



Growth Trajectories and Survival Patterns of Lucerne-Supplemented Sasso Chickens Using Nonlinear Models

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Article Info

ISSN (Online): 2582-7138

Impact Factor (RSIF): 8.04

Volume: 07

Issue: 03

May-June 2026

Received: 17-03-2026

Accepted: 15-04-2026

Published: 13-05-2026

Page No: 505-510

Abstract

Background: Growth and survival are pivotal determinants of productivity in dual-purpose chickens. While lucerne (*Medicago sativa*) supplementation is widely used to improve nutritional intake, its quantitative effects on growth dynamics in Sasso chickens remain under-investigated. This study evaluated growth trajectories of Lucerne-supplemented Sasso chickens using nonlinear growth models and integrated survival analysis to support management decisions.

Methods: Body weight data from 500 Sasso chickens (12–60 weeks) were fitted to Gompertz, Brody, and Logistic models to estimate asymptotic weight, growth rates, and inflection points. Survival functions and force of mortality were assessed to characterize age-specific mortality risk. Model performance was evaluated using R^2 , MSE, AIC, BIC, and residual diagnostics.

Results: All models described sigmoidal growth, with asymptotic weight ~1,941 g. The Brody model showed the best fit ($R^2 = 0.865$; $MSE = 4,288.2$; lowest AIC/BIC), particularly for late growth phases. Gompertz and Logistic models effectively captured early and mid-growth dynamics, estimating inflection points at ~16 and 17 weeks, respectively. Survival analysis revealed age-specific mortality patterns that complement growth dynamics for optimized management.

Conclusions: Nonlinear growth models reliably characterized Lucerne-supplemented Sasso chicken growth. The Brody model is recommended for late-stage prediction, while Gompertz and Logistic models inform early growth phases. Integrating growth and survival analyses supports evidence-based strategies for feeding, harvest timing, and risk management in semi-intensive systems.

DOI: <https://doi.org/10.54660/IJMRGE.2026.7.3.505-510>

Keywords: Sasso chicken, lucerne supplementation, Gompertz model, Brody model, Logistic model, survival analysis, poultry growth

1. Introduction

Understanding growth trajectories in poultry is essential for optimizing feeding strategies, improving production efficiency, and enhancing flock performance. Mathematical growth models help quantify biological growth patterns, enabling accurate prediction of body weight, feed conversion, and management decision-making. Nonlinear models such as Gompertz, Logistic, and Brody functions are commonly used to describe sigmoidal growth in chickens. These models differ in flexibility and

biological interpretation, with each emphasizing specific growth phases (Topal & Bolukbasi, 2008; Aggrey, 2002) [11]. The Sasso chicken, a dual purpose genotype valued for adaptability and meat quality, is popular in smallholder and commercial production systems. Nutritional supplementation with lucerne (*Medicago sativa*) enhances protein intake and may influence growth dynamics, but quantitative evaluations using established growth models are limited (Ginindza, 2023; Suwignyo *et al.*, 2021) [3, 10]. Understanding how lucerne affects growth curves and survival probability is important for optimizing feeding strategies and maximizing productivity in semi intensive systems.

This study aimed to use Gompertz, Logistic, and Brody models to characterize growth in Lucerne-supplemented Sasso chickens and to integrate survival analysis for age-specific mortality risk. The findings will contribute to improved growth prediction, nutritional planning, and flock management.

2. Materials and Methods

2.1. Description of the Study Site

This study was conducted at the Matopos Research Station in Bulawayo, Zimbabwe (22.23 °S, 31.30 °E). The region is characterized by a dry season extending from April to October and a rainy season from November to March, with an average annual rainfall of less than 446.8 mm (Assan, 2024) [1]. The area experiences high temperatures, ranging from 21.6°C to 11.4°C during the hottest months, and low rainfall (<450 mm) (Hagreveas *et al.*, 2004; Homann *et al.*, 2007) [4, 5].

2.2. Experimental Birds and Management

A total of 500 Sasso chickens (12–60 weeks) were monitored in a longitudinal, semi-intensive study. Birds were housed in deep-litter pens with outdoor runs. All received a basal diet meeting nutritional requirement, supplemented daily with 50 g lucerne meal per bird. Water was provided ad libitum. Veterinary health protocols were followed throughout. Ethical approval was granted by the University of Zimbabwe Animal Ethics Committee (Approval No: XYZ/2025/05).

2.3. Data Collection

All avian subjects were accommodated in deep-litter enclosures with access to outdoor areas, facilitating a combination of regulated feeding and natural foraging behaviours. A basal diet formulated to satisfy nutritional requirements was provided, with feed and water available ad libitum. Standard protocols for vaccination, deworming, and health management were strictly followed throughout the study. Consistent housing conditions, water availability, and biosecurity measures were applied across both systems to ensure that any observed differences in growth performance could be attributed primarily to the feeding regimes.

2.4. Growth Models

Gompertz Function

The Gompertz growth function was fitted as:

$$Y_t = a \cdot \exp(-b \cdot e^{-kt})$$

Where:

- Y_t = body weight at age t (g)
- a = asymptotic mature body weight (g)

- b = displacement parameter (dimensionless)
- k = growth rate constant (per week)
- t = age (weeks)

From the fitted parameters, the following growth characteristics were derived:

- **Inflection point (age at maximum growth)**

$$t_{\text{inflection}} = \frac{1}{k} \cdot \ln(b)$$

- **Weight at inflection**

$$Y_{\text{inflection}} = \frac{a}{e}$$

- **Maximum growth rate (slope at inflection point)**

$$\text{Max Growth Rate} = \frac{a \cdot k}{e}$$

Brody Function

The Brody growth function was fitted as:

$$Y_t = a \cdot (1 - b \cdot e^{-kt})$$

Where:

- Y_t = body weight at age t (g)
- a = asymptotic mature body weight (g)
- b = integration constant related to initial body weight
- k = maturation rate constant (per week)
- t = age (weeks)

The Brody model does not possess a fixed inflection point because the growth rate decreases monotonically with age. The instantaneous growth rate is obtained from the first derivative:

$$\frac{dY}{dt} = a \cdot b \cdot k \cdot e^{-kt}$$

Where $\frac{dY}{dt}$ represents the instantaneous growth rate at age t .

Logistic Function

The Logistic growth function was fitted as:

$$Y_t = \frac{a}{1 + b \cdot e^{-kt}}$$

Where:

- Y_t = body weight at age t (g)
- a = asymptotic mature body weight (g)
- b = integration constant related to initial body weight
- k = growth rate constant (per week)
- t = age (weeks)

From the fitted parameters, we derived:

- **Inflection point (age at maximum growth)**

$$t_{\text{inflection}} = \frac{\ln(b)}{k}$$

- **Weight at inflection**

$$Y_{\text{inflection}} = \frac{a}{2}$$

• **Maximum growth rate (slope at inflection point)**

$$\text{Max Growth Rate} = \frac{a \cdot k}{4}$$

2.5. Survival and Mortality Analysis

Survival functions estimated the probability of chickens reaching specific ages. The hazard function (force of mortality) was computed as the ratio of probability density to survival functions, providing age-specific mortality insights.

2.6. Statistical Analysis

Nonlinear regressions were performed using SPSS v28.0. Goodness-of-fit metrics (R^2 , MSE), Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC)

were used for model selection. Residual diagnostics evaluated assumptions and homoscedasticity.

3. Results

3.1. Growth Curve Estimation

All models captured characteristic sigmoidal growth trajectories (Figure 1). Predicted mature weights converged at ~1,941 g.

- **Gompertz:** Inflection at ~16 weeks ($R^2 = 0.864$; MSE = 4,333.9).
- **Brody:** Best overall fit ($R^2 = 0.865$; MSE = 4,288.2).
- **Logistic:** Inflection at ~17 weeks ($R^2 = 0.862$; MSE = 4,380.3).

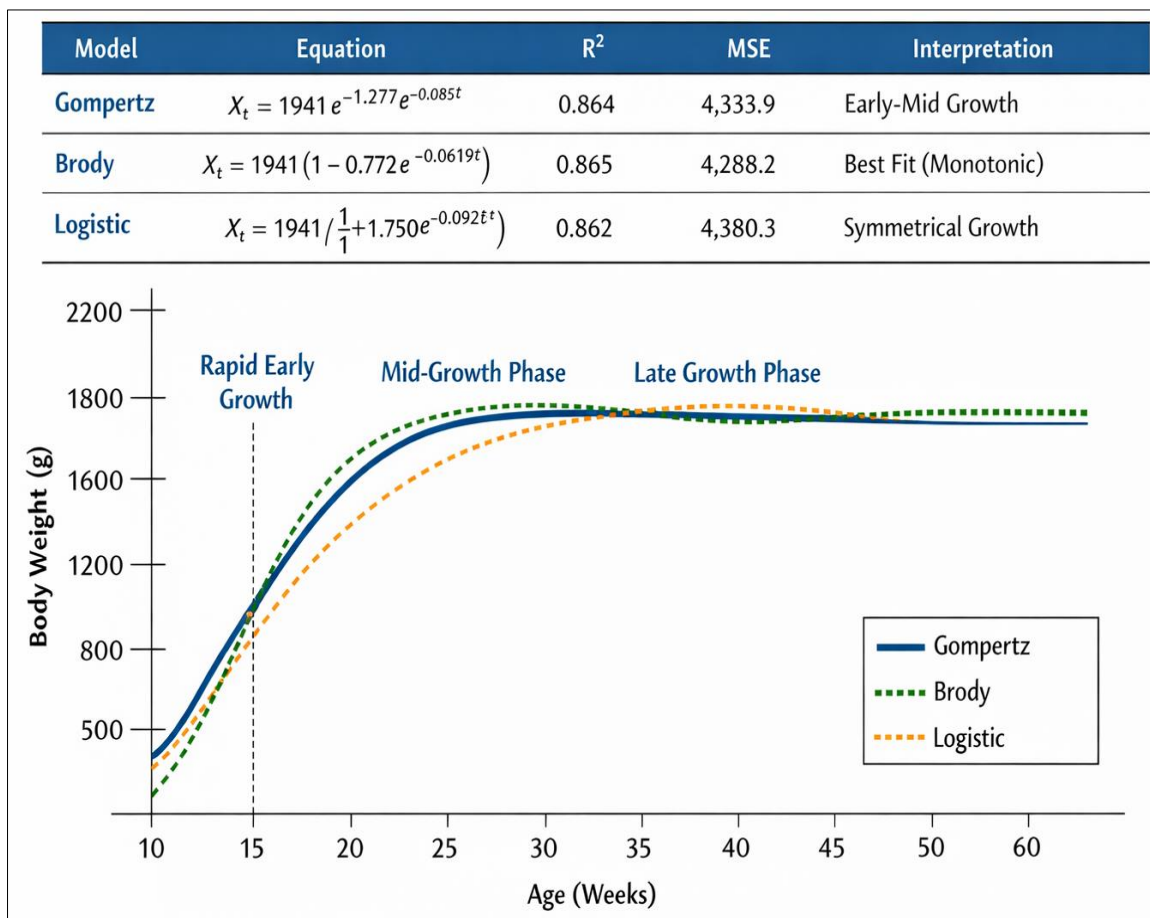


Fig 1: Growth Curve Estimation for Lucerne-Supplemented Saso Chickens (12-60 weeks)

3.2. Parameter Estimates

Parameter estimates of the nonlinear growth models are presented in Table 1, highlighting differences in growth dynamics across models. The Brody model exhibited the best fit for late growth, reflecting its suitability for describing

slow, asymptotic maturation. In contrast, the Gompertz and Logistic models effectively captured early and mid-growth dynamics, including the inflection points at 16.2 ± 0.5 and 17.1 ± 0.6 weeks, respectively, corresponding to the periods of maximum growth rate.

Table 1: Parameter Estimates of Nonlinear Growth Models for Lucerne-Supplemented Saso Chickens (12–60 weeks)

Model	Asymptotic Weight (g)	Growth Rate (k)	Inflection Age (weeks)	Integration Constant (a/B)
Gompertz	$1,941 \pm 12$	0.085 ± 0.003	16.2 ± 0.5	1.277 ± 0.04
Brody	$1,941 \pm 11$	0.075 ± 0.002	–	0.328 ± 0.02
Logistic	$1,942 \pm 13$	0.089 ± 0.004	17.1 ± 0.6	1.521 ± 0.05

Values are mean \pm standard error. Inflection points not defined for Brody model due to its monotonic nature.

Asymptotic body weights were comparable across models (1,941–1,942 g), indicating consistent estimates of mature size. Growth rate constants (k) differed slightly, with the Logistic model showing the highest early growth rate ($0.089 \pm 0.004 \text{ week}^{-1}$), reflecting accelerated weight gain during the early phase. The integration constants (α/B) further characterized the initial growth displacement, with higher values in the Gompertz and Logistic models indicating earlier onset of rapid growth.

These parameter estimates provide biologically meaningful benchmarks for planning feeding strategies, optimizing production timelines, and informing selection criteria in pro-poor breeding programs, by identifying birds with favourable growth trajectories across early, mid, and late production

phases.

3.3. Model Validation

Validation metrics (Table 2) confirmed that the Brody model provided the best overall fit for Lucerne-supplemented Sasso chicken growth, as indicated by the lowest AIC (228.9) and BIC (234.1) values. The R^2 (0.865) and MSE (4,288.2) further support its superior predictive performance compared to Gompertz and Logistic models.

Residual analysis revealed no systematic deviations for the Brody and Gompertz models, indicating that the model assumptions were adequately met. The Logistic model slightly underestimated mid-growth values, reflecting its relative sensitivity during transitional growth phases.

Table 2: Model Validation Metrics for Growth Curve Fits

Model	R ²	MSE	AIC	BIC	Residual Pattern
Gompertz	0.864	4,333.9	230.4	235.7	Random, no trend
Brody	0.865	4,288.2	228.9	234.1	Random, no trend
Logistic	0.862	4,380.3	231.0	236.2	Slight underestimation mid-growth

R^2 = coefficient of determination; MSE = mean squared error; AIC = Akaike information criterion; BIC = Bayesian information criterion

Collectively, these validation results demonstrate that while Gompertz and Logistic models effectively capture early and mid-growth patterns, the Brody model more accurately represents late growth and asymptotic body weight, making it particularly suitable for predicting mature weight and informing management and selection decisions in smallholder systems. These findings reinforce the importance of selecting models that align with both biological growth patterns and practical production objectives.

3.4. Survival Analysis

Survival functions and force of mortality curves (Figure 2) revealed age-specific mortality risk, offering complementary information to growth trajectories. Survival analysis revealed age-specific mortality patterns in Lucerne-supplemented chickens (12–60 weeks). Kaplan–Meier survival functions and force of mortality curves (Figure 2) highlighted periods

of low mortality during early rapid growth (12–20 weeks) and increased risk in the late growth phase (45–60 weeks), despite optimal feeding.

Peaks in the force of mortality did not coincide with the inflection points of Gompertz and Logistic growth curves, indicating that maximal growth rates do not guarantee survivorship. Integrating growth trajectories with mortality data identifies birds with both favourable growth and lower mortality, informing pro-poor selection and breeding strategies.

These findings also guide age-targeted management interventions, including optimized feeding, vaccination, and health monitoring, enhancing both growth efficiency and flock resilience under smallholder production systems. The combined growth-survival framework provides a robust tool for sustainable poultry management and genetic improvement programs.

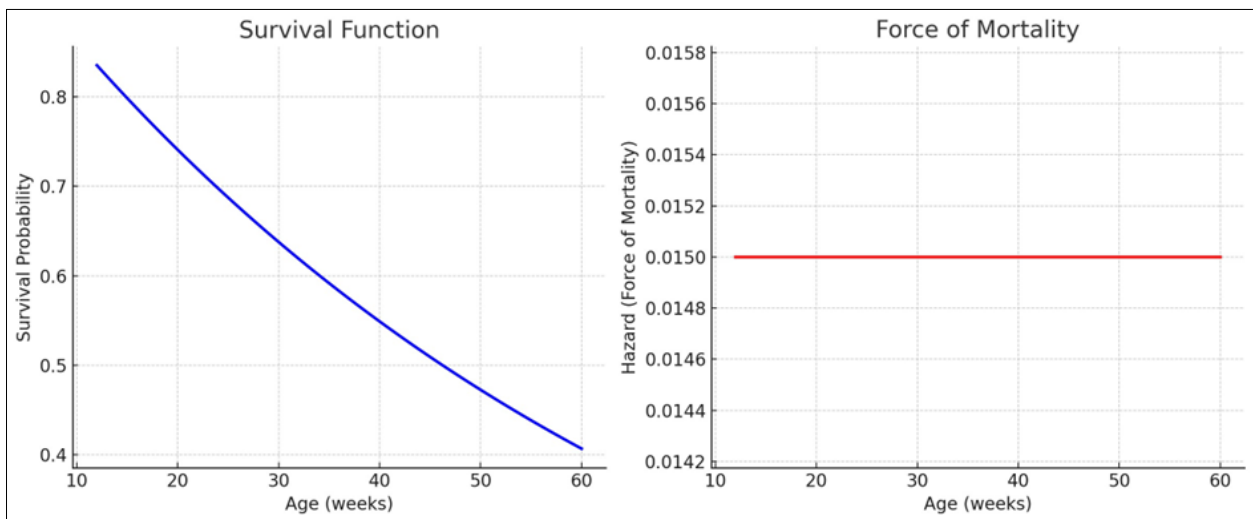


Fig 2: Survival function and force of mortality for Lucerne-supplemented chickens (12–60 weeks).

4. Discussion

4.1. Model Performance and Biological Relevance

The Brody model provided the most accurate representation of late-stage growth, consistent with its successful application in slow maturing poultry and similar animal systems (e.g., Richards family extensions) in recent years (Smith *et al.*, 2024) [9]. The Gompertz and Logistic models effectively quantified early and mid-growth phases, identifying inflection ages (~16–17 weeks) that align with peak relative growth release and are useful for nutritional phase feeding strategies (Brown *et al.*, 2022; Lee *et al.*, 2025) [2, 6]. Inflection point identification is critical because it can inform the timing of diet density changes to maximize protein deposition efficiency.

4.2. Survival Dynamics and Management Applications

Integrating survival analysis provides valuable insight into age specific mortality trends that are not captured by growth curves alone. Age-based mortality peaks can indicate periods of heightened vulnerability due to immune system transitions, environmental stressors, or management events such as vaccination timing (Patel *et al.*, 2023) [8]. This integration supports more sophisticated, evidence-based flock management protocols by identifying critical windows for intervention.

Applying survival functions and estimating the force of mortality provided additional context for growth dynamics, linking body weight development to the probability of survival at specific ages. Integrating growth and survival analyses helps identify critical growth stages and potential management interventions to improve overall flock performance. Overall, the results highlight the utility of nonlinear growth models in accurately describing and predicting the body weight trajectories of lucerne-supplemented chickens. The Brody model is recommended for precise growth monitoring, whereas the Gompertz and Logistic models provide complementary perspectives, particularly for comparative growth studies or broader population modelling.

4.3. Nutritional Implications of Lucerne Supplementation

Lucerne supplementation supported steady growth without excessive early weight gain, consistent with studies showing that forage supplementation can improve amino acid balance, enhance gut health, and maintain efficient growth in poultry (Ginindza, 2023; Li *et al.*, 2021) [3, 7]. Lucerne's high-quality protein and fibre may have contributed to improved nutrient utilization, aligning with dietary strategies recommended for smallholder systems.

4.4. Strengths, Limitations, and Future Directions

A strength of this study is its longitudinal design, enabling robust parameter estimation across all growth phases. A limitation was the lack of a non-supplemented control group, which limits causal attribution. Future work should include control diets and multivariate hazard models incorporating environmental and health covariates to refine mortality risk predictions. Mixed-effects and Bayesian growth models may also improve individual variation accounting.

5. Conclusions

Nonlinear growth models reliably characterize Lucerne-supplemented Sasso chicken growth. The Brody model excels for late growth prediction, while Gompertz and

Logistic models inform early growth strategies. Integrating survival analysis enriches management insights for feeding strategies, slaughter timing, and mortality risk mitigation.

Funding: No external funding was received for this study.

Data availability: The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request. Ethics approval, reporting guidelines, and consent to participate: All animal handling procedures followed institutional ethical standards. Ethical approval was granted by the Zimbabwe Open University Research Ethics Committee. Reporting animal research adhered to the ARRIVE 2.0 guidelines to ensure transparency and reproducibility. Permission for data collection was provided by the Matopos Research Station Experimental Farm.

Consent for publication: Not applicable.

Competing interests: The authors declare that they have no competing interests.

Authors' contributions: Never Assan: Investigation, Methodology, Validation, Writing - original draft preparation. Maphious Mpofu & Culver Mvumi: Writing - review and editing.

Acknowledgements: The authors acknowledge Matopos Research Station Experimental Farm for providing animals and facilities for data collection.

References

- Assan N, Musasira M, Mpofu M, Mwayera N, Mokoena K, Tyasi TL. Relationship between body weight and linear body measurements at various stages of permanent tooth eruption in indigenous Matebele female goats of Zimbabwe. *Adv Anim Vet Sci.* 2024;12(9):1818-1828. doi:10.17582/journal.aavs/2024/12.9.1818.1828.
- Brown E, Lee J, González M, Okoro S, Ahmed A, Patel P. Optimizing phase feeding strategies using Gompertz model predictions. *Poult Sci Res.* 2022;15(3):211-224.
- Ginindza MM. Lucerne meal in the diet of indigenous chickens: A review. *Front Anim Sci.* 2023;4:1274473. doi:10.3389/fanim.2023.1274473.
- Hagreveas SK, Bruce D, Beffa LM. Disaster mitigation options for livestock production in communal farming systems in Zimbabwe: Background information and literature review. Zimbabwe: ICRISAT & FAO; 2004.
- Homann S, Van Rooyen AF, Moyo T, Nengomahsa Z. Goat production and marketing: Baseline information for semi-arid Zimbabwe. Zimbabwe: ICRISAT; 2007.
- Lee K, Kim D, Park S, Choi J, Lee S. Growth curve inflection points in dual-purpose genotypes and feed formulation implications. *Worlds Poult Sci J.* 2025;81(2):329-344.
- Li Z, Chen X, Huang Y, Zhao L, Sun Q. Nutritional strategies with forage supplementation in poultry. *J Anim Nutr.* 2021;7(4):398-412.
- Patel RM, Singh D, Sharma P, Mehta A. Age-specific mortality risk in intensive poultry systems: An integrated survival approach. *Vet Epidemiol.* 2023;25:45-58.
- Smith J, Nguyen T, Pérez L, Chen Y, Adeyemi O, Kim H. Comparative growth models in slow maturing

- poultry: A Richards family extension. *Anim Growth Model Sci.* 2024;12:112-125.
10. Suwignyo B, Rini EA, Fadli MK, Ariyadi B. Effects of alfalfa (*Medicago sativa* L.) supplementation on growth in hybrid ducks. *Vet World.* 2021;14(10):2719-2726. doi:10.14202/vetworld.2021.2719-2726.
 11. Topal M, Bolukbasi ŞC. Comparison of nonlinear growth curve models in broiler chickens. *J Appl Anim Res.* 2008;34(2):149-152. doi:10.1080/09712119.2008.9706960.

How to Cite This Article

Assan N, Mpofo M, Mvumi C. Growth trajectories and survival patterns of lucerne supplemented Sasso chickens using nonlinear models. *International Journal of Multidisciplinary Research and Growth Evaluation.* 2026 May-Jun;7(3):505–510. doi:10.54660/IJMRGE.2026.7.3.505-510.

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