barrow with an initial weight of 20.61 ± 0.85 kg, reaching a final weight of 138.94 ± 0.90 kg over a 120-day growing-finishing period. The system includes inputs such as piglets, feeds, water, energy, transportation, and infrastructure components such as pig buildings, slurry pits, and water consumption. The only variable between the systems was the feeding strategy. Employing a cradle-to-gate approach, this study evaluates climate change, ecotoxicity, eutrophication, human toxicity, land use, resource use, and water use. The OpenLCA software was used with the Environmental Footprint (EF) 3.0 impact assessment method. This comprehensive analysis provides valuable insights into the environmental implications of different feeding strategies, offering guidance for more sustainable pig-farming practices. The results identified DFM as a promising approach to mitigate environmental burdens in pig farming. Feedstuff production primarily contributes to environmental impacts, encompassing climate change, land use, and eutrophication. Thus, mitigating the environmental impact of pig farming necessitates a keen focus on feed production. The DFM consistently outperforms the conventional phase feeding model, offering valuable insights into more sustainable pig-farming practices. Other feeding strategies, including the utilization of household waste and agro-industrial byproducts, reduction of crude protein, supplementation with synthetic amino acids, and precision feeding techniques, can also be applied to pig systems. These strategies offer promising avenues for reducing environmental impacts while addressing the challenges of animal production. In conclusion, the simulations reveal consistent ecological benefits associated with the DFM strategy. Differences were found among the proposed scenarios, primarily due to the modelling approach determining the nutrient requirements. Adjustments to feed formulation to reduce environmental impact can be made, especially with alternative ingredients to maize and soybean. Overall, the study provides valuable insights into the environmental implications of different feeding models and scenarios, offering guidance for developing more sustainable and eco-friendly practices in the pig production industry.

Keywords: environment; pig farming; sustainability; swine nutrition.

UTILIZING SOUND ANALYSIS TO AUTOMATICALLY IDENTIFY NOVEL VOCALIZATION TYPES IN BROILER CHICKENS

Patricia Soster de Carvalho[1,2] , Tomasz Grzywalski[3], Yuanbo Hou[3], Pieter Thomas[3], Annelike Dedeurwaerder[4], Maarten De Gussen[4], Frank Tuyttens[5,6], Paul Devos[3], Dick Botteldooren[3] and Gunther Antonissen[1]

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Exploring the sounds made by chickens using sound analysis is a means to gain insight into their behaviors and affective state. In this study, our aim was to capture all sounds produced by healthy broiler chickens aged 1 to 36 days and through cluster analysis determine potential new types of vocalizations apart from the commonly described ones. Initially, a systematic review was performed to identify vocalizations of broiler chickens and hens described in literature, totalizing 17 vocalizations, with the majority being related to hens. Ten one-day-old male Ross 308 slow-feathering chicks were co-housed in a 2m² pen, isolated from both other broilers and external environmental factors. Positioned at a height of 90 cm in the pen's center, a microphone recorded the chicks' sounds. Four well described vocalizations in broilers from the literature (distress calls, short peeps, warble notes, and pleasure notes) were manually labeled to develop and validate a an automated vocalization detector based on a fully-convolutional neural network, which achieved a balanced accuracy of 87.9% with limited confusion. To determine existing vocalizations, the algorithm was employed in a 24/7 recording vocalizations during the lifespan of broiler chickens. Any vocalization other than one of the four selected vocalizations was categorized as "other" (O). O showed a notable increase over the final three weeks, indicating that as broiler chickens mature, they develop a broader range of vocalizations. The clustering was performed using a recursive invocation of the UMAP (to reduce dimensionality of the data) and HDBSCAN (to provide the predicted cluster labels) algorithms. A total of 38 clusters were identified by O sounds. An auditive evaluation and visual inspection of the linear-frequency spectrogram were performed for each cluster by a trained individual. Eighteen clusters were excluded from the analysis due to their lack of relevance to chicken vocalizations, primarily containing human voices and equipment noise. Six clusters were excluded, since two were identified and characterized as warble notes and four as pleasure notes. Consequently, 14 clusters were retained for further examination. To avoid that the same type of vocalizations were in different clusters, the final clusters

were determined through analysis based on the shortest Euclidean distance between them. Visual and auditory similarities were considered, with clusters being merged if the distance fell within the range of 2.592 to 3.722. This process resulted in the consolidation of four sounds into a single cluster, with an additional two sounds being merged, resulting in the formation of 10 final clusters potentially representing new vocalizations. The study offers new insights into health broiler chicken vocalizations. The next step of our research will be to identify vocalizations related to unhealthy chickens raised in challenging environments and focus on interpreting the meaning of these sounds.

COMPARING TRANSFORMER AND BIOMETRIC FEATURE EXTRACTION FOR THE PREDICTION OF GROWTH AND REPRODUCTIVE PHENOTYPES IN HOLSTEIN HEIFERS

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The cost to raise heifers accounts for approximately 20% of annual costs on dairy farms. Strategies to reduce age at breeding and first calving may increase profitability, but heifer growth and reproductive performance is difficult to monitor and can be influenced by factors such as nutrition, genetics, environment, and illness. However, computer vision systems offer a non-invasive method for extracting body biometrics that can provide insight into individual animal physiology. This study aimed to predict the age of puberty, age of pregnancy, and body weight (BW) of dairy heifers using biometric features and transformer features from images collected during the preweaning phase. Top-down view depth images of 120 Holstein calves (1 to 6 wk of age) were collected on six consecutive weeks (50 images per week) resulting in 300 images per calf. The images were segmented to isolate calf's body, and the masks were applied to each depth image. Body biometrics (BIO) or features without biological interpretation from Masked Autoencoders (AE) were extracted from the depth images. Random Forest algorithms were trained to predict age of puberty, age of pregnancy, and BW from BIO and AE. The open-source package Scikit-image and frameworks Tensorflow and Keras were used to perform all analyses in Python. Performance metrics were moderate to poor for all models, with models trained from AE outperforming BIO. It is important to highlight that the images were obtained between weeks 1 and 6 of age. Other analytical approaches and additional data from subsequent periods of the preweaning phase may enhance the prediction quality.

USING RADIO FREQUENCY EQUIPPED NESTBOXES TO DETERMINE EGG LAYING BEHAVIOUR: QUALITATIVE STORIES FROM INDIVIDUAL HENS

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A radio frequency equipped nestbox designed at the University of Alberta tracks the times of entry, exit and oviposition, nest location, bird identity, and egg weight. The objective of this study was to synthesize big data from the nestboxes and gain insights into egg laying behaviour of individual hens. Lohmann Brown-Lite hens (n=184) used were part of a larger study consisting of a 2 × 4 factorial arrangement of treatments with 2 levels of feed restriction: non-restricted and restricted; and 3 levels of dietary ME during the rearing phase: Low (2,600 kcal/kg), Standard (2,800 kcal/kg), or High (3,000 kcal/kg). The fourth treatment (Choice) enabled birds to choose from the three diets. Restricted birds were fed to follow the lower bound of the breeder-recommended target BW trajectory. All birds were raised in floor pens from 0 to 50 weeks of age. Each bird was equipped with a radio frequency identification tag and fed with multi-feeder precision feeding stations that allocated feed individually according to treatment. Thus, each bird was an experimental unit. All birds were photostimulated at 18 weeks of age. In addition to the nestbox data previously mentioned, hens were palpated daily to verify daily egg laying records. From the raw data, duration of time spent in the nest, time of lay, egg weight distribution, laying sequences, and clutch length were calculated to 50 weeks of age. The data revealed a variety of egg laying behaviours, including the patterns of sequential laying previously described by Fraps (1955), such as patterns of consistent oviposition times prior to, close to, and several hours after the lights in the barn turn on. Some birds displayed inconsistent oviposition patterns. The results also indicate the duration of time spent in the nestbox and its relation to egg weight over time. In spite of experimental challenges such as floor eggs and eggs that did not descend onto the nestbox egg weight scale at the time of oviposition, daily cloacal palpation enabled estimation of oviposition where automated data collection was missed. Future avenues of investigation include egg weight modelling to predict egg weights for individual hens, machine learning, and coordination between nestboxes and precision feeding stations that can track body weight and feed intake data of each individual bird.

Keywords: nesting behaviour, precision farming, sequential laying, oviposition.

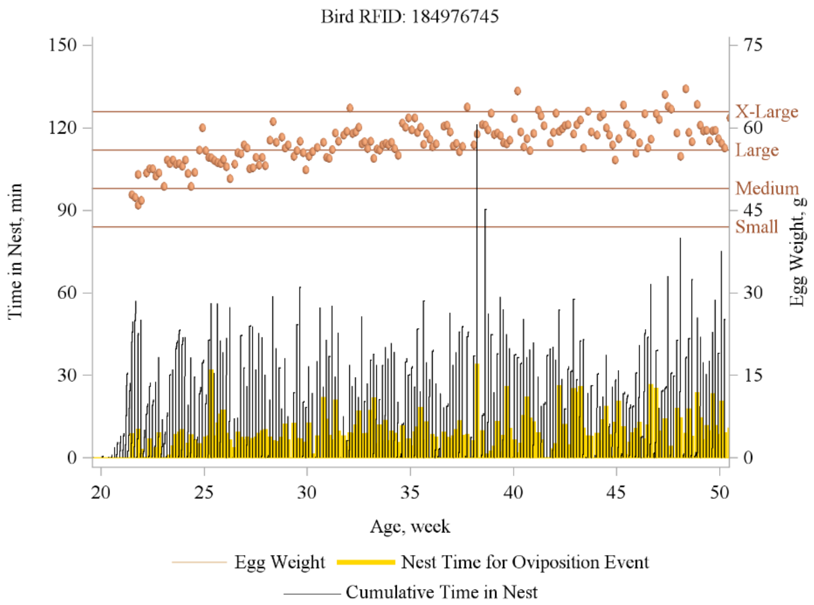

Figure 1. Time spent in the nest and egg weight of bird with radio frequency identification number 184976745 from 20 to 50 weeks of age. The gold bars represent the duration of time spent in the nest when oviposition occurred. The black lines represent the cumulative time spent in the nest. The egg symbol indicates egg weight on the secondary Y-axis. Three reference lines on the secondary Y-axis indicate egg weight distribution according to North American table-egg industry standards.

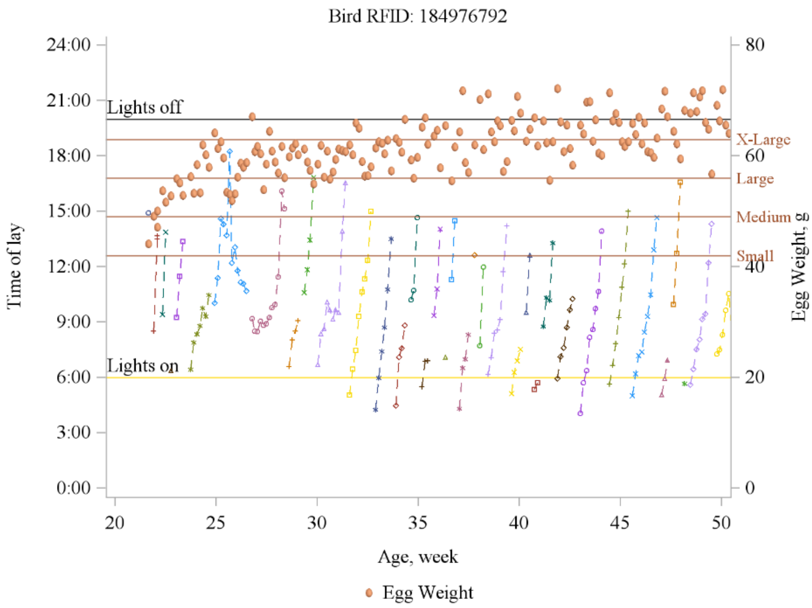

Figure 2. Demonstration of sequential laying by bird with radio frequency identification number 184976792 from 20 to 50 weeks of age. Each line pattern and symbol represents a laying sequence. Two reference lines on the primary Y-axis indicate the time lights turn on and off in the barn. The egg symbol indicates egg weight on the secondary Y-axis. Two reference lines on the primary Y-axis indicate times when lights in the barn turn on and off. Three reference lines on the secondary Y-axis indicate egg weight distribution according to North American table-egg industry standards.

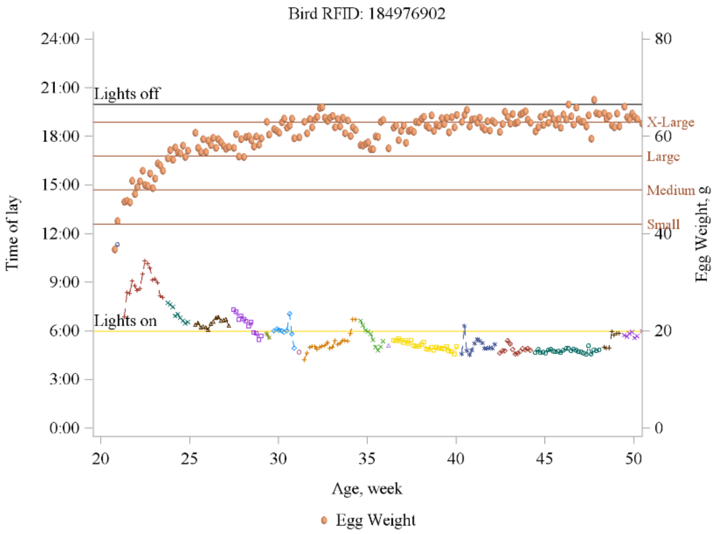

Figure 3. Demonstration of consistent oviposition times by bird with radio frequency identification number 184976902 from 20 to 50 weeks of age. Each unique combination of line pattern and symbol color represents a laying sequence. Two reference lines on the primary Y-axis indicate the time lights turned on and off in the barn. The egg symbol indicates egg weight on the secondary Y-axis. Two reference lines on the primary Y-axis indicate times when lights in the barn turn on and off. Three reference lines on the secondary Y-axis indicate egg weight distribution according to North American table-egg industry standards.

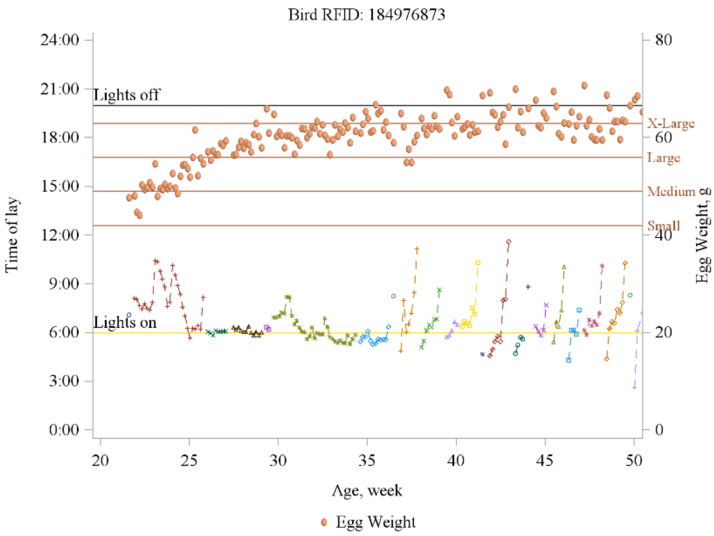

Figure 4. Demonstration of a mixture of consistent oviposition times followed by sequential laying by bird with radio frequency identification number 184976873 from 20 to 50 weeks of age. Each unique combination of line pattern and symbol color represents a laying sequence. Two reference lines on the primary Y-axis indicate the time lights turned on and off in the barn. The egg symbol indicates egg weight on the secondary Y-axis. Two reference lines on the primary Y-axis indicate times when lights in the barn turn on and off. Three reference lines on the secondary Y-axis indicate egg weight distribution according to North American table-egg industry standards.

HOW TO IMPROVE BOAR SEMEN PRODUCTION THROUGH A LOGISTIC REGRESSION MODEL

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Artificial insemination is one of the technologies that optimizes the use of males, as it allows using just one animal to fertilize many sows, maximizing the use of superior genetics, and increasing the number of piglets born with wished characteristics. However, there are some controversial aspects in this issue, because males with highest genetic index are young, and young males provide less sperm production than mature males. The objective of this study was to analyze the distribution of the main variables: volume (ml), concentration (10^9 spz / ml) and abnormal shapes (%); conditioned by markers: service interval (days), boar age (days) and genetic index. Thousand ejaculates from one hundred males were used. For each main variable, a family of range partitions into two intervals was taken (i.e. if a variable takes values in the interval [a,b], a partition in two intervals is to take intervals [a,c] and [c,d]). A logistic regression model was trained for each couple of intervals, using the markers as inputs and as outputs the intervals. Finally, the group and the model which maximized the confidence were chosen. Using this method there were no direct effects between the markers and the abnormal shapes. However, the markers could be used to predict when the ejaculated volume will be over 200 ml with a 60% of confidence, and when the concentration will be over 2.19 * 10^9 spz / ml with a 55% of confidence. Simulations using the method of Monte Carlo showed a maximum increasement of 15 ml (Figure 1) and 2 * 10^9 spz / ml in average (Figure 2). For abnormal shapes the model does not present the same effect, and the chosen explanatory variables (age, genetic index and collection interval) appear to be highly independent of pathology. The preliminary results of this study lead to the conclusion that the use of this model as a decision rule could be a good starting point to increase the semen production in genetic centers. In addition, using more sophisticated models could improve the confidence ratio, leading to a higher productivity.

Keywords: spermatozoa; artificial insemination; dose.

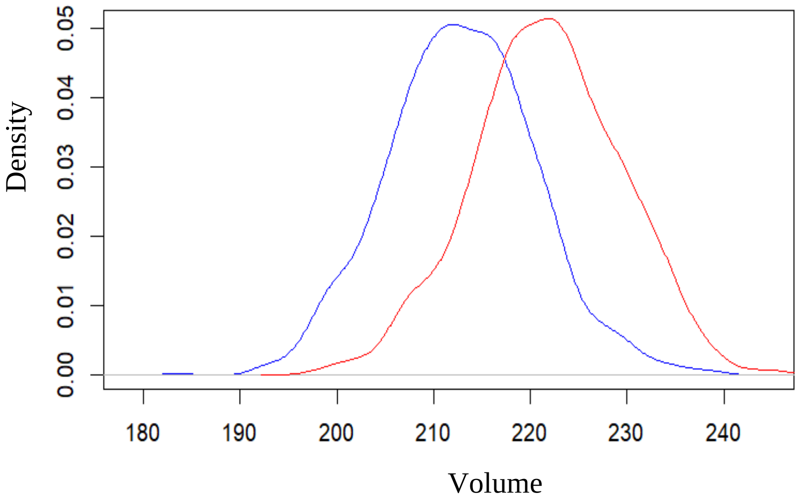

Figure 1. Distribution of the volume (mL) between predicted groups (red line = high production; blue line = less production).

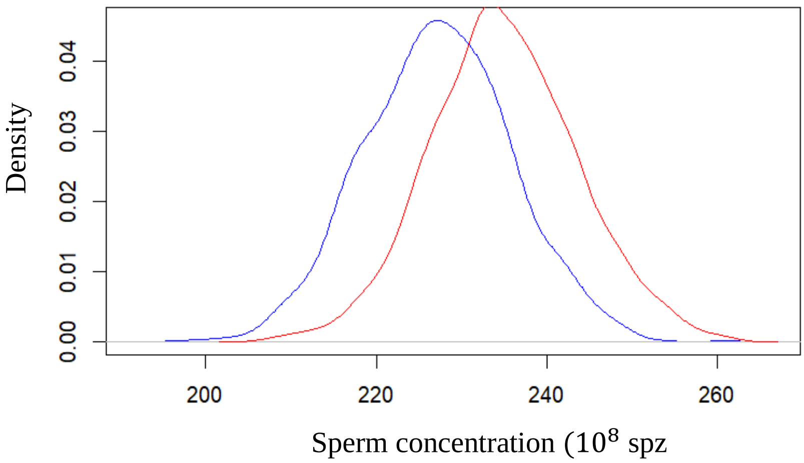

Figure 2. Distribution of the sperm concentration (108spt/mL) between predicted groups (red line = high production; blue line = less production).

BEHAVIORAL RED FLAGS FOR OPTIMIZING CASTRATION-INDUCED PAIN DIAGNOSIS IN CATTLE

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Cattle raising commonly involves carrying out painful procedures. Therefore, refining acute pain diagnosis is a common concern for improving cattle welfare and productivity performance. The Unesp-Botucatu Unidimensional Composite Pain Scale for assessing postoperative pain in cattle (UCAPS) comprises 5 items (Locomotion, Interactive behavior, Activity, Appetite and Miscellaneous) that should be scored from 0 to 2 according to sub-items. In total, there are 22 sub-items regarding normal and pain-related behaviors, which should be evaluated during a 3-min period. Although the UCAPS is a scale widely used in experimental settings, the high number of UCAPS behaviors may represent a barrier to its implementation in the farm's and or hospital's routine. In this study, we aimed to find if there is a combination of fewer UCAPS sub-items that could predict the final diagnosis of the full scale and therefore be applied in large-scale systems. Data from two previous studies regarding UCAPS assessments before (pain free) and after (painful) castration surgery was used, divided into train (70% of data) and test (30%) sets. Using the train set, we fitted a decision tree and obtained a logic using two sub-items. Then, using this logic, we created a new diagnosis following only the two behaviors. Area under the receiver operating characteristic curve (AUC) was estimated in the test set and employed to determine the predictive capacity of the new diagnosis. The logic obtained by the decision tree considered the diagnosis painful when the Activity item was scored 2. When Activity received a score other than 2, but Locomotion item was 0 or 2, the diagnosis was considered painful. In other scenarios, the diagnosis was pain free. The new diagnosis had an AUC of 95.95% for predicting UCAPS diagnosis and 93.09% for predicting overall pain free and painful conditions. Previous studies have already reported Activity 2, Locomotion 0 and Locomotion 2 in ranking analysis using logistic regression to have high importance in UCAPS. Therefore, we considered that the behaviors contained

in the decision tree logic can work as behavioral red flags for diagnosing pain in cattle, working as a pre-assessment. In this context, red flags could be assessed in real-time and, if positive, the animal should be evaluated with the full UPAPS. Altogether, our results may provide advances towards optimizing pain diagnosis in large-scale systems.

PREDICTION OF STRUCTURAL CHARACTERISTICS AND NUTRITIVE VALUE OF *Urochloa decumbens* USING UNMANNED AERIAL VEHICLE IMAGERY

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The estimation of forage mass, height, and nutritional value in pastures is extremely important for efficient production system management. However, this estimation is often costly and time-consuming, demanding significant labor. In this context, remote sensing offers a promising solution for monitoring spatiotemporal variability in pastures, providing timely information on many biophysical parameters. This study aimed to develop algorithms to predict structural characteristics and nutritional value of *Urochloa decumbens*, using multispectral drone images associated with *machine learning*. The experiment was conducted in the Department of Animal Science at the Federal University of Viçosa, between 2019 and 2020, in Viçosa-MG. To induce structural and chemical variations in the grass, different nitrogen doses were applied to the plots (0, 50, 100, 150, and 200 kg ha^{-1} of urea). The experimental design followed a randomized block scheme with five replications, totaling twenty-five plots of 12m² each. Images of the experimental area were captured by a Remotely Piloted Aircraft equipped with a MicaSense RedEdge sensor, totaling seven flights. Before each flight, canopy height measurements were taken in each plot. At the end, samples were collected to quantify green and dry forage masses, dry matter concentration, and crude protein of the grass. Samples were collected every twenty-one days, immediately after the flight. Image preprocessing was performed using Agisoft Metashape Professional software. Image processing began in QGIS, where the five spectral bands, Red, Green, Blue, NIR, and RedEdge, were extracted to calculate vegetation indices. Prediction models were then developed using the Random Forest Regressor algorithm in Spyder software (Python). Spectral bands, vegetation indices, and meteorological data were used as input. In the final modeling phase, adapted nested cross-validation was applied, where each flight was used as test data and the others as training data. Model performance was evaluated using the coefficient of determination (R^2) and root mean square error (RMSE). The results indicated satisfactory predictions for dry forage mass (R^2 0.70, RMSE 673.36) and green forage mass (R^2 0.62, RMSE 4312.67). However, predictions for canopy height, dry matter concentration, and crude protein showed poor performance. Therefore, our results demonstrated a good ability to predict pasture biomass, serving as a valuable tool to assist in grazing management.

Keywords: remote sensing, pastures, biomass, m*achine learning*, multispectral images

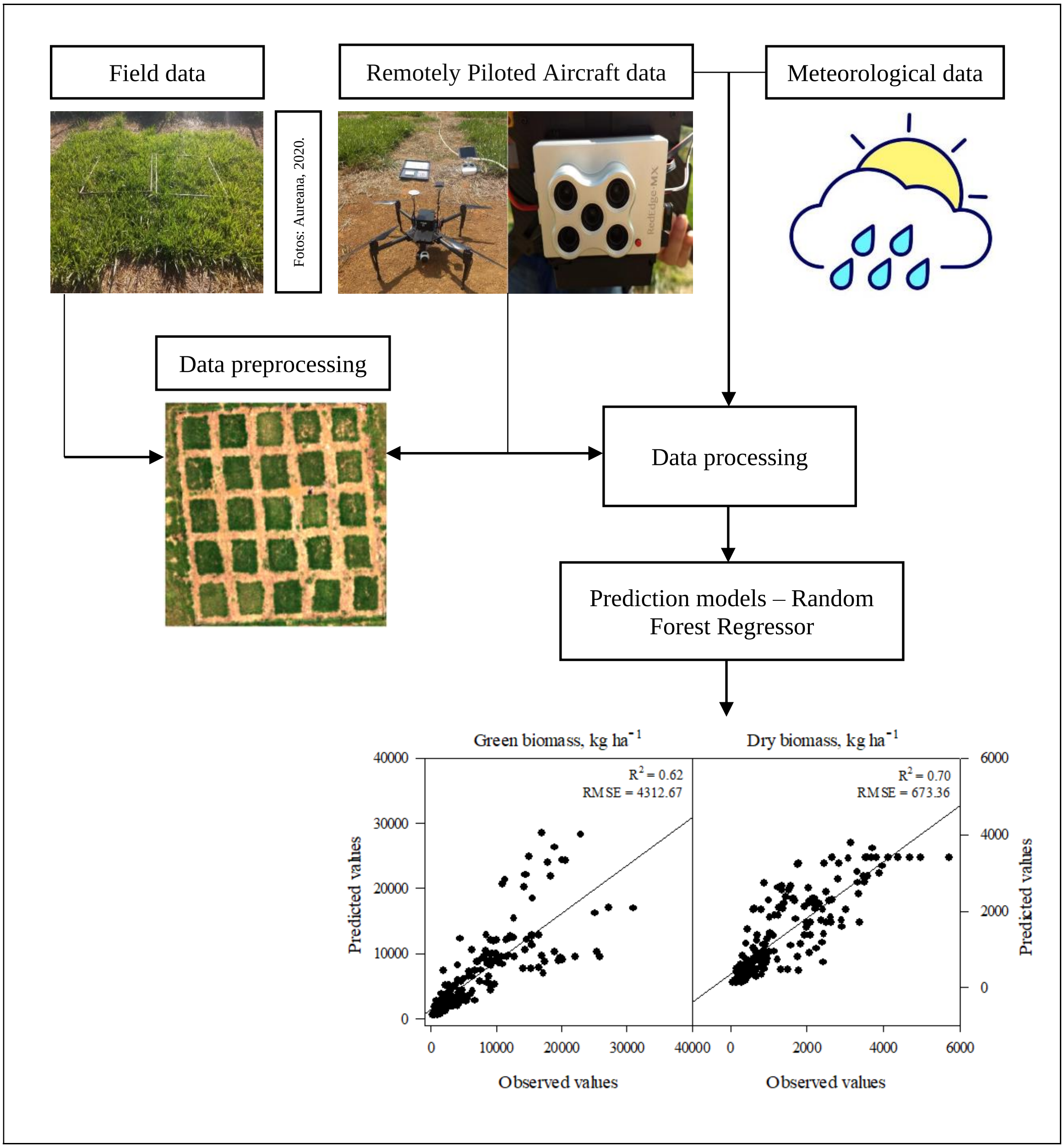

Figure 5. Graphical abstract.

ACOUSTIC BEHAVIOR OF MARINE SHRIMP *Penaeus vannamei* DURING FEEDING ACTIVITY

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The mandibles of the penaeid shrimp *Penaeus vannamei* emit click-like sounds during feeding. Therefore, passive acoustic monitoring (PAM) has been applied to study their feeding behavior. Feeding frequency is one of the most important aspects of feed management in shrimp farming, as it directly influences zootechnical performance and the sustainability of the production system. However, there is no consensus on the ideal number of daily feedings or its potential effects on shrimp behavior. In this study, we evaluated the acoustic behavior of *P. vannamei* under different feeding frequencies. Shrimp with an average weight of 3.31 g were transferred to 12 rectangular tanks at a density of 42 shrimp/m² (six animals per tank). The feeding frequencies tested were once, twice, four times, and eight times a day. All treatments received the same total amount of feed (2 g), divided according to the feeding frequency. Hydrophones connected to a digital recorder were used to capture feeding activity over an 8-hour period. At the end of the recordings, uneaten feed was siphoned out to calculate feed consumption. The recordings were analyzed using Raven®Pro 1.5 software, with a band-limited energy detector automatically selecting the clicks present in the recordings. Recently, Python has proven to be a viable tool for analyzing acoustic data, offering potential as an alternative or complementary method for this type of evaluation. Therefore, in a parallel study, a Python-based method was compared with a reference detector in Raven®Pro, examining various shrimp sizes and stocking densities. When applying PAM to monitor different feeding frequencies, it was observed that the shrimp groups fed more frequently per day exhibited higher total click numbers and increased feed consumption after 8 hours (Figure 1). All treatments showed a peak in acoustic activity during the first feeding of the day. However, in subsequent hours, treatments that received additional feedings displayed new peaks in feeding activity, which were absent in shrimp fed once a day (Figure 2). Additionally, a positive linear correlation was found between the total number of clicks and feed consumption ($p < 0.001$; $r = 0.87$) over the 8-hour period. These results suggest that increasing the feeding frequency up to eight times a day can benefit shrimp rearing by enhancing feeding activity and feed consumption. The comparison between the Python-based method and Raven®Pro for automatic click detection demonstrated substantial agreement between the two methods, particularly for shrimp weighing more than 1 gram across different density groups (Figure 3). This study underscores the efficiency of PAM as a non-invasive method for studying the feeding behavior of *P. vannamei*, as well as the potential of Python as an alternative detector, facilitating computational applications in resource-limited settings typical of aquaculture farms.

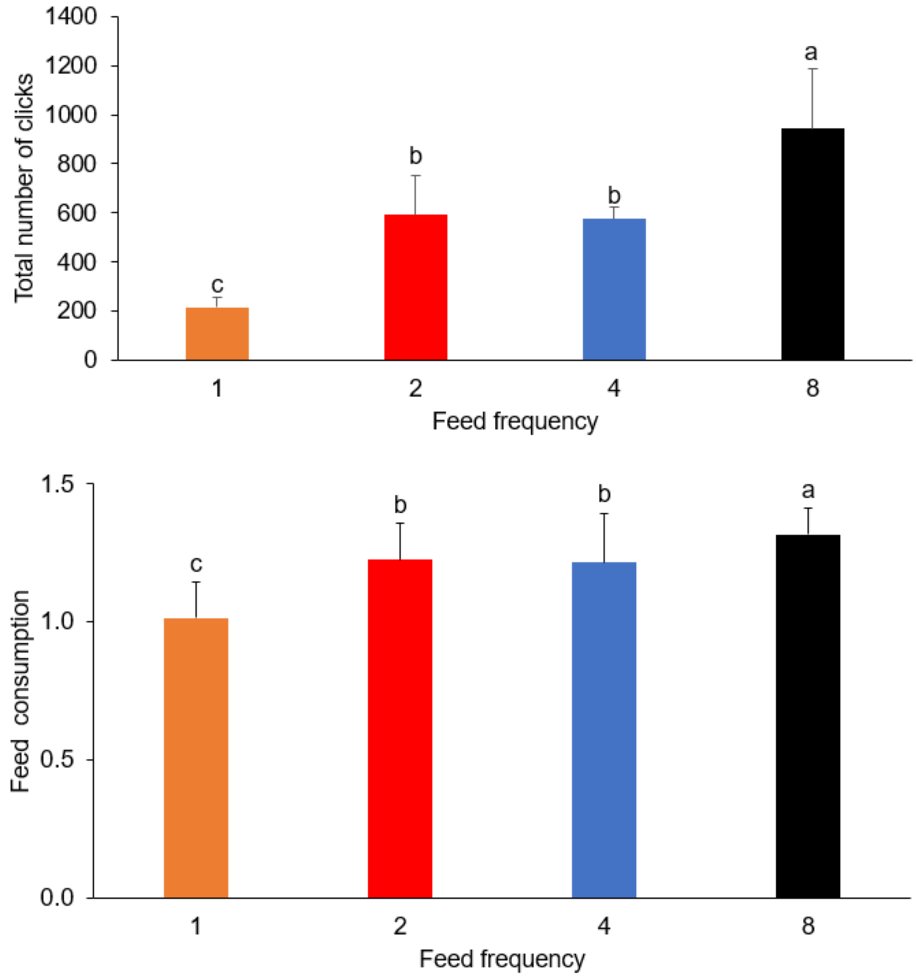

Figure 1. Mean values of the total number of clicks and feed consumption during the monitoring of the feeding activity of *Penaues vannamei* at different feeding frequencies one, two, four and eight times a day during 8h. Different lowercase letters above the bars indicate significant differences ($p < 0.05$) between feeding frequencies.

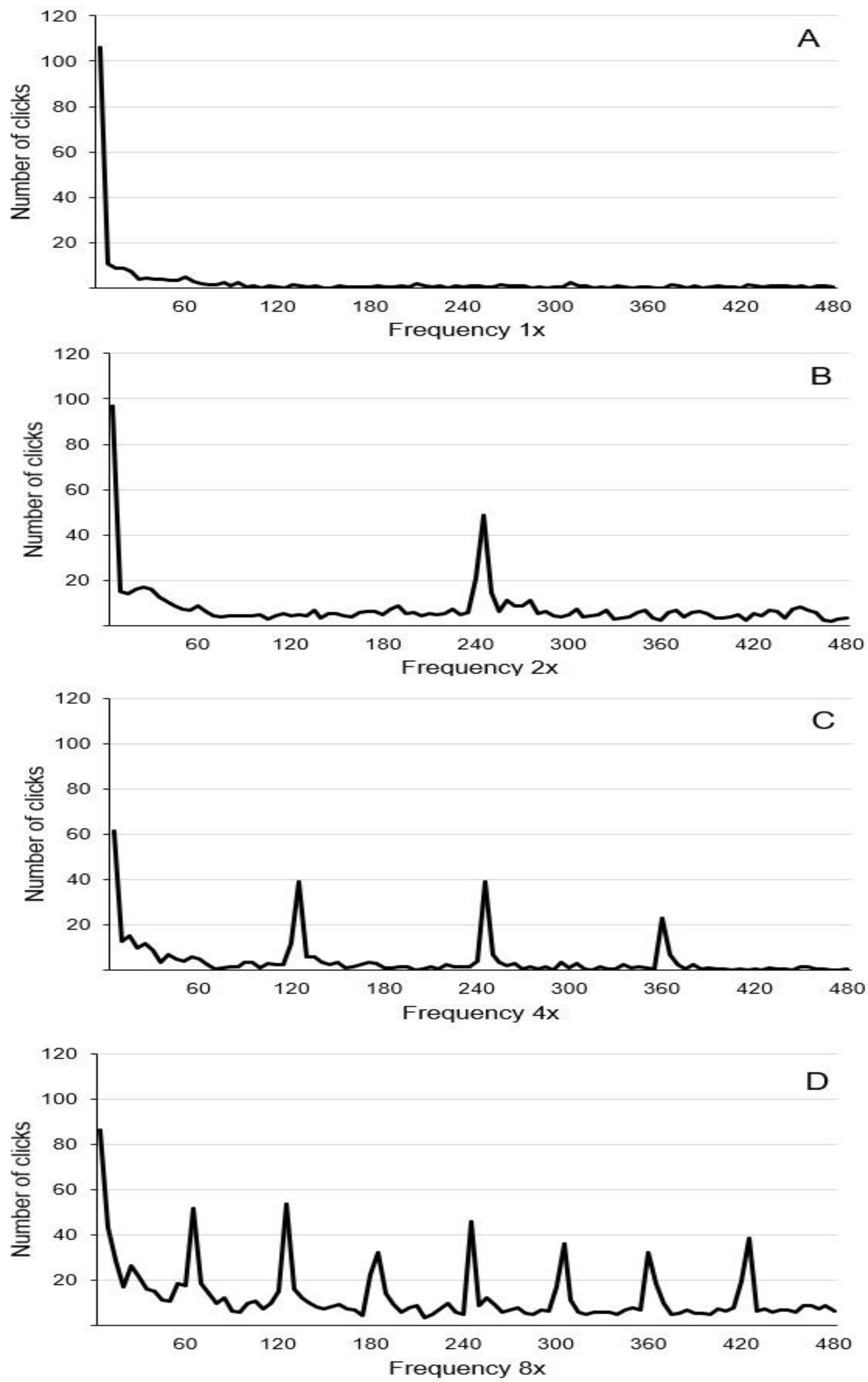

Figure 2. Number of clicks emitted every 5 minutes by *Penaeus vannamei* at different feeding frequencies of one (A), two (B), four (C) and eight times a day (D).

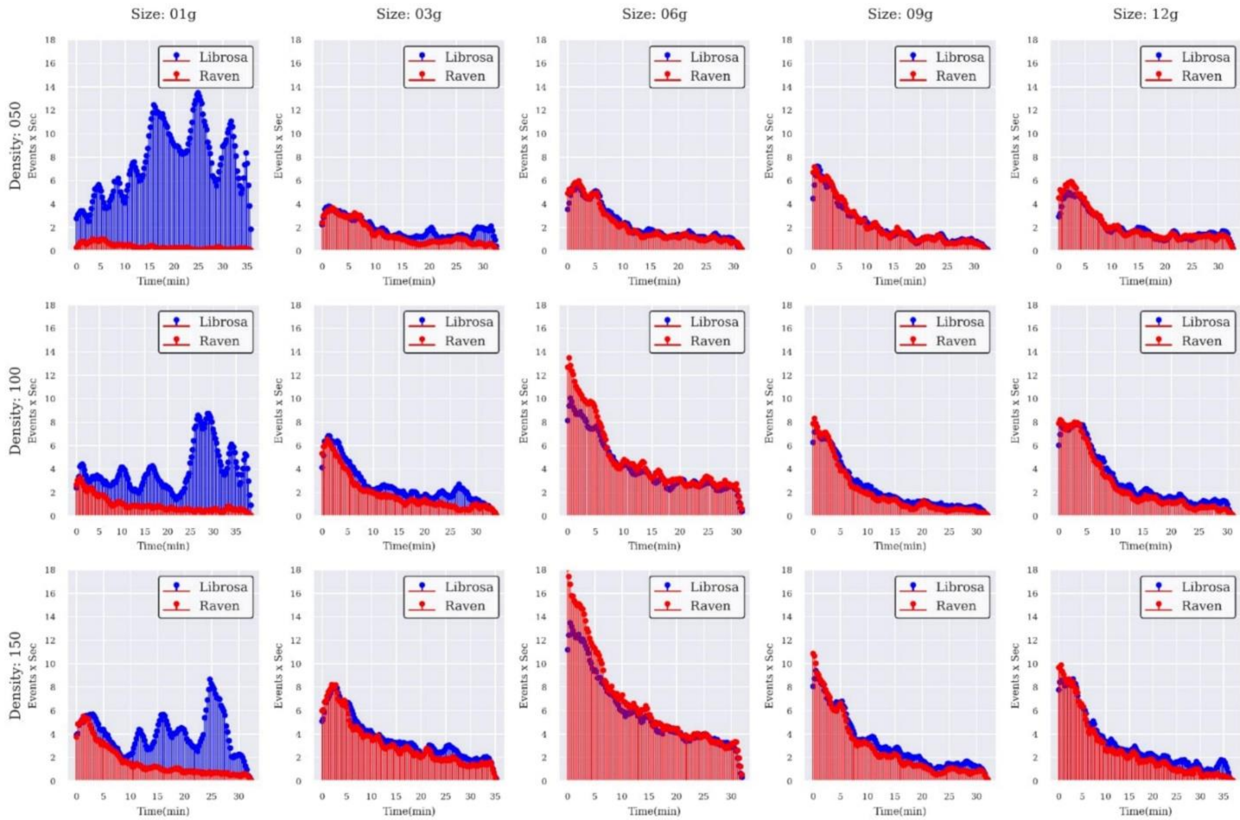

Figure 3. A comparison of click detection during feeding activity for *Penaeus vannamei* using the Librosa and RavenPro® methods, analyzed across various size groups (1, 3, 6, 9, and 12 g) and stocking densities (50, 100, and 150 shrimp per m²).

A PRECISION FEEDING SYSTEM TO ASSESS FEEDING EFFICIENCY ON AUTOMATIC MILKING SYSTEMS

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Computing advancements and the widespread adoption of new technologies by the dairy industry enable development and application of tools that translate complex biological systems into field practices. Individual animal (IA) responses are influenced by multiple factors, but the variability among and within animals remains poorly understood, due to interactions with diverse inputs and animal genetics. The IA challenge is partly attributed to insufficient technological integration within dairy operations resulting in a failure to identify inter-sector relationships and constrained decision-making. This study aimed to describe the ongoing development of a performance diagnostic and feeding control system for IA data as a dairy farm management supplement. Coupling the 2 elements allows IA nutrient titration to discover IA economic optimums. Assuming the pen is fed to population-mean requirements, feeding to IA optimums will result in transfer of excess nutrients from cows being overfed to those being underfed resulting in greater performance, and it may result in reduced feeding costs. It also allows ranking of IA by nutrient efficiencies which can be considered in culling decisions. The system integrates real-time discrete and continuous farm data with existing mathematical models (MM), machine learning (ML) algorithms, and advanced optimization techniques. It extracts, stores, parses, and analyzes data and information; and returns management information and feeding programs to dairy managers, and feeding instructions to the automatic feeding system. Its web-based framework includes bidirectional data streams with existing data architectures allowing manual or automated control making use of feedback loops (Figure 1). The existing architecture is designed and maintained by automatic milking systems (AMS) and implemented on-farm containing *in-loci* and cloud-based data storage. The built architecture, created by our development team, consists of a front-end website for data entry and report visualization and a back end centralized in sequential query language database dynamically populated via website entry, the local weather station application programming interface, and the cloud-based AMS data system. Collected data are analyzed using a collection of processes aggregated into 4 modules: Performance Prediction, Anomaly Detection, Diet Optimization, and

Nutrient Titration. The modules were developed, tested, and enhanced independently. Initial testing was conducted off-line using on-farm data to run simulations. Subsequent on-line testing involved using real-time farm data to evaluate animal responses and compare across predicted performance metrics. The prediction performance module predicts individual dry matter intake (DMI) utilizing traditional MM supplemented with chewing activity and informed by a single 3d assessment of IA DMI. The anomaly detection module works as an automated performance and health problem detection system. Health elements are currently restricted to mastitis detection. The diet optimization module is based on a compact-vectorized version of the NASEM 2021 model used to predict milk component production, body weight change, and nutrient excretion. The objective function is: income over feed costs (IOFC) = milk value – feed cost – nutrient excretion cost. Diets are solved for each cow, and the solutions aggregated to yield pen assignments and forage feeding by pen using constrained clustering, and grain mixes to be fed in each pen and at the robots to each cow using constrained optimization to minimize differences between the individual solutions and the aggregated solutions. The nutrient titration module manipulates grain feeding at the AMS to conduct nutrient titration curves for IA. The resulting relationships are used to tailor feeding solutions to each animal and to set optimal nutrient targets for group feeding. The initial farm application trial utilizing metabolized protein titrations indicated US$0.90/cow/d greater IOFC than the previously used diets (Table 1). The system demonstrates the ability and flexibility to expand on existing modules and accommodate additional modules. Future work will include on-site complete system integration, automation, testing, and evaluation.

Keywords: precision dairy farming, automatic feeders, optimization.

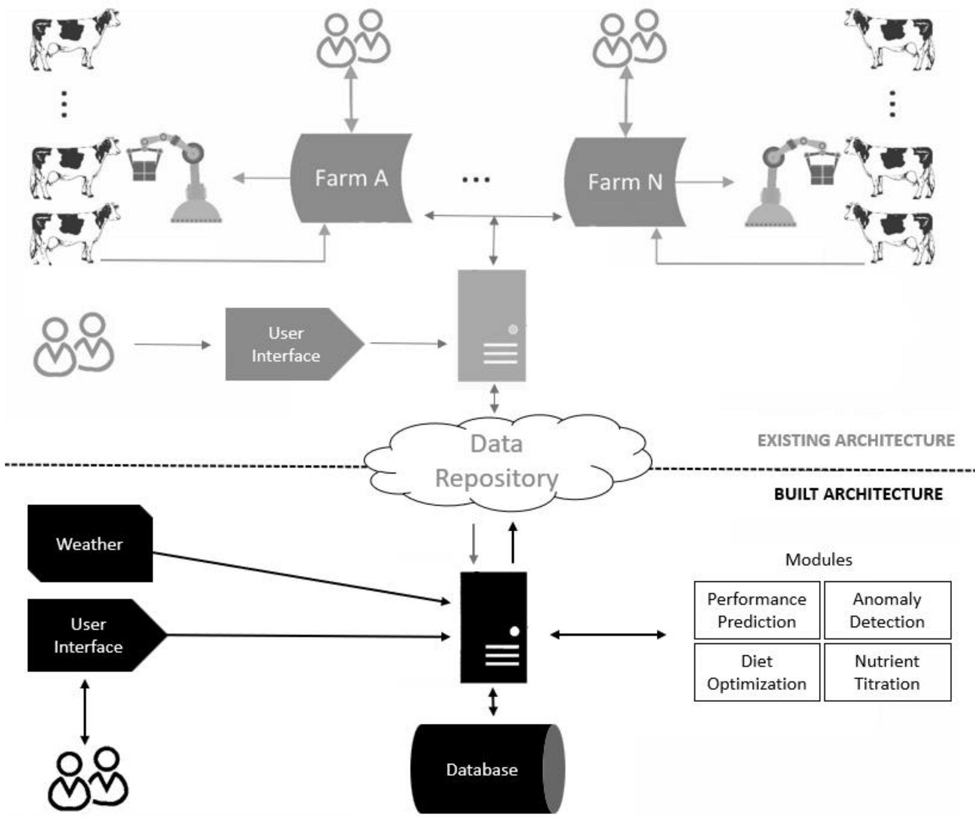

Figure 6. Overall system framework for the bidirectional data stream.

The downstream data processing pipeline (*gray scheme*) relies on automated exchanges of farm data between the local database and data repositories (DR). The AMS data repository is connected to a cloud-based data repository, both located at the EA and independently accessed by the user. The centralized DR serves as the main storage hub and central node for bidirectional data flow between EA and BA. Access to the DR is facilitated by a pre-configured application programming interface (API) token, which allows for automated data retrieval via structured query language (SQL) calls. Extracted herd data are stored in the AMS data repository and are used by BA components. The data is additionally transferred to the Virginia Tech data repository which undergoes continuous updates from inputs gathered via website data by user (feeding, health, management) and the National Oceanic and Atmospheric Administration (NOAA) DR. The collected data are subjected to data analytics in BA. The upstream data pipeline (*black scheme*) initiates by pushing the output generated by the BA data analytic modules back to the centralized DR, subsequently reaching the local farm software. Data transmission includes individualized feeding instructions tailored to each animal. The automated feeders execute these instructions, serving as part of a feedback loop for the feeding system and facilitating self-learning.

Table 1. Preliminary animal performance and economic outcomes of lactating dairy cows fed optimized diets submitted to nutrient titration screening.

Item	Baseline MP[1]			MP Level[2], g/d				
	Farm	Predicted	Observed	2396	2524	2653	2781	2909
Milk Production, kg/day	44.8	44.6	46.3	43.2	43.9	44.8	45	44.6
Milk Fat, %	4.06	3.62	3.83	3.84	3.79	3.79	3.79	3.79
Milk Protein, %	3.1	3.06	3.14	3.09	3.09	3.1	3.1	3.12
Milk Income, US$/cow/day[3]	14.3	14.3	14.8	13.8	14.1	14.3	14.4	14.3
Diet Cost, US$/cow/day	11.5	11.7	11.1	10.3	10.6	10.9	11.3	11.6
IOFC, US$/cow/day[4]	2.8	2.6	3.7	3.5	3.5	3.4	3.1	2.7

[1] MP= metabolizable protein baseline level (2696 g/d); Farm = average production a day before trial started; Predicted = optimizer predictions; Observed = average production on the last day of the baseline block;

[2] MP Level = 5-point dose response metabolizable protein levels.

[3] Calculated by the multiplication of milk production (kg/day) and milk price (US$ 0.32/kg).

[4] Calculated by the subtraction of milk income and (US$/cow/day) and diet cost (US$/cow/day).

ANDROLOGICAL CLASSIFICATION OF BULLS EVALUATED BY MACHINE LEARNING

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The study aimed to verify the behavior of classifying Andrological Exams (AE) of bulls used in natural breeding through Machine Learning (ML). A database of AE of 2308 bulls was used, with the following attributes for each examination: region, breed, genotype, age class, testicular consistency, scrotal circumference, semen volume, sperm swirl, sperm motility, sperm vigor, acrosome defect, proximal cytoplasmic drop, head defect, midpiece defect, total major defects, distal cytoplasmic drop, normal isolated head, tail defects, total minor defects, total defects and total normal sperm. The classification of these animals for each test was made as fit (n = 1088), unfit (n = 672) and questionable (n = 548). This database was submitted to the ML tool Orange Data Mining, twelve algorithms were tested, Gradient Boosting (GB), Random Forest (RF), Neural Network (NN), Tree, AdaBoost, kNN, Logistic Regression, CN2 Rule Induction, Stochastic Gradient Descent, Naive Bayes, SVM and Constant, these the first tree presented better results. Where the GB had 83,7% of Precision, against 83,3% of the RF and 82,7% of the NN, the values for Classification Accuracy were 83.8%, 83.2%, and 82.7%, respectively. GB was able to identify results similar to AE for most bulls, especially for animals classified as fit 93.8% (1020/1088) and unfit 77.1% (518/672). For animals classified as doubtful, the results of the ML matched those of the AE in only 72.1% (395/548) of the bulls. Thus, 83.6% (1930/2308) of the bulls generally have the same results using ML or AE. In comparison, RF classified as fit 92.6% (1008/1088) and unfit 77.7% (522/672). For animals classified as doubtful, the results of the ML matched those of the AE in only 72.3% (396/548). Thus, 83.4% (1926/2308) of the bulls generally have the same results using ML or AE. Finally, NN classified as fit 89.7% (976/1088) and unfit 80.1% (538/672). For animals classified as questionable, the results of the ML matched those of the AE is also 72.1% (395/548), this time, in general, 82.7% (1909/2308) of the bulls have the same results using ML or AE. We concluded that ML can be used to assist andrologists in classifying the results of AE. Further studies could increase the accuracy and even determine which features best represent the classes in the final classification using ML.

Keywords: andrological exams, gradient boosting, natural breeding, neural network, orange data mining, random forest.

QUANTIFYING THE RELATIONSHIP BETWEEN CATTLE BEHAVIOUR AND DAILY ACTIVITY USING TRIAXIAL ACCELEROMETER DATA

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An animal's energy expenditure is partially dependent on its activity or movement levels and driven by the amount of time it spends engaging in different behaviours. In this study, we investigate the relationships between five core cattle behaviours and measures of total daily activity based on data from collar-mounted triaxial accelerometers. This accelerometer data, which represents the intensity of animal movement, was used to compute an activity metric quantifying the total motion within a window of time in units of gravitational force (g). We also used pre-trained accelerometer-based machine learning models to classify cattle behaviour into grazing, ruminating, walking, resting, drinking or other behaviour classes. Our objective was to investigate how different behaviours contribute to overall daily activity, a straightforward yet effective measure of movement, and explore its implications for animal energy expenditure. Sixty Brahman steers were studied for one month in an Australian pasture, with average daily activity values ranging from 5.44g to 23.69g. The average daily time spent grazing, ruminating, resting, walking, drinking and other was 8.97 (±1.12), 7.78 (±1.03), 5.83 (±1.05), 1.00 (±0.40), 0.18 (±0.12) and 0.24 (±0.11) hours, respectively (mean ± standard deviation). To investigate the associations between behaviours and activity, we employed a linear mixed-effects model incorporating the four behavioural components derived from principal component regression to address collinearity among behaviours. Our analysis revealed that grazing and walking are positively correlated with activity scores (r = 0.44 and 0.3, respectively), whereas ruminating and resting are negatively correlated with activity scores (r = -0.18 and -0.39, respectively). Furthermore, our linear mixed model accounted for 76.2% of the total variation in activity, highlighting significant individual variations among cattle. This study underscores the importance of understanding how different behaviours contribute to overall activity levels, which in turn affects energy expenditure in cattle. By leveraging automated monitoring sensor technology, we can accurately capture these variations, providing a robust data basis for future animal genetic evaluation programs.

Keywords: accelerometer; wearable sensors; daily activity; animal behaviour.

EXPLORING THE SOCIAL GENETIC EFFECTS IN SWINE PRODUCTION

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Automatic feeders allow the measurement of individual feeding behaviour in porcine. Social interactions within a group of growth pigs could influence feeding behaviour. This study aims to estimate the percentage of phenotypic variance explained by the social effect on feed consumption (FPV) and duration per visit (TPV). Data analysed had 843,605 visits from 1608 purebred Pietrain pigs and 775,054 visits from 856 Iberian pigs housed in groups of 12.7 ± 1.8 pigs with a 1.5 m² per pig density. The FPV and TPV were measured with automatic feeders (PPT, Nedap, Netherlands). Bayesian analyses were carried out to model each independent visit using a classical animal model $\mathrm{y} = \mathrm{Xb} + \mathrm{Z_d}\,\mathrm{a_d} + \mathrm{e}$, and a "social model" $\mathrm{y} = \mathrm{Xb} + \mathrm{Z_d}\,\mathrm{a_d} + \mathrm{Z_s}\,\mathrm{a_s} + \mathrm{e}$, which included in $\mathrm{Z_s}\,\mathrm{a_s}$ the social effect of the "follower" pig that visited the feeder immediately after the visit under analysis. The analyses were performed with the complete database, as well as for two extreme subgroups classified as competitive visits (intervals between visits < 60 seconds) and no competitive visits (>600 seconds). Social genetic effects were expected to be higher in the competitive visits. Fixed effects included the contemporary group, the hour of the day, and the age in days. The assumed distributions were $\begin{bmatrix} \mathbf{a_d} \\ \mathbf{a_s} \end{bmatrix} \mid \mathbf{G_0} \sim MVN\,(0, \mathbf{G_0} \otimes \mathbf{A})$, in which $\mathbf{G_0} = \begin{bmatrix} \sigma_a^2 & \sigma_{as} \\ \sigma_{as} & \sigma_s^2 \end{bmatrix}$, where σ_a^2, σ_s^2 and σ_{as} represent the additive genetic variance, social genetic variance and genetic covariance between additive and social effects, respectively. Models' effects and variance components were obtained from the posterior marginal distribution generated with Gibbs1f90 (Misztal et al., 2002). The estimated heritabilities (h^2) in the Pietrain population oscillated around 0.23 for TPV and 0.15 for FPV. The social genetic effect was not relevant in the Pietrain population, explaining less than 2% of the phenotypic variance. However, the Iberian population showed interesting results. Here, the h^2

was around 0.16 for TPV and 0.18 for FPV. The social genetic effects explained 5% in the total data base, 7% in the competitive visits and ~0% in the non-competitive visits. This approach successfully identified higher estimations of social effect in the competitive visits compared with no competitive visits. This study shows the potential benefits of incorporating social genetic effects into breeding programs, using a simple “visit-based” approach.

Keywords: pigs, automatic feeders, social genetic effect, feeding behaviour.

YOLOV9 FOR REAL-TIME BEHAVIOR RECOGNITION IN HOLSTEIN CATTLE: PERFORMANCE AND APPLICATIONS

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Precision livestock farming relies heavily on the accurate identification and monitoring of animal behaviors to improve welfare and management practices. Automated behavior recognition in cattle can significantly enhance decision-making processes at both herd and individual levels (Fuentes et al., 2020; Gao et al., 2023). This study explores the use of the YOLOv9c model (Wang et al., 2024) for identifying different behaviors in Holstein cattle, including Laying, Sleeping, Standing, Feeding, Drinking, Calving, and Heat mount. By integrating PGI (Programmable Gradient Information) and the GELAN (Generalized Efficient Layer Aggregation Network) architecture, YOLOv9 enhances the model's learning capacity and ensures the retention of crucial information throughout the detection process, possibly achieving exceptional accuracy and performance (Wang et al., 2024). The dataset comprised images of size 640x640, divided into 5502 for training and 712 for validation. Despite the limited number of images for behaviors such as Drinking, Heat, and Calving, the model demonstrated robust performance across all categories (Wang et al., 2023). Our methodology involved training the YOLOv9c model for up to 100 epochs, with early stopping implemented based on validation performance, resulting in training stopping at epoch 53 after 10 epochs without improvement. The model was evaluated using different splits of the dataset for training and validation, ensuring robust performance assessment. The training process was completed in 4.783 hours, using a validation set evaluated on a NVIDIA GeForce RTX 3060 GPU. The YOLOv9c model achieved high accuracy with 0.951 precision, 0.934 recall, 0.976 mAP50, and 0.860 mAP50-95 across all classes. Specific metrics for individual behaviors were as follows (Table 1). These results indicate that the YOLOv9c model can reliably identify various cattle behaviors, even with limited data for certain behaviors. The model's high inference speed (0.4ms preprocess, 23.1ms inference, 0.0ms loss, 0.9ms postprocess per image) makes it suitable for real-time applications such as DVR (Digital Video Recorder) systems. The ability to accurately monitor and assess cattle behavior at both the herd and individual levels can significantly aid in decision-making processes in precision farming, improving animal welfare and farm management (Fuentes et al., 2020). Future work will focus on expanding the dataset, further optimizing the model, and refining preprocessing and postprocessing techniques to enhance real-time performance and robustness.

Keywords: YOLOv9, behavior recognition, holstein cattle, precision farming, real-time monitoring.

Table 1: Trained yolov9 model performance metrics to detect different behaviour classes on Holstein Cattle.

Behaviour	Precision	Recall	mAP 50	mAP 50-95
Calving	1.000	0.924	0.995	0.898
Drinking	0.948	0.883	0.940	0.795
Feeding	0.966	0.883	0.949	0.795
Heat	0.876	1.000	0.995	0.995
Laying	0.962	0.943	0.975	0.840
Sleeping	0.949	0.902	0.967	0.828
Standing	0.956	0.934	0.977	0.825

Behaviour = object identification class; Precision = Precision values at threshold given by max F1 metric for each class; Recall = Recall values at threshold given by max F1 metric for each class; mAP 50 = Average accuracy calculated with an intersection-over-union (IoU) threshold of 0.50; mAP 50-95 = A média da precisão média calculada em diferentes limiares de IoU, variando de 0,50 a 0,95.

ENHANCED OPEN-SET RECOGNITION OF HOLSTEIN-FRIESIAN CATTLE USING CUSTOM TRIPLET GENERATORS AND DEEP METRIC LEARNING

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Systems based on machine learning and computer vision have the potential to revolutionize cattle monitoring, particularly for Holstein-Friesian dairy cattle. This study presents a novel approach to the open-set recognition of individual cattle using the OpenCows2020 dataset (Andrew et al., 2021), aiming to develop a deep metric learning model capable of accurate identification, even for cattle unseen during training (Wang et al., 2024). We employed a Triple network with a custom triplet data generator to create anchor, positive, and negative pairs (Schroff et al., 2015), optimizing embeddings through a combination of triplet loss and classification loss. Our triplet generator dynamically selects the most informative triplets, enhancing the learning process by focusing on hard examples. The model was trained using TensorFlow, leveraging the *tf.data.Dataset* API (Application Programming Interface) for efficient data handling and batch processing (Bisong and Bisong, 2019). To ensure robust performance, a callback mechanism monitored precision, recall, F1 score, and accuracy at each epoch. The optimal threshold for distinguishing between individuals was determined using a validation set, maximizing the F1 score. Our model achieved a validation accuracy of 98.83% and a test accuracy of 94.52%, with validation precision at 0.8362, recall at 0.8625, and F1 score at 0.8492. Test results showed precision at 0.8661, recall at 0.8116, and F1 score at 0.8380. These results demonstrate the effectiveness of our approach in open-set recognition tasks, highlighting its potential for precision farming and livestock management. The high accuracy rates indicate reliable identification of individual cattle, enhancing automated tracking and monitoring systems. This research contributes to animal biometrics by providing a scalable and non-intrusive solution for cattle identification and monitoring. Future work will focus on facial recognition and expanding the dataset and refining the model to improve generalization across different scenarios and conditions. Additionally, further training and algorithmic adjustments are expected to optimize performance.

Keywords: open-set recognition, deep metric learning, holstein-friesian cattle, convolutional neural networks, precision farming.

FORECASTING BEEF CATTLE GROWTH USING COMPUTER VISION AND MACHINE LEARNING

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Body weight (BW) is an important phenotype in livestock farming as it allows the monitoring of animal health and production, breeding selection, as well as feed management and efficiency. Particularly, in the context of beef cattle, final BW is an important aspect of decision making for optimal harvesting and efficient use of resources. Since performing BW measurements on a large scale is costly and labor-intensive, various studies have investigated the application of Computer Vision (CV) and Machine Learning (ML) techniques for BW predictions. However, existing works primarily focus on predictions of current BW, but do not explore forecasting BW months into the future. To address this gap, we propose an approach that leverages CV and ML to predict BW several months ahead based on animals' currently available data. In this study, we evaluated the use of Gradient Boosting Trees (GBT) to predict BW at 12 months of age of 95 beef-on-dairy animals followed from a starting age of 159 ± 33 d to a final age of 399 ± 15 d, with final BW 630.2 ± 51.8 kg (mean ± SD). Monthly data consisted of manual measurements (height, length, girth, hip width, weight, age, birthweight, bodyweight, and gender) and biometrics extracted from 3D images captured from the dorsal area (volume, area, circularity, extent, eccentricity, perimeter, major axis length, and pixel area). A pre-processing step was implemented to fill in the data between consecutive monthly manual measurements with a linear interpolation, allowing a consistent age selection in the following experiments. When predicting BW at 360 days of age using all available features, GBT achieved RMSE = 25.8 kg, RMSEp = 4.62 kg, R^2 = 0.55 using input features at 160 days of life, RMSE = 23.48 kg, RMSEp = 4.3%, R^2 = 0.65 at 230, and RMSE = 15.5 kg, RMSPE = 2.8%, R2 = 0.85 at 300 d. We removed three-dimensional features such as height, and volume, and other complex features such as girth and birthweight. With these features, GBT achieved RMSE = 25.35 kg, RMSEp = 4.5%, R^2 = 0.57 using input features at 160 days of life, RMSE = 22.68 kg, RMSPE = 4.17%, R^2 = 0.67 at 230 days of life, and RMSE = 15.59 kg, RMSPE = 2.81%, R^2 = 0.84 at 300 days of life. Interestingly, GBT seems to better learn growth patterns when fewer features are provided. In summary, this work shows the potential of CV and ML to forecast body growth in beef cattle,

which can be a helpful tool to improve growth development based on optimized nutritional strategies. However, further investigations are needed to replace observed bodyweight with its predictions as input feature, and to evaluate performance on more heterogeneous datasets.

FUNCTIONAL AMINO ACIDS SUPPLEMENTATION AND PRECISION FEEDING SYSTEM FOR GROWING PIGS RAISED IN POOR SANITARY CONDITIONS

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The activation of the immune system reduces the nutrient availability for growth and increases the variability among pigs. Functional amino acids (AA) supplementation can reduce the negative effects of immune activation. Additionally, providing daily tailored diets using individual precision feeding (IPF) was shown to account for individual variability. Therefore, we hypothesized that the association of IPF and functional AA supplementation could reduce the negative effect of immune challenged pigs fed with daily tailored diets. The aim of this study was to assess growing pigs performance and blood parameters variation under poor sanitary conditions while being fed functional AA 120% above the estimated INRA AA ratios within IPF, compared to a conventional group-phase (GP) feeding system. The sanitary condition was characterized by oral inoculation of 2×10^9 cfu of *Salmonella* Typhimurium and manure spreading on the pen floor on day 0. Sixty gilts (23 ± 2.8 kg BW) were distributed in a complete randomized block design in a 2 x 2 factorial arrangement composed of 2 diets: CN with 100% INRA AA ratio or AA+ with 120% of the ratio for Met, Thr and Trp; and 2 feeding systems: GP or IPF. GP pigs received a single diet matching the SID Lys requirement of the 80th-percentile pig at the beginning of the trial whereas IPF pigs received a diet tailored daily to each pig requirement. All pigs were group-housed and fed *ad libitum* for 28 days by automatic feeders. Body weight (BW) was measured at d 0 and 28 and feed intake was recorded daily. Blood samples were collected at d 0, 7 and 28. Data were analyzed with diet and feeding systems and their interactions as fixed effects and BW blocks as random effect. Blood parameters were analyzed as repeated measurements over time. The pig was considered the experimental unit. No diet effect or interactions were observed for any variable (P > 0.05), suggesting that only supplementing Met, Trp, and Thr is not enough to support growth during a sanitary challenge.

Haptoglobin and IgG increased linearly whereas IgA, urea, and creatinine had a quadratic increase over time ($P < 0.05$). IPF decreased the growth performance and increased the serum IgA and creatinine ($P < 0.05$), mostly due to the fact that IPF reduces AA provision compared to GP system. The IPF model, as most mathematical models, does not account for the AA and energy costs related to the immune challenge. Therefore, IPF might have underestimated pigs' requirements and limited the amount of nutrients provided. In conclusion, the combined effect of individual precision feeding and functional AA supplementation was not able to reduce the negative effect of the sanitary challenge.

Keywords: immune challenge, individual feeding, amino acid supplementation, immune response

Table 1. Growth performance of growing pigs raised in poor sanitary conditions fed a control (CN) or AA supplemented diet (AA+) with conventional group-phase (GP) or individual precision feeding (IPF) systems.

	GP		IPF			*P*-value		
Item	CN	AA+	CN	AA+	SEM	FS	Diet	FS × Diet
Final BW, kg	38.6	37.2	33.0	35.6	0.762	0.01	0.60	0.09
ADG, g/d	554	515	367	447	21.07	0.01	0.60	0.13
ADFI, g/d	1112	1036	972	1009	28.87	0.11	0.71	0.28
G:F, g/g	0.49	0.49	0.37	0.43	0.001	0.01	0.16	0.18

BW = body weight; ADG = average daily gain; ADFI = average daily feed intake; G:F = feed efficiency; FS = feeding system; Diet = diet; FS × Diet = interactions between FS and Diet; SEM = standard error of the mean. Values are least square means.

Table 2. Blood parameters of growing pigs raised in poor sanitary conditions fed a control (CN) or AA supplemented diet (AA+) with conventional group-phase (GP) or individual precision feeding (IPF) systems.

	FS		Diet		Day				*P*-value		
Item	GP	IPF	CN	AA+	0	7	28	SEM	FS	Diet	Day
Haptoglobin, g/L	0.913	1.139	1.020	1.032	0.516 ^{B}	1.291 ^{A}	1.271 ^{A}	0.065	0.10	0.92	0.01
Albumin, g/dL	2.96	3.02	2.99	2.98	2.97	2.98	3.01	0.038	0.50	0.87	0.91
IgG, g/dL	1.152	1.263	1.208	1.207	1.012 ^{C}	1.193 ^{B}	1.417 ^{A}	0.043	0.30	0.99	0.01
IgA, g/dL	0.110	0.370	0.125	0.123	0.127 ^{B}	0.146 ^{A}	0.098 ^{C}	0.004	**0.01**	0.69	0.01
Urea, mg/dL	16.5	15.8	17.0	15.3	13.7 ^{B}	19.5 ^{A}	15.2 ^{B}	0.602	0.61	0.25	0.01
Creatinine, mg/dL	1.45	1.22	1.32	1.36	1.27 ^{B}	1.42 ^{A}	1.32 ^{B}	0.017	**0.01**	0.24	0.01

FS = feeding system; Diet = diet; Day = sampling days; SEM = standard error of the means.
A,BDifferent superscripts in the same row indicate differences between sampling days by the Tukey test ($P < 0.05$).
No interactions between FS, Diet and Day were observed for any studied variable ($P \geq 0.05$).
Values are least square means.

BREED IDENTIFICATION IN MEAT PRODUCTS USING MACHINE LEARNING MODELS AND SNP MARKERS

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Traceability in the meat industry is essential for maintaining food safety, quality, and consumer confidence. Genetic traceability, in particular, is an effective tool for identifying and preventing fraud or mislabeling in meat market, ensuring the origin of meat products and supporting supply chain transparency. This study aimed to develop a breed identification model applicable at the market level using breed-informative single nucleotide polymorphsims (SNPs) to detect possible mislabeling in meat products. To achieve this, we evaluated a number of machine learning classification methods using a total of 15 SNPs across three different cattle breeds: Holstein, Jersey, and Korean Hanwoo. A total of 305 data points were used for model development, with the dataset split into 70% for training and 30% for validation. We employed the PyCaret 3.2.0 library and utilized stratified 10-fold cross-validation to compare model performance. Out of 17 models, the top five based on the highest F1 score for the Hanwoo class were the Logistic Regression (LR), Extra Trees (ET), Ridge Regression (RR), Linear Discriminant Analysis (LDA), and Support Vector Machine (SVM), with F1 scores ranging from 0.9501 to 0.9569. These models were then fine-tuned and evaluated on an unseen dataset consisting of 132 samples. The LDA model wrapped with One-vs-Rest (OvR) strategy achieved the highest F1 score for the Hanwoo class at 0.968. These results demonstrate the significant potential of breed identification models, even when employing a limited number of SNP markers, for practical application in the field. The adoption of such a genetic traceability system at the market level could substantially enhance transparency and foster greater consumer trust in the meat industry.

Keywords: genetic traceability, automated machine learning, multi-class classification.

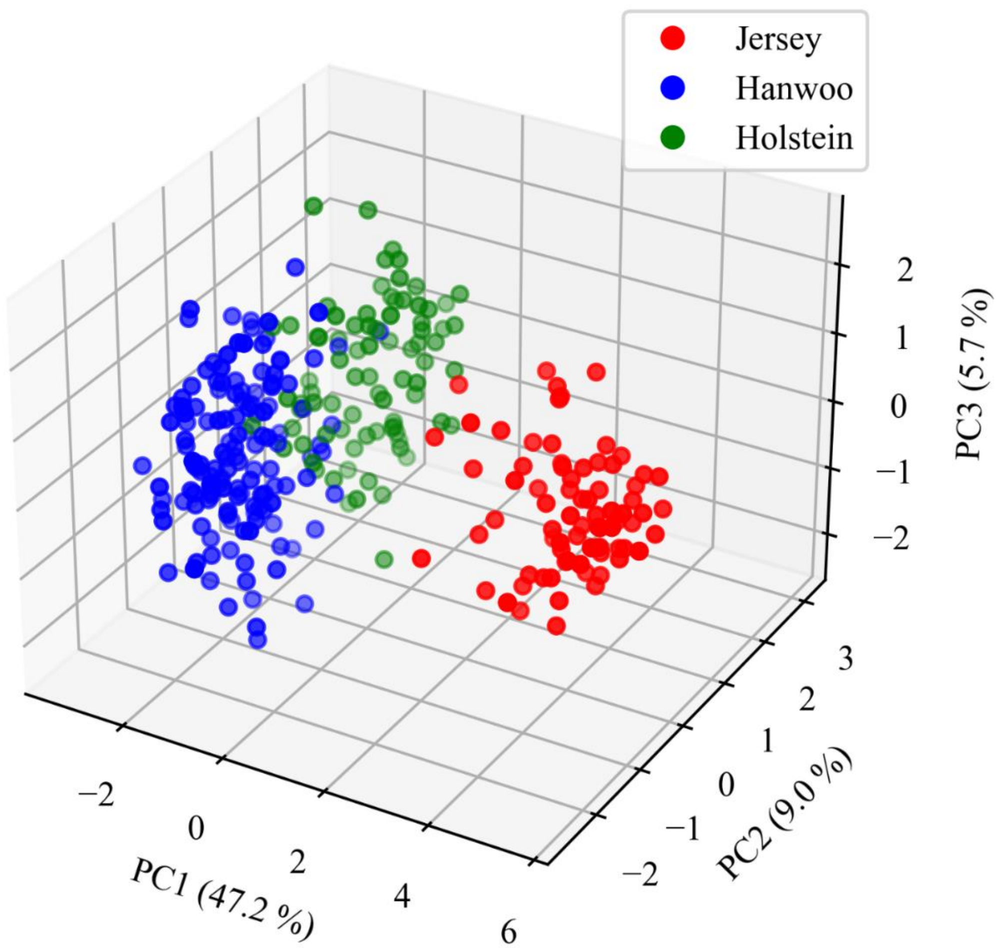

Figure 1. 3D scatter plot of the principal component analysis (PCA) results. The plot shows the distribution of three cattle breeds: Jersey (red), Hanwoo (blue), and Holstein (green) in the training dataset. The three first principal components (PC1, PC2, and PC3) explain 47.2%, 9.0%, and 5.7% of the total variance, respectively.

APPLICABILITY OF MACHINE LEARNING TECHNIQUES FOR CRUDE PROTEIN PREDICTION IN TAMANI GRASS PASTURES

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Knowing the quality of forage is essential to meet animal requirements, achieve objectives and increase the efficiency of the production system. Machine learning techniques have been employed to estimate crop productivity, including available climate data. The objective was to test the applicability of machine learning techniques with climatic data (temperature, solar radiation and precipitation), nitrogen fertilization, interval between grazing and pre- and post-grazing height to predict the protein content of the leaf of grass pastures. -tamani. A robust database collected over 18 months from BRS Tamani pastures in the Embrapa Gado de Corte experimental area was used. The pastures were managed with two doses of nitrogen (80 and 240 kg/ha/year of N) and two grazing frequencies (90 and 95% IL). The Linear Regression (RL), Multilayer Perceptron (MLP), REPtree (RT) and Random Forest (RF) algorithms were tested in the Python program. The train_test_split function from the scikit-learn library was used, dividing the data into 80% for training and 20% for testing. Each model was subjected to 500 iterations to ensure the robustness of the results. The performance of the models was evaluated using the Pearson coefficient (r) and mean absolute error (MAE) metrics, calculated between the predicted and observed values. The means of each performance metric were grouped using the Scott-Knott test at 5% probability. The traditional RL technique showed the lowest performance, with r of 0.58 MAE of 1.85 ($p<0.05$). When testing neural networks, MLP improved performance over RL and showed no significant difference compared to the RT algorithm. The Random Forest (RF) model achieved the best performance, with r of 0.75 and MAE of 1.52 ($p<0.05$). Our study demonstrates that the Random Forest machine learning technique has the potential to predict the protein content of tamani grass leaves using non-destructive and easily obtained data.

Keywords: random forest, linear regression, BRS Tamani, pasture management.

COMPARISON OF MACHINE LEARNING ALGORITHMS FOR PREDICTIVE MODELING OF IN VITRO DIGESTIBILITY OF IPYPORÃ GRASS LEAVES

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Forage digestibility indicates the nutrient utilization capacity by animals; however, this is a costly variable to measure. Thus, machine learning (ML) techniques can be employed to obtain estimates of the nutritional quality of forages. The aim was to analyze the performance of ML algorithms based on productive variables and chemical composition, and a combination of these two data sets for predicting in vitro digestibility of organic matter (IVDOM) of ipyporã grass leaves. The data analysis was performed using an artificial neural network: the Multilayer Perceptron (MLP), decision tree algorithms: REPTRee, M5P, and Random Forest (RF), and Linear Regression (LR). For model performance validation, Pearson correlation metrics (r), mean absolute error (MAE), and root mean absolute error (RMAE) were used. The data were standardized and submitted to multivariate principal component analysis (PCA). The PCA highlights the strong association of IVDOM with crude protein (CP) content. in the first component, a high correlation between IVDOM and CP content of Ipyporã grass leaves can be observed. Regarding the tested models and inputs, there was interaction ($p<0.05$) for MAE and RMAE for the prediction of leaf IVDOM, while for the correlation coefficient (r), there was no significant interaction ($p = 0.78$), showing an isolated effect of the models and the input used. The best algorithm models for predicting leaf IVDOM of Ipyporã grass were MLP, LR, and RF, which did not differ among themselves, while the worst model for this analysis was REPTree. As for the evaluated inputs, there was no significant difference between the complete data and the composition data, and the lowest value was observed for the input using only production data. The r of the composition input for MLP and LR was 0.76. for the prediction of leaf IVDOM, chemical composition data are sufficient to generate accurate and precise models, with the MLP and LR models being indicated. The REPTRee model showed poor performance regardless of the

data input. The use of machine learning techniques is a promising path in predicting the nutritional quality of forage grasses.

Keywords: chemical composition, grass, neural networks, nutritional value.

EXPLORING ARTIFICIAL NEURAL NETWORKS FOR PARAMETER ESTIMATION IN POULTRY CARCASS AFFECTIONS SEGREGATED BY THE INSPECTION SERVICE

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Industrial poultry farming plays an essential role in the global food supply, with chicken meat being a widely accepted option due to its affordability and high protein quality. In Brazil, where poultry farming is a significant economic force, the Federal Inspection Service (SIF) ensures the safety of poultry products. Despite advancements, challenges persist, such as carcass condemnations in slaughterhouses, leading to considerable economic losses. In this context, Artificial Neural Networks emerge as a promising innovation, enabling the prediction of poultry affections and condemnations during slaughter. Research projects led by the Avian Pathology Diagnostic and Research Center (CDPA) at UFRGS have been exploring the potential of ANNs, highlighting their applicability in optimizing poultry production. This study aimed to demonstrate the effectiveness of ANNs in estimating parameters associated with pathological conditions, providing a valuable tool for the management and operational efficiency in poultry companies. A historical series of data from commercial poultry farming, spanning from breeding to slaughter, obtained from a poultry integration in Rio Grande do Sul between January 2019 and December 2022, was utilized. The partner company provided the data, demonstrating important collaboration for the research. The records consist of detailed information from 3,370 batches and 89 variables related to poultry production. The research adopts an observational, analytical, and cross-sectional approach. The batches of birds are of single origin, ensuring genetic uniformity and facilitating modeling. The ANNs were built to datapredict afflictions and injuries using NeuroShell® Predictor software. The genetic training method was employed due to its strong generalization capabilities. The results indicated the effectiveness of ANNs in predicting inspection parameters of broiler carcasses, especially in cases where conventional statistical methods are limited. The ANN models were selected based on criteria and statistical indicators of fit and generalization such as the coefficient of multiple determination (R^2), correlation coefficient (R), and mean squared error (MSE), standing out for their precision and efficacy. The best values of R^2 (0.973742), R (0.986783), and MSE (0.014472) were obtained for

the total condemnation model, demonstrating high accuracy, correlation, and low error in the ANN. The results varied among the output variables, with models showing superior fits for condemnation (total and partial), contamination, airsacculitis, repulsive appearance, and dermatosis, while cellulite and arthritis performed poorly. The analysis of correlation between predicted and actual values highlighted the adequacy of the developed models, although generalization to new datasets was challenging in some cases. Evaluating individual model characteristics emphasized the importance of a detailed understanding of each variable. The inferior performance of some models can be explained by the significant individual variability in carcass judgment and allocation criteria by the SIF team. Results suggest that ANNs are promising and have great potential applicability in the continuously growing poultry farming sector.

Keywords: federal inspection service; carcass condemnation; deep learning; food safety; predictive modeling; pathological affections; neural network modeling; condemnation prediction.

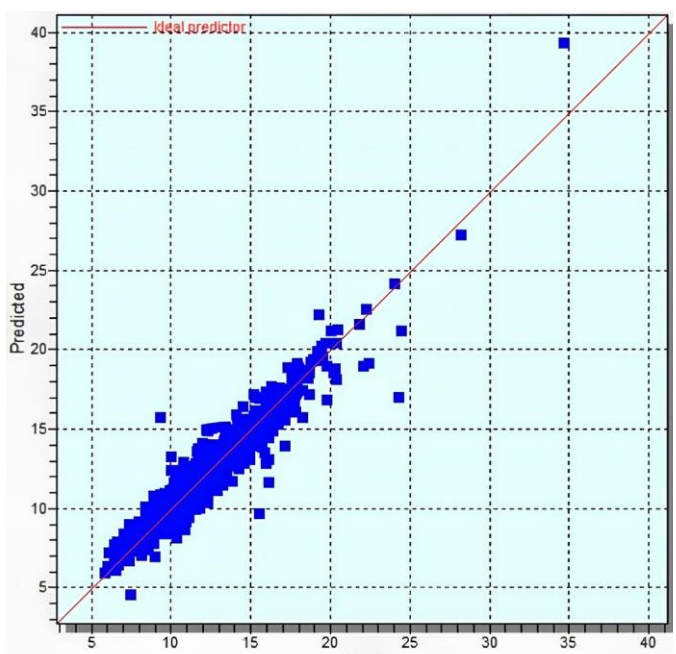

Figure 01: Assessment of the linear regression between the observed real values and the values predicted by the artificial neural network model for the output variable "Partial Condemnation". R=0.952838; R2= 0.907218.
R = linear correlation coefficient
R^2 = multiple determination coefficient;

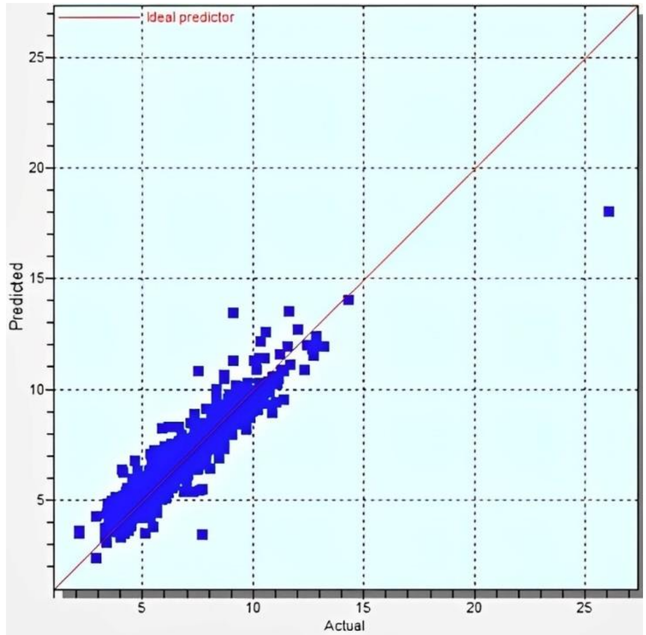

Figure 02: Assessment of the linear regression between the observed real values and the values predicted by the artificial neural network model for the output variable "Partial Contamination". R=0.931131; R^2=0.866817.

R = linear correlation coefficient

R^2 = multiple determination coefficient.

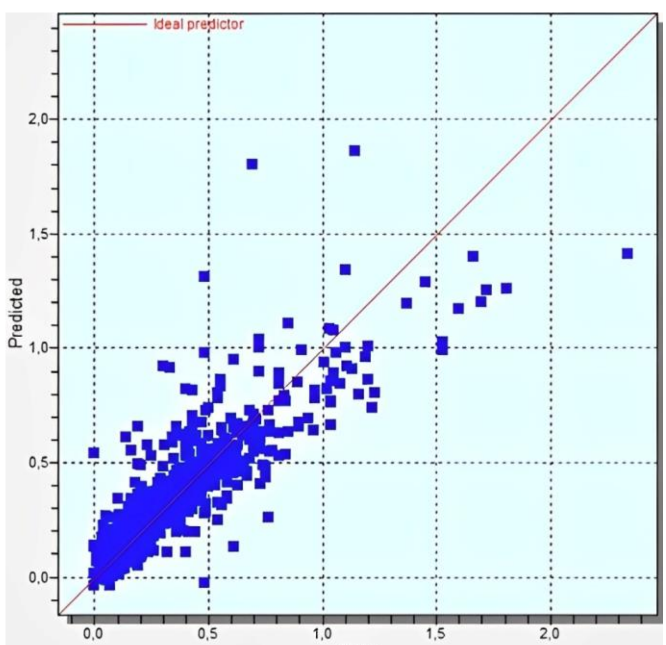

Figure 03: Assessment of the linear regression between the observed real values and the values predicted by the artificial neural network model for the output variable "Repugnant Aspect". R=0.870637; R^2=0.757545.

R = linear correlation coefficient

R^2 = multiple determination coefficient;

Table 1: Mathematical results of the models developed for the variables of partial condemnation, total condemnation, partial contamination, total contamination, airsacculitis, repugnant aspect, dermatosis, cellulitis, and arthritis. These pieces of information were obtained after the completion of the training process.

Inspection Parameter (output)	R^2	R	ME	MSE
Partial Condemnation	0,952496	0,975959	0,534450	0,285637
Total Condemnation	0,973742	0,986783	0,120299	0,014472
Partial Contamination	0,921628	0,960015	0,425962	0,181444
Total Contamination	0,922993	0,960725	0,076568	0,005863
Airsacculitis	0,907201	0,952764	0,067341	0,004535
Repugnant Aspect	0,886728	0,941662	0,070710	0,00500
Dermatosis	0,833176	0,912785	0,408577	0,166935
Cellulitis	0,685342	0,827854	0,209285	0,043800
Arthritis	0,575263	0,758462	0,064278	0,004132

R^2 = multiple determination coefficient; R = linear correlation coefficient; ME= mean error; MSE = mean squared error.

Table 2: Mathematical results of the models developed for the variables of partial condemnation, total condemnation, partial contamination, total contamination, airsacculitis, repugnant aspect, dermatosis, cellulitis, and arthritis. These pieces of information were obtained after the completion of the validation process.

Inspection Parameter (output)	R^2	R	ME	MSE
Partial Condemnation	0,907218	0,952838	0,600014	0,360017
Total Condemnation	0,907020	0,954212	0,130868	0,017126
Partial Contamination	0,866817	0,931131	0,485755	0,235958
Total Contamination	0,768185	0,876984	0,096937	0,009397
Airsacculitis	0,803060	0,896533	0,070500	0,00497
Repugnant Aspect	0,757545	0,870637	0,080033	0,006405
Dermatosis	0,692441	0,833968	0,488761	0,238887
Cellulitis	0,446624	0,669070	0,231749	0,053708
Arthritis	0,451097	0,671640	0,071450	0,005105

R^2 = multiple determination coefficient; R = linear correlation coefficient; ME= mean error; MSE = mean squared error.

Table 3: Relative importance, %, of the input variables in the ANN models generated for the output variables: Partial Condemnation (PC), Total Condemnation (TC), Partial Contamination (P Cont), Total Contamination (T Cont), Airsacculitis (Airs), Repugnant Appearance (Ra), Dermatosis (Der), Cellulitis (Cel), and Arthritis (Art).

Variables	PC	TC	P Cont	T Cont	Airs	Ra	Der	Cel	Art
Incubator	-	-	-	-	13,8	-	-	-	-
Hatchery	-	-	-	-	13,9	-	-	-	-
Incubation Minutes	-	-	-	-	-	-	-	-	-
Hatching Minutes	-	-	-	-	-	-	-	-	-
GPD (Grams per Day)	-	0,6	0,4	-	-	0,2	0,3	-	-
Starter Feed	24,6	8,8	20	47,8	10,2	16,5	22	11,6	23,6
Grower Feed	25,4	5,9	19,8	13	13,8	19,1	22,1	25,1	15,1
Finisher Feed	24,8	8,7	19,3	22,2	10,5	16,6	22,3	12,2	24,7
Headcount Housed	0,1	22,7	6,8	1,1	9,9	10,6	6,9	1,7	8,7
Kg of Feed Consumed	24,6	1,1	19,9	10,4	17,5	23,4	18,8	47,8	19
Kilograms of Chicken	-	1,0	-	-	-	-	0,2	-	-
Age at Slaughter	-	0,9	0,2	-	9,2	0,2	0,2	-	-
Heads Slaughtered	0,1	23	6,8	0,8	1,2	9,9	6,6	1,5	8
Total Mortality	0,2	25,3	6,3	4,5	-	3,1	0,2	-	0,8
Average Weight of Birds	-	1,8	0,5	-	-	0,3	0,4	-	0,1

TOWARDS THE AUTOMATIC LOCALIZATION OF *Vespa velutina* NESTS USING RFIDS

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The Asian hornet (*Vespa velutina*) poses a significant threat to European apiculture and biodiversity. Since its introduction, this invasive species has caused considerable harm to native bee populations and beekeeping industries. Traditional methods employed by European beekeepers to locate and eradicate Asian hornet nests are time-consuming, labour-intensive, and involve several intricate steps. Beekeepers usually set out some scent jars to lure and capture Asian hornets. The captured hornets are marked, after the hornets are immobilized by freezing. The marked hornets are released and their flight direction is observed. A hornet flies to its nest and returns with a known velocity. By repeatedly measuring the hornet return times on multiple scent jar locations, beekeepers are able to localize the nest. However, this method is fraught with challenges, including the necessity for continuous human monitoring and the difficulty of accurately tracking the hornet's movements. Our project aims to streamline the nest location process by employing radio-frequency identification (RFID) technology. By attaching an RFID coil to the hornet and using an RFID reader near the scent jars, we hypothesize that the monitoring efficiency can be improved. To test the feasibility of our approach, a series of experiments was performed to test the following questions: *How can the RFID coil be attached to the hornet?*, *What flight limitation can be observed after RFID coil attachment?*, and *Is it possible to read out the RFID coils attached to the hornet?* Firstly, lightweight RFID coils were attached to the Asian hornet thorax using a thin wire. Secondly, following the RFID coil attachment, the hornet was released in an enclosed environment. The flight behaviour was closely visually monitored, with a focus on flight stability, speed and general behaviour to ensure the hornets could operate normally. Finally, an RFID reader, programmed to register each detection of the RFID coil, was positioned near a scent jar within the enclosure. The results of our experiments were promising. The hornets demonstrated normal flight behaviour post-attachment, indicating that the RFID coil did not hinder their mobility. The RFID reader effectively detected the presence of the tagged hornets each time they approached the scent jar. Our findings indicate that the use of RFID technology to track Asian hornets is a viable method for simplifying the nest localization process. The success of the RFID attachment and detection in an enclosed environment supports the feasibility of deploying this system in the field.

Keywords: RFID, asian hornet, european honey bee, pest management.

ADVANCING AGRICULTURAL EFFICIENCY: UNMANNED AIRCRAFT VEHICLE IN SOIL AND PASTURE MANAGEMENT

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The utilization of Unmanned Aerial Vehicles (UAVs) has become a powerful method for supporting decision-making in pasture management. Under weather stress conditions and management issues, pastures and soils often alter their chemical composition. As a consequence, changes in the pigments of plant leaves are often observed, affecting the reflectance in both near-infrared and visible light. This can be assessed through several vegetation indices that combine NIR, Red, Green, and Red-Edge bands. In this context, multispectral imaging from UAVs could provide quantitative data, on the nutritional composition of pasture and potentially serve as an indicator of soil properties. Our goal was to predict pasture and soil chemical composition using multispectral images taken from UAV. Data were collected from 11 farms located in Wisconsin, and the model was trained using indices derived from NIR, Red, Green, and Red-Edge bands. Partial Least Squares, Gradient Boosting Machine, and Support Vector Regression models were used and assessed through leave-one-out cross-validation. Additionally. the average of the predicted values was used as an ensemble model. The model predicted crude protein with an R^2 of 0.68 and a root mean square error of prediction (RMSEP) representing 10.9% of the average observed values. It also showed promising results for predicting total digestible nutrients and net energy for lactation in the pasture, with R^2 values of 0.78 and 0.79, and RMSEP representing 3.0% and 3.2% of the average observed values, respectively. The fiber content in the pasture was predicted with R^2 values of 0.80 and 0.69 and an RMSEP of 10.2% and 10.8% of the average observed values for Acid Detergent Fiber and Neutral Detergent Fiber, respectively. The model predicted soil pH with R^2 of 0.52 and an RMSEP representing 6.4% of the average observed values, and soil base saturation with R^2 of 0.62 and an RMSEP with represents 12.2% of the observer values. Equipped with multispectral cameras, UAVs facilitate the assessment of soil and pasture quality, enabling remote sensing on a large

scale for optimal pasture management. Such development is crucial for generating the data required to enhance our understanding of soil-plant-animal interactions in grazing systems.

Keywords: vegetation indices, multispectral images, drone, UAV.

IMPACT OF EXPOSED MANURE SURFACE AREA ON AMMONIA AND NITROUS OXIDE EMISSIONS IN DAIRY SYSTEMS: INSIGHTS FROM THE RUMINANT FARM SYSTEMS MODEL'S SENSITIVITY ANALYSIS

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Ammonia (NH_3) is a key factor in the creation of fine particulate matter and leads to nutrient overload, increased acidity, and nutrient pollution in ecosystems, which negatively affect human health as well as soil and water quality (Rotz and Oenema, 2006). Nitrous oxide (N_2O) contributes to the greenhouse effect and ozone layer depletion due to its emissions from agricultural soils and livestock manure management (Singaravadivelan et al., 2023). Accurately quantifying NH_3 and N_2O emissions is crucial for optimizing manure management practices. The Ruminant Farm Systems (RuFaS) model provides advanced decision support by integrating various farm activities such as the growth of crops, management of feed inventory, lifecycle tracking of animals, and manure handling (Kebreab et al., 2019). RuFaS's manure module predicts pen-level housing NH_3 emissions based on exposed manure surface area (EMSA), which depends on pen types (e.g., freestall, tiestall) and animal types (e.g., lactating cows, non-lactating animals). These emissions influence nitrogen availability for downstream NH_3 and N_2O emissions during manure storage. Our study aims to examine the impact of EMSA on barn NH_3 volatilization and storage NH_3 and N_2O emissions in a freestall and slurry storage system. Default EMSA values (3.5 m^2 per cow for lactating cows (LAC_EMSA) and 2.5 m^2 per animal for growing animals and dry cows (NLAC_EMSA) from Rotz and Oenema (2006) were used, with a sensitivity analysis across a range of ±2.5 m^2 for each animal type. A lower bound of 0.1 m^2 was used when the default value was 2.5 m^2. Sensitivity analysis, conducted using the Sobol method (Sobol', 2001) from the SALib library implemented in Python (Herman and Usher, 2017), revealed high first-order effects of LAC_EMSA and NLAC_EMSA on emissions within their respective pens. For example, the first-order sensitivity index for NLAC_EMSA was 0.827, indicating its significant direct impact on the outputs. Minimal to no second-order effects further supports the dominance of these direct contributions. NLAC_EMSA affected housing NH_3 emissions similarly among calves (0.827), heifers (0.827), and dry cows (0.827), but had lower impact on storage NH_3 (0.604) and N_2O (0.604) emissions in the calf pen compared to heifer (0.890, 0.836) and dry cow (0.890, 0.836) pens. LAC_EMSA showed stronger impact on emissions (1.01, 1.04, 1.04 for housing NH_3, storage NH_3, and N_2O, respectively) than NLAC_EMSA. Our results confirm that EMSA is correctly utilized in predicting housing NH_3 emissions in RuFaS, significantly impacting housing NH_3 and storage NH_3 and N_2O emissions in freestall and slurry storage systems. Future research should explore the effects of other manure module inputs (e.g., storage surface area, dietary factors) on NH_3 and N_2O emissions.

Keywords: ammonia emissions, Ruminant Farm Systems model, manure management, sensitivity analysis, sustainability.

IMPACT OF LOWERING NITROGEN CONTENT IN PIG MANURE ON ANAEROBIC DIGESTION PROCESS STABILITY, BIOGAS YIELDS, AND DIGESTATE COMPOSITION: IMPLICATIONS FOR PRECISION LIVESTOCK FARMING

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Novel feeding strategies can mitigate the environmental impacts associated with pig production by tailoring pig diets to specific nutritional requirements. For instance, precision feeding and low crude protein diets may decrease the use of high-impact feed ingredients and reduce nitrogen (N) excretion. Additionally, anaerobic digestion (AD) has emerged as a promising technology for transforming pig manure into biogas and bio-based fertilizers (i.e., digestate). However, little research has been conducted on the effects of N content in pig manure on AD. This study aimed to investigate the influence of lowering N content in pig manure through low crude protein diets on AD process stability, biogas generation, and digestate properties. Three dietary treatments were investigated in growing pigs, resulting in different N concentrations in manure. These included control (CON), low N (LN), and very low N (VLN) manures with Total Kjeldahl Nitrogen concentrations of 5.87, 5.42, and 5.15 g/L, respectively. The daily biogas production, composition (CH_4, CO_2, and H_2S), and digestate properties were monitored over 13 fed-batch cycles (25 ± 4 days per cycle). The experiment was conducted at lower temperatures (20 ± 1 ºC), using six digesters (three treatments × two replicates) operated as single-stage reactors. Data were analyzed by ANOVA using PROC MIXED with repeated measures. Results showed that the differences in N content in pig manure had a limited impact on biogas generation, with specific methane yields remaining similar over time. Despite variations in N levels, CH_4 concentrations remained stable between 60 and 65%, ensuring high-quality biogas. Differences between treatments became more pronounced with increased organic loading rates (OLRs) due to variations in the amount of volatile solids fed. Digested pig manure proved to be an alternative to chemically produced fertilizers by recycling nutrients back

to the land, with essential minerals suitable for plant growth. Acetic and propionic acids were the predominant volatile fatty acids (VFAs), with lower N contents leading to lower VFA accumulation. The pH of all digesters remained stable between 7.5 and 7.75 due to concurrent increases in total alkalinity (TA). The VFA/TA ratio for all treatments remained below 0.25, indicating stable AD processes with no major inhibition. Notably, precision livestock farming can significantly reduce N excretion. A much greater reduction in N content than the range of N values tested in this experiment. Thus, it is likely that the differences observed in this experiment (CON *vs*. VLN) could be maximized by using precision feeding, with even more contrasting N concentrations in manure. A lower manure N content holds promise for mitigating some environmental impacts such as the risk of N runoff and water pollution. Therefore, within precision feeding operations, an optimal N content range should be identified to balance environmental impacts and AD performance.

Keywords: precision feeding, sustainability, waste, swine, feeding strategy, manure management.

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