The economics of layer diet amino acid levels throughout lay

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Foreword

This project was conducted to demonstrate the benefit of considering economics in addition to least-cost diet formulation for the layer hen operation and industry.

Due to the high cost of feed for poultry, there is vast pressure to formulate 'least-cost' diets that meet nutritional requirements. However, the main aim of any commercial enterprise is usually to maximise profits with the resources or inputs available, which is not accounted for in least-cost formulation. Thus, the output of this project is a review that discusses and compares traditional least-cost diet formulation with max-profit and stochastic approaches to demonstrate the importance of production and market data in formulating diets by more economically sustainable means.

This project was funded from industry revenue which is matched by funds provided by the Australian Government.

This report is an addition to Australian Eggs Limited's range of peer reviewed research publications and an output of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian egg industry.

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Executive Summary

Due to the high cost of feed for poultry, there is vast pressure to formulate 'least-cost' diets that meet nutritional requirements. However, the main aim of any commercial enterprise is usually to maximise profits with the resources or inputs available, which is not accounted for in least-cost formulation.

Thus, the traditional least-cost diet formulation approach has been compared with max-profit and stochastic approaches to demonstrate the importance of production and market data in formulating diets by more economically sustainable means. The Australian layer industry faces particular egg sale price volatility in the market and many challenges as our production system changes from a cage-based system to that of a free range-based system. Thus, increased flexibility during these uncertain times may give the layer industry greater opportunity and capacity to cope with market fluctuations.

A practical example of how a layer operation may benefit from these approaches demonstrates the differences between these feed formulation strategies, highlights their capacity as decision making tools and the extra profits that may be available when formulating to a max-profit model. In this example, the focus is on dietary methionine level as it is an expensive dietary constituent and holds important implications for egg size. The response of intake, egg weight, total egg mass and percentage production of cage layers 52-58 weeks of age to 5 true digestible dietary methionine levels was sourced from Bregendahl et al. (2008) to model the response of layers over the 6 week period. Diets reported were reconstructed using modern prices (4th quarter 2019, $AUD) sourced from industry. The standard least-cost diet formulated to standard nutrient recommendations consisted of 0.48% methionine costing $461.26, resulting in an estimated egg mass of 52 g/bird/day and an egg production of 83%. Therefore, a farm of 20,000 hens from 52-58 weeks of age (42 days) may expect to produce a total of 58,100 dozen eggs (on average 700g egg grade) with a sale price of $2.20/doz. Variable and fixed costs were calculated at $93,575 and revenue (egg sales + spend hens) at $128,220 giving a profit of $34,645 for the 6 week least-cost simulation. Calculations were repeated for all methionine levels reported in Bregendahl et al. (2008) and the highest dietary methionine level of 0.6% generated the greatest profit of $34,830. Thus, the most economic nutrient level may not correspond with the biological nutrient recommendation, and the greater flexibility and revenue provided by max-profit formulations may aid the poultry industry particularly during challenging economic periods.

Therefore, the way in which poultry diets are formulated should be given consideration in light of the capacity we now have to collect, transport, analyse and store production and market data. Diets formulated to least-cost are not necessarily the same as those formulated to maximise profit. As producers better understand how their hens respond to different dietary specifications, the opportunity arises to choose the set of specifications that result in maximum profits for their unique situations.

Overall Conclusions

The Australian poultry industry experiences challenges with the high cost of poultry feed and the layer industry in particular experiences large market volatility. Present least-cost feed formulation to requirements for optimal biological performance restricts the options that nutritionists and poultry managers have to navigate these difficult times. Max-profit and stochastic approaches use production and market data to formulate diets by more economically sustainable means, giving increased flexibility, opportunity and capacity for the Australian poultry industry to cope and thrive under market challenges. Therefore, the method by which poultry diets are formulated should be given consideration in light of the capacity we now have to collect, transport, analyse and store production and market data. With some improvement to production and market data collection, and as producers better understand how their hens respond to different dietary specifications, the opportunity arises to choose the set of specifications that result in maximum profits for their unique situations.

1 The importance of flexible feed formulation strategies

Feed constitutes more than 65% of live production costs in poultry production within Australia (Wilkinson, 2018); thus there is vast pressure to formulate 'least-cost' diets that meet nutritional requirements. Least-cost linear programming formulates the cheapest possible diet while still fulfilling the specified nutrient requirements of the bird. While the goals of companies or producers differ, generally, the main aim of a commercial enterprise is to produce maximum profits with the resources or inputs available. In this context, it is necessary to hold a firm understanding of the cost of inputs, value of outputs and model the relationship between the two to determine the maximum profit achievable. Unfortunately, least-cost diet formulation is limited as it does not take this relationship into account, and does not necessarily generate the optimal solution to maximise profits (Cerrate and Waldroup, 2009). Nutrient requirements recommended for each commercial breed are determined by studies that ensure the minimal amount of nutrient can be offered without significantly affecting the optimal biological performance. However, the biological optimum of a bird does not necessarily equal maximum profits. For example, it may be more profitable to feed a slightly lower protein diet than what is required to meet the breed recommendations as protein is an expensive dietary component. Or, if a particular market preferred larger eggs for example, it may be profitable to feed layers methionine inclusions above recommendations to achieve the greater egg size and hence access a price premium. Care must be taken to consider the upper and lower bounds of nutrients as bird welfare must not be sacrificed in the process.

With big data and communications technology rapidly evolving, there is opportunity to capture and provide timely updates of production and market data to feed into poultry diet decision making and formulation (Wilkinson, 2018). Thus, there is opportunity to shift the way diets are formulated to better reflect the end goals of producers in the poultry industry. The Australian layer industry may experience particularly volatile changes in egg price, principally due to changes in supply rather than demand and in the past has been reported to possess less physical form and financial data reporting than other industries (O'Connor and Giles 2001). Thus, it may be of particular interest for producers within the Australian layer industry to enhance record keeping where possible, which would aid in future forecasting, help to steady egg supply, and allow layer diets to be formulated to optimise economic returns over the forecasted period.

Not only does the industry experience uncertainty due to volatile egg price, but ensuring that formulated and mixed diets contain the intended amount of nutrient is another uncertainty facing many agricultural industries. Within the poultry industry, integrated nutritionists may have access to NIR for diet formulation. However, they may experience delays in receiving this information. Additionally, many consultant nutritionists may not have access to a NIR system. Thus, nutritionists may need to rely on historical or 'book' values. To combat the potential variation between the nutrient content of the actual feed ingredient and those in the book values, safety margins must be applied to formulations to ensure the minimum nutrient requirements of poultry are being met. However, increasing safety margins raises diet cost and thus compromises profitability. Furthermore, how can nutritionists decide the size of a safety margin to implement? In this instance, stochastic feed formulation may be of assistance, as it uses nutrient variability data to allow nutritionists to decide the level of uncertainty they are comfortable with in their diet formulations.

Therefore, this paper will review the considerations of formulating diets in a traditional least cost versus max profit and stochastic approaches and simulate a practical example to demonstrate the differences between these feed formulation strategies. The aim is to demonstrate the importance of improving collection of ingredient, production and market data and using this data to formulate diets by more economically sustainable means. As the layer industry faces particular challenges due to uncertainty in their market and the requirements for protein and amino acids of layers are an expensive constituent of the diet and hold important implications for egg size, this paper will hold focus on methionine levels in layer diets for the diet formulation examples.

2 Feed formulation models

2.1 Least-cost

In traditional least-cost feed formulation, a series of nutrient requirements that maximise performance are set; however, profitability may be compromised when rigid nutrient requirements are imposed (Cerrate and Waldroup, 2009). Least-cost feed formulation takes into account fluctuations in feed ingredient price, and uses the cheapest combination of ingredients which satisfy the given nutrient requirement and any other limitations set on the feed ingredient inclusion rates. However, the resulting final product or output is not considered in the calculation. Additionally, least-cost linear programing models disregard variability in feed ingredients (D'Alfonso et al., 1992), which can also be problematic.

2.2 Max-profit

A max-profit model of feed formulation takes into account fluctuations in feed ingredient price, as well as the variation in performance at various nutrient levels and the final value of the resulting product (Cerrate and Waldroup, 2009). Thus, as outputs are considered in formulation, diets may be formulated in a non-linear fashion with 'nutrient responses' rather than 'nutrient requirements'. Equations or restrictions can also be entered to consider the impact of nutrients on the health and welfare of the bird, to ensure that the max profit solution meets these requirements. Many max-profit models (for example, Pesti et al., 1986; Cerrate and Waldroup, 2009) centre around the law of diminishing returns; advantages gained from a slight improvement in input will only advance marginally per unit and may plateau, or decrease, after a given point (Brue, 1993). For example, as we increase methionine level egg size may increase, but at a diminishing rate. While some studies only use one equation to define profit over a whole production cycle, Cerrate and waldroup (2009) showed the importance of maintaining multiple diets by incorporating multiple stages into their model to define the performance over multiple stages of growth leading to optimal end profits.

2.3 Stochastic

Stochastic models attempt to quantify the level of uncertainty of ingredient nutrient variability that exists in both linear and non-linear feed formulation models. Due to feed ingredient variability, feeds formulated on average values are expected to contain less than the minimum restriction (least-cost) or optimal content (max-profit) 50% of the time (Pesti and Seila, 1999). This inaccuracy or uncertainty means that many nutritionists implement safety margins into their formulations. However, the size of the safety margin is difficult to decide if we do not know the level of uncertainty that exists. Stochastic models essentially shift the diet up or down the diet's nutrient distribution (calculated as a sum of the ingredient's nutrient distributions) as the probability of failing to meet a nutrient requirement or chosen nutrient level will decease as the mean amount of nutrient in the diet is increased (D'Alfonso et al., 1992). Thus, this method allows a nutritionist to achieve a set level of probability that the diet will fall within the desired nutrient levels. While this naturally increases diet cost, standard levels of variation within practical diets can induce substantial issues. For example, Pesti et al. (2020) reported that the variation found in a practical broiler diet is enough that 12.9% are expected to have less than 0.40% non-phytate phosphorus and 12.8% are expected to have more than 0.50% non-phytate phosphorus. Thus, the normal levels of variation within industry may be enough to induce leg issues such as phosphorus rickets or tibial dyschondroplasia. However, this approach does assume that the distributions of the ingredients are normal, which need not necessarily be the case (Kirby et al., 1993).

3 Feed formulation example

3.1 Methodology

The response of intake, egg weight, total egg mass and percentage production of cage layers 52-58 weeks of age to 5 true digestible dietary methionine levels was sourced from Bregendahl et al. (2008) to model the response of layers over the 6 week period. Diets reported were reconstructed using modern prices (4th quarter 2019, $AUD) sourced from industry.

3.2 Least-cost vs max-profit

Four diets containing typical Australian feed ingredients, priced at the typical cost for this current period (4th quarter 2019, $AUD) were constructed via a least-cost approach with the methionine levels reported in Bregendahl et al. (2008) to determine the change in diet cost and production output as methionine level changes (Table 1).

Table 1 Production and economic data to model the effect of methionine (Met) level on production and profitability, production data sourced from Bregendahl et al. (2008), economic data estimated from current values provided by the Australian layer industry to serve as a guide for this exercise.

Dietary true digestible Met level (%)	Intake (g/bird/day)	Diet cost (tonne)	Egg Production[1] (%)	Egg Weight[1] (g)	Egg grade
0.13	60.8	455	23	56	600
0.25	92.3	456	74	59	700
0.37	97.5	457	83	62	700
0.48	92.3	461	83	62	700
0.6	91.0	465	83	62	700

[1]Calculated from equations provided in Bregendahl et al. (2008) as means were not tabulated

All diets were barley-wheat-soybean meal based, were iso-energetic and formulated to the same digestible lysine concentration (0.91%), keeping all other amino acids (but methionine) constant in a ratio to digestible lysine. The mean methionine requirement reported over several studies in Bregendahl et al. (2008) is 47% (in relation to lysine requirement, set at 100%). Thus, diet 3 from the aforementioned study containing 48% methionine will be chosen as the ‘standard industry diet’ to compare to as it is the closest diet to the recommendation and thus will give suitable hen performance data. The response of layers to changing dietary methionine level was modelled from the data provided in Bregendahl et al. (2008) and the price of egg sales was also estimated to represent the typical Australian price that may be attained for cage eggs (Table 2).

Table 2 Profit margins calculated for each dietary methionine level

Dietary true digestible Met level (%)	Diet cost (tonne)	Egg grade	Egg sale price (doz)	Profit ($AUD)
0.13	455	600	207	-14,571
0.25	456	700	220	25,817
0.37	457	700	220	32,943
0.48	461	700	220	34,645
0.6	465	700	220	34,830

Therefore, in this simplistic example, the standard industry diet consisted of 0.48% methionine costing $461.26, resulting in an estimated egg mass of 52 g/bird/day and an egg production of 83%. We will assume the following costs; pullets ($9.50 each; as we are only focussing on a 6 week period of production out say a likely 74 weeks of production, we will simply equate this to $0.13 per week per hen or $0.77 per hen for the sake of our profit calculation over this 6 week period), packaging cost ($0.23 per doz), other costs (labour, utilities, insurance, leasing and transport; $0.50 per doz). Therefore, a farm of 20,000 hens from 52-58 weeks of age (42 days) may expect to produce approximately 35 eggs per hen for a total of 58,100 dozen eggs, at an average of 62 grams/egg over this period which falls into the 700g egg grade with a sale price of $2.20/doz. Spent hen sale price may be equated to represent $0.02 over this 6 week period (calculated as per pullet price). With an intake of approximately 77.5 tonnes of feed for all birds over the 6 week period, at $461 per tonne, this equates to $35,762 total diet cost. Thus, the profit in this simplistic 6 week simulation is equal to;

Profit = Egg sale + Spent hen sale – packaging cost/doz – other cost/doz – pullet cost – diet cost
= (58,100*2.20) + (20,000*0.02) – (58,100*0.23) – (58,100*0.50) – (20,000*0.77) – 35762
= $34,645

Profit margins were calculated for the remaining four dietary methionine levels, as given in Table 3. It is evident that the greatest profit of $34,830 over the 6 week simulation may be achieved with the 0.6% dietary methionine level giving a diet cost of $465 per tonne, $4 per tonne higher than that of the least-cost model but generating a total of $186 more profit.

Table 3 Calculated change in marginal profit for each dietary methionine level

Dietary true digestible Met level (%)	Change in marginal profit ($AUD)
0.13	
0.25	40388
0.37	7126
0.48	1702
0.6	186

3.3 Least-cost versus stochastic

The 'standard' 48% methionine diet costing $461 per tonne previously described will be used for this exercise. To manipulate the diet via a stochastic model, the freely available Microsoft® Office Excel based spreadsheet 'LSMFT' developed by Professor Gene Pesti from the University of Georgia was used (Pesti and Seila, 1999). The spreadsheet was altered so that diets would solve to the variability of digestible methionine in the ingredients, rather than true protein as it was previously set, in order to suit the following example. Standard deviations of digestible methionine in feed ingredients were sourced from the Australian feed ingredient database developed by Moss et al. (2020a). At a probability of P = 0.5, the stochastic solution matches the linear solution; that is, there is a 50% chance that nutrients within the diet will fall below or above the mean value. For example, for digestible methionine, the frequency distribution of simulated dietary methionine level for P = 0.5, the ‘standard’ diet, is shown in Figure 1.

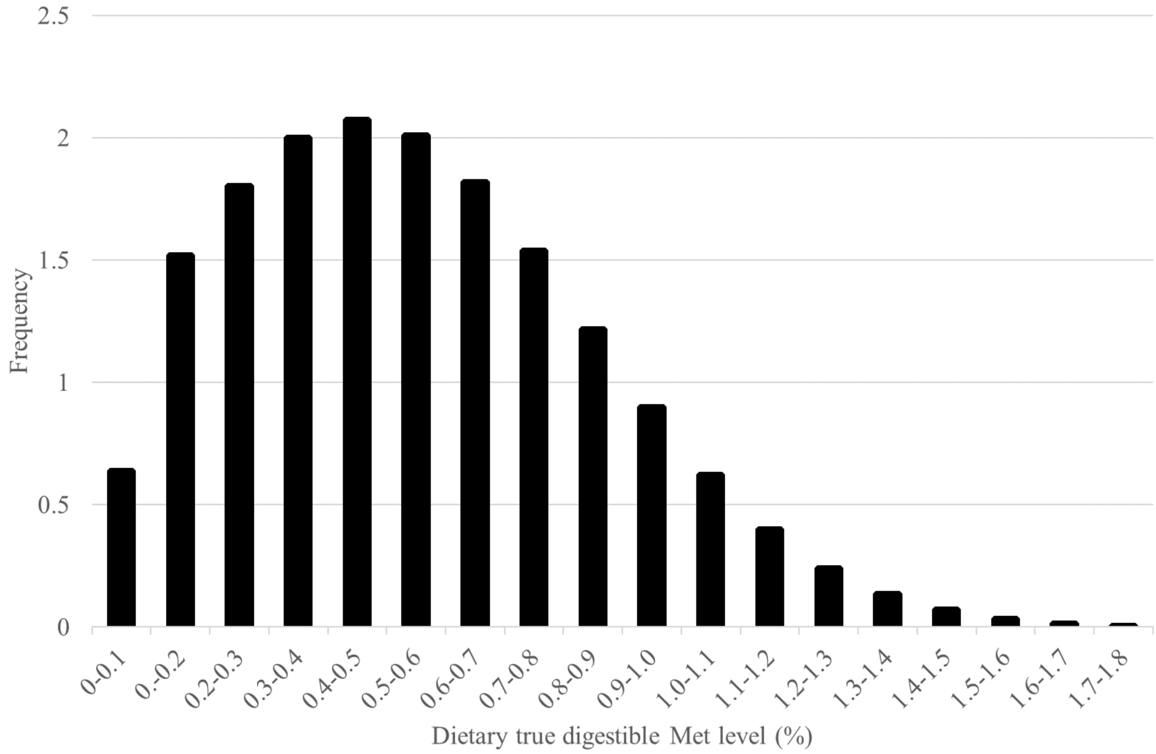

Figure 1 Frequency graph displaying the distribution of simulations of dietary true digestible methionine level (%) formulated to 0.45% dietary true digestible methionine, with P = 0.5 (mean is equal to 0.45% dietary true digestible methionine).

The standard diet formulated at P = 0.5 (methionine level = 0.48) costs $461 but has approximately a 20% chance of a diet with a dietary true digestible methionine level of < 0.3, which could potentially be disastrous for profitability as previously shown. However, when formulated to P = 0.8 (methionine level = 1.26; Figure 2), the diet now costs $486, $25 more than the standard diet, but has <1% chance of a diet with a dietary true digestible methionine level of < 0.3.

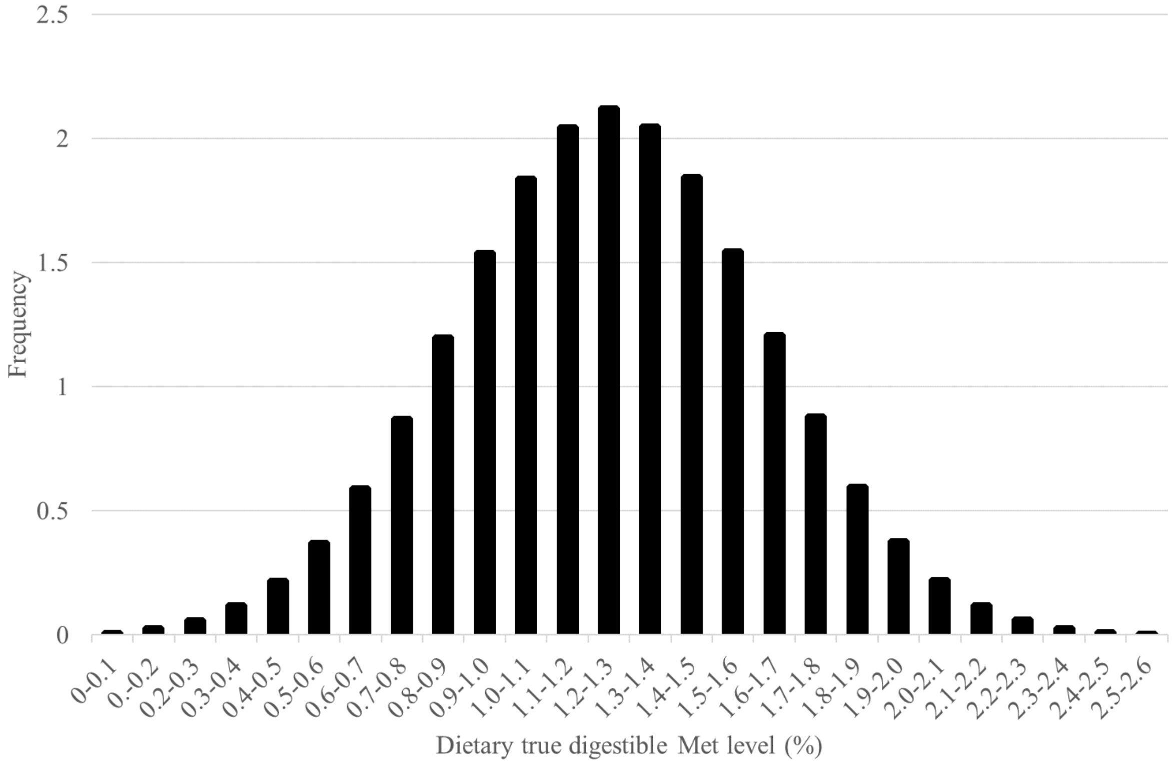

Figure 2 Frequency graph displaying the distribution of simulations of dietary true digestible methionine level (%) formulated to 0.45% dietary true digestible methionine, with P = 0.8 (mean is now equal to 1.26% dietary true digestible methionine).

Nevertheless, 25$ more per tonne is quite expensive; thus, a middle ground may be achieved at P = 0.6 for example, which costs $468, $7 more than the standard diet, but has a 9% chance of a diet with a dietary true digestible methionine level of < 0.3. The mean dietary true digestible methionine (a), price (b) and approximate odds of a diet of <0.3% dietary true digestible methionine (c) as the probability is shifted from P = 0.5 to P = 0.9 is shown in Figure 3. The odds of a diet falling below levels which may cause serious health, wellbeing or production consequences may also be added to a max-profit model to determine the optimal safety margin to use.

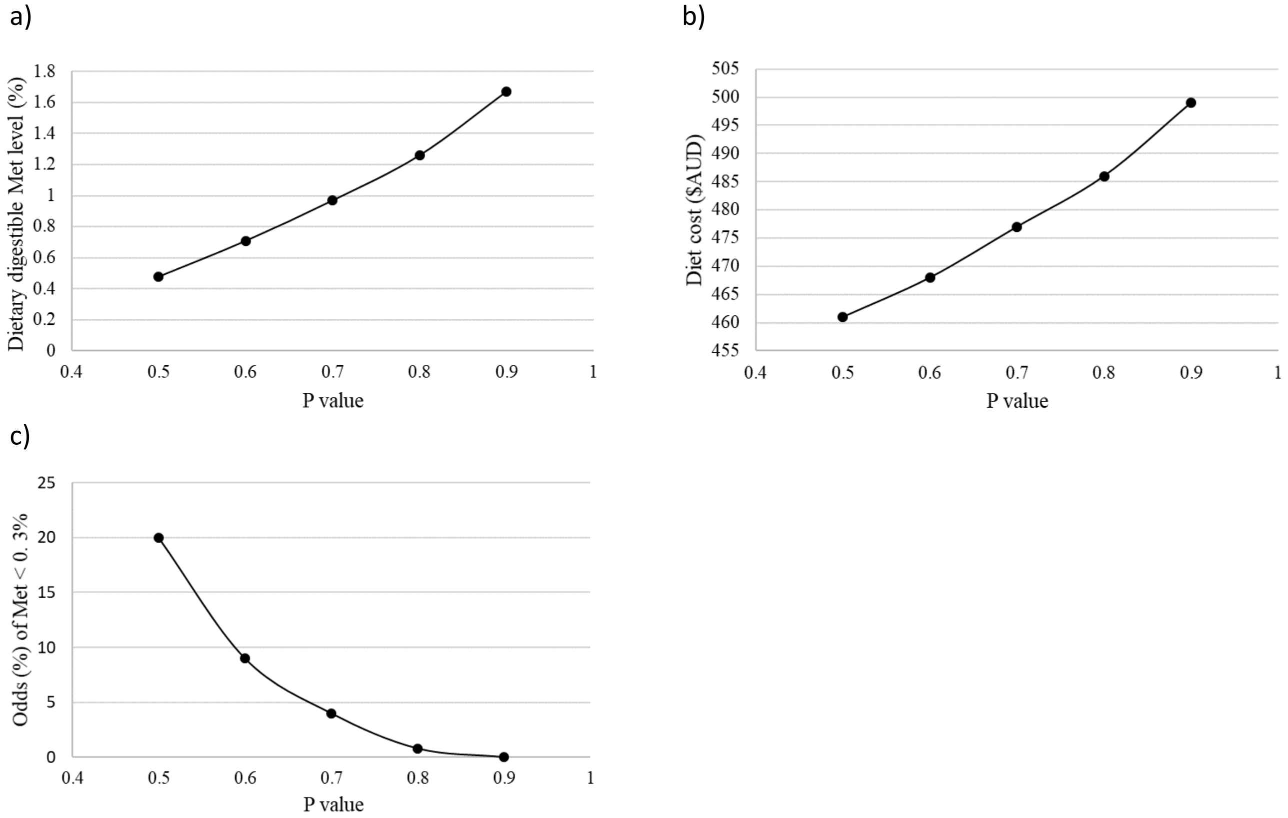

Figure 3 Mean dietary true digestible methionine (a), price (b) and approximate odds of a diet of <0.3% dietary true digestible methionine (c) as the probability is shifted from P = 0.5 to P = 0.9.

4 Further considerations

The Australian layer industry faces particular market volatility, and thus the increased flexibility that formulating to max-profit provides may help the long term sustainability of businesses and stochastic models may assist nutritionists in decision making. Due to the volatile egg prices, it may be beneficial for farms to stock smaller batches of feed that have frequent small changes to reflect the current market conditions, and make any changes more gradual allowing the hens to adapt to the new feed. However, this may be impractical as frequent diet transport is expensive. A median ground needs to be sought, and perhaps multiple diet changes would be more practical if precision feeding technology is adopted, which allows dietary components to be blended on farm for frequent adjustments (Moss et al., 2020b). The layer industry possess less physical form and financial data reporting than other industries (O'Connor and Giles 2001), and the array of business models from large integrated facilities through to smaller independent farms makes the broad implementation of stochastic and max-profit diet formulation difficult. However, if the industry makes a dedicated effort and focus is placed on improving data collection now, with time and further advances in technology, these concepts may become easily implemented and adopted, leading to more sustainable outcomes in the long term.

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Plain English Summary

Project Title:	The economics of layer diet amino acid levels throughout lay
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Objectives	This project was conducted to demonstrate the benefit of considering economics in addition to least-cost diet formulation for the layer hen operation and industry.
Background	Due to the high cost of feed for poultry, there is vast pressure to formulate 'least-cost' diets that meet nutritional requirements. However, the main aim of any commercial enterprise is usually to maximise profits with the resources or inputs available, which is not accounted for in least-cost formulation.
Research	Thus, this project compares traditional least-cost diet formulation with max-profit and stochastic approaches to demonstrate the importance of production and market data in formulating diets by more economically sustainable means.
Outcomes	Present least-cost feed formulation to requirements for optimal biological performance restricts the options that nutritionists and poultry managers have to navigate these difficult times. Max-profit and stochastic approaches use production and market data to formulate diets by more economically sustainable means, giving increased flexibility, opportunity and capacity for the Australian poultry industry to cope and thrive under market challenges. Therefore, the method by which poultry diets are formulated should be given consideration in light of the capacity we now have to collect, transport, analyse and store production and market data.
Implications	With some improvement to production and market data collection, and as producers better understand how their hens respond to different dietary specifications, the opportunity arises to choose the set of specifications that result in maximum profits for their unique situations.
Key Words	diet, formulation, least-cost, max-profit, stochastic, layer
Publications	Alternatives to formulate layer diets beyond the traditional least-cost model Moss, A.F., Parkinson, G., Crowley T.M., Pesti G.M. Submitted to Animal Nutrition