Shed management simulation training tools for the Australian chicken meat industry

by Samuel Cockerill and Rachele Osmond
January 2021
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AgriFutures Australia publication no. 21-156
AgriFutures Australia project no. PRJ-011701
Foreword

Digital technologies are continually evolving and Australia’s agricultural industries are embracing this technology as an opportunity for enhanced learning and training. Intensive meat chicken farming is a very dynamic environment that can benefit greatly from using digital training opportunities.

The objective of this project was to analyse existing predictive modelling and computerised shed management training tools that address internal and external shed management conditions, and determine whether they would be suitable for the Australian chicken meat industry.

Simulation software that uses predictive modelling already exists in several forms. This report analyses 11 programs, calculators and mobile applications, and will be a useful basis for developing future training opportunities for the industry that build upon current knowledge and available digital technologies. Simulating various ‘what if’ scenarios based on a computerised practice shed can influence decision making and management techniques that can lead to improved bird welfare and performance.

This report for the Chicken Meat Program adds to AgriFutures Australia’s diverse range of research publications. It forms part of our Growing Profitability Arena, which aims to enhance the profitability and sustainability of our levied rural industries. Research, development and extension (RD&E) helps the Australian chicken meat industry provide quality, wholesome food to the nation. The project was funded by industry revenue, the Australian Government and the Queensland Government Department of Agriculture and Fisheries.

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John Smith
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Acknowledgments

The authors sincerely thank everyone who participated in the electronic industry survey and phone interviews that were conducted for this project. We also thank the individuals who provided online tutorials and clarification on how to use the various programs analysed for this report.
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Executive summary

What the report is about

The purpose of this project was to investigate predictive or simulation tools to assist with training industry participants and to improve the awareness and understanding of how internal and external shed factors influence key chicken meat industry outputs such as litter, air quality, chicken welfare and performance. Due to differences in climate and standard management practices that exist between countries, it was important to analyse these programs for their suitability for the Australian chicken meat industry.

This report outlines the different tools currently available and their suitability for use as shed management simulation training tools for Australian meat chicken growers. It also provides recommendations on how these tools could be implemented and used by industry.

Who is the report targeted at?

This report is targeted at integrated poultry companies and their growers, plus other relevant members of the Australian chicken meat industry, including training providers. It provides a detailed analysis of many simulation models that are currently available and their appropriateness for use within the industry.

Background

It is essential that the chicken meat industry constantly evolves and improves production methods in order to meet increasing product demand and consumer expectations, particularly with regard to chicken welfare. Intensive meat chicken farming is a very dynamic environment, influenced by fluctuating internal and external shed environmental factors that affect shed conditions, which in turn can impact flock welfare and production.

A new training tool would help industry predict production and welfare outcomes, and support the training of new and experienced industry personnel, by predicting the effect of different shed inputs and management practices on key outputs. A virtual experience may never completely replace on-farm training; however, it could be valuable in better preparing people with minimal experience and improving or refreshing the knowledge of those already working within industry.

Aims and objectives

The primary objective of this project was to analyse currently available predictive modelling and shed management tools that address internal and external shed management conditions and determine their usefulness (current or potential) as training tools for Australian meat chicken growers, breeder managers and livestock service managers. The focus of this project was to identify and analyse simulation tools that predict how variations in the shed environment can affect litter conditions, air quality, production and welfare outcomes.

Methods used

As this project was primarily a scoping study, a variety of search engines such as ScienceDirect, Web of Science, Scopus and Google were used to identify simulation tools and literature that discusses the use of predictive modelling in poultry production. Due to the nature of this research, direct contact with authors and researchers was required and made up the bulk of the investigation into simulation software. An online industry survey and telephone interviews were also conducted to determine what programs are currently used and to gain insight into what people wanted from predictive simulation training tools.
Results and key findings

Thirty simulation programs were discovered that exist as web pages, downloadable programs, Microsoft Excel spreadsheets and mobile applications. Eleven were investigated in more detail. They all address some or many of the environmental and management factors that influence the outcome of meat chicken production – temperature and ventilation being the most universal factors. These programs mostly dealt with production as a calculated factor presented as bird weight; however, bird welfare, litter quality and air quality were largely absent from the observed programs. Analysis of these programs determined that no single model had all the desired traits identified by the Australian industry survey.

Implications for relevant stakeholders

This research will assist industry with determining if there is the need to develop a new shed management training tool or adapt a tool that already exists. It will benefit all stakeholders, in particular growers, who may be unaware of currently available simulation programs, tools and research regarding meat chicken production.

Recommendations

This project has shown that there is no single predictive meat chicken shed simulation model currently available that can be used as a training tool that meets all the requirements of the Australian chicken meat industry. Tools are currently used by industry, but they are limited. The recommendations of this project are:

- that a specific training and simulation tool be developed for the Australian chicken meat industry
- that the training tool has ‘scenario-based applications’ that are common to most sheds
- that the training tool uses a conceptual ‘practice shed’ for simulations and includes a range of inputs, outputs and visual learning features.
Introduction

Intensive meat chicken farming is a very dynamic environment, influenced by fluctuating internal and external shed environmental factors that affect shed conditions, which in turn can impact flock welfare and production. Being able to simulate various ‘what if’ scenarios will help growers understand the variabilities of shed interactions and assist with their decision making and management techniques. A training tool that can simulate how internal and external shed factors affect bird performance and welfare would be beneficial to the industry by improving the awareness and knowledge of the interactions between shed conditions.

Simulation software that uses predictive modelling already exists in several forms. The purpose of this project was to identify and analyse predictive flock and shed management tools that are currently available, and to assess how useful they could be for the Australian chicken meat industry. An industry survey was also conducted to improve our understanding of what variables the industry deemed most valuable, so that we could make recommendations about the features that should be included in models or tools developed for Australian conditions.
Objectives

The primary objectives of this project were to:

- research and analyse the availability of predictive modelling and shed management tools relevant to chicken meat production
- determine how effective these tools could be as a training tool for farmers with varying levels of experience
- determine how reliable they could be if implemented by the Australian industry.

Conducting this scoping study before committing to the full development of a shed management simulation training tool has the following benefits:

- potential adaptation of existing models to fit the Australian climate
- identification of characteristics of current models that would benefit an Australian industry-specific model.
Methodology

A variety of techniques were used to identify and review current simulation models used for chicken meat production, including:

- industry surveys – online survey and telephone interviews
- literature review to identify existing programs and people to contact for more information
- ‘expert’ interviews with authors of key papers identified in the literature review
- critical review of selected programs using criteria from industry feedback and researcher experience.

Literature review

Firstly, a broad search was conducted to access relevant scientific papers, plus commercially and freely available simulation programs specific to meat chicken production.

The search engines used to search scientific journal papers were ScienceDirect, Web of Science and Scopus. The following key focus words and phrases, including combinations, were used:

- predictive broiler modelling
- simulation tools for broiler farming
- broiler shed simulation
- broiler management tool
- predictive programming for broiler performance and welfare
- environmental simulations for broiler farming
- simulating poultry litter quality
- simulating poultry bird movement.

To increase the scope of each search, ‘broiler’ was substituted with ‘poultry’ and ‘chicken meat’; and ‘shed’ was substituted with ‘house’ and ‘barn’.

A general Google search was also conducted using the same key words and phrases. Searching in both a broad and specific manner identified models that deal with a variety of shed factors, as well as those that were more focused. Commercial data monitoring and precision livestock programs that rely on the input of real-time data were disregarded, as the purpose of this study was to find predictive tools that could use any input data to simulate shed conditions and did not have to rely on actual data being automatically fed into the program.

Expert interviews

In the second search phase, authors of suitable papers were contacted directly. This resulted in gaining insight and opinions from experts on the reliability of using models and the likelihood that they could be comprehensive enough including all relevant factors but still be scientifically accurate and reliable. Many authors responded with advice or opinions that were able to assist, despite not being able to provide information on specific predictive models that could be used as a learning tool. This also led to referrals of other suitable researchers or industry professionals to contact in relation to this topic.

For example, John Black, the Australian author of the paper titled ‘Brief history and future of animal simulation models for science and application’ (Black, 2014), indicated that there was a very ‘comprehensive poultry model,’ and provided contact information for the developers of the EFG Broiler Growth Model, which is one of the models included in this report.
In addition to contacting authors of journal papers, Australian shed manufacturers and international poultry management technology companies were contacted to get more information on whether predictive modelling tools were available or in use under any other circumstances.

Finding mention of predictive management in chicken meat production was not difficult as it is not a unique concept and has been the subject of a significant amount of research, as well as currently being in commercial use. However, the specific requirements of this project to find adequate predictive simulation models that could be used as a training tool was far more complicated.

**Industry surveys**

An industry survey was conducted (Appendix 1) with the purpose of identifying shed management training models or tools that are currently available and used by industry, and to identify what shed environmental factors were considered important to include if an Australian-focused program was to be developed.

The survey was sent to eight chicken meat processing companies in Australia via their national operations managers, who distributed the survey internally to livestock managers and farm managers.

The survey was kept short, with drop-down options wherever possible, to make it easy and quick for people to complete. In summary, the survey questions were:

1. Do you currently use, or know of, any computer-based shed management training tools?
   
   If answered ‘No’ to Q1…

2. Why don’t you use shed management training tools?
   
   If answered ‘Yes’ to Q1…

3. Please list the shed management training tools that you use
4. What do you like about these training tools?
5. What don’t you like about these training tools?

If a new shed management training tool was developed…

6. What level of employment would you like to see a shed training tool pitched at?
7. What are the most important inputs to include in a shed simulation tool?
8. What types of information would you like to see a shed simulation tool generate?
9. How would you like a training tool made available?
10. How would you like people to interact with a shed training tool?
11. How likely are you to use a computer-based tool to train growers/staff in shed management?
12. Would you like a shed training tool available in multiple languages?
13. Can we contact you to find out more about your experience in shed management training?

Only individuals that said ‘Yes’ to be contacted at the end of the survey were interviewed to discuss their responses and obtain more in-depth information. Of the 35 survey respondents, only three interviews were conducted. While this was a low number, the information provided further insight to what would be useful in a shed management tool and how industry would use it. The information gained from both the surveys and interviews was considered when assessing the tools that currently exist. Insights from those involved in the industry were used to align the outcomes of this project with industry expectations.
Selecting suitable training tools for analysis

Suitable predictive training tools were selected for further analysis and reviewed based on feedback from the industry survey, in particular responses to questions 3 (tools currently used by industry), 7 (inputs) and 8 (outputs), which resulted in the following criteria:

- tool has predictive capability
- tool does not require real-time data
- tool has applicability to Australian chicken meat production systems
- tool requires environmental variables as inputs (for example, temperature and humidity)
- tool is accessible.

Tools were then tested for:

- ease of use, including background knowledge required to operate the program
- information/outputs generated for the user, including how the information was displayed
- how different simulations could be compared
- adherence of the model to established scientific principles, including the application of referenced scientific findings.
Literature review

Several studies have focused on developing on-farm monitoring and machine learning systems that make use of real-time data recording to forecast potential outcomes of current flocks and future flocks. Johansen et al. (2017) used data obtained from 12 flocks in the same shed to forecast future broiler weight. The model considered environmental factors such as heating, ventilation and temperature, along with bird-related factors such as feed and water consumption. It was determined that the model they constructed was able to forecast body weight based on the environmental conditions, and that inputting data from a previous flock resulted in comparable outcomes (Johansen et al., 2017). This example provided another potential route to gaining a predictive model that can forecast production outcomes during the grow-out period.

Diez-Olivan et al. (2019) investigated a decision support system (DSS) that used a data-driven quantile regression forests modelling approach that allowed the estimation of growth, welfare and mortality parameters based on environmental deviations from optimal farm conditions. A total of 20 different flocks of broiler meat chickens from different farms were used to validate this system, with an accuracy of at least 81% for every flock. This model was also reported to accurately predict leg problems and mortality. By implementing this system, decision making about environmental conditions and control could be improved, potentially leading to increased body weights, along with reduced leg problems and mortality rate (Diez-Olivan et al., 2019). It was stated that further work should include other environmental parameters such as CO2 or ammonia levels to improve the predictive capabilities of the proposed models. This concept of predictive modelling is very similar to that covered by Johansen et al. (2017), indicating further that this is a viable option. Ideally, a predictive model such as these could also be used where simulated input variables replaced actual results.

Roberts et al. (2012) stated that assessing bird welfare relies largely on labour-intensive or post-mortem measurements. A continuous monitoring system that used data from on-farm cameras and Bayesian modelling was able to accurately predict the future health and welfare of a flock (Roberts et al., 2012). Adverse health conditions were able to be predicted well before any actual signs of disease were present, such as hock burn, which could be predicted at 1-2 days of age despite issues only arising after at least two weeks. Being able to predict health and welfare issues has the potential to allow for proactive management changes to mitigate the likely future scenario. As it stands, this study unfortunately had limited relevance to the objectives of this project (in the form of a current simulation training tool); however, if this mode of research was combined with other instantaneous predictive management systems, a more holistic system could be achieved encompassing more of the desired objectives.

Marian Dawkins, co-author of Roberts et al. (2012), was contacted to see if their research has led to a training tool or simulation program being developed that used video data to predict welfare outcomes in flocks. Unfortunately, so far, the data is only used to predict welfare outcomes for an individual flock. We found this to be a common feature of research involving predictive modelling, which is more flock-specific in nature rather than a generalised simulation program.

Machine learning algorithms were reviewed by Milosevic et al. (2019), who used real-time data collection and statistical analysis to predict production outcomes. By exploiting machine learning approaches through different training inputs, a prediction accuracy of growth and body weight in broiler chickens of 98-99% was achieved (Milosevic et al., 2019). There was also a 100% accuracy of predicting the presence or absence of ascites (a common disease in meat chickens). After reviewing machine learning applications in the chicken meat industry, we concluded that certain problems could be solved using this method and that further research would definitely be beneficial.

Computational Fluid Dynamics (CFD) is another, universally applicable modelling technique that could be used to predict outcomes related to meat chicken farming, especially for modelling...
environmental conditions. CFD modelling uses fundamental mathematical formulas to solve problems related to the flow of liquids or gases. Pawar et al. (2007) used CFD to demonstrate that air quality in poultry houses could be improved if airflow was from bottom to top, rather than from top to bottom, which is standard for poultry houses. CFD was able to predict results related to airflow, temperature and ammonia concentration. These predictions could assist with making management decisions to improve overall air quality in the shed. Air quality is a very important influential factor on bird performance and welfare, therefore being able to predict air quality in simulations would be highly valuable.

Zhang et al. (2019) used CFD to examine the ventilation of a self-designed smart broiler shed to determine if specific settings would provide ideal thermal conditions and optimum airflow. Once simulated results were obtained, they were compared with actual recorded results and were determined to be very comparable, indicating a certain amount of accuracy in this model. Many results obtained were of a specific nature to their designed broiler house; however, the idea of being able to design a specific poultry house virtually and then compare outcomes to actual results of the real shed could be a very beneficial component of a training tool.

Rojano et al. (2015) stated that improved living conditions in broiler houses can be achieved through better control of heat and mass transfer, and air quality. They used a two-dimensional CFD model to assess these dynamics with regards to their specific design, so that simulated results could be compared with actual outcomes. This study found that the predicted values obtained from the CFD programming were in ‘good agreement’ with experimental data for temperature, absolute humidity and CO2 (Rojano et al., 2015). CFD was also used to study external factors such as temperature, absolute humidity, solar radiation and wind velocity, and how they affected the internal climate of the house (Rojano et al., 2016). The predicted results were again very similar to the recorded data, which further demonstrated the likely accuracy of this method. These two studies demonstrate that CFD could be a reliable tool in predicting environmental conditions of poultry houses.

Another example of using CFD to simulate in-house conditions related to poultry farming was conducted by Curi et al. (2017), who evaluated ventilation strategies on Brazilian acclimatised houses. This study concluded that the CFD technique was an efficient way of predicting airflow while testing a variety of ventilation settings. It was again apparent that using CFD is a very valuable tool when simulating environmental conditions. If CFD theories could be applied in a predictive learning tool that also included how birds potentially react or grow in these conditions, this could be a valuable training tool. Further research into how CFD specifically could be adapted and used in a predictive poultry learning scenario would be beneficial to the industry.

Results

Industry surveys

A total of 35 people completed the industry survey, providing useful information on both currently available shed management training tools and information regarding the desired inputs and outputs of a potential training tool. There was a focus on tools that are computer-based, which includes all electronic tools available on mobile devices and personal computers. Several constructive comments were also provided to further improve the outcomes of the survey. The survey was targeted at company livestock service managers and growers. While the response rate was low in terms of the number of people targeted, the responses still provided a useful overview of what is being used by industry and their expectations of what information a training tool should be capable of providing.

It was apparent that the concept of a computer-based shed management training tool was generally unknown. Overall, only 34% of people that completed the survey currently use computer-based training tools for shed training.
Reasons why people don’t use computer-based shed management training tools are ‘No suitable training tools are available’ (64%), ‘Not aware of any tools’ (17%), and ‘Not needed’ (14%) (Figure 1).

![Figure 1: Why shed management training tools are not used](image)

When we asked the people who do use computer-based shed management tools why they liked using them, the main reasons were that they are good for growers/staff to use as a learning tool (34%), they provide good information (22%), and they are used to make management decisions (22%) (Figure 2).

![Figure 2: What respondents like about the training tools they currently use](image)

In contrast to this, these tools did not provide enough information (25%) and also took too long to learn (25%) (Figure 3). Other reasons provided included ‘I prefer hands-on training’, ‘Tools should be more product-specific’, and ‘Sometimes the issue is managers do not always understand how to drive the controllers properly’.
There are no conclusive outcomes from these questions, though it became clear that if a training tool was to be developed, it would need to cover the multitude of factors that affect the overall shed environment while being very user friendly. This balance would be difficult to achieve, but is vital to the success and implementation of a training tool focused on shed management.

An important factor to consider before developing or adapting a training tool is determining the experience level that would benefit the most and where it should be pitched at (Figure 4). Respondents were able to select all options that applied. Interestingly, 48%, 55% and 44% of responses suggested that a training tool would be valuable for those at a basic, intermediate and advanced experience level respectively, while only 37% agreed that a shed training tool should be pitched for those at the entry level. It would be expected that a training tool would be most beneficial for those with no experience; however, these responses indicate the preference is geared towards being suitable for all levels of experience.

![Figure 3: What respondents don't like about the shed training tools they currently use](image)

![Figure 4: The preferred level of employment that a shed training tool is developed for](image)

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Regardless of the experience level a training tool is pitched at, the most vital aspect is to ensure that the input and output information aligns with industry expectations. The survey results for industry input requirements are shown in Figure 5.

The responses indicate that the most important input options for a shed simulation training tool are ventilation type (93%), temperature (90%) and relative humidity (86%). It was unsurprising that these factors were the most selected as they have a significant amount of influence on internal shed conditions and require a high degree of control. Additional inputs such as lighting programs (66%) and stocking density (48%) were also considered to be important. Diet type (21%) was the only available option that received minimal selection, which was expected as growers do not have much influence over feed. However, as diet can affect management practices, it should still be considered an input option. ‘Other’ inputs suggested included ammonia concentration and drinker management. These survey results suggest that some input factors should be more heavily weighted in importance for the development of a training tool.

![Figure 5: The most important inputs to include in a shed simulation training tool](image)

The desired outputs selected were litter moisture (90%), air quality (86%), thermal comfort (79%), growth (79%), water usage (76%) and mortality (59%) (Figure 6). The fact that all the presented options were selected by the majority of respondents strongly indicates that a shed management training tool requires as many outputs as possible. ‘Other’ desirable outputs included feed conversion ratio (FCR), airspeed and windchill.
Figure 6: Preferred type of information that a shed simulation tool should generate

The ideal mode of delivery for a shed management tool was also important to identify. The most selected option was phone or tablet application (64%), indicating a high preference for a highly accessible tool that can be accessed on mobile devices, anywhere and at any time, potentially within the production shed when decisions are being made. Web-based and downloadable software programs received favourable responses, with 57% and 54% respectively (Figure 7). These results indicate that these are also desirable delivery options for a shed management training tool. ‘Other’ responses given were ‘on-farm training’ and ‘leave it on paper’.

Figure 7: Preference for how a training tool should be made available
Another important aspect of a training tool is the design and how users interact with it. Options provided in the survey were (Figure 8):

- training package with questions included (68%)
- virtual reality (36%)
- spreadsheet based (25%)
- animated (21%)
- game based (7%)
- other (7%).

A training package that included some form of assessment would be useful to ensure that concepts learnt were retained. While the other options had fewer responses, being able to implement more modern strategies such as virtual reality could be an interesting way of developing a training tool. Spreadsheets can certainly use mathematical formula to predict outcomes but, outside of graphical representations, they lack the visual aspect to make training tools user friendly. A game-based training tool was the least selected option, receiving only 7% of selections, which may be because this option could be viewed as not being as professional. Two additional recommendations made in the ‘Other’ category were ‘with boss on farm’, and ‘calculators’.

Figure 8: How people would prefer to interact with a shed management training tool

The potential development of a computer-based shed management training tool would hinge directly on whether the demand was high enough from the industry to warrant its creation. Figure 9 shows the varying degree of interest in potentially using a training tool, with 82% of respondents suggesting that they would ‘likely’ or ‘very likely’ use a computer-based tool for shed management training purposes. This indicated that regardless of whether such a tool would be the primary method of educating new staff or maintaining the knowledge of more experienced growers, it would be a valuable addition to current training resources. Only 3% of respondents responded that they would ‘never’ use a model such as this, indicating that a very small percentage of people surveyed would completely rule out using a computer-based training tool.
The feedback from the industry survey was generally positive regarding the concept of a shed management training tool, with potential implementation appearing favourable. The survey results highlight the importance and need of having a training tool/simulator to support industry and improve production and welfare outcomes, and will be used to develop the specifications for training tools. These industry specifications and feedback were used to analyse currently available predictive models and consequently develop the recommendations for future work.

Phone interviews with industry members revealed vital information about current and potential future use. A primary concern is that some growers don’t understand how to properly use shed controllers and that many of these programs require a significant amount of background knowledge to set them up. It was also stated that each shed’s operation is very specific to the controller, sensors and ventilation equipment installed, which all have different features and functions that make it more complicated for a single training module to cater for all situations.

Additional comments made included:

- webinars have been successfully used for training as they are in a format that is easy to understand for growers
- calculator tools developed by the University of Georgia (UGA) have been used in conjunction with webinars and are much easier to use after guidance.
- older growers tend to be more difficult to reach regarding the adoption of new material and tools
- there is a separation between livestock managers, who are more inclined towards research-based outcomes, and growers, who prefer more practical-based information.

The tools currently used by industry are:

- *Poultry411* app
- *Cobb flock management* app
- University of Georgia spreadsheets and webinars
- *Poultry toolkit* app
- Shed controllers and sensors
- Company farming learning portal
The Poultry411 application was the most mentioned tool currently used by industry. Feedback from the interviews indicated that this app is consistently used across businesses and is particularly useful for breeder farm managers. However, a primary difficulty with this application is that windspeed and fan capacity (in cubic feet per minute; cfm) is needed to ensure the correct information is used. This respondent indicated that a simulation tool/model would work well as it can assist with future planning, particularly leading into certain weather events/seasons. Another important factor would be understanding the baseline calculations used (in this case for the Poultry411 application) so that more self-learning could be achieved and to make more sense of the data.

An important outcome from the phone interviews was hearing suggestions on how to implement training tools and what factors would be beneficial. Survey responses and additional feedback has been used to develop recommendations for future work on simulation training tools and is essential to guarantee that outcomes align with industry expectations.

**Summary of selected predictive simulation and training tools**

Predictive shed management programs that address different variables with regards to chicken meat production were found as downloadable programs, websites, spreadsheets and mobile device applications. These models vary greatly in complexity and potential relevance but were all tested to observe what results and outcomes were available and to determine if they could have some impact as a training tool within the Australian industry. As per the objectives of this project, the main variables tested were environmental and management aspects such as temperature, humidity and ventilation. In programs that required a diet formulation as an input, generic diet information was put into the program and then left constant while other variables were manipulated. A comparison table of all predictive simulation and training tools tested is shown in Appendix 2.

**Predictive meat chicken production simulator programs**

**Broiler Growth Model**

The Broiler Growth Model (BGM) developed by the Department of Animal Sciences, Sao Paulo State University, Brazil (www.bgm.poultrymodel.com) is a predictive program that is predominantly nutrition-based. It allows the user to formulate a broiler scenario and provides a variety of outputs regarding performance and bird growth. The main inputs required for this model include diet formulation, feed program, animal profile and environmental variables. The environmental variables available for manipulation are humidity, temperature and air velocity. This model is freely available to download via the developers but requires some training to understand how it works and how to operate it.

To test how the environmental factors influence bird performance, a control setting was first created as ‘standard’ using nutrition values obtained from the PoultryHub website (Nutrient requirements of meat chickens broilers). Once all the input options were completed, the simulation was run, resulting in a variety of output information such as body weight, body composition, and several feed-related outputs including protein deposition, amino acids and energy. For the purpose of this analysis, body weight was the primary factor compared across simulations as it is the most relevant output from this model regarding performance.

In this model, only two scenarios can be compared at a time via graphical representation, therefore the experimental environments created were all compared with the control. The first test increased the temperature by 3 °C at set points throughout the entire grow-out period to assess the effect of a sustained temperature increase. Figure 10 shows that by only altering temperature and keeping all other variables the same, overall weight output decreased. Over the course of a full flock, this simulated decrease in individual bird weight became substantial. Figure 11 shows the predicted output of a flock when temperature is not altered throughout the grow-out period to ideal settings but rather set at 32 °C for the duration. It can be observed that exposing birds to 32 °C for the duration of the
simulation resulted in a significant reduction in overall body weight. This drastic reduction in body weight when compared with the control indicates that these conditions would result in severe welfare issues; however, as this model does not address these impacts directly, they cannot be simply inferred from body weight results.

![Figure 10: Comparison between control and 3 °C higher for the duration of the grow-out](image1)

![Figure 11: Test simulating 32 °C constant temperature for duration of the grow-out](image2)

A similar scenario was set up to look at how low temperatures affect bird performance. Figures 12 and 13 show the simulation output for bird weight when temperatures were reduced by 3 °C (by age) on the control environment and set at 20 °C for duration respectively. Both figures show that body
weight output is not affected by either reduction to shed temperature. Cooler temperatures are more suitable growing conditions for birds once they can self-thermoregulate; however, this model does not appear to consider the impacts of cold temperatures during brooding.

![Figure 12: Comparison between control and 3 °C lower for the duration of the grow-out](image-url)

![Figure 13: Test simulating 20 °C constant temperature for duration of the grow-out](image-url)

Relative humidity was also tested in this model by observing what effects extreme conditions would have on performance output. Simulations were run at both 100% and 40% relative humidity; however, no difference in output related to relative humidity was observed. Similar simulations were conducted for stocking density and airspeed, which showed no effect on bird body weight. Regarding environmental factors, the conclusion for this model would be that only high temperature directly
affects bird weight, and as welfare outputs are not available, it is unknown how the birds would respond to these environments. This model focuses only on the growth output of the bird and does not consider how the environmental conditions within the shed can have other impacts that affect conditions and performance.

The strength of this model is in manipulating feed composition and observing the associated growth of the bird. While this model does have versatile predictive programming, it is fairly limited as far as environmental aspects are concerned.

**EFG Broiler Growth Model**

The *EFG Broiler Growth Model* is similar to the *BGM* but with a few more capabilities. Again, this model is nutrition-based and focuses on the growth of birds due to different diet compositions, as well as various other inputs. The inputs required for this model are breed, management, environment, cropping (thinning) schedule and feeding schedule. The program costs US$4000 per annum and can be purchased from EFG Software in South Africa (www.efgsoftware.net).

When simulating different settings for this model, the following pre-set input variables were used:

- **breed type:** Cobb standard type (other options include 1970s broiler, modern broiler, Ross standard type and Ross high-yield type)
- **economic costs including insurance, labour, heating, litter and water**
- **total mortality:** default setting 5%. It is interesting to note that mortality is an input of this program; however, it is not considered to change depending on changes to other inputs.
- **cropping schedule:** 42 days
- **diet formulations:** ‘starter’, ‘grower’ and ‘finisher’. These formulations were consistent with the nutrient values identified in PoultryHub, 2020. Alternatively, diet formulation can be amended to fit the user’s exact specifications.

These preliminary settings were maintained when testing environmental factors. The environmental inputs include temperature, humidity and lighting, which can be displayed graphically (Figure 14) as well as numerically. When testing temperature effects, both humidity and lighting were kept constant to observe how changes to temperature directly affected the output. The control temperature was set as per temperature settings in Figure 14, and four test temperature environments were created:

- 3 °C above daily temperature
- 3 °C below daily temperature
- constant temperature of 32 °C
- constant temperature of 20 °C
Figure 14: Control temperature input

Figure 15 graphically presents the predicted chicken growth rates based upon the five temperature scenarios. This model has similar outcomes to the BGM when temperature changes were tested. Higher-than-normal temperatures resulted in predictions of poor growth rates whereas lower-than-normal temperatures had little impact. Mortality or other indicators of welfare are not direct outputs of this model, and therefore adverse effects that would be expected to occur due to low temperature at the beginning of production are not adequately highlighted.

Figure 15: Output of temperature simulations
Other environmental variables tested were humidity and lighting program. Figure 16 shows the predicted chicken growth rates when humidity was the variable, and temperature and lighting were kept standard. While there is some variation in live weight between different humidity levels, it is negligible. However, despite relatively small changes, the model predicted that live weight would reduce as humidity increased.

Figure 16: Humidity simulation

Figure 17 shows that the model predicted minimal impact on bird live weight when birds were exposed to varying amounts of light during grow-out. The inclusion of lighting as an environmental variable in this model is unique but after observing the results, the outputs of this are questionable.

Figure 17: Lighting simulation
Like the BGM, the strength of the EFG Broiler Growth Model is in manipulating feed composition and observing the associated growth of the bird, which is demonstrated by this model being used predominantly by poultry nutritionists and nutrition researchers. This model does have greater input and predictive capabilities than the BGM, but these appear to be relatively insensitive to changes in most environmental variables, and therefore the model is not suitable for the purposes of simulating the meat chicken shed environment.

**Poultry Simulator**

The *Poultry Simulator* model is a free online calculator (www.poultrysimulator.com). It works very differently to both the BGM and the EFG Broiler Growth Model. This is because it primarily focuses on the shed environmental settings rather than the nutrition and growth of the bird. So that the *Poultry Simulator* can do the calculations specific to each shed, it requires input information such as shed size, wall structure and details about ventilation, heating and cooling. Otherwise it can do an environmental simulation based on a standard shed with its own data. The standard shed set up in this model is based on the shed features, inputs and outputs outlined in Table 1. Energy costs are calculated in Euros.

**Table 1: Inputs and output of environmental simulations in the Poultry Simulator model**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 m long x 17 m wide, 2.2 m wall and 4.2 m ceiling heights</td>
<td>Temperature</td>
</tr>
<tr>
<td>Cross ventilation in winter, tunnel ventilation in summer</td>
<td>Relative humidity</td>
</tr>
<tr>
<td>37 radiant brooders</td>
<td>Carbon dioxide (CO₂) concentration</td>
</tr>
<tr>
<td>78 m² cooling pads</td>
<td>Wind chill</td>
</tr>
<tr>
<td>Ceiling material is 4 cm thick polyurethane foam board</td>
<td>Ventilation rates</td>
</tr>
<tr>
<td>Wall material is 5 cm thick polyurethane sandwich panel</td>
<td>Fan run times</td>
</tr>
<tr>
<td>Outdoor temperature and humidity</td>
<td>Air inlet opening</td>
</tr>
<tr>
<td>Desired indoor temperature and humidity</td>
<td>Growth rate</td>
</tr>
<tr>
<td>Number of birds</td>
<td>Feed consumption</td>
</tr>
<tr>
<td>Static pressure</td>
<td></td>
</tr>
<tr>
<td>Ventilation and cooling</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>Feed</td>
<td></td>
</tr>
<tr>
<td>Energy consumption</td>
<td></td>
</tr>
</tbody>
</table>

The simulator is claimed to provide users with the following (Freire, 2013):

- ability to calculate the quantity and performance of equipment for a poultry shed
- ability to calculate optimum ventilation rate
- forecast in-shed environmental conditions
- ability to quantify growth rate, feed performance, heating and electricity costs
- estimate of lost profit due to sub-optimal conditions.
A major difference between this model and the nutrition-based models is the mode of output. The *Poultry Simulator* does not allow the comparison of two different scenarios; however, results and warnings are shown as soon as input values are made (Figure 18). This is different to the previous models, which use comparative graphs. The *Poultry Simulator* provides only specific value outputs that cannot be compared in the model. This is not considered detrimental as the information provided in the results is directly related to the shed operations and warnings are triggered if environmental settings do not appear to be right.

This model uses the inputs to identify the temperature perceived by the birds due to the different internal and external shed conditions, including wind chill. It then uses the ideal production temperature of 21.8 °C and the temperature perceived by the birds to predict flock growth and how much it would be above or below ideal. As an example, the model calculated a perceived temperature of 25.3 °C using the input values shown in Figure 19, which resulted in a reduction of 2540 kg/week and 1285 kg/week for feed consumption and growth respectively. Following on from this example, if the outdoor temperature alone is reduced to 28 °C (from 30 °C), the resulting perceived temperature is calculated to be 24.6 °C, thus changing the feed consumption and growth reduction to 1956 kg/week and 969 kg/week respectively (Figure 20). Reducing the outdoor temperature (while maintaining the same level of relative humidity) reduced the calculated perceived temperature felt by the birds, therefore creating a more comfortable climate leading to greater feed consumption and growth, but also reducing ventilation rate and the associated energy costs. This example demonstrates that the *Poultry Simulator* has greater capacity than the nutrition-focused *Broiler Growth Model* and *EFG Broiler Growth Model* in terms of psychrometric calculations and resulting bird comfort level estimation.
Figure 18: Example of the inputs and results from the Poultry Simulator program
Figure 19: Example of how performance is reduced due to high temperature

Figure 20: Example of performance when external temperature is reduced by 2 °C
The ventilation and cooling system programming were not used in the previous example. However, when these settings were adjusted to activate at 1 °C lower than the desired temperature, this created a perceived temperature of 23.7 °C, thus creating a temperature environment closer to the model’s optimum temperature (Figure 21).

Figure 21: Simulation showing how perceived temperature falls by reducing the temperature when ventilation and cooling systems are activated

The Poultry Simulator allows the user to observe and understand that both temperature and ventilation settings are vital components in creating a sustainable living environment while providing a performance output relative to the simulator’s ideal temperature setting. It also provides wind chill and CO₂ levels, something that the other programs do not. Separate to the environmental simulator aspect of this model, there is also a ‘calculation of equipment’ tab that allows specific shed design for shed measurements, ventilation, cooling and heating types, building material used, including the type of insulation, number of pan feeders and drinkers per bird, energy data, and calculation of insulation coefficients. This additional option would allow the user to create a virtual shed to a specific design that best represents their own shed specifications, or use these tools to experiment with shed design. While many building materials are suitable for Australian conditions, some improvements and additions would need to be added to make this more relevant for Australian conditions. This simulator was developed in 2013 and does not appear to have undergone any updates since this time.
Predictive Excel spreadsheets and calculators

University of Georgia (UGA) spreadsheets

Several predictive spreadsheets from the UGA Department of Poultry Science ventilation website (www.poultryventilation.com) were also analysed to determine their suitability as shed training tools (Department of Poultry Science, 2020). All spreadsheets are freely available to download online. The spreadsheets cover a variety of different shed management factors primarily for heating, ventilation, moisture and air pressure. Uniquely, these spreadsheets do not have bird performance outputs, rather they deal specifically with shed conditions. As shed conditions can directly influence bird performance, ensuring they are managed correctly is a vital tool for anyone who has minimal experience in this field. Currently these spreadsheets are tailored for American users, although metric versions are available on most spreadsheets. The Minimum Ventilation Calculator and House Leakage Calculator were converted to metric for Australian purposes in 2013 and are available on the AgriFutures Australia website (but unfortunately are no longer working). However, updated metric versions are available on the UGA poultry ventilation website.

The most relevant UGA spreadsheets are the 2018 Poultry House Moisture Control spreadsheet (Moisture Control Minimum Ventilation Calculator) and the Poultry House Leakage Area Calculator – 2014 metric version (Poultry House Leakage Estimator). Both tools are used by the Australian chicken meat industry.

The Moisture Control Minimum Ventilation Calculator spreadsheet requires the input of daily water consumption (litres), outside temperature (°C), outside relative humidity (%), inside temperature (°C) and minimum ventilation fan capacity (cubic metres per hour – m³/h) to provide the output of minimum ventilation fans percentage run time and on/off time on a five-minute interval setting. It is recommended that night-time values are used for this model as they will result in more accurate outputs. This recommendation does limit the potential usefulness of this predictive model; however, when compared with other spreadsheets, this one achieves the relevant output quickly and requires less user knowledge. In general, this model works on the basis that ventilation requirements increase if daily water consumption, outside temperature and outside humidity increase. Ventilation will also increase if desired indoor temperature is reduced. This information is valuable, especially for people with limited knowledge of shed ventilation.

The Poultry House Leakage Estimator allows the user to estimate house tightness using a static pressure test. Outside of shed specifications, the only environmental factor required is static pressure. Outputs are presented as relative leakage and total house leakage. Understanding that there are influential factors that can impact the amount of leakage within a production shed could allow the user to use their minimum ventilation rates to reduce moisture build up in the shed and to better prepare themselves for the reality that heating costs can increase if leakage is not factored in or controlled.

While these two spreadsheets were considered to be the most applicable as a shed management training tool, there are several other UGA spreadsheets that are related to shed management. These are discussed briefly in the following sections.

The Estimated Broiler House Heating Cost spreadsheet deals with heating costs based upon environmental factors including temperature, relative humidity and minimum ventilation. This tool is focused on winter conditions when heating is more relevant. It contains its own comparative system where values are put into separate data columns, which alter a graph allowing for comparison. This spreadsheet allows the user to understand that external environmental factors can impact shed conditions and thus need to be addressed, in this case through heating. Other than external temperature, another factor that increases heating cost is minimum ventilation. This spreadsheet outlines the dynamic system that exists between heating, ventilation and associated costs, but requires the user to already know what conditions would be ideal if birds were included in the system.
The **Tunnel-Ventilated Poultry House Heat Gain Analysis** spreadsheet calculates the minimum tunnel fan capacity required so that the air exchange rate is high enough so that there is no more than a 2.8 °C temperature difference between the tunnel inlet and exhaust fan end of the house. The user inputs outside and inside temperature, shed specifications, number of birds, lighting and air-moving capacity of fans. The spreadsheet calculates outputs that include total poultry house heat, which is broken down into several areas (ceiling, lights, walls and birds), minimum tunnel fan capacity, approximate number of tunnel fans required, airspeed and the temperature difference between tunnel inlet and fan end. This spreadsheet can provide valuable information to assist with maintaining uniform temperature throughout the shed.

The **Tunnel Air Speed/Static Pressure Estimator** requires many of the same input options as the other spreadsheets with regards to shed specifications; however, this model also requires the user to rate the condition of their fans and cooling pads with a scoring system. For example, for cooling pads, a score of 1 is ‘new’ and 5 is considered extremely dirty. For fans, the range is ‘new’ (1) to ‘very poor’ (4). If the fans were set to a score of 4 (very poor), pressure and air-moving capacity were both reduced when compared with a fan score of 1 (new). This allows the user to understand how static pressure and airspeed is affected by the condition of equipment.

These predictive spreadsheets as a whole address many management factors such as heating, ventilation and moisture control, but do not relate these back directly to bird production or welfare. Even though these models would be valuable for people with no experience in shed management, they do not give any direct information specifically about the birds.

Communications with Czarick (pers comm, 2020), developer of the UGA spreadsheets and calculators, provided significant insight into the complexity of developing a predictive model that attempts to determine how environmental factors such as ventilation affect bird welfare and performance outcomes. Czarick explained that it is a simple task to demonstrate how changes in ventilation affect temperature, humidity and heating costs, but determining the outcomes of a bird’s relationship with its environment is far more complex. He also stressed that many assumptions have to be made when combining many of the relevant factors, making the model potentially ‘dangerous’ if outcomes of a model do not accurately mirror the reality of production. He also explained that some formulae and algorithms are decades old and that they have little relevance to the birds that are being grown today.

Obviously understanding the outcomes of these spreadsheets is essential for people in chicken meat production, but they are far from the complete model. Finding a way to optimise these factors into outcomes that relate directly to bird welfare are highly integral to improving learning outcomes and making these spreadsheets a more complete training tool.

**Mobile device apps**

Predictive broiler production applications for mobile devices (commonly known as ‘apps’) were assessed for potential suitability as a training or simulation tool. A predictive model available on mobile devices would be desirable as it would be more accessible and always available to users (assuming they have mobile internet reception or an on-farm wi-fi network with internet access).

**Poultry411**

This application is free to download onto Apple and Android devices. It was developed from the spreadsheets and other information created by the University of Georgia and available on their poultry ventilation website. It currently calculates minimum ventilation rate (with a leakage calculator to be included at a later date). This calculator determines the minimum ventilation rate based upon internal and external conditions and the amount of moisture to be removed over the course of a day. The application states that the minimum ventilation required to control CO₂, CO and NH₃ may be greater than what is determined by the calculation.
The app can be used with either metric or imperial units. The app provides the same information as the UGA *Moisture Control Minimum Ventilation Calculator* spreadsheet. The inputs are internal temperature (°C) and relative humidity, required moisture to be removed per day (L), and minimum ventilation fan capacity (m³/h). Outputs are moisture control ventilation rate (m³/h), five-minute interval timer (seconds on and off) and runtime (%). An example is shown in Figures 22 and 23.

As this is a calculator primarily used for cold weather ventilation, the outdoor temperature must be cooler than the inside temperature. This application also included links to the UGA website where more information regarding chicken meat production can be found (along with the original spreadsheets).

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**Figure 22:** Example scenario for Poultry411

**Figure 23:** Output results from Poultry411

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**Poultry Farming Toolkit**

The *Poultry Farming Toolkit* mobile app is available free of charge for download onto Apple and Android devices. It was developed by the Alabama Extension Cooperative and Auburn University, USA. The app includes calculators for minimum ventilation, evaporative cooling pads and radiant heaters, which can only input information as imperial measurements. The minimum ventilation calculator is similar to the one by UGA and requires the airflow capacity of fans, number of birds and flock age. The app allows the user to add additional scenarios such as high ammonia, moisture and dust conditions, which add or subtract time to ventilation. The output for this calculator was represented as seconds that the fans should be on during the five-minute timer. When the number of
birds was increased, the time on for ventilation fans also increased. The age of flock input exists as a drop-down selection based upon the week of production. As this application had no visual output, the data was manually input into a spreadsheet to compare the effect of age of the flock (week) on calculated ventilation-on time (%) (Figure 24). The amount of ventilation required increased approximately linearly as the flock aged increased. If high ammonia or moisture were selected as options, the fan-on time output increased by 15 seconds each. However, if high dust was selected, then fan-on time output decreased by 15 seconds.

![Poultry Toolkit Minimum Ventilation Calculator](image)

**Figure 24: Poultry Toolkit Minimum ventilation calculator**

Overall, this application has limited potential when considering the multitude of variables that influence the meat chicken shed environment. Similar calculators are already available from other organisations that provide more detailed information and are readily available to Australian users (and are programmed in metric units).

**Cobb flock management app**

This mobile application, developed by Cobb-Vantress Inc., allows users to manage birds and view key performance metrics across their entire farm considering weight, feed, uniformity, mortality and several other factors. It is available free to download on Apple and Android devices; however, a barcode is required to gain full access.

Once values based upon the user’s specific flock are entered, the user can identify metrics that are within standard performance expectations or whether action needs to be taken because current values are outside standard/expected levels. Simple graphs are also used to assist with data visualisation, allowing the user to track performance against the updated standard.

This model lacks the outright predictive elements of what would be desirable to fulfill the objectives of this project and acts more as a farm management tool that keeps track of important trends. The primary benefit of this application is the ‘health’ status that uses a colour coding system. Green is acceptable, orange indicates a significant variation that requires action and red means that a very significant change from normal has occurred that requires urgent attention.
**Broiler Expert**

*Broiler Expert* is an example of a mobile application relevant to this study, which works more as a pocket assistant than an outright predictive model. This app is only available for download from the Google Play store and can only be installed on Android mobile devices, limiting its use.

The only inputs are flock age (days) and flock size, which generate a significant number of outputs (Figure 25). This application does not have a way to manipulate these output options as do other models but informs the user what values they would expect to see based upon flock age.

![Broiler Expert](image)

**Figure 25: Example of the Broiler Expert app outputs**

Along with the lack of manipulation and environmental inputs, there was no other way to view or export the output results. Therefore, any results generated had to be manually inserted into a spreadsheet to visualise the data over the length of an entire flock. An example of this is provided in Figure 26, which shows the weight output for the entire flock after 49 days of production. The growth trend is similar to that observed in other models. The model also provided information on feed and water consumption plus environmental conditions based upon age of flock, such as temperature, humidity, ventilation and lighting requirements during the grow-out.

This application also features several other sections that provide information on a variety of factors such as feed cost, liveability and vaccines. In addition to this, there is a problem-solving option that provided answers to why certain outcomes were being observed, such as poor early growth, feather cover, feed conversion, late growth and litter quality. A pathology section outlines common diseases that birds can experience. While these specific sections are not necessarily relevant for a predictive model, it would be valuable to someone with minimal experience, especially as a mobile application.
Despite expected ideal conditions being very useful information, the complete lack of manipulation indicated that this model would provide very limited assistance as a training tool. This application provides very basic information and could help people with minimal knowledge of ideal conditions, and could potentially be used in conjunction with other applications that require expected values at certain stages throughout growth.

![Graph showing weight output for a 49-day grow-out](image)

**Figure 26: Broiler Expert weight output for a 49-day grow-out**

### Other applications

The *i-WatchBroiler* app, available on Android devices only, was developed as a welfare assessment tool by researchers at Basque Institute of Agricultural Research and Development Neiker Tecnalia, Spain in collaboration with researchers from the University of Milan, Italy and Purdue University, USA. It uses a transect method to record birds affected by specific welfare-relevant conditions to assess the health and welfare of the flock (BenSassi et al., 2019). Initially developed for commercial turkeys, it was adapted for commercial broiler farms. It uses shed-specific inputs, litter assessment and real-time flock information to generate the welfare assessment, which is aligned with European Welfare Standards. While this app is currently aligned to European standards, there is certainly scope for aspects of this app to be adapted for Australia.

*Poultry Performance* is another mobile application that provides predicted bird weight based upon age but has significantly fewer outputs when compared with the *Broiler Expert*, consisting only of daily feed, cumulative feed, body weight and FCR. Outside of providing several more options for breed, this application does not provide any further information.

Other mobile applications found were *Poultry Manager*, *Broiler Growth Prediction* and *Pocket Poultry*. These applications did not provide anything more that was unique or relevant to this project that would require complete analysis. These applications provided some relevant information but did not suit the specific requirements of this project, especially when compared with the more scientific models and calculators.
Real-time monitoring and predicting flock outcomes

The scope of this project was to find a simulation program with predictive formula that allows for the input of shed environmental and management variables and would provide outputs that relate to internal shed conditions, bird performance and welfare. The primary desired outputs were specified as performance, litter and air quality, bird movement, and bird health. With regards to a full simulation, these specific output options were not all available (some not available in any capacity). However, predictions for some of these aspects have been well documented in literature using a variety of on-farm monitoring or using real data analysis to predict outcomes of specific flocks. Covering these predictive management strategies is important. While it does not follow the complete simulated frame for a training tool, if these programming tools could potentially be optimised to fit the requirements of this project in some way, then more of the objectives could be achieved.

While the original criteria did not allow for assessing real-time data programs, it would be remiss of this project to not acknowledge the use of such programs on commercial poultry farms. On-farm management systems that use sensors to record real-time data and feed them through a program to predict the outcome of that flock have been used commercially, specifically those developed by companies such as Intelia, Fancom, Cargill, MTech and SKOV. Despite unsuccessful attempts to discuss with them and further understand the versatility of their software for potential use in completely simulated scenarios, the option does remain. A potential difficulty associated with these options is due to their commercial ownership and whether these companies would agree to their programming to be optimised into a simulated training tool for widespread use. Despite this, these commercial products have the option to fulfill several of the desired objectives of this project.

Of these models, the only one that we could analyse was the DOL 539CT+ model provided by SKOV via their Australian supplier, FarmMark. In a training simulation, set up with the purpose to train new users in operating the shed computer system, this computer program worked to instantaneously monitor real-time sensory input from an actual farm and provide updates directly to growers so they are made aware of any issues as they arise. This occurred through the set-up of an extensive alarm system for environmental factors such as temperature, humidity, airspeed and ammonia. Once several flocks of real data have been fed through this program, a predictive aspect exists that can use current values to determine what likely outcomes would occur based on previous results, primarily for body weight. Completely simulated results can also be input into this model. While this is not the primary purpose of this program and would be very time consuming to accomplish, it is certainly a potential option.
Discussion

The models investigated in this project were assessed for their potential as training tools for the Australian chicken meat industry. As predicted, no single model achieves all the desired or required objectives. This placed greater importance on analysing what aspects of available models could be used or built upon to ensure that any training tool used by industry would be insightful and user friendly. The following sections discuss the predictive capability and suitability of the programs, spreadsheets and apps for the Australian chicken meat industry.

Predictive meat chicken production simulator programs

Broiler Growth Model

The Broiler Growth Model (BGM) is primarily designed for people looking to optimise feed rather than test environmental conditions. The BGM does exhibit some different aspects when compared with the EFG Broiler Growth Model. Airspeed and flock density are both included as environmental inputs, which are considered necessary factors to include in a shed management learning tool. The BGM also allows the user to problem solve after providing outputs to see where exactly their system has issues. This allows issues to be identified and addressed, and would be a beneficial feature for many users, as problem solving would test how well concepts have been retained.

The BGM has a similar backing in reliable scientific research to the EFG Broiler Growth Model. According to Matheus Reis (our contact for the model who provided the tutorial), they had worked with Dr Robert Gous (EFG Broiler Growth Model) who assisted throughout its development.

Like the EFG Broiler Growth Model, a complete tutorial would be required to fully understand how to use the BGM, however, the user is also required to create their own feed compositions, which may be too complex and seen as unnecessary by some potential users. Again, it is highly desirable that a training tool would have a user-friendly interface and only require a minimal learning curve. Despite the problem-solving aspect of this model, it would need some work to become easy for users to determine where issues are occurring. An easy way to fix this would be alerting the user to where issues are with either notifications or different text colour. As only two scenarios can be compared at one time, it would take a significant amount of time to observe differences in conditions when compared with the EFG Broiler Growth Model, which allows for multiple comparisons at once. This model does not address any welfare or litter management aspects of meat chicken production, so despite being quite thorough with regards to production, the lack of other shed factors and welfare information does reduce this model’s overall success in satisfying the objectives for a training tool.

EFG Broiler Growth Model

This model has a significant amount of research contributing to the formula and calculations dating back to the 1990s, making it one of the most widely used and trusted nutrition-based models available. Dr Robert Gous, who was a significant contributor to the EFG Broiler Growth Model, has many papers relevant to the field (Gous and Berhe, 2006; Gous, 2014) that reference the use of this model. Gous (pers comm, 2020) explained that the EFG Broiler Growth Model has already seen a significant amount of commercial use, including in Australia.

It allows the user to apply a large number of variable factors to assess bird performance (weight); however, the only environmental factors available were temperature, humidity and lighting. Being able to compare different scenarios to observe how a variety of conditions affect output is a strength of this model, as it can show differences between inputs and allow the user to quickly compare scenarios. Figure 15 is an example of how several temperature settings can be viewed on a single graph to provide a more complete summary of the testing scenarios. The graphical representation of the key outputs, while being more visual than some of the other models, is not always appealing to the
more practically minded growers, who would be the key people using such a training tool. Also, diet formulation is not a desired aspect of a training tool for growers as they have minimal input into the feed and this model requires a feed input option to generate its results.

Despite being an advanced predictive model, there are many aspects that are not ideal for a shed management training tool. This model concentrates significantly on optimising feed to maximise production outcomes, but altering some of the environmental factors, even drastically, sometimes results in minimal differences to the predicted production outcomes (particularly when lighting and humidity were altered). As this model required a significant number of inputs, it is likely that some form of tutorial or training would be required. Unfortunately, this model does not have any output options related to welfare. Mortality exists as an input option, but is not affected by other settings and exists to estimate how production is affected when mortality changes. Therefore, if the user has minimal understanding on how conditions affect bird mortality to begin with, they will receive no information from this model on whether birds are experiencing ideal conditions. The lack of welfare options unfortunately means that despite this model’s commercial use and years of scientific research, it does not fit our objectives of a training tool. Overall, it appears that this model is a high-end program used primarily to fine tune feed specification to improve production output. Therefore, while it is not an ideal training tool for our purposes, it has many aspects that could be used as a framework for a more complete model.

**Poultry Simulator**

*Poultry Simulator* is an environment and shed management simulator with inputs including outside temperature conditions and shed specifications (shed design, heating, ventilation, humidification, feeders and drinkers), which gives users a significant amount of control. It calculates ventilation settings, cooling and minimum ventilation settings, which assists managers with making decisions, plus it helps users work out their shed insulation R-values.

An aspect of the *Poultry Simulator* that has not been observed in other models are error messages where the formula can determine if certain parameters exceed what would be desirable conditions. Red text appears detailing the issue that has occurred and, in some cases, provides a value that would rectify the conditions. Output are primarily focused on performance, with values being provided relative to what is considered ‘ideal’ conditions. This does give the user a specific value to aim for, which can be achieved by altering the inputs. Another positive of this program is that users can input all their own shed values so that the information generated would be relevant to the user.

This model would also require some guidance for initial use but would be far quicker to grasp than the previous nutrition-focused models. This model did not factor in lighting and mortality. While it was not a significant issue, several values in the model were quoted as being according to European standards, which indicated that outcomes from this model may not be that relatable to Australian conditions, but overall concepts obtained from using this model would be valuable.

The use of the *Poultry Simulator* as a teaching tool was referenced in the paper titled ‘Proper environmental management using poultry simulator’ by Garcia Freire (2013). As previously stated, this simulator is excellent for understanding the concepts involved with managing a poultry shed and would be an ideal model to use and adapt for Australian conditions. However, while there was reference to how some of the calculations were developed, most of the author’s papers are written in Spanish and we were unable to make contact with the author to confirm where and how all the research behind the formula was sourced.

**Predictive Excel spreadsheets**

The UGA spreadsheets are very topic-specific regarding the information provided and focus on optimising shed settings for ideal internal shed conditions for chicken production, assuming that the user knows what the ideal conditions are that they should be targeting. While individually they are not
a ‘complete package’ and provide the fewest number of outputs with direct reference to the primary objectives of this project, valuable shed management information can be obtained on many vital systems such as ventilation, heating, moisture control and shed air/pressure leakage. Having a sound understanding of these principles is beneficial for people with minimal experience. Using several spreadsheets simultaneously would provide a more comprehensive understanding of these management strategies. Spreadsheet-based predictive tools can be useful to growers when investigating ideal shed conditions. If their use was to simply help improve understanding of these concepts, then they definitely have value as training tools.

These spreadsheets can be used as stand-alone tools but are also useful in a learning environment such as workshops, run by people and organisations that have a significant amount of experience in the field. The UGA Poultry House Environment Management and Energy Conservation website, where the spreadsheets are located, also acts as a search engine for all publications related to poultry management that have been written (Department of Poultry Science, 2020). This information covers a wide variety of issues not isolated to ventilation, heating and air pressure, which make up the primary topics of the spreadsheets. Due to the sheer magnitude of experience and research conducted in this field by the primary contributors, there is no question that the information gained from using the spreadsheets is reliable.

Mobile applications

Industry-based survey respondents indicated that mobile applications are favoured in terms of ease of use and accessibility as a training tool. After assessing several apps that are currently available, we concluded that they have varying value as training tools. Some use management calculators while others simply provide an outlet for relevant information. The Broiler Expert app provided information on likely conditions and output during a grow-out, but could not be manipulated in any way, which means that it is of limited use apart from as a beginner-level learning tool. The problem-solving aspect of this app that provided possible reasons for poor growth or disease issues had some feasibility, but without a versatile predictive aspect, it does not meet the requirements of several of the shed management training tool objectives.

The Poultry411 and Poultry Toolkit apps also used some form of management calculations, predicting required minimum ventilation based upon a variety of input variables. They predominately dealt with ventilation required to control moisture, which is a vital management aspect that greatly affects litter quality. While this aspect alone is only one part of the overall requirements for a desired training tool, implementing ventilation outcome calculations based upon these input variables would provide valuable insight. The Poultry411 mobile app was developed by the University of Georgia, USA based on spreadsheet calculators available on their website. The Poultry Toolkit app was developed by Auburn University, USA, which also specialises in poultry research.

The i-WatchBroiler app uses a transect-based approach that has been trialled in commercial sheds and is considered reliable in the outcomes that it produces. Input information specific to the flock, such as bird strain, age, housing and management conditions, also makes this app suitable in how it is able to predict welfare outcomes, something that many other tools and programs are unable to do. It does rely on the user conducting regular observations in a consistent manner and inputting this information into the app. It is also only available on Android devices, making its availability limited. Currently, this app is specific for European users and for it to be relevant for the Australian industry, the welfare outcomes would need to be aligned with Australian welfare standards.

Real-time monitoring and predicting flock outcomes

Several models have been developed that use on-farm monitoring or data analysis from previous flocks to predict outcomes related primarily to bird production but also welfare issues. While only one model was observed to test its features, due to the lack of availability or returned correspondence, several commercially available models and published papers could not be analysed to determine what
relevance they potentially had to the objectives of this project. Ideally, some of these models and predictive software could be optimised to be included into a training tool allowing for a more complete simulation, factoring in more influential variables and outcomes. The reliability of these predictive methods is very high, whether it be the use of CFD or machine learning algorithms, due to the use of actual data from live batches or the comparison of simulated results with real conditions. Unfortunately, due to these studies being conducted overseas, their direct relevance to Australia is low; however, they give a framework for potential research that could lead to the development of a predictive simulation training tool that has a direct correlation with Australian conditions and our standard practices.

Several commercially available management programs were found, with some being used within Australia. Unfortunately, due to the nature of these, they were mostly unable to be observed directly. The DOL 539CT+ program provided from SKOV was an example of a real-time monitoring system that addressed the wide variety of environmental shed factors, along with several management options. By itself, this program wouldn’t be optimal as a training tool due to its highly complex setup and its limited outright predictive capabilities (without direct input from a real farm). However, it does include many relevant inputs (temperature, humidity, ammonia, ventilation, heating and CO2) and during the tutorial of the program it was revealed that a compatible program ‘Farm Online’ could be used in conjunction that provided the user with a simulated farm where conditions could be altered with outcomes provided.

Summary of assessment of the training tools

After analysing the available models, it is highly unlikely that a single model would perfectly fit Australian conditions, especially when all desired objectives are considered.

- The primary purpose of the mostly nutrition-based models (EFG Broiler Growth Model and Broiler Growth Model) was feed composition and optimisation for greater growth, with environmental aspects being present but not integral.

- The Poultry Simulator provided a mixture of environmental variables, along with optimising management systems such as ventilation and cooling, but failed to address where issues might arise with additional moisture potentially going into the litter.

- The Excel spreadsheets work excellently to provide information on specific management aspects of chicken meat production but fail to directly relate these back to the birds themselves.

- The mobile applications, while being a more favourable delivery method, vary greatly in usability, with several providing some relevant calculations and simulations but never singularly addressing a wide variety of factors.

Especially when considering a primary objective of this project was to find a model that provided information on poultry litter, air quality, bird welfare and bird movement, it was unfortunate that these factors were not directly observed in any of the models. Despite this, several of these welfare factors were available in literature on real-time monitoring programs, which also made use of predictive calculations. This indicates that while more complicated, it would be possible to include some of these factors in a model if it was to be developed, but would require direct contact with those related to the research or companies with commercially available management software.
Implications

After researching and analysing available models, it was determined that the potential for these to be used as a shed management training tool by the Australian industry would be limited as they currently stand. These models have been developed and used predominantly overseas and the accuracy of outputs with respect to current Australian practices has not been confirmed. Despite this, the concepts addressed in these models can definitely be useful to the Australian chicken meat industry. While none of these models address the majority of the desired objectives of a shed management training tool, their combined use would assist anyone trying to gain a greater understanding of how certain environmental and management factors influence shed conditions, production and animal welfare outcomes. It is important to understand that these models provide a conceptual understanding of likely production outcomes, but hands-on experience is ultimately required to apply, test and further develop the concepts.

All models assessed throughout this report were free to use except for the *EFG Broiler Growth Model*, which costs US$4000 per annum for access. The *Broiler Growth Model*, despite not requiring a paid subscription, requires permission from the developers to use and an account must be created. Despite the lack of likely widespread use and specific relevance to Australian conditions, most of these models can be accessed for free and can provide some beneficial outcomes.
Recommendations

Our investigation of predictive meat chicken shed simulation models has shown that there is no one model that can be used as a training tool that fits all the requirements of the Australian chicken meat industry. Results of the chicken meat industry survey indicate that if a suitable training tool is available to the industry, then it is likely to be used. Tools are currently used by industry, but they are limited. We therefore recommend:

- a specific training and simulation tool be developed for the Australian chicken meat industry. Such a tool would allow people with minimal knowledge of poultry shed conditions to better understand how they directly and indirectly contribute to the production and welfare of the birds, and would provide an invaluable training experience in a virtual and safe setting
- the simulation tool also be developed for use by experienced farmers, so they can evaluate the likely outcomes of changing their management practices or fine tune conditions in their sheds
- the information provided in this report, primarily from the industry survey, be used to develop a framework for a training tool that will contribute to its actual development
- the training tool has ‘scenario-based applications’ that are common to most sheds, which was one of the recommendations made during the phone interviews.

The training tool should use a conceptual ‘practice shed’ for simulations and should include the following recommended inputs, outputs and visual learning features:

**Recommended inputs for a training/simulation tool**

- temperature and relative humidity (indoor and outdoor)
- shed dimensions
- ventilation type, ventilation capacity, heating and cooling type
- flock inputs (breed, age, placement and seven-day weight)
- stocking density and thinning program
- lighting program
- static pressure
- diet type
- airspeed
- ammonia and CO\textsubscript{2} levels
- water consumption
- litter condition
- welfare indicators
  - lameness
  - contact dermatitis (e.g. footpad and hock burn)
  - occurrence of disease (e.g. coccidiosis, ascites, necrotic enteritis)
  - dirty feathers
  - wounds
  - mortality

**Recommended outputs for a training/simulation tool**

- ventilation rates
- temperature and relative humidity
- growth rates
• FCR
• moisture
• airspeed
• shed leakage
• wind chill
• air quality
  o ammonia
  o $\text{CO}_2$
• welfare outcome
  o poor, good, excellent
  o mortality

Visual learning features

Visual learning cues should be included in the user interface to simplify understanding of the simulation inputs and help users understand the simulation outputs, including:

• visual learning cues such as those in the Poultry Simulator, as they provide instant feedback about unrealistic or unfavourable inputs
• drop-down menus or a click-and-drag feature for inputting data
• visual tools for environmental inputs, such as a thermometer for temperature or spinning fans to represent ventilation
• warnings for when outputs are outside normal or acceptable ranges (for example: “Ammonia levels are likely to exceed 20 ppm at these ventilation rates”)
• outputs expressed as words, numbers or a combination of both
• outputs presented as graphs showing the trends of each parameter throughout the grow-out (or period of time of interest).

Extension pathways and options

The purpose of a shed management training tool is for growers and others involved in managing chicken sheds to understand how ventilation systems and the interactions of shed conditions can impact the internal shed environment. Users will get the greatest benefit and understanding about how different processes interact by being able to virtually manipulate the shed conditions and ventilation settings in different situations and scenarios. While there are many complex processes to consider in shed management, basic training in this area is considered important by industry and it is interested in having a suitable training tool made available.

We recommend that the following actions be taken to develop the tool and roll it out to industry for uptake:

• develop some short how-to explanatory videos to improve understanding of how to use shed management tools, and how users can find the relevant input information
• provide grower ventilation training opportunities that:
  o use the major ventilation supplier companies
  o provide information and tutorial sessions on how growers can get the best performance from their shed
  o include the use of a computer-based training tool to help growers understand how its use can help with decision making
  o provide common issues as scenarios on how to troubleshoot potential problems
• develop tutorials and training for new users to help improve uptake and user experience
• work with researchers, commercial distributors of ventilation management programs, user-centred design specialists and trainers to develop the most relevant and reliable model that addresses the widest variety of relevant factors.
Appendices

Appendix 1 – Industry survey questions

Q1: Do you currently use, or know of, any computer-based shed management training tools?
   - Yes
   - No

If no…

Q2: Why don’t you use shed management training tools?
   - No suitable training tools available
   - Not needed
   - Other (please specify)

If yes…

Q3: Please list the shed management training tools that you use

Q4: What do you like about these training tools?
   - Easy to use
   - Provides good information
   - Good for growers/staff to use as a learning tool
   - Used to make management decisions
   - Other (please specify)

Q5: What don’t you like about these training tools?
   - Don’t provide enough information
   - Takes too long to learn how to use it
   - Too complicated
   - Other (please specify)

All respondents

If a new shed management training tool was developed…

Q6: What level of employment would you like to see a shed training tool pitched at? (Select all that apply)
   - Entry level – no assumed knowledge
   - Basic – Farm hand
   - Intermediate – Assistant manager
   - Advanced – Farm manager
   - Other (Please specify)

Q7: What are the most important inputs to include in a shed simulation training tool? (Tick as many as required)
   - Temperature
   - Relative humidity
• Stocking density
• Lighting program
• Ventilation type
• Diet type
• Other (please specify)

Q8: What types of information would you like to see a shed simulation tool generate? (Tick as many as required)

• Litter moisture
• Thermal comfort
• Water usage
• Air quality
• Growth
• Mortality
• Other (please specify)

Q9: How would you like a training tool made available?

• Online – web based (required internet connection)
• Software download directly onto computer (does not need internet once downloaded)
• Phone or tablet app
• Other (please specify)

Q10: How would you like people to interact with a shed training tool? (Select all that apply)

• Spreadsheet based
• Game based
• Animated
• Virtual reality
• Training package with questions included (competency based)
• Other (please specify)

Q11: How likely are you to use a computer-based tool to train growers/staff in shed management?

• Never
• Unlikely
• Unsure
• Likely
• Very likely

Q12: Would you like a shed training tool available in multiple languages?

• Yes
• No
• If yes, please specify which languages

Q13: Can we contact you to find out more about your experience in shed management training?

• Yes
• No

Q14: If yes to Q13, please provide your contact details
<table>
<thead>
<tr>
<th>Inputs</th>
<th>Predictive simulation programs</th>
<th>Predictive spreadsheets and calculators</th>
<th>Mobile device applications</th>
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</thead>
<tbody>
<tr>
<td>Broiler growth model</td>
<td>EFG Broiler growth model</td>
<td>Moisture control spreadsheet</td>
<td>Poultry 411</td>
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<td>Broiler expert i-Watch</td>
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<td>Poultry house leakage calculator</td>
<td>Poultry Farm toolkit</td>
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<td>External environment</td>
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<td>Poultry house heat gain analysis</td>
<td>Broiler expert</td>
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<td>Temperature</td>
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<td>Tunnel air speed / static pressure</td>
<td>i-WatchBroiler</td>
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<td>Relative humidity</td>
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<td>Shed conditions</td>
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<td>Temperature - inside shed</td>
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<td>Litter condition</td>
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<td>Lighting</td>
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<td>Bird inputs</td>
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<td>Animal type/genetics</td>
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<td>Water consumption</td>
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<td>Disease/health</td>
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<td>Mortality</td>
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<td>Outputs</td>
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<td>Growth/weight gain</td>
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<td>FCR</td>
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<td>Ventilation rate</td>
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<td>Shed leakage</td>
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<td>Thermal comfort</td>
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Key:
- Included
- Included with limited capacity
- Not included
References


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training tools for the Australian chicken meat industry

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January 2021

AgriFutures Australia publication no. 21-156
AgriFutures Australia project no. PRJ-011701

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