

# Zero-Concentrate Feeding in Dairy Cows: A Sustainable Approach to Milk Quality, Animal Health, and Welfare

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## Abstract

*The study explores the benefits of eliminating concentrate feeds in dairy cow nutrition. As sustainability becomes a central concern in agriculture, zero-concentrate feeding offers a promising solution to reduce the environmental footprint of dairy farming while promoting optimal animal health and welfare. This approach primarily focuses on maximizing the use of high-quality forages, such as grasses and legumes, to meet the nutritional needs of dairy cows. By minimizing the use of concentrates, the system aims to lower greenhouse gas emissions, reduce dependency on external feed inputs, and encourage more sustainable farming practices. The paper examines the effects of zero-concentrate feeding on milk composition, highlighting improvements in fatty acid profiles, including higher omega-3 and conjugated linoleic acid (CLA) concentrations. Additionally, it addresses the positive impacts on animal health, particularly in terms of improved rumen function, reduced metabolic disorders, and enhanced immune responses. The welfare benefits of this feeding strategy are also discussed, including better behavioral expression, reduced stress, and improved reproductive efficiency. By aligning with organic and regenerative farming principles, zero-concentrate feeding systems support long-term sustainability in dairy farming, offering a holistic approach that benefits both the environment and dairy cows. This study emphasizes the importance of integrating zero-concentrate feeding into future dairy management practices for a more sustainable and ethical dairy industry.*

**Keywords:** Animal welfare, dairy cows, environmental sustainability, forage-based diet, milk quality, rumen health, zero-concentrate feeding

## INTRODUCTION

The dairy industry is under increasing pressure to adopt more sustainable and ethical practices to meet the growing global demand for dairy products while minimizing its environmental impact [1]. Traditional dairy farming systems rely heavily on concentrate feeds, which often consist of grains and by-products that are energy-dense but may come with significant ecological costs [2]. These concentrate feeds are associated with higher greenhouse gas emissions, deforestation, and excessive water use. As

the need for more sustainable agricultural practices intensifies, zero-concentrate feeding offers a compelling alternative by reducing the reliance on external feed inputs and maximizing the use of locally available forages [3]. This approach not only promotes sustainability but also holds the potential to improve milk quality, animal health, and welfare, addressing key concerns in modern dairy farming [4].

Zero-concentrate feeding in dairy cows focuses on providing a diet primarily based on high-quality forages such as grasses, legumes, and other natural pasture resources [5]. This strategy supports the optimal function of the rumen, which plays a crucial role in breaking down fibrous plant materials [6].

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By relying on a forage-based diet, zero-concentrate feeding can help improve the rumen microbial ecosystem, leading to better fiber digestion, reduced metabolic disorders, and enhanced nutrient absorption [7]. Furthermore, a diet centered around forages is known to produce milk with a healthier fatty acid profile, including higher concentrations of omega-3 fatty acids and conjugated linoleic acid (CLA), both of which are beneficial to human health [8]. In addition, this approach aligns with the principles of organic farming and regenerative agriculture, offering a more sustainable pathway for dairy production [9].

The novelty of this study lies in its comprehensive evaluation of zero-concentrate feeding, specifically focusing on its impacts across multiple domains: milk quality, animal health, and welfare. While previous studies have highlighted individual aspects of concentrate-free diets, this study integrates a broader perspective by assessing the overall sustainability of such systems. By exploring how zero-concentrate feeding affects milk composition, metabolic health, rumen function, and behavioral well-being of dairy cows, this research offers a holistic view of how alternative feeding practices can contribute to both ecological and ethical improvements in dairy farming. The findings from this study have the potential to reshape conventional dairy farming practices, offering valuable insights for policymakers, dairy farmers, and researchers aiming to promote a more sustainable, healthy, and welfare-oriented dairy industry.

## **ECONOMIC BENEFITS**

### **Reduces Feed Cost Significantly**

Zero-concentrate feeding significantly cuts feed costs as it eliminates the need for expensive concentrates. By focusing on locally available forages, which are generally more affordable, farmers reduce reliance on high-cost feed ingredients [10]. Concentrates are often the most expensive component of dairy nutrition, so shifting to a forage-based diet makes a substantial difference in lowering overall feed expenses.

### **Enhances Farm Profitability**

By reducing feed costs and improving resource efficiency, zero-concentrate feeding enhances farm profitability. With fewer financial resources spent on purchasing and storing concentrate feeds, farms can allocate their budget to other essential areas such as improving cow health or expanding pasture management [11]. The result is a more profitable operation, even in the face of rising concentrate prices or market uncertainty.

### **Decreases Dependence on External Feed Suppliers**

Zero-concentrate feeding allows dairy farms to reduce their reliance on external feed suppliers by utilizing home-grown or locally sourced forages [12]. This shift lessens the vulnerability of farmers to fluctuations in concentrate feed availability or price hikes. By depending more on their own resources, farmers gain greater control over their feeding systems and decrease the need for outsourcing feed.

### **Reduces Market Price Volatility Impact**

Feed prices are subject to market volatility, and dairy farmers often face financial instability due to fluctuations in concentrate feed costs [13]. By adopting zero-concentrate feeding, farmers can shield themselves from such volatility, as the need for external concentrates is reduced. This enables a more predictable and stable cost structure, helping to stabilize farm economics in unpredictable markets.

### **Minimizes Financial Risk from Concentrate Price Fluctuations**

The cost of concentrates can fluctuate based on supply chain disruptions, weather events, or market demand. Zero-concentrate feeding mitigates these financial risks by decreasing or eliminating the need to purchase concentrates [14]. This means that dairy farmers are less vulnerable to the economic pressures caused by price hikes in concentrate feed, allowing for a more stable financial outlook.

### **Lowers Investment in Feed Storage Infrastructure**

Zero-concentrate systems reduce the need for complex feed storage facilities that are essential for storing large quantities of concentrates. Since forages can often be stored more easily or grazed directly from pastures, farmers can save money on storage infrastructure. This reduction in capital investment frees up resources for other operational needs, further improving the farm's economic viability [10].

### **Reduces Transportation Costs Associated with Concentrate Feeds**

Transportation costs for concentrate feeds can be a significant financial burden, especially when long distances are involved. With zero-concentrate feeding, the reliance on externally sourced feeds is minimized, thus reducing transportation costs. This not only makes the system more economical but also contributes to a lower environmental footprint by decreasing the need for transporting large volumes of feed [11].

### **Encourages Cost-Effective Forage Utilization**

Zero-concentrate feeding promotes the efficient use of available pasture and forage resources. By focusing on utilizing local forages, such as grasses and legumes, farms are able to minimize waste and optimize the nutritional value derived from these resources [12]. This reduces the need for costly supplemental feeds and ensures a more cost-effective approach to livestock nutrition.

### **Promotes Self-Sufficiency in Feed Resources**

One of the key benefits of zero-concentrate feeding is that it fosters self-sufficiency in feed production. By relying on homegrown forage, dairy farmers can avoid the dependency on external feed suppliers. This self-reliance reduces exposure to price fluctuations and supply chain disruptions, ensuring a more resilient and independent farming operation that is less influenced by global market dynamics [14].

### **Reduces Capital Expenditure on Feed Processing**

Zero-concentrate feeding systems lower the need for feed processing, which often requires significant capital investment in machinery, storage, and facilities. Since forages are typically fed with minimal processing, the capital expenditure required for specialized feed equipment is reduced. This shift allows farmers to allocate resources more efficiently and lower overall operational costs, leading to a more financially sustainable farm model [10].

## **ENVIRONMENTAL SUSTAINABILITY**

### **Lowers Greenhouse Gas Emissions from Concentrate Feed Production**

The production of concentrate feeds, particularly grains and soybeans, contributes to substantial greenhouse gas emissions due to the intensive farming practices and energy requirements involved [15]. Zero-concentrate feeding reduces the need for these external inputs, thereby lowering emissions associated with feed production. By utilizing locally sourced forages, the dairy industry can significantly reduce its contribution to climate change, promoting a more sustainable and eco-friendly farming system.

### **Reduces Deforestation Associated with Soybean and Grain Production**

Large-scale production of soybeans and grains for livestock feed has been a major driver of deforestation, particularly in regions like the Amazon [16]. By eliminating the need for concentrates, zero-concentrate feeding directly reduces demand for these crops. This helps mitigate deforestation and the loss of critical ecosystems, preserving biodiversity and contributing to a more sustainable agricultural landscape.

### **Minimizes Water Consumption for Concentrate Feed Processing**

The processing of concentrate feeds requires substantial amounts of water, both for irrigation of crops and for feed processing itself [17]. Zero-concentrate feeding systems, by relying on forages, drastically

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reduce the need for water-intensive concentrate production. This not only saves water but also helps conserve local water resources, particularly in areas where water scarcity is a growing concern, thus promoting more responsible water management in dairy farming.

### **Lowers Carbon Footprint of Dairy Operations**

By reducing or eliminating the need for concentrate feeds, zero-concentrate feeding significantly lowers the carbon footprint of dairy operations [18]. The production, processing, and transportation of concentrate feeds are energy-intensive and contribute to carbon emissions. In contrast, a forage-based feeding system relies on local resources and minimizes external inputs, reducing energy consumption and overall emissions from dairy farming, making it a more environmentally sustainable practice.

### **Enhances Biodiversity in Pastures**

Zero-concentrate feeding encourages the use of diverse pasture ecosystems, which naturally supports higher biodiversity. By promoting a variety of plants, grasses, and legumes for livestock grazing, these systems foster a more resilient and ecologically balanced environment. Biodiversity in pastures also improves soil health and helps mitigate the risk of pest outbreaks, contributing to the long-term sustainability of dairy farming [15].

### **Reduces Soil Degradation and Nutrient Depletion**

The reliance on concentrate feeds often leads to soil degradation and nutrient depletion, particularly in areas where monoculture crops like corn and soybeans are grown intensively. Zero-concentrate feeding systems, which depend on rotational grazing and diverse forage crops, help maintain soil health by encouraging natural nutrient cycling and reducing the pressure on soil systems. This sustainable approach reduces the need for artificial fertilizers and preserves soil fertility for future generations [16].

### **Prevents Contamination from Feed Additives and Synthetic Supplements**

Concentrate feeds often contain various additives, such as antibiotics, growth hormones, and synthetic nutrients, which can contribute to environmental contamination through runoff or improper disposal. Zero-concentrate feeding reduces or eliminates the use of these additives, thereby preventing potential environmental harm. By focusing on natural, forage-based diets, this system ensures that dairy production remains free from harmful synthetic chemicals, leading to cleaner, healthier ecosystems [17].

### **Reduces Fossil Fuel Usage for Feed Production and Transportation**

The production, processing, and transportation of concentrate feeds rely heavily on fossil fuels, contributing to pollution and environmental degradation [15]. Zero-concentrate feeding reduces the need for these energy-intensive processes by utilizing locally grown forages, which require less transportation and processing. This reduces the reliance on fossil fuels, lowers energy consumption, and promotes a more sustainable energy model within dairy farming operations.

### **Encourages Regenerative Farming Practices**

Zero-concentrate feeding promotes regenerative farming practices, such as rotational grazing, which can improve soil health, enhance water retention, and sequester carbon in the soil. By integrating these practices into dairy operations, farmers can restore and protect natural ecosystems, increase farm resilience to climate change, and reduce the negative environmental impacts often associated with industrialized dairy production. Regenerative practices foster long-term sustainability in the agricultural sector [16].

### **Promotes Sustainable Land Use for Dairy Production**

By relying on forages rather than concentrate feeds, zero-concentrate feeding systems promote more sustainable land use for dairy production [18]. Forage-based diets encourage rotational grazing, which helps to restore and maintain healthy pasturelands. This practice reduces land degradation and ensures

that land is used in a way that is both economically and ecologically sustainable, supporting long-term productivity while minimizing environmental harm.

## **RUMEN HEALTH AND DIGESTIVE EFFICIENCY**

### **Supports Natural Rumen Fermentation Processes**

Zero-concentrate feeding promotes natural rumen fermentation by allowing cows to graze on fibrous forages [19]. The rumen microorganisms are better adapted to break down fibrous plant materials, which supports the natural fermentation process that is essential for the cow's overall health and digestive efficiency. This more natural digestion process improves nutrient absorption and rumen function, contributing to better animal health.

### **Maintains Optimal Rumen pH, Preventing Acidosis**

A high-concentrate diet often leads to excessive acid production in the rumen, which can cause acidosis, a condition that negatively affects animal health and productivity. Zero-concentrate feeding helps maintain a more balanced rumen pH by reducing the intake of rapidly fermentable carbohydrates [20]. Forage-based diets are slower to ferment, resulting in less acid production and a more stable environment in the rumen, reducing the risk of acidosis.

### **Reduces the Risk of Subacute Ruminal Acidosis (SARA)**

Subacute ruminal acidosis (SARA) is a common issue in high-concentrate feeding systems, where rapid fermentation of grains can overwhelm the rumen's buffering capacity. By providing a forage-based diet with lower fermentable carbohydrates, zero-concentrate feeding reduces the risk of SARA [21]. The slower, more consistent fermentation process in the rumen helps maintain a healthier microbial balance and a lower incidence of this metabolic disorder.

### **Enhances Microbial Diversity in the Rumen**

Zero-concentrate feeding enhances the diversity of rumen microbes by offering a wider variety of plant fibers that support different microbial communities [19]. This increased microbial diversity is beneficial for digestion, as it ensures that a broader range of nutrients can be processed efficiently. A diverse microbial population also contributes to the stability and resilience of the rumen ecosystem, supporting overall digestive health and efficiency.

### **Reduces the Incidence of Bloating and Indigestion**

Bloating and indigestion are often a result of sudden dietary changes, particularly the introduction of high-starch concentrates [20]. Zero-concentrate feeding, which relies on consistent, fiber-rich diets, helps prevent these digestive issues by allowing the rumen to adjust more gradually. The fiber content in the diet promotes normal ruminal motility and gas production, thus reducing the risk of bloating and improving overall digestive comfort.

### **Improves Fiber Digestibility Through Enhanced Microbial Activity**

Zero-concentrate feeding improves fiber digestibility by stimulating beneficial microbial activity in the rumen. Rumen microbes that specialize in breaking down fibrous plant materials thrive in a forage-based diet, enhancing the efficiency of fiber fermentation. As a result, cows are better able to extract nutrients from roughages, improving overall digestive efficiency and nutrient utilization, leading to better growth, milk production, and overall health [20].

### **Prevents Digestive Disorders Linked to High-Starch Diets**

High-starch diets, typically associated with concentrate feeding, can disrupt the rumen's balance, leading to digestive disorders such as acidosis, bloating, and indigestion. Zero-concentrate feeding prevents these issues by reducing starch intake and relying on fiber-rich forages that promote slower, more stable fermentation. This dietary shift helps maintain a healthy rumen environment, preventing the digestive disturbances often linked to starch-heavy feeds [19].

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### **Enhances Volatile Fatty Acid Production for Energy Metabolism**

Fermentation of fiber in the rumen produces volatile fatty acids (VFAs), which serve as a primary energy source for dairy cows. Zero-concentrate feeding promotes the production of VFAs by encouraging the fermentation of complex carbohydrates in forages. This results in improved energy metabolism, helping cows maintain optimal production levels, support milk yield, and sustain overall health while reducing reliance on external energy sources like concentrates [21].

### **Promotes a Stable and Resilient Rumen Ecosystem**

By prioritizing forages, zero-concentrate feeding helps create a stable and resilient rumen ecosystem [4]. The diverse array of fibers in forages promotes a balanced microbial population, enhancing rumen functionality and its ability to withstand environmental or dietary stressors. This stability leads to improved digestion, better nutrient absorption, and a reduced risk of digestive disorders, ensuring long-term health and productivity for dairy cows.

### **Reduces Risk of Metabolic Disorders Associated with High-Energy Diets**

High-energy diets, particularly those rich in concentrates, can lead to metabolic disorders such as ketosis, fatty liver, and metabolic syndrome [22]. Zero-concentrate feeding reduces the risk of these conditions by lowering the intake of rapidly fermentable carbohydrates. This helps maintain balanced energy metabolism, reducing the likelihood of excessive fat accumulation, improving liver health, and supporting a healthier overall metabolic profile in dairy cows.

## **MILK COMPOSITION AND QUALITY**

### **Enhances Milk Fatty Acid Profile with More Omega-3 And CLA**

Zero-concentrate feeding results in milk with a more favorable fatty acid profile, particularly by increasing levels of omega-3 fatty acids and conjugated linoleic acid (CLA). These beneficial fats are linked to improved human health outcomes such as reduced inflammation and enhanced cardiovascular health [23]. Forage-based diets, rich in omega-3s from grasses and legumes, contribute to these changes, offering both health and nutritional benefits in milk.

### **Increases Protein Efficiency in Milk Synthesis**

Forage-based diets improve the efficiency of milk protein synthesis by providing a steady supply of high-quality proteins and amino acids [4]. Unlike concentrate feeds, which can sometimes result in inefficient protein utilization, a natural forage-based diet encourages a more balanced protein intake. This improves milk production efficiency and ensures that the protein in the milk is derived from more natural, sustainable sources.

### **Produces Milk with a More Desirable Fatty Acid Composition**

Milk produced from cows on a zero-concentrate feeding system typically contains a more favorable fatty acid composition, including higher levels of unsaturated fats. Forage-based diets promote the synthesis of healthy fats in the milk, such as omega-3s and monounsaturated fats, while reducing the levels of saturated fats [22]. This enhanced milk composition supports both animal health and consumer preferences for healthier milk products.

### **Reduces the Likelihood of Antibiotic Residues in Milk**

Zero-concentrate feeding reduces the need for antibiotic use in dairy production, as forage-based diets are generally more natural and less likely to require interventions such as growth promoters or antibiotics. By minimizing concentrate intake, farmers can reduce the potential for antibiotic residues in milk, resulting in cleaner, safer products for consumers and helping to combat antibiotic resistance issues in livestock production [23].

### **Enhances Milk Taste and Nutritional Quality**

Milk from cows on a zero-concentrate feeding system often has improved flavor and enhanced nutritional quality. The natural diets, consisting of fresh forages and grasses, contribute to better milk

taste, with a cleaner, fresher profile. Additionally, milk from these systems tends to have higher levels of beneficial nutrients, including vitamins and fatty acids, making it a more nutritious option for consumers [4].

### **Reduces Milk Contamination from Concentrate Feed Contaminants**

Concentrate feeds are sometimes contaminated with residues from pesticides, heavy metals, or synthetic chemicals. By eliminating or reducing concentrate intake, zero-concentrate feeding systems lower the risk of milk contamination from these harmful substances. This results in milk with fewer contaminants, which is safer for both the cows and the consumers, promoting healthier and more natural dairy products [4].

### **Supports Higher Beta-Carotene Levels in Milk**

Cows on a forage-based diet typically produce milk with higher levels of beta-carotene, a precursor to vitamin A. The green forages, especially fresh grass, are rich in beta-carotene, which is transferred into the milk, improving its nutritional profile. Higher beta-carotene levels not only enhance the color of the milk but also provide additional health benefits, including improved immune function and vision support for consumers [23].

### **Improves Casein Content for Better Cheese Yield**

Casein is the main protein in milk, essential for cheese production. A zero-concentrate feeding system, which relies on natural, fiber-rich forages, helps maintain optimal casein levels in milk. This increase in casein content results in better cheese yield and quality, making it a more efficient and profitable method for dairy farmers who focus on cheese production [22].

### **Produces Milk with Lower Somatic Cell Counts**

Milk from cows on a zero-concentrate feeding system generally has lower somatic cell counts (SCC), which is an indicator of mastitis or infection. A more natural, balanced diet enhances overall cow health and reduces the likelihood of infections, leading to better milk quality. Lower SCC not only improves milk safety but also increases shelf life and overall product quality, making it more desirable for consumers and dairy processors [4].

### **Maintains Consistent Milk Production with Proper Forage Management**

While zero-concentrate feeding systems rely on forages, proper management of these forage resources is key to ensuring consistent milk production. By maintaining high-quality, well-managed pastures and ensuring year-round access to fresh forages, milk production remains steady. This stable and sustainable system contributes to a more reliable milk supply without the unpredictability often associated with concentrate-based feeding programs [23].

## **ANIMAL WELFARE AND LONGEVITY**

### **Reduces Stress from Diet-Induced Metabolic Imbalances**

Zero-concentrate feeding reduces the likelihood of metabolic imbalances, such as ketosis and acidosis, which often arise from high-starch, concentrate-based diets [1]. By providing a more natural, fiber-rich diet, cows experience less stress from metabolic disturbances. This stable nutritional approach minimizes fluctuations in energy balance, helping to maintain a healthier, stress-free cow, which leads to better overall welfare and productivity.

### **Enhances Longevity and Productive Lifespan of Cows**

A balanced, forage-based diet supports the overall health and longevity of dairy cows. By reducing the risk of metabolic disorders and promoting natural body function, zero-concentrate feeding can enhance the productive lifespan of cows. A healthier, more resilient cow is likely to have a longer productive life, offering both economic benefits for the farmer and better welfare outcomes for the animals [9].

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**Lowers the Incidence of Lameness from High-Starch Feeding**

Feeding cows high-starch concentrates has been linked to an increased risk of lameness, primarily due to the effect of these diets on rumen function and overall health [19]. Zero-concentrate feeding reduces this risk by promoting more natural digestion and less strain on the rumen. The resulting improvement in overall cow health leads to a reduction in the incidence of lameness, helping to maintain animal comfort and welfare.

**Reduces Culling Rates Due to Metabolic Diseases**

Metabolic diseases, often caused by high-concentrate feeding, are a significant contributor to higher culling rates in dairy herds [8]. Zero-concentrate feeding reduces the occurrence of such diseases by providing a balanced diet that minimizes the risk of conditions like acidosis, ketosis, and fatty liver. As a result, cows experience fewer health issues, reducing the need for early culling and ensuring greater herd longevity.

**Encourages Natural Feeding Behavior**

Zero-concentrate feeding promotes natural foraging behavior, allowing cows to graze freely and eat a diverse range of plants [9]. This natural feeding behavior is not only more physically and mentally stimulating for the cows but also supports better rumen function and digestion. Cows fed in this way experience greater welfare by being allowed to exhibit their natural instincts, which contributes to higher levels of comfort and reduced behavioral stress.

**Reduces Heat Stress by Avoiding Metabolic Overload**

High-starch diets can cause metabolic overload, leading to increased heat production in cows, which exacerbates the effects of heat stress, especially in hot climates. Zero-concentrate feeding reduces the metabolic burden by providing cows with a more natural, balanced diet. This helps prevent excessive heat production from overactive metabolism, reducing the risk of heat stress and maintaining animal comfort in warmer conditions [1].

**Supports Higher Reproductive Efficiency**

Cows on a zero-concentrate feeding system are less prone to metabolic imbalances that can impair reproductive efficiency. By providing a more stable and natural energy supply through forages, cows are better able to maintain a healthy body condition, promoting normal reproductive cycles [19]. As a result, zero-concentrate feeding helps improve fertility rates and overall reproductive success, supporting the sustainability and productivity of dairy operations.

**Reduces Dependency on Veterinary Interventions**

The natural, fiber-rich diet of zero-concentrate feeding minimizes the occurrence of metabolic disorders and health complications that often require veterinary intervention [19]. By reducing the need for antibiotics, hormonal treatments, and corrective procedures associated with concentrate-based feeding, zero-concentrate systems promote a more holistic, sustainable approach to animal health. This reduction in veterinary reliance not only improves animal welfare but also lowers farm costs associated with medical interventions.

**Enhances Immune Function Through Better Gut Health**

The improved digestive health associated with zero-concentrate feeding supports a stronger immune system in cows. By promoting a healthy gut microbiome and reducing digestive disorders, cows experience better overall immune function. A more stable and balanced digestive system enhances the cow's ability to fight infections and diseases, resulting in fewer health problems and a more resilient animal population [8].

**Improves Overall Body Condition Stability**

Zero-concentrate feeding helps maintain a more stable body condition by supporting a natural and balanced nutrient intake. Without the metabolic fluctuations that come from high-concentrate diets,

cows are able to maintain a consistent body weight and condition. This stability is essential for ensuring cows remain in optimal health throughout their productive lifespan, reducing the likelihood of health issues associated with poor body condition and improving overall animal welfare [9].

## **REPRODUCTIVE HEALTH**

### **Reduces Postpartum Metabolic Disorders**

Zero-concentrate feeding helps reduce the incidence of postpartum metabolic disorders, such as ketosis, fatty liver, and hypocalcemia, by maintaining a more stable energy balance [24]. The high fiber content in forage-based diets prevents the metabolic stress typically induced by high-starch concentrates. By avoiding these imbalances, cows recover more quickly after calving, ensuring healthier postpartum periods and improved reproductive outcomes.

### **Enhances Ovarian Activity and Fertility Rates**

A balanced, natural diet provided through zero-concentrate feeding supports better ovarian activity and hormonal balance [25]. This, in turn, leads to higher fertility rates. Forage-based diets, rich in essential nutrients, optimize hormonal regulation, ensuring that cows are in the best physical condition for conception. The resulting increase in ovarian function translates to improved fertility and more efficient breeding cycles.

### **Reduces the Risk of Dystocia and Calving Difficulties**

Dystocia (difficult calving) can be linked to metabolic issues caused by poor nutrition, particularly from excessive concentrate feeding. Zero-concentrate feeding ensures cows maintain a healthier body condition, reducing the risk of overly large calves or calving complications. With a more balanced diet that prevents excessive weight gain, cows are more likely to experience smoother and less stressful calvings, improving their overall reproductive health [11].

### **Improves Conception Rates with Better Energy Balance**

By promoting better energy balance through a high-fiber, low-concentrate diet, zero-concentrate feeding helps optimize reproductive performance. Cows on these diets are less likely to experience metabolic stress, which can impair conception. A steady, natural supply of energy from forages supports the cow's reproductive system, leading to higher conception rates and improved overall fertility [26].

### **Reduces Embryonic Mortality Linked to Metabolic Stress**

Metabolic stress from high-concentrate diets can compromise embryonic development, leading to higher rates of embryonic mortality. By reducing the risk of metabolic imbalances and providing a more stable nutrient intake, zero-concentrate feeding helps ensure healthier pregnancies. This results in a lower incidence of embryonic loss and improved early pregnancy outcomes, supporting greater reproductive efficiency in dairy herds [27].

### **Supports Better Colostrum Quality for Newborn Calves**

Cows on a zero-concentrate feeding system tend to produce higher-quality colostrum, as their overall health and nutrient intake are optimized. Colostrum, which is critical for the newborn calf's immunity, is more abundant and nutrient-dense in cows fed on natural forages. This ensures that calves receive the essential antibodies and nutrients they need for a strong start to life, contributing to better calf health and survival [25].

### **Enhances Reproductive Longevity of Dairy Cows**

A natural, forage-based diet supports overall cow health, which directly impacts reproductive longevity. By minimizing metabolic stress and health disorders, zero-concentrate feeding contributes to a longer productive life for cows. These cows experience fewer reproductive challenges, such as cystic ovaries or hormonal imbalances, ensuring that they can continue breeding successfully for a longer period, thereby enhancing the sustainability of dairy operations [25].

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### **Reduces Calving Intervals with Optimized Energy Balance**

With better energy balance from zero-concentrate feeding, cows are able to return to estrus more quickly after calving. A stable, balanced diet reduces postpartum metabolic stress, which allows cows to resume normal reproductive cycles sooner. This leads to shorter calving intervals, improving farm efficiency and profitability by ensuring that cows are more frequently pregnant and consistently producing milk [11].

### **Improves Uterine Health Post-Calving**

Uterine health post-calving is crucial for successful reproduction. By reducing metabolic stress and promoting overall health, zero-concentrate feeding supports faster uterine involution and better uterine health after calving. This reduces the risk of infections, such as endometritis, and ensures that the uterus is ready for the next pregnancy, improving both cow welfare and reproductive outcomes [26].

### **Reduces the Occurrence of Ovarian Cysts**

Ovarian cysts, often caused by metabolic imbalances and hormonal disruptions, are less common in cows fed a balanced, forage-based diet. Zero-concentrate feeding helps maintain proper hormonal function, reducing the incidence of cystic ovaries. This results in healthier reproductive systems, higher fertility rates, and better overall reproductive health, ultimately supporting more efficient dairy farming [27].

## **DISEASE RESISTANCE AND IMMUNITY**

### **Reduces the Incidence of Mastitis**

Mastitis, an infection of the udder, is often linked to metabolic imbalances and poor diet, particularly from high-concentrate feeding [28]. Zero-concentrate feeding supports better overall health and immune function, reducing the risk of mastitis. By promoting natural digestion and a healthier microbiome, cows are less likely to develop infections, resulting in lower somatic cell counts and improved milk quality.

### **Strengthens Immune Response Through Better Gut Health**

A healthy digestive system is crucial for a strong immune response, and zero-concentrate feeding supports this by improving gut health [29]. Forage-based diets encourage the growth of beneficial microbes in the rumen, which not only enhances nutrient absorption but also strengthens the immune system. This results in cows that are better equipped to fight off infections and diseases, contributing to improved overall health.

### **Lowers Susceptibility to Metabolic Diseases**

Zero-concentrate feeding reduces the risk of metabolic diseases, such as ketosis, acidosis, and fatty liver syndrome, by maintaining a more stable energy balance. High-concentrate diets can overwhelm the rumen and metabolic system, leading to imbalances. Forage-based diets reduce this risk by providing a slow, consistent source of energy, ensuring that cows remain healthy and less prone to these metabolic disorders [19].

### **Reduces Risk of Ketosis and Fatty Liver Syndrome**

Ketosis and fatty liver syndrome are common metabolic disorders that result from high-concentrate feeding. By switching to a zero-concentrate diet, cows experience less metabolic stress, leading to lower rates of ketosis and fatty liver syndrome. This is achieved by promoting better rumen function and a more natural nutrient absorption process, supporting healthier liver and energy metabolism [8].

### **Minimizes Cases of Displaced Abomasum**

Displaced abomasum (DA) is a condition often linked to high-grain, concentrate diets that cause excessive gas production and rumen dysfunction. Zero-concentrate feeding helps to avoid this problem by promoting proper rumen fermentation and digestion. Forage-based diets, which are higher in fiber,

help regulate the cow's digestive system, reducing the incidence of DA and supporting overall digestive health [9].

### **Enhances Natural Detoxification Pathways**

Forage-based diets promote natural detoxification processes in dairy cows by supporting liver function and enhancing waste elimination [30]. Zero-concentrate feeding helps reduce the buildup of toxins that may result from the high starch content in concentrates. This leads to improved liver function, better toxin removal, and a stronger immune system, making cows less susceptible to diseases and enhancing their overall health.

### **Reduces the Incidence of Laminitis**

Laminitis, an inflammation of the hooves, is often caused by dietary imbalances, particularly from high-concentrate feeding. Zero-concentrate feeding, with its emphasis on fiber-rich forages, helps to prevent laminitis by maintaining a stable rumen pH and supporting overall metabolic health. This results in healthier hooves, less inflammation, and fewer instances of this painful and debilitating condition [19].

### **Minimizes Antibiotic Usage and Resistance Issues**

By reducing the occurrence of infections and diseases, zero-concentrate feeding minimizes the need for antibiotics. Lower disease incidence leads to reduced reliance on antimicrobial treatments, which helps to combat antibiotic resistance. This is particularly important in the context of improving food safety and promoting sustainable farming practices. As cows become more resilient through better nutrition, their health improves without the overuse of antibiotics [29].

### **Supports a Balanced Gut Microbiome**

Zero-concentrate feeding fosters a healthy and balanced gut microbiome, which is essential for overall health and disease resistance. The high fiber content in forage-based diets supports the growth of beneficial bacteria in the rumen, which improves digestion, nutrient absorption, and immune function. A balanced microbiome enhances the cow's ability to resist infections and reduces the risk of digestive disorders, ensuring better long-term health [8].

### **Enhances Resilience to Environmental Stressors**

Cows on zero-concentrate feeding systems are better able to handle environmental stressors such as heat, cold, and poor pasture conditions. The natural, balanced diet supports a robust immune system, allowing cows to remain healthy and resilient in challenging conditions. This improved stress tolerance leads to fewer health problems, better welfare, and more stable productivity in various environmental settings [30].

## **LAND AND RESOURCE MANAGEMENT**

### **Promotes Efficient Use of Locally Available Feed Resources**

Zero-concentrate feeding encourages the use of locally grown forage and by-products, reducing the dependency on imported concentrate feeds [31]. This promotes a more sustainable farming system by making use of available resources within the local environment. By focusing on locally available, cost-effective feed, dairy farms can reduce their reliance on external feed markets, ensuring better economic and environmental outcomes.

### **Encourages Pasture-Based Dairy Systems**

The zero-concentrate feeding approach is ideal for pasture-based systems, where cows graze on natural forages. This method helps optimize pasture usage, improves soil health, and reduces the need for high-input feeding systems [32]. By encouraging cows to graze and consume a variety of plant species, pasture-based systems contribute to sustainable land management, fostering a balanced and resilient farming model that works with nature.

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**Reduces Reliance on Imported Feed Ingredients**

Zero-concentrate feeding reduces the need for imported concentrate ingredients, such as soy, corn, and other grains, which can contribute to deforestation and environmental degradation. By promoting the use of locally grown, naturally available forages, this system minimizes the carbon footprint of feed production and transportation [33]. It also ensures that dairy operations are less affected by global feed price fluctuations and trade disruptions.

**Enhances Soil Fertility Through Manure Recycling**

Manure from dairy cows on a zero-concentrate diet can be an excellent resource for enhancing soil fertility. By recycling manure onto fields, farmers can increase the organic matter and nutrient content of their soil, improving its health and productivity. This reduces the need for synthetic fertilizers and supports the sustainable management of farmland, contributing to better long-term soil quality and farm sustainability [34].

**Improves Water-Use Efficiency in Dairy Farming**

Zero-concentrate feeding systems tend to use less water compared to intensive concentrate-based feeding systems. Pasture-based systems are typically more water-efficient, relying on natural rainwater to sustain grass and forage growth. Furthermore, by avoiding large-scale irrigation for concentrate crops, dairy operations reduce their overall water consumption, contributing to more sustainable farming practices, particularly in water-scarce regions [31].

**Reduces Nutrient Runoff and Water Pollution**

With zero-concentrate feeding, the risk of nutrient runoff and water pollution from concentrated feed ingredients is significantly reduced. Since the diet consists mainly of natural forages, which are less prone to causing nutrient surpluses in the soil, there is a lower chance of excessive nitrogen or phosphorus runoff. This helps protect nearby water bodies from eutrophication, improving water quality and promoting cleaner agricultural landscapes [34].

**Encourages Integrated Crop-Livestock Farming Systems**

Zero-concentrate feeding fits well with integrated crop-livestock systems, where dairy cows graze on pastures alongside crops grown for food, fiber, or other purposes. This system fosters a more circular approach to resource use, where crop residues and manure can be used to improve soil health and feed livestock. This integration encourages biodiversity, reduces waste, and supports more sustainable farming practices that maximize land use [31].

**Reduces Land Degradation**

Monocropping for concentrate production, such as growing large quantities of soy or corn, often leads to land degradation and loss of biodiversity. Zero-concentrate feeding reduces the need for intensive monocropping by promoting pasture-based systems. This approach supports crop diversity, reduces soil erosion, and helps maintain the natural balance of ecosystems, leading to healthier soils and more sustainable land use over time [32].

**Enhances Resilience to Climate Variability**

Pasture-based systems, which are a key component of zero-concentrate feeding, tend to be more resilient to climate variability compared to systems reliant on imported feed. Pasture and forage production can be adjusted to local climate conditions, improving farm resilience to droughts, floods, and other climate-related challenges. By reducing dependency on high-input feed systems, dairy farms become more adaptable and better equipped to cope with changing environmental conditions [33].

**Encourages Sustainable Agricultural Landscapes**

By reducing the reliance on high-input, concentrated feed systems, zero-concentrate feeding promotes sustainable agricultural landscapes. It encourages practices, such as rotational grazing, crop diversification, and conservation tillage, all of which help to preserve soil health, increase biodiversity,

and reduce the environmental footprint of farming. These sustainable practices create a more balanced and resilient farming ecosystem, benefiting both the land and the surrounding environment for future generations [34].

## **ETHICAL AND CONSUMER BENEFITS**

### **Meets Growing Consumer Demand for Natural Dairy Products**

Zero-concentrate feeding aligns with the increasing consumer preference for natural, minimally processed dairy products. Consumers are becoming more aware of the environmental and health impacts of their food choices, and there is a growing demand for dairy products that are produced sustainably without the use of artificial additives or concentrates. This system meets such consumer expectations by promoting natural, forage-based milk production [35].

### **Reduces Ethical Concerns About Feed Additives in Dairy Production**

Feed additives, particularly synthetic chemicals and growth hormones, raise ethical concerns regarding animal welfare and food safety. Zero-concentrate feeding eliminates the need for these additives, as the cows consume a natural, grass-based diet. This approach not only improves the ethical profile of dairy production but also contributes to the overall well-being of animals by avoiding artificial substances in their diets [23].

### **Supports Organic and Regenerative Dairy Farming Initiatives**

Zero-concentrate feeding is inherently supportive of organic and regenerative dairy farming practices, as it focuses on natural forage-based diets without the need for chemical fertilizers, pesticides, or synthetic feeds. By reducing reliance on external inputs, this system aligns with the principles of organic farming, which promote soil health, biodiversity, and sustainable farming practices. It also encourages regenerative agriculture practices that improve land health for future generations [9].

### **Enhances Consumer Confidence in Milk Quality**

As more consumers seek to understand the origins and quality of the food they consume, zero-concentrate feeding helps to build consumer trust. Natural feeding systems that avoid concentrates and synthetic inputs result in milk that is often perceived as healthier and more wholesome. This, in turn, enhances consumer confidence in the quality of the milk, contributing to better marketability and consumer satisfaction [30].

### **Promotes Transparency in Dairy Production Systems**

Consumers are increasingly demanding transparency in the food production process. Zero-concentrate feeding supports transparency by ensuring that the feed and nutrition provided to cows are natural and locally sourced. Dairy producers can provide clear information about how their milk is produced, fostering a direct connection with consumers who are concerned about the ethical and environmental aspects of their food choices [23].

### **Supports Fair-Trade and Sustainable Farming Practices**

Zero-concentrate feeding promotes fair-trade and sustainable farming practices by reducing the reliance on external, often imported, feed ingredients. By focusing on locally sourced forages and supporting small-scale, community-based farming systems, this approach can contribute to fair-trade initiatives. It ensures that farmers are not dependent on global feed markets, thereby supporting more equitable and resilient local economies [35].

### **Reduces Artificial Ingredient Dependency in Milk Production**

One of the key advantages of zero-concentrate feeding is the reduction in artificial ingredients used in dairy production. Concentrates often contain synthetic additives, preservatives, and growth hormones, which are avoided in this system. This natural feeding practice ensures that the milk produced is free from artificial substances, making it more appealing to health-conscious consumers who are increasingly concerned about additives in their food [35].

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### **Aligns with Evolving Food Safety Regulations**

As food safety regulations continue to evolve, especially in response to consumer demand for healthier, safer products, zero-concentrate feeding ensures that dairy products comply with these new standards. This system avoids the risks associated with feeding cows concentrates that may contain additives, chemicals, or contaminants. By focusing on natural, safe feed sources, zero-concentrate feeding aligns with food safety regulations, ensuring that milk production systems meet consumer expectations and legal standards [23].

### **Encourages Community-Based Dairy Production Models**

Zero-concentrate feeding encourages the development of community-based dairy production models by supporting local farmers who can grow their own forages and feed. This decentralization of food production reduces reliance on large-scale, industrial feed producers and promotes more resilient local food systems. Community-based dairies benefit both the farmers and the local economies, while fostering stronger connections between producers and consumers [9].

### **Enhances Traceability of Milk Production Systems**

Traceability in food production is a growing concern for consumers who want to know where their food comes from. Zero-concentrate feeding makes it easier to trace the entire milk production process, from pasture to consumer. With a focus on natural, local feed resources and transparent farming practices, dairy producers can provide clear, verifiable information about how their milk is produced, which enhances consumer confidence and ensures that the products are ethically and sustainably sourced [30].

## **FEED EFFICIENCY AND NUTRIENT UTILIZATION**

### **Enhances Fiber Utilization in Ruminants**

Zero-concentrate feeding improves fiber digestion in dairy cows by encouraging natural rumen fermentation. Forages rich in fiber are better utilized, thanks to a more balanced microbial population in the rumen that breaks down cellulose and hemicellulose efficiently. This not only enhances overall fiber utilization but also reduces the need for expensive concentrates, contributing to a more sustainable feeding system while maintaining cow health and productivity [4].

### **Reduces Feed Wastage**

By adopting zero-concentrate feeding, dairy farmers can better manage the quality and quantity of the forage available to cows. This approach helps in reducing feed wastage by ensuring that cows consume an appropriate amount of high-quality forage. Pasture and forage management techniques, such as rotational grazing, maximize nutrient intake and minimize leftovers, improving feed efficiency and lowering feeding costs [7].

### **Increases Nutrient Bioavailability from Forages**

Zero-concentrate feeding systems promote improved nutrient bioavailability from forages by enhancing the efficiency of the digestive system [36]. The natural feeding model helps cows access more nutrients from plant-based forages, thanks to improved rumen microbial activity. This better nutrient absorption contributes to improved milk production and cow health while reducing the need for supplemental concentrate feeds, lowering overall feeding costs.

### **Improves Microbial Protein Synthesis Efficiency**

In a zero-concentrate feeding system, the balance between energy and protein in the diet supports optimal microbial growth in the rumen. This, in turn, enhances microbial protein synthesis, which provides cows with a high-quality, cost-effective protein source. By efficiently converting fiber into microbial protein, dairy cows can meet their protein requirements without the need for expensive concentrated protein feeds [30].

### **Reduces Nitrogen Excretion and Environmental Losses**

Zero-concentrate feeding reduces nitrogen excretion by optimizing the utilization of forages and improving rumen efficiency. Since cows rely on high-quality, fibrous feeds, they produce less excess nitrogen that is excreted in manure. This reduction in nitrogen excretion mitigates the environmental impact of dairy farming, such as water pollution and greenhouse gas emissions, making the practice more eco-friendly [21].

### **Optimizes Calcium and Phosphorus Metabolism**

Zero-concentrate feeding improves the metabolism of essential minerals like calcium and phosphorus. Pasture-based diets that emphasize forage consumption provide a more natural source of these nutrients, allowing cows to absorb them more efficiently. This results in better bone health and reproductive performance, while also minimizing the need for expensive mineral supplements, which can have environmental drawbacks when overused [30].

### **Enhances Dry Matter Intake Efficiency**

Cows fed on high-quality forages through zero-concentrate feeding systems show improved dry matter intake efficiency. These animals can consume more fibrous feeds and convert them into energy more effectively. The enhanced efficiency in dry matter intake leads to better milk production and overall health, reducing the need for additional feed inputs and promoting the sustainability of the farming system [36].

### **Reduces the Need for Synthetic Vitamins and Minerals**

Zero-concentrate feeding minimizes the reliance on synthetic vitamins and minerals by using naturally nutrient-rich forages. The natural nutrients in pastures provide essential vitamins and minerals needed for cow health and production, reducing the need for artificial supplementation. This shift towards more natural nutrient sources enhances animal welfare and promotes environmental sustainability by reducing chemical input requirements [4].

### **Supports Natural Enzymatic Activity in Digestion**

By relying on forages and minimizing the use of concentrates, zero-concentrate feeding supports natural enzymatic activity in the rumen. The diversity of plant fibers encourages the growth of rumen microbes that aid in the natural breakdown of fiber and other nutrients. This process improves digestive efficiency, ensuring that cows absorb more nutrients from their feed and convert them into productive outputs like milk [7].

### **Promotes a Balanced Energy-Protein Ratio**

Zero-concentrate feeding helps promote an optimal balance between energy and protein in a cow's diet, which is crucial for maintaining health and productivity. With natural forages, cows consume a well-rounded diet, which ensures a balanced nutrient intake without the need for supplementary concentrates. This approach promotes sustained milk production, better cow health, and overall farm efficiency [21].

## **CONCLUSION**

Zero-concentrate feeding offers a promising, sustainable alternative to traditional dairy farming practices, with significant benefits for milk quality, animal health, and welfare. By prioritizing high-quality forages, this approach enhances rumen function, improves the fatty acid profile of milk, and reduces the risk of metabolic disorders, contributing to better overall cow health. Additionally, zero-concentrate feeding aligns with environmentally sustainable practices, lowering the ecological footprint of dairy production. The novelty of this study lies in its integrated analysis of the multifaceted advantages of zero-concentrate diets, demonstrating their potential to foster a more ethical, sustainable, and productive dairy industry. These findings provide a valuable framework for the future of dairy farming, encouraging the adoption of more holistic and resource-efficient feeding systems.

### Future Directions

Future research should explore the long-term effects of zero-concentrate feeding on dairy cow productivity, especially in diverse environmental conditions. Investigating how different forage types and pasture management practices influence the nutritional value of milk, as well as the cows' health and welfare, will be crucial for optimizing these systems. Further studies are needed to assess the economic viability of zero-concentrate feeding in different farming contexts, taking into account factors, such as feed availability, labor costs, and market demand, for sustainably produced dairy products. Additionally, exploring the genetic and microbiological aspects of cows adapted to zero-concentrate diets could provide valuable insights into enhancing rumen efficiency and resilience. The role of precision farming technologies in monitoring and managing forage-based feeding systems should also be investigated to improve feeding strategies and optimize performance. Collaborative efforts between farmers, researchers, and policymakers will be essential to promote the widespread adoption of zero-concentrate systems in dairy farming.

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