Volume 14, Issue 2 (2026) pp. 239-250 DOI: 10.48309/IJABBR.2026.2072349.1666

Original Article

Estimate Residual Feed Intake (RFI) in Iranian Dairy Cows Using Multitrait Stochastic Regression Framework

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Submitted: 2025-09-21, Revised: 2025-10-11, Accepted: 2025-11-25

Abstract

In the dairy industry, nutritional efficiency is typically assessed using the residual feed intake (RFI) method. The traditional application of this method relies on linear regression, which inherently overlooks how the components of RFI change over time, leading to potential inaccuracies in the findings. By employing a multitrait stochastic regression framework, the relationships were explored between milk production, live weight, intake of dry matter (DMI), and body condition score (BCS) throughout the lactation period. Furthermore, at each measurement point, an animal effect was estimated for intake through a matrix regression analysis based on the variance covariance matrix and the animal effects of the three predictor traits. By comparing this predicted effect with the actual intake effect, an estimate was derived for the RFI. The model was evaluated using historical data collected from the Iranian National Breeding Centre from 2008 to 2023, encompassing 1,852 lactations from 870 cows. The analysis revealed strong positive correlations between various animal effects, particularly for milk production and intake of dry matter (DMI), as well as between body weight and DMI. These correlations peaked around mid-lactation and remained stable over time, averaging around 0.4 for body weight and BCS. Additionally, the correlations for milk and weight, DMI and BCS, as well as milk and BCS, showed a gradual decline as lactation progressed. On the Legendre polynomial coefficient scale, the correlations were measured with high precision, indicated by an average standard error of 0.04, with minimum and maximum values of 0.02 and 0.05, respectively. The estimated animal effect for feed intake consistently demonstrated a strong correlation with milk production and, for most of the lactation period, also with body weight. However, the correlation with BCS was only moderate and turned negative during the latter half of lactation. The relationship between the average RFI throughout lactation and RFI at individual time points was consistently positive, exceeding 0.5, with peak correlations observed mid-lactation, exceeding 0.9. This suggests a robust and reliable model for understanding the dynamics of nutritional efficiency and its relationship with milk production and other physiological parameters in dairy cows.

Keywords: Correlations, Feed Efficiency, Multitrait Random Regression, Residual Feed Intake (RFI).

Introduction

In dairy production, feed costs account for more than 50% of total expenses, making nutritional efficiency a critical focus for the industry [1]. Feed efficiency is about optimizing the relationship between what is produced (output) and what is consumed (input), particularly in terms of feed intake. RFI measures the gap between an animal's actual feed consumption and its expected feed intake, which is calculated based on its production performance. This expected intake is determined by evaluating the energy requirements of various biological processes through regression analysis. One of the key advantages of this approach is that RFI is designed to be independent of its predictors, both phenotypically and genetically, which means it can effectively capture variations in digestion and metabolism [2]. This feature allows for a clearer understanding of how different animals utilize feed, thereby supporting efforts to enhance overall nutritional efficiency in dairy farming. The commonly accepted definition of Residual Feed Intake (RFI) in dairy cows, as noted by Connor [3], presents several challenges. One significant issue is the impact of time on RFI measurements. Typically, RFI is assessed over a specific period, and if this duration is insufficient, the limited number of measurements can lead to inaccuracies in predictions. Additionally, various biological processes occur at different stages of lactation, such as the mobilization of body reserves during early lactation and the accumulation of reserves during pregnancy. Consequently, the regression coefficients linked to various predictors may differ across lactation stages, resulting in a skewed evaluation of RFI when calculated from single-point measurements throughout the entire lactation period [4].

Furthermore, with the rise of precision farming technologies, there is now access to high-frequency time series data, which enhances the ability to monitor nutritional efficiency over time. This advancement raises important questions regarding how to effectively manage temporal changes, the optimal timing for RFI measurements, and the appropriate duration for these assessments. Another aspect to consider is the inherent complexity of RFI itself, which may influence the interpretation and application of this metric in evaluating dairy cows' performance.

Residuals, it turns out, are a bit like those enigmatic black boxes in science fiction – they encapsulate not just the true efficiency of an animal, but also a charming concoction of modeling quirks and measurement eccentricities. In this context, Fischer *et al.* [5] explored the individual cow-level random regression to explicitly characterize the animal-specific random effect component of Residual Feed Intake (RFI). However, their journey was not entirely smooth sailing; they bumped into some rather significant correlations among their predictors, which, much like a mischievous toddler's mood, shifted unpredictably throughout the lactation period. This, along with a limited dataset, hindered their modeling efforts and the conclusions they could draw.

To effectively address these multifaceted complexities, this study systematically investigates the dynamic interplay between an animal's feed intake and its associated predictors across the entire lactation period. This comprehensive analysis is facilitated by the application of a sophisticated multitrait stochastic regression framework to the acquired experimental data. By implementing this structured model, the capacity to estimate an animal's feed intake was derived as a function of the other measured traits. Subsequently, a rigorous comparison is performed between these model-predicted intake values and the empirically observed feed intake data. This sophisticated strategy not only affords a more beautifully coherent definition of RFI, but also equips with regression coefficients that are as dynamic as a stage performer, shifting gracefully over time. A much richer, more nuanced understanding of intake dynamics as the animal stars navigate the diverse scenes of lactation.

Materials and Methods

Data and Editing

Data was gathered from 1,852 lactations involving 870 cows from the Iranian National Breeding Centre during 2008 to 2023. Each week, the average daily milk yield for each cow was calculated based on daily milk yield records for that week. Milk samples were collected weekly to analyze fat and protein content. Simultaneously, the dry matter (DM) content in the partial mixed ration (PMR) and concentrates was routinely assessed. These values were then combined with feed intake records to calculate the weekly intake of dry matter (DMI) for every individual cow. The cows were weighed automatically during each milking, allowing for the calculation of average body weight (BW) per cow on a weekly basis. Additionally, body condition scores (BCS) were assessed biweekly, using a scale from 1 to 5 to evaluate the health and condition of the animals. A corrected milk (cmilk: Corrected milk) trait was established following the FAO guidelines, which stipulate that standard milk should contain 4.0% fat and 3.3% protein [6]:

$$Corrected\ milk\ (kg) = raw\ milk\ (kg) \times (0.337 + 0.116 \times Fat\ content\ (\%) + 0.06 \times Protein\ content\ (\%)) \quad (1)$$

Statistical Analysis - Multitrait Random Regression Model

To unravel the secrets of how these four traits waltz together throughout the lactation period, the digital wizardry of Wombat software was utilized. A multitrait random regression analysis, as eloquently detailed by [7], was the chosen magic carpet for this investigation. This approach allows for a comprehensive examination of how these traits interact and evolve over time, providing valuable insights into their relationships during lactation. By using this sophisticated statistical tool, researchers can assess the dynamics of these traits, which can significantly contribute to the understanding of lactation processes. The specific model employed in this analysis is outlined as follows:

$$y_{ilmr} = c_i + \sum_{n=0}^{3} \beta_{ln}\varphi_{nr}(t) + \sum_{n=0}^{2} \beta_{mn}\varphi_{nr}(t) + e_{ilmr} \quad (2)$$

In this grand analytical theatre, y_{ilmr} plays the role of the observation for the r-th trait – think of it as the specific data point. The ci steps in as the fixed effect, reflecting the stable influence of the month-year combination of the record date; it is like the unchanging backdrop of this scenario. The plot thickens with β_{in}, the fixed regression coefficients, each carefully crafted for a specific parity class l. These are like the established rules of the game for each group. Subsequently, ϕmn is defined as the random regression coefficient specific to animal mmm. These coefficients serve to model the unique, animal-specific deviations observed across the temporal evolution of the data. Adding another layer of sophistication, $\varphi_{nr}(t)$ represents the n-th coefficient derived from the Legendre polynomial, specifically tuned with degrees d = 2 for animal effects and d = 3 for parity classes. This coefficient is evaluated at a specific day in milk, t (the 'DIM': Days in Milk), and acting as a time-traveling dial for the effects. And finally, the ever-present e_{ilmr}, the random residual effect. These little residuals are like a reliable chorus, maintaining a consistent variance throughout the entire performance. It is all about keeping the harmony, even with those random fluctuations. Each lactation for the same animal is treated independently, as if they belong to different animals, which effectively disregards any lasting environmental influences that might span multiple lactations. This framework allows for a nuanced understanding of the factors influencing the traits under study, while simplifying the analysis by separating each lactation's data. Additionally, an RFI estimate can be estimated which is the difference between the actual animal effect for DMI and the one predicted from the three other variables:

$$RFI\ (t) = a_{DMI}(t) - \widehat{a_{eDMI}}(t)\ (3)$$

Where, $\widehat{a_{eDMI}}$ is the predicted animal effect for DMI at time t.

Results and Discussion

Descriptive Statistics

Descriptive statistics for the raw data related to the four estimated traits, the four animal effects, and the Residual Feed Intake (RFI) are presented in Table 1, averaged over the entire lactation period. The four traits display considerable variability, with a wide range of values observed. This assumption is supported by the fact that the data were averaged weekly and are relatively consistent with previous measurements for the same animals, thanks to the filtering process applied. It is plausible that these extremely low values may be linked to underlying health concerns affecting the animals.

Now, let's peek at the latter half of the table, where the spotlight shines on the animal effects for the four traits. These effects are the unique signatures each animal leaves on the data, showing how they personally deviate from the average performance. Imagine the average performance as a smooth, well-trodden path for a specific trait and parity group – the animal effects are the little detours each individual takes off that path, after we've smoothed out all the other known influences (the fixed effects). For those who appreciate a visual journey, the curves depicting these fixed effects are elegantly laid out in the supplementary Figure 1. Here is a rather neat little fact: the average of these animal effects for all four traits, as calculated by the presented model, is precisely zero at every single time point and also across the entire study. It is as if this model insists on a perfect balance. However, the statistics presented in Table 1 were exclusively gathered from those animal effects that had actual, real-world data points to back them up.

Table 1. Means, SD, 5% and 95% centiles for the raw data of the four considered traits of dairy cattle, animal effects (a_{trait}), and RFI

Type of data	Trait	Mean	SD	5% Centile	95% Centile
Raw data	Milk (kg of corrected milk)	34.5	8.8	32.8	50.4
	Weight (10 kg)[1]	65.7	8.2	49.8	81.4
	DMI (kg)	20.9	4.3	17.4	30.2
	BCS (scale of 10 to 50)[1]	32.8	4.8	26.7	38.7
Computed data	a_{cmilk}	0.31	6.32	-10.11	11.33
	a_{weight}	-0.12	4.25	-11.48	12.58
	a_{DMI}	0.07	3.21	-5.14	5.73
	a_{BCS}	-0.04	3.14	-4.28	4.67
	RFI	0.06	1.22	-2.08	3.35

[1]: *The original scale was divided (for Weight) or multiplied (for BCS) by 10 in order to have raw data in the multiple trait analysis with similar orders of magnitude for the 4 traits.*
a_{DMI}: *Average daily feed intake.*

The presented model is quite the predictor, capable of estimating animal effects even for times beyond when an individual animal's data were collected. But, to keep things honest and grounded in reality, these clever 'future predictions' were not invited to the statistics party in Table 1. This is why the mean values you see there might not perfectly hit zero – they are based on the available evidence, not future forecasts. A parallel analysis was conducted on the Residual Feed Intake (RFI) estimates, yielding a calculated mean RFI of 0.04. This beautifully illustrates a key point: while this model is a whiz at extrapolating and offering insights beyond the direct observations, it is always wise to exercise a bit of caution when interpreting these extended predictions. They are like educated guesses, offering valuable direction, but the most reliable insights often come from where the data truly shines. In this research, a new modeling approach was introduced that effectively integrates time series data to calculate RFI. This method goes beyond simply measuring the differences between the start and end of selected time frames. Instead, it dynamically accounts for various traits throughout the entire lactation period. Traditional methods of defining RFI, particularly through linear regression, fall short when it comes to accurately capturing the nonlinear changes in traits that dairy cows experience during lactation [4]. The energy distribution among different energy sinks changes throughout lactation, causing regression coefficients to fluctuate over time. Consequently, RFI in dairy cows is often assessed over brief periods [5]. This short-term focus results in analyses based on limited data points, making them particularly vulnerable to inaccuracies from measurement errors or isolated incidents, such as mastitis. Moreover, even with short-term evaluations, RFI estimates can be misleading since fixed regression coefficients may not adequately represent biological variations, such as transitions between weight loss and weight gain in body reserves. This highlights the need for a more comprehensive and adaptable approach to analysing nutritional efficiency in dairy cows. The current investigation into the Residual Feed Intake (RFI) methodology builds upon a substantial foundation of prior research. Numerous seminal studies have previously examined the nuances of RFI or investigated the correlational relationships among its constituent traits. For example, Manzanilla Pech *et al.* [8] embarked on a journey to create a multitrait stochastic regression framework. Their goal was to unravel the dynamic interplay between dry matter intake (DMI), milk production, and live weight over time. While they didn't directly calculate RFI, their work laid important groundwork for understanding these complex relationships. Then, Lu *et al.* [9] brought a clever tool to the table: a modified Cholesky decomposition within a multitrait linear model. Think of it as a sophisticated way to organize and analyze the data, which notably boosted the accuracy of predicting genetic merit, even when faced with the occasional data gap – quite resourceful. Let's not forget Strathe *et al.* [10], who introduced their own RFI model. They cleverly employed a bivariate random regression framework, focusing on the fascinating relationship between body weight (BW) and total feed intake in pigs. Collectively, these advancements paint a picture of a field brimming with innovation, showcasing a clear and growing enthusiasm for sharpening the understanding of RFI and all its related wonders. It is like each study adds a new brushstroke to a masterpiece, refining the view of feed efficiency. Recently, Islam *et al.* [11] employed a Bayesian multivariate random regression method to investigate various factors such as DMI, energy-corrected milk, BW, and BCS. Through this analysis, they were able to extract a genetic measure of RFI. This innovative approach marks a significant advancement in the ongoing efforts to enhance the modeling of nutritional efficiency in livestock. By focusing on these interrelated traits, researchers can better understand the genetic underpinnings that contribute to nutritional efficiency, ultimately leading to more effective breeding strategies and improved animal production systems. This work represents a crucial step forward in optimizing livestock management practices.

Correlations between Animal Effects across Time

The relationships between the animal effects for the four traits during lactation are illustrated in Figure 1. Early in lactation, there is an observed increase in the correlation between DMI and milk production (cmilk), as well as between DMI and body weight. However, these correlations tend to decline as lactation progresses into its later stages.

As lactation advances, the correlation between milk production and weight gradually diminishes, eventually turning slightly negative towards the end of the lactation period. This suggests that animals producing above-average milk early in lactation tend to be heavier, which allows them to consume more feed. However, these high-producing animals show less persistence in their milk yield as lactation continues. Throughout the entire lactation period, a negative correlation between milk production and BCS indicates that animals producing more milk generally maintain a lower BCS, particularly evident in the later stages of lactation. This could be due to greater energy depletion early on, making it harder for them to replenish body reserves as lactation nears its conclusion. In contrast, the correlation between weight and BCS remains fairly consistent at around 0.39, highlighting that animals with greater energy reserves are heavier at all stages of lactation. This reflects a stable relationship where increased body condition corresponds with increased body weight throughout the lactation period. The relationship between Dry Matter Intake (DMI) and Body Condition Score (BCS) initially hovers around zero, gradually declining to approximately − 0.2 towards the end of the lactation period.

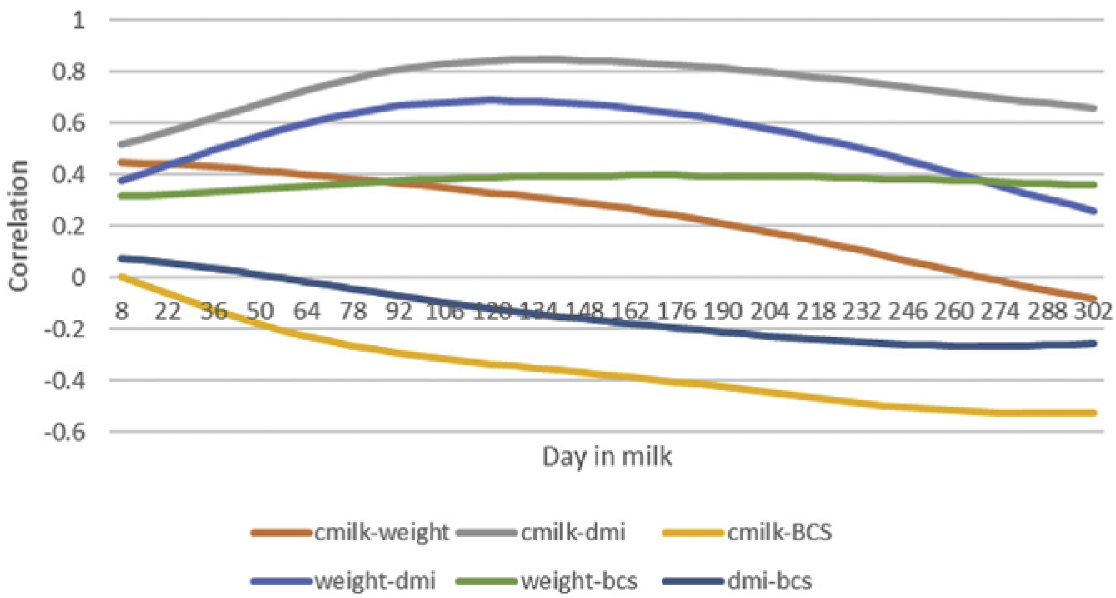

Figure 1. Time trends of the correlations between the animal effects (*i.e.* the animal differences from the average at any given time point, across the lactation of dairy cattle) of the corrected milk (cmilk), the body weight, the DM intake (DMI), and the body condition score (BCS)

When utilizing the Legendre polynomial coefficient scale for estimation, the correlations showed a high level of precision, with an average standard error of 0.04, ranging from a minimum of 0.02 to a maximum of 0.05. This level of accuracy corresponds to variance estimation errors during lactation that are notably low: under 5% for milk production, 1% for body weight (BW), 7% for feed intake, and 4% for BCS. These findings indicate a clear trend in how DMI impacts BCS as lactation progresses, suggesting that monitoring these metrics can provide valuable insights into the health and productivity of dairy cows throughout their lactation cycle. The correlations among animal effects at various time points for each trait are illustrated in Supplementary Figure 2. The observed trend holds true across all four traits, displaying exclusively positive correlations. Notably, the correlations tend to be stronger between animal effects recorded at closer time intervals. For weight, which is a cumulative trait, the correlations remained consistently high, exceeding 0.7, while the other three traits exhibited more variability with correlations over 0.6. The most significant fluctuations occurred primarily at the beginning or the end of the lactation period, whereas the mid-lactation phase showed remarkable stability, with correlations above 0.8. These correlation estimates are robust, with sampling errors reported to be below 4% for intake, 2% for milk yield and Body Condition Score (BCS), and just 1% for Body Weight (BW). This indicates a high level of reliability in the measurements taken throughout the study.

Correlations between the Predicted Animal Effect of DMI and the Other Traits

The correlations between the estimated animal effect for intake and the four original animal effects were assessed at various points in time, as illustrated in Figure 2. Notably, one predictor showed a very strong correlation with the animal effect for cmilk, consistently above 0.9 and nearing 1 at the onset of lactation. The second highest correlation was observed with the animal effect for weight, which began at 0.8 and gradually declined to 0.38 throughout the lactation period.

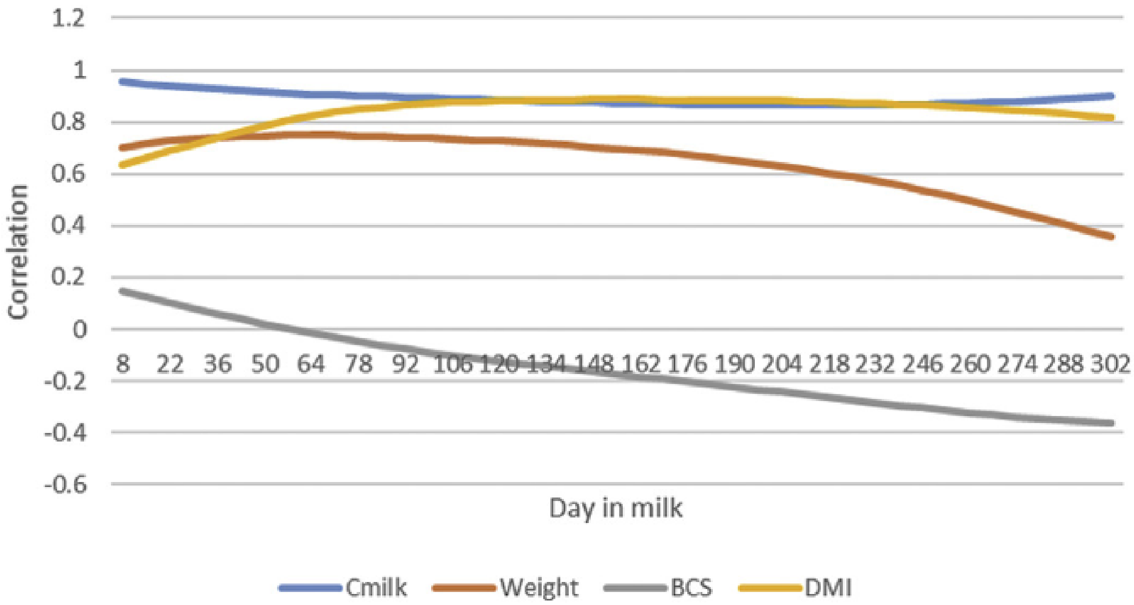

Figure 2. Correlations between the predicted animal effect for intake ($\widehat{a_{eDMI}}$) and the four original animal effects (corrected milk (cmilk), weight, DM intake (DMI), and body condition score (BCS)) in the considered dairy herd

In contrast, the correlation with the animal effect for Body Condition Score (BCS) remained low, starting with a positive value but RFI below 0.18 in the early stages of lactation and eventually dipping to -0.38 by the end of the lactation cycle. Additionally, the correlation between the predictor and average daily feed intake (a_{DMI}) ranged from 0.6 to 0.8 during early lactation, and then stabilized above 0.8 after the first 50 days of lactation. This analysis highlights the dynamic relationship between different animal effects and how they change over the course of lactation, emphasizing the importance of monitoring these correlations for better management of animal health and productivity. The correlations of the animal effects concerning all traits in relation to Residual Feed Intake (RFI) were assessed. As anticipated, due to the design, the relationships between RFI and the three predictors, along with the estimated intake, remained consistently zero throughout the lactation period. Initially, the correlation between RFI and average Dry Matter Intake (a_{DMI}) was approximately 0.77. This correlation gradually declined to 0.45 from the first to the third stages of lactation. After that, it stabilized until reaching 250 Days in Milk (DIM), where it showed a slight increase, ending at approximately 0.58 by the close of lactation. This pattern indicates that while the initial feeding efficiency is high, it tends to decrease before achieving a level of stability, which could reflect changes in the animals' metabolic processes or feeding behavior throughout the lactation cycle. Analyzing these correlations is crucial for understanding the dynamics of nutritional efficiency in relation to milk production. Research by Manzanilla Pech *et al.* [8] aligns with earlier findings, indicating that genetic correlations among traits during lactation tend to be predominantly positive, peaking in mid-lactation. They observed that correlations diminish when evaluated over longer intervals. The correlations observed for the animal effects of the four traits at a single time point align well with existing literature. Spurlock *et al.* [12] reported strong positive genetic correlations between Dry Matter Intake (DMI) and weight. Hüttmann *et al.* [13] indicated that this genetic correlation varies over time, showing an almost negligible correlation between 31 and 60 days in milk (DIM), which then increased to a correlation of 0.4 between 121 and 180 DIM. In contrast, Manzanilla Pech *et al.* [8] noted that this correlation peaked at 34 DIM (0.56) and dropped to its lowest at 153 DIM (0.29). The findings reflect a pattern akin to those of Hüttmann *et al.* [13], yet the correlations consistently exceed theirs and are more in line with the values reported in other studies. BCS is often overlooked in studies related to dairy cows, leading to limited data on its correlations. It is generally understood that cows tend to utilize body fat reserves during the early stages of lactation, particularly when they are experiencing a negative energy balance [14]. In this research, a negative relationship was observed between the effects of the cows on milk production and their BCS, indicating that cows producing more milk than average tend to have a lower BCS. Additionally, the consistent relationship observed between weight and BCS aligns with earlier findings suggesting that changes in live weight can effectively indicate the mobilization of body reserves [8,15]. This reinforces the notion that monitoring BCS and weight can be crucial for understanding energy dynamics in lactating cows.

Evolution of Residual Feed Intake (RFI) across the Lactation

Let's turn the attention to Figure 3, where the fascinating correlations were mapped out between the animal effects for all traits related to Residual Feed Intake (RFI).

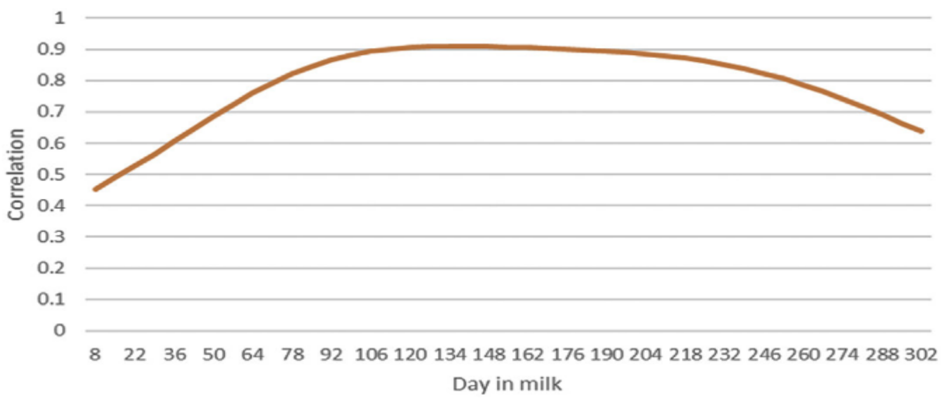

Figure 3. A correlation between the averaged residual feed intake (RFI) over the whole lactation and the RFI calculated at any given time point in the considered dairy herd

Think of these correlations as the dynamic conversations happening between different aspects of an animal's nutritional journey. The relationships between RFI and the three key predictors (along with the expected intake) were perfectly neutral, showing a correlation of zero throughout the entire lactation period. It is as if these specific elements decided to keep to themselves, maintaining a respectful distance from RFI's core dynamics. The correlation between RFI and the adjusted Dry Matter Intake (aDMI) started off quite chummy, kicking things off at a high of approximately 0.8. This suggests that, early in lactation, animals that were more or less efficient in their feed intake (RFI) were quite clearly reflected in how much dry matter they were consuming. However, this close relationship began to mellow out. The correlation gradually decreased, settling around 0.5 during the first third of lactation. It is like they moved from an intense embrace to a more comfortable companionship. After this initial dip, the correlation remained quite steady, maintaining its companionship until about 250 days were reached in milk (DIM). As lactation wrapped up, the correlation saw a slight uptick, climbing to 0.6 by the final stages. The initial strong bond, the gradual easing off, and the slight resurgence beautifully illustrate the dynamic nature of nutritional efficiency. It shows how an animal's efficiency and its actual intake patterns can evolve quite distinctly across different phases of lactation. Understanding these shifting correlations is absolutely key. It is like having a map to optimize feeding strategies and, ultimately, boost the overall performance of the animals. It suggests that what could be true at the beginning of lactation might need a little adjustment as one approaches the end.

The methodology offers a powerful lens through which the individual animal changes in Residual Feed Intake (RFI) can be tracked over the entire lactation period. This capability unlocks exciting new avenues for optimizing animal management. A notable finding was observed: the average RFI across the entire lactation period is strongly correlated with RFI measurements taken specifically during mid-lactation. This echoes previous research by Prendiville *et al.* [16] and Connor *et al.* [17], lending significant weight to the results. This insight is particularly practical: if the primary goal is to identify the most efficient animals on average, the resource-intensive feed intake measurements can be statistically concentrated to just a few weeks in mid-lactation, specifically between 115 and 175 days in milk. The analysis strongly supports this targeted approach. It appears to be the most stable period of milk production, characterized by fewer significant fluctuations. Animals demonstrating efficiency during this phase tend to maintain that efficiency. However, it is crucial to acknowledge the dynamic nature of energy demands throughout lactation. The physiological shifts mean that animals that excel in mid-lactation might not necessarily be the top performers in the early or late stages. This nuanced understanding is key for a holistic view of animal efficiency.

Using Changes rather than the Trait Itself

The relationships between RFI and $RFI_{\Delta BCS}$, as well as between RFI and $RFI_{\Delta BW}$, are illustrated in Figure 4. The correlation between RFI and $RFI_{\Delta BCS}$ is notably strong, exceeding 0.87, and reaching as high as 0.99 at both the onset and conclusion of lactation.

This is where the statistical magic really shines what is seen here strongly suggests that RFI and $RFI_{\Delta BCS}$ (which, if you recall, is RFI adjusted for changes in Body Condition Score) are practically peas in a pod – nearly identical measures. This suggests that the underlying genetic and environmental factors influencing the random component of feed intake traits are highly correlated, implying a shared biological basis for these deviations. Similarly, the connection between RFI and $RFI_{\Delta BW}$ (RFI adjusted for changes in Body Weight) remains incredibly robust. Think of it as a very dependable friendship, consistently staying strong, generally holding steady above 0.73, especially in those crucial early lactation stages. This high correlation tells something quite profound: the clever way used the three Legendre polynomial coefficients to capture these adjustments (like changes in body condition and weight) is working beautifully. These coefficients are essentially acting as sophisticated derivatives, effectively mapping the rates of change in the traits which is the truly remarkable part: the consistently high correlation for Body Condition Score (BCS) changes, particularly at the beginning and end of lactation. This implies that during these specific periods, the changes themselves become the most informative signals.

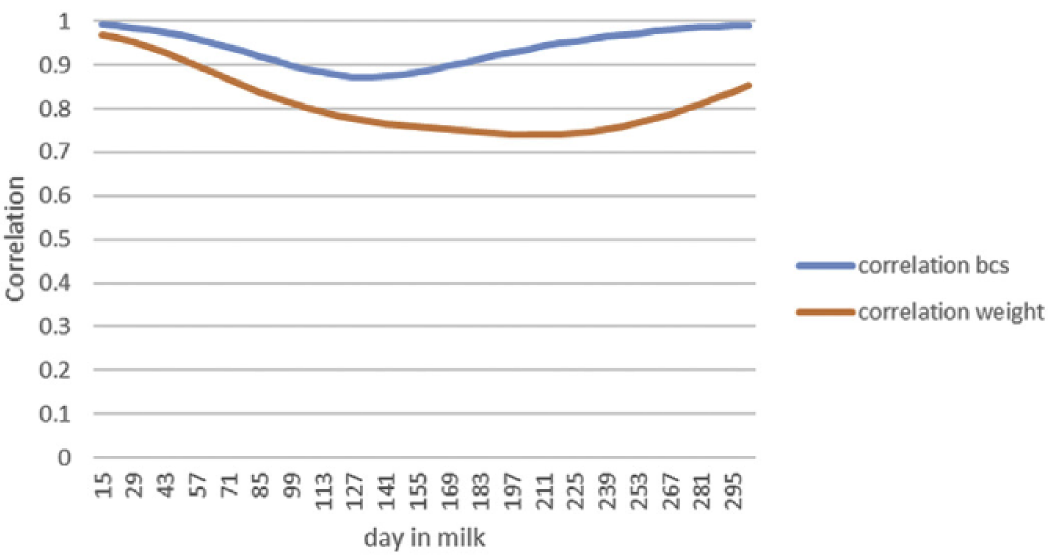

Figure 4. A correlation between the residual feed intake (RFI) for both weight and body condition score in the study dairy cows

It is as if the animal is shouting at its efficiency status through these transitions, allowing to use these changes as highly reliable predictors without losing any significant pieces of the puzzle. It is a testament to how focusing on dynamics can reveal so much. However, this trend does not hold true during the mid-lactation phase, where the emphasis on changes diminishes and the traits themselves provide additional valuable insights. This analysis highlights the dynamic nature of these correlations and their implications for understanding lactation performance.

Conclusion

It was successfully shown that it is not only possible, but also highly effective to determine Residual Feed Intake (RFI) using a multitrait stochastic regression framework. This sophisticated approach allows to simultaneously analyze Dry Matter Intake (DMI) alongside its various predictors, giving us a richer, more comprehensive picture. What is truly exciting about this method is its inherent flexibility. It allows for a much more nuanced estimation of traits, sidestepping those pesky time-related complications that often muddy the waters with conventional RFI calculations. Consider it as cutting through the complexity to get to the heart of the matter, providing a clearer, more adaptable way to understand nutritional efficiency. The model enhances the understanding of how predictors interact during lactation and can be adjusted for use in genomic or breeding selection programs processes. By adopting this model, researchers and breeders can gain deeper insights into the relationships among various traits, ultimately leading to more effective selection strategies in improving livestock efficiency.

Competing Interests

The authors declared that there were no competing interests.

Authors' Contributions

Fatemeh Ala Noshahr conceived and designed the study; Reza Seyedsharifi supervised this project; Reza Seyedsharifi, Jamal Seifdavati, and Nemat Hedayat-Evrigh conducted the study; Reza Seyedsharifi and Jamal Seifdavati supervised the research; Fatemeh Ala Noshahr, Reza Seyedsharifi, and Abdolfattah Zeidan Mohammad Salem prepared the manuscript. Fatemeh Ala Noshahr contributed data or analysis tools. All authors approved the manuscript.

Funding

This research was funded by University of Mohaghegh Ardabili (Ardabil and Iran).

Availability of Data and Materials

All data and materials are available.

Acknowledgments

This research is supported by the research grant from the University of Mohaghegh Ardabili, extracted from the postdoctoral project with contract number 380, 2024/09/22.

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How to cite this article:
F. Ala Noshahr, R. Seyedsharifi, J. Seifdavati, N. Hedayat-Evrigh, A.Z.M. Salem. Estimate Residual Feed Intake (RFI) in Iranian Dairy Cows Using Multitrait Stochastic Regression Framework. *International Journal of Advanced Biological and Biomedical Research*, 2026, 14(2), 239-250.
DOI: https://doi.org/10.48309/ijabbr.2026.2072349.1666
Link: https://www.ijabbr.com/article_732245.html