Original Research

Journal of Advanced Veterinary Research
(2025) Volume 15, Issue 6, 897-900

Meta-analysis: Effect of forage and concentrate ratio on reproduction, quality, and quantity of milk in dairy cows

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ARTICLE INFO

Recieved: 30 September 2025

Accepted: 10 November 2025

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Keywords:

Concentrates, Forages, Meta-analysis, Production, Reproduction

ABSTRACT

Dairy cows require a balanced intake of nutrients from forages and concentrates to support rumen health and optimize milk production. This study used to identify the ideal ratio between forages and concentrates varies depending on the parameters measured. This meta-analysis research used methods by utilizing scientific publications in the form of journals with reproduction parameters including service per conception, calving interval, conception rate, and production parameters including milk production, milk protein, milk fat, milk lactose, and dry matter intake (DMI). This research was completed in April 2025. For milk production, milk fat, lactose, and S/C, a 50:50 ratio is considered most effective, while to increase milk protein content, CI, and CR, a 70:30 ratio is more recommended. The 60:40 ratio increases DMI of dairy cows. The right feed balance is not only important for digestive health but also affects energy efficiency, which in turn impacts milk production and cow reproduction. The study results revealed that applying the 50:50 ratio further improves the production and reproduction parameters of dairy cows.

Introduction

Small-scale dairy farmers often still provide low-quality feed that does not adequately meet the nutritional needs of dairy cows. The nutrient and energy requirements of dairy cows during lactation are determined by their basic needs, influenced by body weight, and milk production, which is influenced by the amount of milk secreted and the fat content in the milk (Bath *et al*., 1985). Optimal milk production is also influenced by an optimal reproductive cycle. Milk production and reproduction are inseparable, as milk production is part of the continuation of the reproductive process, with mechanisms such as lactogenesis and galactokinesis occurring after the cow reproduces (Netika *et al*., 2019). Abnormal reproduction can lead to longer calving intervals and decreased milk production (Reswati *et al*., 2014).

Improving dairy cow milk production can be achieved by enhancing feed quality, particularly protein content. The protein content in feed affects milk production and quality. Higher milk production demands higher protein intake, as the protein in the feed is used in the synthesis of milk components, such as milk protein and lactose (Syafri *et al*., 2014). Therefore, feed needs have a significant impact on milk production and the reproductive cycle of cows, where increased protein levels in the feed can enhance postpartum estrus rates. One of the factors affecting dairy cow reproductive status is adequate protein availability in the feed (Ahmad and Shafirudin, 2019). Feed protein not only influences milk component synthesis but also affects the estrus cycle, where higher protein content in feed contributes to the formation of estrogen hormones, showing estrus signs (Abidin *et al*., 2012).

Poor feed management can result in reduced milk production due to insufficient energy in the feed to meet the cows' needs, leading to suboptimal metabolism and milk biosynthesis, thereby not achieving the cow's production potential (Rokhayati, 2010). Achieving optimal milk production efficiency requires balanced feed with adequate forage and concentrate, ensuring sufficient energy availability. Forage is the primary source of fiber and feed for dairy cows, while concentrates provide protein and energy (Parakkasi, 1999). Adequate intake of forage and concentrates directly impacts the productivity of dairy cows, both quantitatively and qualitatively. Balanced forage and concentrate feed also enhance reproductive performance, supporting biological processes and ovarian recovery, particularly after calving (Hoesni *et al*., 2022). Meta-analysis provides more accurate results regarding the effect of the balance between forage and concentrate, leading to better outcomes.

Materials and methods

The material used in the meta-analysis research consisted of internationally accredited journals, with a literature search totaling 371 journals containing data from various study aspects such as milk production, milk fat, milk protein, S/C, calving interval, and days open, 196 related journals were found that could be included and there are 46 journals that use in meta analysis. The tools used included PDF applications for screening the journals to be used and data processing applications such as Microsoft Excel for data collection, RStudio for performing meta-analysis, and Review Manager 5.4 for interpreting the data.

The method used in this research was the quantitative method with a meta-analysis study. The studies used in this meta-analysis research employed a feed ratio of concentrate and forage with ratios of 60:40, 50:50, and 70:30 in this experiment. This was done to determine the impact of these feed ratios on production, milk composition, and reproduction of dairy cows. This research went through nine stages of meta-analysis, namely topic determination, literature collection according to inclusion criteria, data extraction, heterogeneity testing, calculating effect size, hypothesis testing with summary effect, moderator variable analysis, publication bias evaluation, and reporting results.

ISSN: 2090-6277/2090-6269/

Statistical analysis

Following the extraction of data concerning the ratio of concentrate to forage feed and its effects on milk yield and reproductive metrics like S/C (services per conception), CR (conception rate) and CI (calving interval), a heterogeneity test was performed to evaluate the consistency of findings across different studies. A p-value below 0.05 indicates the use of a random effects model; otherwise, a fixed effects model is employed. The random effects model considers variations between studies, whereas the fixed effects model presumes a uniform effect size across all studies. Subsequently, the effect size is determined to quantify the strength of the relationship between variables or groups, serving as the foundation for integrating study results in the meta-analysis. A hypothesis test utilizing the summary effect is then conducted to demonstrate the average effect size across all studies. This test assesses whether the treatment has a statistically significant effect, using confidence intervals to evaluate the reliability of the findings. Lastly, a ranking process using p-scores is implemented to assess the effectiveness of each treatment within a comparison network. The p-score is derived from point estimates and standard errors, aiding in identifying the most statistically effective treatment.

Results

Milk yield

The milk production parameter study data in Table 1 consists of 30 studies with three comparisons. The NMA analysis results indicate that the forage-to-concentrate ratio of 50:50 is the best value, followed by the 70:30 and 60:40 ratios. Based on the comparative test, the 50:50 forage-to-concentrate ratio is not significantly different from 70:30 but differs from 60:40.

Table 1. Data calculation of network meta-analysis on milk production

Net-rank	Number of studies	Milk Production (liters/day)	P-score (common)	P-score (random)
50:50:00	12	$32.85^{a} \pm 6.75$	1	1
70:30:00	12	$21.95^{b} \pm 4.26$	0.5	0.30
60:40:00	12	$28.32^{b} \pm 8.60$	0	0.20

Milk protein

The milk protein parameter study data in Table 2 consists of 30 studies with three comparisons. The NMA analysis results indicate that the forage-to-concentrate ratio of 50:50 is the best, followed by the 60:40 and 70:30 ratios. Based on the comparative test, the 50:50 forage-to-concentrate ratio is not significantly different from either 60:40 or 70:30.

Table 2. Data calculation of network meta-analysis on milk protein.

Comparison	Number of studies	Milk Protein (%)	P-score (common)	P-score (random)
60:40:00	10	$3.33^{a} \pm 0.25$	1	0.73
50:50:00	10	$3.40^{a} \pm 0.27$	0.5	0.58
70:30:00	10	$3.15^{a} \pm 0.18$	0	0.19

Milk fat

The milk fat parameter study data in Table 3 consists of 30 studies with three comparisons. The NMA analysis results indicate that the forage-to-concentrate ratio of 50:50 is the best, followed by the 70:30 and 60:40 ratios. Based on the comparative test, the 50:50 forage-to-concentrate ratio is not significantly different from either 70:30 or 60:40.

Table 3. Data calculation of network meta-analysis on milk fat.

Comparison	Number of studies	Milk Fat (%)	P-score (common)	P-score (random)
50:50:00	10	$4.08^{a} \pm 0.58$	0.52	0.93
70:30:00	10	$3.91^{a} \pm 0.29$	0.98	0.33
60:40:00	10	$3.98^{a} \pm 0.62$	0	0.24

Milk lactose

The milk lactose parameter study data in Table 4 consists of 30 studies with three comparisons. The NMA analysis results indicate that the forage-to-concentrate ratio of 60:40 is the best, followed by the 70:30 and 50:50 ratios. Based on the comparative test, the 50:50 forage-to-concentrate ratio is significantly different from 60:40 and 70:30, but 60:40 does not differ from 70:30.

Table 4. Data calculation of network meta-analysis on milk lactose.

Comparison	Number of studies	Milk Lactose (%)	P-score (common)	P-score (random)
60:40:00	10	$4.83^{a} \pm 0.17$	0.72	0.90
70:30:00	10	$4.42^{b} \pm 1.20$	0.78	0.53
50:50:00	10	$4.79^{b} \pm 0.13$	0	0.07

Dry matter intake (DMI)

The DMI parameter study data in Table 5 consists of 30 studies with three comparisons. The NMA analysis results indicate that the forage-to-concentrate ratio of 70:30 is the best, followed by the 50:50 and 60:40 ratios. Based on the comparative test, the 50:50 forage-to-concentrate ratio is significantly different from both 60:40 and 70:30.

Table 5. Data calculation of network meta-analysis on DMI.

Comparison	Number of studies	DMI (kg/day)	P-score (common)	P-score (random)
70:30:00	10	$19.47^{a} \pm 2.6$	1	0.94
50:50:00	10	$18.09^{b} \pm 2.4$	0.5	0.56
60:40:00	10	$9.84^{b} \pm 0.7$	0	0

Service per conception (S/C)

The S/C parameter study data in Table 6 consists of 30 studies with three comparisons. The NMA analysis results indicate that the forage-to-concentrate ratio of 50:50 is the best, followed by the 60:40 and 70:30 ratios. Based on the comparative test, the 50:50 forage-to-concentrate ratio is not significantly different from either 60:40 or 70:30.

Table 6. Data calculation of network meta-analysis on S/C.

Comparison	Number of studies	S/C	P-score (common)	P-score (random)
50:50:00	10	$3.32^{a} \pm 1.2$	1	0.88
70:30:00	10	$1.74^{a} \pm 1.1$	0.04	0.39
60:40:00	10	$2.54^{a} \pm 1.0$	0.46	0.23

Calving interval (CI)

The CI parameter study data in Table 7 consists of 12 studies with three comparisons. The NMA analysis results indicate that the forage-to-concentrate ratio of 70:30 is the best, followed by the 50:50 and 60:40 ratios.

Table 7. Data calculation of network meta-analysis on CI.

Comparison	Number of studies	CI	P-score (common)	P-score (random)
70:30:00	4	92.10 ± 48.2	0.10	0.10
50:50:00	4	66.48 ± 20.1	0.50	0.50
60:40:00	4	95.75 ± 36.2	0	0

Conception rate (CR)

The CR parameter study data in Table 8 consists of 12 studies with three comparisons. The NMA analysis results indicate that the forage-to-concentrate ratio of 70:30 is the best, followed by the 60:40 and 50:50 ratios.

Table 8. Data calculation of network meta-analysis on CR.

Comparison	Number of studies	CR	P-score (common)	P-score (random)
50:50:00	4	63.98 ± 6.1	1	0.84
60:40:00	4	57.75 ± 20.8	0.5	0.65
70:30:00	4	30.80 ± 7.6	0	0.00

Discussion

The meta-analysis calculations indicate that the forage-to-concentrate ratio of 50:50 is the ideal proportion for dairy milk production. This ratio generally refers to the balance between forage and concentrate in the daily ration of dairy cows. Maintaining this balance is crucial for rumen health and optimal milk production, as the 50:50 ratio helps regulate the equilibrium between acid production and buffering capacity in the rumen. Excess concentrate can lead to ruminal acidosis (low rumen pH), disrupting digestion, reducing appetite, and negatively affecting milk production and overall cow health. A balanced forage-to-concentrate ratio (50:50) tends to support optimal volatile fatty acid (VFA) production in the rumen. According to Kholis *et al.* (2024), propionate, one of the VFAs produced during rumen fermentation, is closely related to milk volume production. Propionate is converted into glucose in the liver, which serves as the primary precursor for lactose synthesis in the mammary gland. Vidyanto *et al.* (2015) stated that lactose plays a vital role in regulating milk volume, meaning that increased lactose production directly contributes to higher milk yield.

The meta-analysis calculations also indicate that the 50:50 forage-to-concentrate ratio is the ideal proportion for milk protein production. Riski *et al.* (2016) explained that milk protein levels are influenced by concentrate intake, as milk protein content is positively correlated with feed, particularly the carbohydrates found in concentrate. This process generates ammonia (NH_3) and amino acids. Some of the ammonia is utilized by rumen microbes to synthesize microbial protein, which is later digested in the small intestine and serves as an essential source of amino acids for the cow. Sanh *et al.* (2002) stated that an increase in amino acid availability contributes to enhanced milk protein synthesis. According to Nugraha *et al.* (2016), the synthesis of milk protein occurs within the alveolar epithelial cells, with part of the process taking place in ribosomes attached to the endoplasmic reticulum, while others remain free in the cytoplasm.

The meta-analysis calculations indicate that the forage-to-concentrate ratio of 50:50 is the ideal proportion for milk fat production. This ratio optimizes milk fat yield because, according to Nousiainen *et al.* (2009), the energy balance between concentrate and forage affects milk fat composition. An improper ratio can disrupt rumen fermentation and nutrient absorption, leading to reduced milk fat production. Concentrate supplies sufficient energy, while forage provides adequate fiber to stimulate fermentation, which produces volatile fatty acids (VFAs). According to Roza *et al.* (2022), nutrient balance enhances VFA production, particularly acetic acid, which is derived from amino acid breakdown and serves as the primary precursor for milk fat synthesis. Without sufficient forage, ruminal acetate production decreases, directly limiting the availability of key precursors for milk fat synthesis.

The meta-analysis calculations also indicate that the forage-to-concentrate ratio of 60:40 is the ideal proportion for milk lactose production. A balanced ratio of 60% forage and 40% concentrate provides adequate energy to increase lactose production without destabilizing rumen pH. This ratio supports energy and protein balance, ensuring optimal nutrient availability for rumen microbes to enhance fermentation. According to Rosmalia *et al.* (2024), nutrient balance improves VFA production in the rumen, positively impacting microbial growth. Utomo & Miranti (2010) stated that VFAs—particularly propionate—stimulate glucose synthesis, which is then utilized as a precursor for milk lactose production.

The meta-analysis calculations indicate that the forage-to-concentrate ratio of 70:30 is the ideal proportion for DMI. According to Purwanti & Hastiningtyas (2023), a higher forage proportion provides more crude fiber, which enhances saliva production (a natural buffer) and supports a healthy rumen environment. A well-balanced rumen improves feed digestion efficiency, indirectly sustaining long-term optimal DMI. However, Pratama *et al.* (2019) warned that low crude fiber content can lead to rumen pH decline, reducing nutrient absorption efficiency and potentially causing ruminal acidosis.

The meta-analysis calculations also indicate that the forage-to-concentrate ratio of 50:50 is the ideal proportion for S/C in dairy cows. Beam & Butler (1999) stated that S/C values in dairy cows are influenced by energy availability in feed, as an imbalance in energy intake can impact follicular development and ovulation, consequently affecting S/C values. However, the 50:50 ratio ensures an optimal balance between energy and protein, enhancing VFA production efficiency. According to Bere *et al.* (2019), VFAs are synthesized into glucose in the liver, leading to insulin secretion, which stimulates IGF-1 (Insulin-Like Growth Factor 1) production. Kurniawati *et al.* (2021) explained that IGF-1 plays a crucial role in follicular development, accelerating estrous cycles and increasing conception chances, thereby optimizing S/C values.

The meta-analysis calculations indicate that the forage-to-concentrate ratio of 70:30 is the ideal proportion for CI. This ratio is considered optimal because it balances crude fiber for rumen health with dense energy and nutrients to support both milk production and reproduction. This nutritional balance stimulates rumen microbial fermentation, producing VFAs, which serve as precursors for glucose synthesis, a key factor in reproductive functions.

According to Ramandani & Nururrozi (2015), nutritional imbalances that disrupt fermentation reduce glucose production, limiting the energy supply for FSH and LH synthesis, which in turn hinders follicular development. Suranindyah *et al.* (2020) explained that maintaining balanced energy and protein levels helps minimize negative energy balance (NEB), supporting reproductive health and optimizing calving intervals, making them shorter and more efficient.

The meta-analysis calculations also indicate that the forage-to-concentrate ratio of 50:50 is the ideal proportion for CR. According to Garnsworthy (2008), CR imbalances are caused by negative energy balance during lactation, which can impair dairy cow fertility. The 50:50 ratio provides a crucial nutritional balance to enhance CR in dairy cows.

Nigussie (2018) stated that energy and protein balance influences the estrous cycle after calving. Meanwhile, Lake & Purwatiningsih (2020) emphasized that energy deficiencies can cause reproductive cycles to stall, further affecting fertility.

Conclusion

Based on the research results, a 50:50 ratio of forages and concentrates is the ideal balance. This balance shows an increase in dairy cow production and reproduction parameters. Recommendation: The 50:50

ratio can be continued for future research while still paying attention to the composition of the feed ingredients that will be used for dairy cows.

Conflict of interest

The authors have no conflict of interest to declare.

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