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"Nutritional Benefits of Spirulina (Arthrospira platensis) for Livestock"

Rushikesh Ramchandra Kore[1], Rushikesh R. Sathe[2], D. K. Deokar[3], S. A. Dhage[4] and D. K. Kamble[5]
[1]Ph.D. Scholar, PGI, Mahatma Phule Krishi Vidyapeeth, Rahuri.
[2]Ph.D. Scholar, PGI, Mahatma Phule Krishi Vidyapeeth, Rahuri.
[3]Associate Professor, Department of Animal Husbandry and Dairy Science, PGI, MPKV, Rahuri
[4]Associate Professor, Department of Animal Husbandry and Dairy Science, PGI, MPKV,
[5]Head, Department of Animal Husbandry and Dairy Science, PGI, MPKV, Rahuri

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Abstract

Livestock is a cornerstone of India's agricultural economy, contributing significantly to food security, rural livelihoods and national GDP. In the search for sustainable and cost-effective feed resources, Spirulina (*Arthrospira platensis*), a fast-growing blue-green microalga, has emerged as a promising livestock feed supplement due to its high nutrient density and low resource requirements. Spirulina contains 55–70% high-quality protein on a dry matter basis with a balanced essential amino acid profile, comparable to soybean meal and fishmeal. It is also rich in polyunsaturated fatty acids, vitamins, minerals and bioactive compounds such as phycocyanin and carotenoids, which impart antioxidant and immunomodulatory effects.

In ruminants, Spirulina enhances rumen microbial protein synthesis, feed efficiency and provides rumen-undegradable bypass protein, leading to improved milk yield, milk composition, growth performance and meat quality. In poultry, dietary inclusion at low levels (0.5–2%) improves growth, feed conversion, immunity, meat quality, egg production and yolk pigmentation. Spirulina also shows potential in aquaculture and monogastric species, although processing interventions are required to improve digestibility. Overall, Spirulina represents a sustainable, multifunctional feed supplement with significant potential to enhance livestock productivity, health and environmental resilience in Indian production systems.

Key Words: Spirulina, Livestock, Animal Health, Productivity and environmental resilience.

Introduction

Livestock plays a very important role in the Indian economy, especially in rural areas where many families depend on animals for their income and livelihood. According to the 20th Livestock Census, India has a large and growing livestock population. The total number of livestock reached about 535.78 million, showing an increase compared to the earlier census. Among different animals, goats form a significant share. Their population was around 148.88 million, which shows a growth of about 10.1 per cent. In terms of overall contribution, cattle have the largest share, followed by goats, buffaloes, sheep and pigs (Anonymous, 2019).

Goat farming is an important activity for small and marginal farmers because it requires less investment and provides regular income. However, one of the biggest challenges in goat production is the high cost of feeding. A large portion of the total production cost is spent on feed. Therefore, farmers try to reduce feed expenses while also maintaining good quality animal products like meat and milk. To achieve this, it becomes necessary to find new and better feed resources that are both nutritious and cost-effective. In recent years, there has been growing interest in using alternative feed sources that can improve animal performance without harming human health. Many traditional feed additives have been used earlier to increase growth and productivity, but some of them may create health concerns for consumers. Because of this, natural and safe feed options are being preferred.

One such promising feed source is Spirulina platensis, commonly known as spirulina. It is a type of blue-green algae that is rich in nutrients. Spirulina contains all essential amino acids along with important vitamins and minerals. It is also a good source of carotenoids and healthy fatty acids, especially gamma linoleic acid (GLA), which provides additional health benefits (Howe *et al*., 2006). According to Becker (2007), spirulina is an edible, spiral-shaped microorganism that can be easily included in animal diets. Overall, using spirulina as a feed supplement can help improve the nutritional value of animal products while supporting better growth and health in goats. It also offers a more sustainable and safe option for future livestock feeding practices.

Origin of problem

Feed cost is one of the biggest challenges in livestock and dairy farming. A large share of total production expenses often around 60 to 70 per cent is spent only on feeding animals. When the price of feed increases, it directly reduces the profit of farmers. This problem becomes even more serious for organic dairy farmers, who usually spend much more on feed because they have to use certified organic ingredients like corn, soybean and oats, which are costlier than regular feed.

Another major issue is the high price of protein-rich feed ingredients. Items such as soybean meal, fishmeal and commercial protein supplements are expensive because they require processing and are also in demand for human food and industrial use. Due to this competition, their prices keep rising, making it difficult for farmers to afford quality feed for their animals.

In many cases, the available feed resources also have lower nutritional value. Factors like poor soil quality, climate change and continuous cropping of the same crops reduce the nutrient content of fodder. As a result, animals need to consume more feed to meet their nutritional needs. This reduces feed efficiency and negatively affects performance indicators like the feed conversion ratio (FCR), which measures how effectively animals convert feed into milk or body weight.

At the same time, the demand for animal products such as milk and meat is increasing rapidly. Growing population and rising income levels are encouraging people to consume more protein-rich foods. This puts additional pressure on livestock production systems and increases the demand for feed. As demand rises, the cost of feed ingredients also goes up, especially protein sources, making them less accessible for farmers.

Because of all these challenges, scientists and nutrition experts are trying to find cheaper and better alternatives to traditional feed. They are exploring non-conventional feed sources such as agricultural byproducts and algae. One such promising option is *Spirulina platensis*. It is considered a sustainable and nutrient-rich feed supplement that can help improve animal productivity while reducing feeding costs.

Benefits of Spirulina

Spirulina is becoming popular as a feed supplement in livestock farming because of its rich nutritional value and health benefits. It is considered a high-quality natural feed ingredient that can support better growth and productivity in animals. One of the main advantages of *Spirulina platensis* is its excellent nutrient composition. Commercial spirulina powder contains a very high amount of protein, around 60 per cent, along with carbohydrates, small amounts of fat, minerals and moisture. Because of this balanced composition, it acts as a low-fat and cholesterol-free protein source, which is beneficial for animal nutrition (Habib *et al*., 2008). This makes it a valuable alternative to expensive conventional protein feeds.

Another important benefit of spirulina is that it is safe and environmentally friendly. Studies have shown that adding spirulina to animal feed can improve the immune system and increase antioxidant levels, especially in growing goats (Yadav and Kumar, 2018). It works as a natural antioxidant, helping animals fight stress and disease. Compared to synthetic additives, spirulina has fewer side effects and is also more cost-effective (Abdel-Daim *et al*., 2014). Although its use in ruminant feeding is still developing, early research shows positive effects on animal health, productivity and the quality of animal products. More studies in the future will help to fully understand its potential in livestock feeding.

In addition, spirulina is a natural feed component with several beneficial properties. As a type of blue-green algae, it contains important nutrients like proteins, vitamins and minerals, along with certain medicinal qualities. When it is included in the regular diet of ruminants, it can improve growth and overall performance. Because of these benefits, spirulina is seen as a promising option for sustainable and healthy livestock production.

Why Spirulina is a Superfood for Livestock?

1. **High Nutrient Density:** Spirulina is one of the most nutrient dense feed ingredients known. In livestock it improves weight gain and feed conversion ratio (FCR), enhances immune function and milk/meat/egg quality and natural source of color enhancers (for egg yolks, fish flesh).
2. **Rapid Growth**: Spirulina produces ~20× more protein per acre than soybeans. Spirulina farms yield dramatically more protein per land area compared to soybeans estimates cite over 20× higher output per acre, thanks to its compact and high-density cultivation in ponds or photobioreactors. Spirulina can be grown on non-arable land (saline or alkaline), which conserves fertile soil and avoids competition with food crops.
3. **Biomass doubles every 24–48 hours under ideal conditions:** Rapid cell division at optimal growth (e.g., at 35 °C & ~2,000–10,000 lux light exposure) enables doubling times within 24–48 hours. Adjusting light intensity, temperature, pH and nutrients in controlled systems (photobioreactors or open ponds) yields high specific growth rates and biomass productivity e.g., 0.62 g/L/day in dense culture setups.
4. **Ensures reliable, consistent feed supply:** The rapid growth cycle supports frequent harvesting daily or every few days ensuring a steady supply of spirulina biomass, unlike traditional crops which are seasonal. With the right infrastructure, spirulina can be farmed throughout the year, avoiding weather-dependent delays and land limitations.
5. **Integration with farms:** Spirulina cultivation systems (ponds or bioreactors) can be implemented directly on livestock farms even small scale lowering reliance on external feed suppliers and stabilizing supply. Lower carbon footprint by reduced transportation cuts CO_2 emissions. Coupled with spirulina's high protein yield per unit land and water, it's a more sustainable protein source than soy. (Satya *et al*., 2021).

Nutrient Composition

1. **Proteins (55–70%):** Spirulina boasts 55–70% high-quality protein by dry weight, surpassing soy (~35%) and legumes, and comparable to animal sources (beef, chicken). It contains a complete set of essential amino acids, though somewhat lower in methionine, cystine, and lysine than animal proteins still outperforming most plant proteins. In livestock, this protein supports muscle growth, improved feed conversion and can partially replace soybean meal, reducing the need for synthetic amino acid supplements.

2. **Carbohydrates (15–20%):** Mainly polysaccharides, including sulphated forms like calcium spirulina, which have immune-modulating, antiviral and anti-inflammatory functions. Spirulina's carbs also include glucose and high-molecular-weight polysaccharides that support intestinal health and feed efficiency.
3. **Lipids (6–14%):** Lipid content ranges from 6–14%, with a notable percentage of polyunsaturated fatty acids (PUFAs) like palmitic acid, GLA, EPA and DHA. These functional lipids support cellular health, anti-inflammatory responses and can enhance the fatty acid profile of meat and milk.
4. **Fatty Acids and Pigments:** Gamma-linolenic Acid (GLA): Spirulina contains 36% of its total PUFAs as GLA, a rare omega-6 fatty acid with anti-inflammatory and immune-modulating properties. GLA enhances skin, coat quality, joint health and overall immune function in livestock.
5. **Carotenoids and Chlorophyll:** β-Carotene, xanthophylls, zeaxanthin, lutein are present in high quantities (150–400 mg/100 g). Chlorophyll (1,300–1,700 mg/100 g) contributes to detoxification and gut health.
6. **Phycobiliproteins (Phycocyanin):** Significant pigment protein complexes, phycocyanin and allophycocyanin, make up to 47% of dry weight and are potent antioxidants. Enhances antioxidative capacity, anti-inflammatory defense and supports overall health in animals (Jung *et al*., 2019).
7. **Vitamins (B-complex, A, E, K):** B-vitamins (B1, B2, B3, B6, B9, B12) support energy metabolism, enzyme function and overall health. Vitamin A (β-carotene) boosts vision, growth and immunity. Vitamin E (tocopherol) protects against oxidative stress. Vitamin K plays a role in bone health and blood coagulation.
8. **Minerals (Fe, Mg, Zn, Ca, etc.):** High in iron (28–50 mg/100 g dry), calcium, magnesium, zinc, potassium, selenium, and more (Spínola *et al*., 2024). These minerals are bioavailable, boosting enzymatic systems, bone development, and blood hemoglobin in livestock.

Belay (2002) observed the possible use of spirulina as a dietary and therapeutic supplement in health management and reported that the blue-green cyanobacterial algae spirulina (*Spirulina platensis*) was used in foods which contain 60 to70 percent protein. Gamma linoleic acid (GLA), carotenoids, vitamins and minerals were also to be abundant in it as well as both necessary and non-essential amino acids also observed.

Howe *et al.* (2006) conducted research on the contribution of meat sources to dietary intake of long-chain omega-3 polyunsaturated fatty acids. According to his study, spirulina was nutrient-rich. All necessary vitamins, minerals, and amino acids are present. Additionally, it contains a lot of carotenoids and fatty acids, particularly linoleic acid (GLA), which is thought to have health advantages.

Habib *et al* (2008) studied the cultivation, production, and usage of spirulina as food for people and feed for domestic animals It was discovered that commercial spirulina powder has 60 per cent protein, 20 per cent carbohydrates, 5 per cent lipids, 7 per cent minerals and 3-6 per cent moisture, making it a low-fat, low-calorie, cholesterol-free source of protein

Production of Spirulina

1: Cultivation- Spirulina is cultivated in shallow ponds of approx. 15cm deep. Nutrients (minerals and salts) are added to obtain the optimum conditions for the algae to grow. The strongly alkaline water (pH 10.2) ensures that no other algae, micro-organism can develop in the culture. The culture in the ponds is stirred continuously in day, in order to stimulate photosynthesis.

2: Harvesting- When the water is heavy with spirulina, it is scooped up and passed through a set of filters. The spirulina biomass is collected in the finest filter, where it is drained and cleansed with water.

3: Pressing- The fresh biomass is folded into a finely meshed fabric, then placed between two granite slabs and pressed. As much excess water as possible is pressed out (up to 80%). The spirulina mass thus becomes a solid paste

4: Drying- The spirulina mass is squeezed and dried in the sun. Due to the favorable climate in South India, this typically takes a few hours only. During the process, the spirulina takes its characteristic flavour, The final stage

of the drying process is done in a hot-air dryer, in order to achieve the exact humidity, as well as a 100% food-safe product.

5: Processing and Packaging- Part of the spirulina is grinded to a fine powder, part of which in turn is used to fill capsules and make tablets. (Musa *et al*., 2025).

Ideal Growth Conditions

1. **Temperature:** Optimal range 25–35 °C; slows below 15 °C or above 40 °C.
2. **Growth and metabolism:** Spirulina thrives in warm conditions typically between 30–37 °C under controlled settings. Growth may slow outdoors when temperatures drop below 15 °C or exceed 40 °C.
3. **Pigment stability:** Ideal pigmentation (chlorophyll, carotenoids, phycobiliproteins) often peaks around 30–35 °C; higher temperatures can degrade these components.
4. **Cultivation tip:** Maintain around 30–35 °C to balance biomass yield and pigment stability; avoid extreme temperatures to prevent bleaching or slowed metabolism.
5. **Light:** Requires abundant sunlight; shading might be needed early days.
6. **Intensity importance:** Photosynthesis and pigment production are highly sensitive to light intensity and color. Optimal intensities range from ~300–500 µmol photons m^{-2} s^{-1}.
7. **Spectrum matters:** Red light (620–630 nm) enhances growth and phycocyanin synthesis more effectively than blue or green light.
8. **Shading benefit:** High light exposure can inhibit growth (photoinhibition); partial shading during early growth stages can prevent damage.
9. **pH:** Prefers alkaline conditions (9.0–11), which favor Spirulina and suppress contaminants. Best growth and pigment yield occur at pH 8.5–10.0, with around 9.0–9.5 being ideal for biomass.
10. **Contamination control:** High pH levels (above 9.5) inhibit unwanted organisms, reducing contamination risks.
11. **Antioxidant boost:** Alkaline conditions support enhanced phycocyanin and antioxidant enzyme activity (Musa *et al*., 2025).
12. **Culture maintenance:** Regularly monitor pH, as photosynthesis naturally alkalizes the medium; adjust with bicarbonates or alkali to stabilize levels.
13. **Nutrients:** Requires nitrogen (N), phosphorus (P), bicarbonate, and trace minerals
14. **Macronutrients:** Adequate nitrogen (e.g., nitrate or ammonium), phosphorus and bicarbonate support protein synthesis and biomass growth.
15. **Trace minerals:** Elements like potassium, magnesium, calcium, sodium, and iron are vital for enzymatic and photosynthetic functions.
16. **Culture formulas:** Successful lab formulas include ~10 g/L $NaHCO_3$, 2 g/L $NaNO_3$, 0.6 g/L KH_2PO_4, along with magnesium sulfate and potassium sulfate.

17. **Monitoring needed:** Nutrient depletion alters pH and impairs growth regular checks and adjustments are essential.

Quality Control and Safety

1. Contamination Prevention

- **High-pH media:** Spirulina thrives in alkaline environments (pH ~8.5–11), which naturally inhibits the growth of harmful bacteria and other contaminants. Maintaining this high pH is crucial to keeping the culture safe (Luo *et al.,* 2024).
- **Sterile equipment:** During spirulina harvesting and processing, all tools and containers must be clean and sanitized to prevent introducing pathogens or spoilage organisms.
- **Monitor microbial load:** Regular testing of water and biomass helps detect any contamination early, such as bacteria, fungi, or protozoa that could harm livestock or reduce spirulina's nutritional quality.
- **Flush ponds periodically**: Ponds can accumulate organic waste and biofilms. Periodic flushing removes buildup, ensuring a clean environment for healthy spirulina growth.

2. Drying Standards

- **Reduce moisture <7%:** After harvesting, spirulina must be dried quickly and thoroughly to a moisture content below 7%. This low moisture level prevents microbial growth and spoilage during storage and transport.
- **Prevent mycotoxins & pathogens:** Inadequate drying or poor hygiene can lead to contamination with fungi (producing mycotoxins) or harmful bacteria such as *Salmonella* or *Staphylococcus*. These are dangerous to livestock and must be strictly avoided.

3. Product Testing

- **Microbial testing:** Confirms the spirulina is free from dangerous pathogens and within acceptable limits for total microbial count.
- **Nutrient profiling:** Spirulina is valued for its high protein, vitamins (eg. B12) and minerals (e.g., iron, calcium). Testing ensures it meets nutritional claims and delivers consistent quality for animal health and growth.
- **Heavy metal analysis:** Spirulina can accumulate heavy metals (e.g., lead, arsenic) from contaminated water. Testing ensures levels are within safe limits for livestock feed, protecting both animals and the human food chain.

Overview of Livestock Categories in Relation with Spirulina

Spirulina: Cattle

Ruminants digest spirulina's protein, stimulating microbial protein synthesis. About 20% escapes rumen degradation, supplying high-quality protein downstream.

1. **Milk Yield** – Protein & Microbial Synthesis. *"*Ruminants digest spirulina's protein, stimulating microbial protein synthesis." Spirulina is rich in high-quality protein (55–70%) and essential amino acids, much of this protein contributes to rumen microbial growth, improving microbial protein synthesis a major source of amino acids for the host animal. This leads to, improved digestibility of the overall diet, enhanced nutrient absorption, increased milk production.
2. **Milk Fat Content-** "Spirulina is a source of omega fatty acids, which enrich milk fat and adjust fatty acid profiles." Spirulina contains omega-3 and omega-6 fatty acids (e.g., linoleic and γ-linolenic acid). These fatty acids, improve milk fat quality, enhance the healthy fat fraction in milk (reducing saturated fat), support udder health, etc.
3. **Antioxidant Levels-**Spirulina contains antioxidants like phycocyanin, carotenoids. It is loaded with natural antioxidants such as, Phycocyanin**,** Carotenoids (β-carotene)**,** Phenolic compounds**.** These antioxidants boost the activity of protective enzymes like superoxide dismutase (SOD), catalase, glutathione peroxidase. Lower oxidative stress in lactating animals, especially under heat or metabolic stress. Promote udder health and milk stability.

Spirulina: Goat and Sheep

Enrichment of meat with antioxidants from spirulina reduces lipid peroxidation the compositional improvements strongly suggest enhanced oxidative resistance. Spirulina supplementation in goats can significantly enhance body weight and overall health (Kore, *et al.,* 2023). This nutrient-rich algae are packed with protein (60-70%), vitamins, and minerals, promoting healthy growth and immunity. Spirulina's antioxidant properties reduce oxidative stress, improving feed efficiency and weight gain. Studies show that adding 1-2% spirulina to goat feed can increase body weight, milk production, and meat quality. It's also rich in iron, calcium, and B vitamins, supporting overall well-being. Regular spirulina supplementation can lead to healthier, more robust goats, boosting farmers' productivity and income.

Mechanisms at Work

1. **Enhanced PUFA Content:** "Alters fat composition in muscle by integrating healthier fatty acids, reducing saturation." PUFA (Polyunsaturated Fatty Acids) like linoleic and gamma-linolenic acid found in spirulina are incorporated into muscle tissue when fed to sheep and goats. This improves meat quality by increasing the proportion of healthy fats (PUFAs), reducing saturated fatty acids, which are less desirable from a consumer health perspective and meat becomes more suitable for health-conscious markets and may have improved tenderness and flavor.
2. **Antioxidant Protection:** "Phycocyanin and carotenoids scavenge free radicals, protecting muscle lipids and preserving quality." Spirulina is rich in phycocyanin, carotenoids and phenolic compounds all known for their antioxidant activity. These compounds neutralize free radicals**,** prevent lipid peroxidation in muscle tissues (which leads to rancidity) and help maintain meat color, shelf life, and oxidative stability
3. **Rumen & Muscle Modulation**: *"*Bioactive compounds may influence microbial fermentation, affecting nutrient assimilation and muscle metabolism.*"* Spirulina's bioactives (e.g., peptides, polyphenols, and phycobilins) influence the rumen microbiome (Al-Yahyaey *et al*., 2023).

Spirulina: Broilers & Layers

1. Broilers

Impact on Growth and Weight Gain:

Improved body weight gain (BWG) and feed conversion ratio (FCR): Studies show that supplementing broiler diets with 0.5–1.5% spirulina typically leads to significantly higher BWG and better FCR (i.e., birds convert feed more efficiently into body weight). For instance, a 1% inclusion improved final BW by up to ~17–26%, BWG by ~12–19%, and FCR was reduced by ~10–20%. This works as, spirulina is rich in high-quality protein (≈60% crude protein), essential amino acids, vitamins, minerals, and antioxidants like β-carotene, phycocyanin, and phenolics. These nutrients support digestion, nutrient absorption, and immune function, collectively enhancing growth performance. Moreover, it acts like a prebiotic modulating gut microbiota (raising Lactobacillus, reducing E. coli/salmonella) and improving villus height in the intestine for better nutrient uptake.

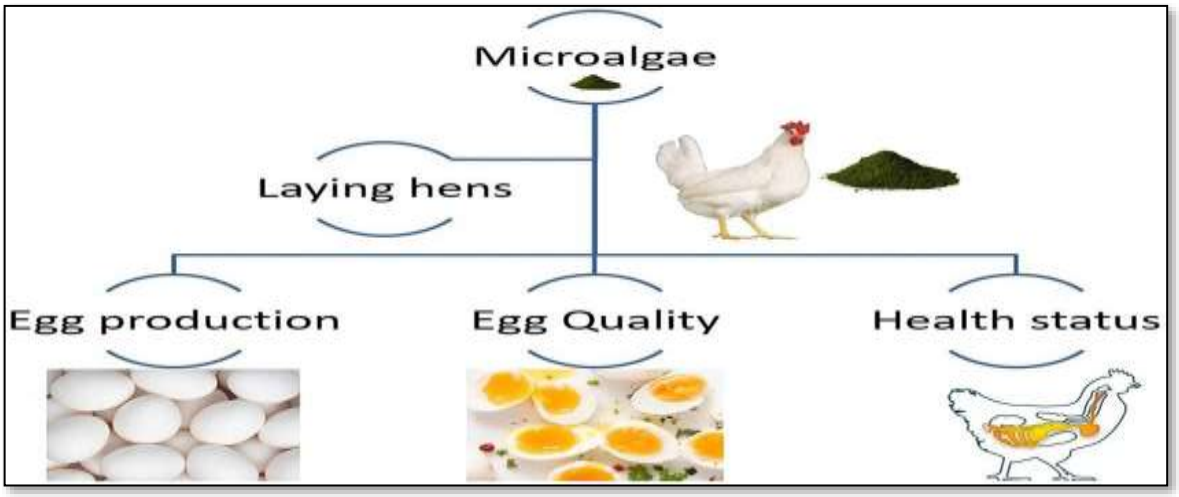
Benefits for Meat Quality

i. Spirulina enhances meat pigmentation and colour as it has natural carotenoids (especially zeaxanthin) deposit in muscle, imparting richer redness and yellowness to breast and thigh meat this improves visual appeal and consumer acceptance.

ii. **Improved Nutritional Composition:** At low inclusion levels (0.5–1%), meat tends to have increased crude protein and essential amino acids like lysine, methionine, tryptophan, histidine, and aspartic acid in breast tissue. Studies using 2% spirulina report increased total protein and improved fatty-acid profiles in meat, including higher n-3 PUFA and lower n-6/n-3 ratio.

iii. **Enhanced Oxidative Stability and Sensory Traits:** Spirulina increases antioxidant enzyme activity (SOD, catalase, GPx), reduces lipid oxidation (lower malondialdehyde/MDA), and decreases drip/cooking loss improving tenderness, juiciness, flavour, and shelf life. Sensory evaluation shows spirulina-fed birds score higher in tenderness, juiciness, flavour, and overall acceptability (Abdelfatah *et al*., 2024).

2. Layers:



Spirulina supplementation (usually 0.1–0.5% or 2.5–5 g/kg) enhances egg production, egg weight, egg mass and improves health biomarkers in hens including ALT, ALP, total proteins, globulins and antioxidant balance. Doses of 2.5 g/kg and 5 g/kg regularly show significant improvements in productivity and egg quality (Salahuddin *et al*., 2024).

Egg Production & Quality

1. **Yolk Color:** Spirulina is rich in carotenoids and xanthophyll pigments which deposit in the yolk, intensifying its orange-red tones. Studies show dose-dependent effects: higher spirulina yields deeper yolk pigmentation. For example, layers given 2.5–5 g/kg produced much more intensely colored yolks compared to controls, while quails fed ~1% spirulina observed optimal yolk hue. Colorimetric measures (redness "a*") increase with spirulina inclusion, though yellowness ("b*") may decrease slightly.
2. **Shell Strength & Thickness:** Layers given spirulina (2.5–5 g/kg) show stronger shells and greater shell thickness at ~44 weeks, attributed to spirulina's high calcium and iron content. Shell percentage (shell mass relative to total egg weight) decreases at moderate doses (improving efficiency), but may rise again at 10 g/kg highlighting nonlinear dose effects.
3. **Productivity, Shelf Life & Albumen Quality:** "Spirulina improves egg production rate, egg weight and total egg mass at moderate inclusion (2.5–5 g/kg)."
4. **Spirulina boosts:** Nutrient absorption → more energy available for egg production, protein synthesis → larger eggs and more frequent laying, albumen (egg white) quality → better internal egg freshness and longer shelf life (Salahuddin *et al*., 2024).

Scientific Basis Highlights

1. The pigment effects come from carotenoids/xanthophylls (e.g. β-carotene, zeaxanthin) naturally present in spirulina.
2. Shell improvements arise from spirulina's supply of minerals like calcium and iron supporting shell calcification.
3. Immune and antioxidant benefits are from bioactive compounds like phycocyanin, flavonoids, phenolics, vitamins, and essential fatty acids.
4. Gut health is modulated via spirulina's prebiotic effects supporting Lactobacillus and reducing pathogens.
5. Reduction in Antibiotic Use: By enhancing innate and adaptive immunity, reducing inflammation and promoting gut barrier integrity, spirulina can reduce dependency on antibiotics in livestock production. Spirulina boosts immunity through its rich content of:
6. Phycocyanin, polysaccharides and phenolic compounds → stimulate immune cell activity (T-cells, macrophages)

7. Broilers fed spirulina showed improved immune organ development and disease resistance that could lower incidence of bacterial infections and medication needs.
8. Antibacterial and antiviral effects, including calcium-spirulina mediated viral entry inhibition and bacterial clearance, provide natural prophylaxis that may substitute routine antimicrobial use.

Sustainability Advantages of Spirulina

1. **Land use efficiency:** Compared to conventional livestock like beef (which requires extensive grazing or feed-crop land), spirulina cultivation uses minimal land often non-arable land, including vertical or controlled-environment systems. A hectare of spirulina can yield 15× to 200× more protein per land unit than soy or beef farming, depending on system design.
2. **Water Use Efficiency:** Spirulina cultivation requires drastically less water: about 2.9 m^3 of water per kg of protein in pond systems, compared to tens or hundreds of cubic meters for beef or soy protein. It can thrive in brackish or saline water, leaving scarce freshwater for other uses, and most losses occur through controlled evaporation.
3. **Minimal Pressure on Biodiversity & Ecosystems:** As spirulina cultivation doesn't require converting forests or grasslands into cropland or pasture, it helps avoid deforestation and habitat loss (Hu, X *et al*., 2024). Controlled-production environments reduce risks of nutrient runoff, pesticide use, and ecosystem disruption compared to traditional livestock or row-crop systems.

Barriers to Adoption

1. **High production cost & price competitiveness:** Spirulina production whether via open ponds or closed photobioreactors incurs high costs. Dry biomass production often ranges from €3.2–€4.5 /kg or US $3,000–5,000 per ton, compared to soybean meal which costs about US $400–600/ton. Post-harvest processes such as dewatering, centrifugation, and drying can account for 20–30% of total operational costs. This cost disparity makes spirulina financially uncompetitive against established feed proteins, especially for small-scale farmers in emerging markets
2. **Limited Scale of Production:** Despite growing interest, spirulina is mostly produced in relatively small-scale operations for human supplements rather than feed. Large-scale, dedicated feed-grade production is still rare globally.
3. **Awareness & Sensory Acceptability:** Many farmers and feed manufacturers are not fully aware of spirulina's potential benefits in livestock diets. Adoption is slowed by skepticism or lack of proven case studies. In poultry and fish, feeding trials often result in intense yellow-red meat coloration from algal carotenoids (notably zeaxanthin). Consumer preferences vary: in some markets yellow-red meat is associated with quality, while in others it may be unappealing. Visual appearance impacts consumer expectations and acceptance; sensory qualities (taste, juiciness) must align with appearance to avoid disappointment.
4. **Regulatory & Policy Hurdles:** Regulatory frameworks for algae-based feed ingredients are still emerging and vary across regions. Lack of harmonized standards delays authorisation and market entry. Specific to India, spirulina is regulated as a novel food under FSSAI. It must meet strict criteria for protein content ($\geq 55\%$), moisture ($\leq 7\%$), carotenoids ($\geq 0.2\%$), and contaminant limits for heavy metals and microbes (Altmann & Rosenau, 2022). Compliance such as FSSAI licensing and testing is mandatory but can be resource-intensive, especially for small-scale producers entering animal feed markets rather than human supplements.

Conclusion

1. *Spirulina platensis* is a nutritionally rich microalga containing high-quality proteins, essential fatty acids, minerals, and vitamins, making it a promising alternative feed supplement for pasture-based dairy systems. Its inclusion can help improve nutrient density and overall feed efficiency.
2. Dietary supplementation of Spirulina in sheep and goats positively influences growth performance, feed utilization, and carcass traits, leading to improved meat quality and productivity in small ruminant production systems.

3. In dairy cows, the use of *Spirulina platensis* as a combined fodder additive during early lactation significantly enhanced milk yield by 21% ($P < 0.05$) and increased the combined output of milk fat, protein, and lactose, indicating improved metabolic efficiency and milk composition.

References

Abdel-Daimet, M. (2014). Pharmacodynamic Interaction of Spirulina platensis with Erythromycin in Egyptian Baladi Bucks (*Capra hircus*). Small Ruminant Res. Vol. 120: 2-3.

Abdelfatah, S. H., Yassin, A. M., Khattab, M. S., Abdel-Razek, A. S., & Saad, A. H. (2024). *Spirulina platensis as a growth booster for broiler; Insights into their nutritional, molecular, immunohistopathological, and microbiota modulating effects*. *BMC Veterinary Research, 20*, 11.

Al-Yahyaey, F., Al-Marzooqi, W., Shaat, I., Smith, M. A., Al-Sabahi, J., Melak, S., & Bush, R. D. (2023, September 20). Effect of *Spirulina platensis* Supplementation on Carcass Characteristics, Fatty Acid Profile, and Meat Quality of Omani Goats. *Animals (Basel)*, 13(18), 2976.

Anonymous (2019). 20th Livestock Census 2019-All India Report. Department of Animal Husbandry and Dairying, Ministry of Agriculture, GOI., New Delhi.

Becker, E. W. (2007). Micro-algae as a source of protein. Biotech. Adv. 25: 207-210.

Belay, A. (2002). The potential application of Spirulina (*Arthrospira*) as a nutritional and therapeutic supplement in health management. J. American Nutraceutical Asso., 5, 27-48.

Habib, M. A. B., Parvin, M., Huntington, T. C. & Hasan, M. R. (2008). A review on culture, production and use of Spirulina as food for humans and feeds for Domestic animals and fish, FAO Fisheries and Aquaculture Circular. Food and Agri. Organisa. of the United Nations (FAO), Rome, pp. 1–26.

Howe, P., Meyer, B., Record S. & Bathurst K. (2006). Dietary intake of long chain omega-3 polyunsaturated fatty acids: contribution of meat source. Nutrition.22, 47-53.

Hu, X., Soma, K., Odinga, B., Obwanga, B., Agricola, H., & Kanyuguto, C. M. (2024, November 10). *The protein transition—environmental footprints of farmed fish, microalgae and chicken for food: A case study in Kenya*. Environment, Development and Sustainability.

Jung, F., Krüger-Genge, A., Waldeck, P., Küpper, J.-H., & others. (2019). *Spirulina platensis*, a super food? *Journal of Cellular Biotechnology, 5*(1), 45–54.

Luo, G., Liu, H., Yang, S., Sun, Z., Sun, L., & Wang, L. (2024). Manufacturing processes, additional nutritional value and versatile food applications of fresh microalgae Spirulina. *Frontiers in Nutrition, 11*, Article 1455553.

Musa, M. N., Jirgi, G. M., Zango, Z. U., Isah, M. N., Abdurrazak, M., Adamu, A. A., Wadi, I. A., Adeleke, A. A., Garba, Z. N., Bello, U., Adamu, H., Hosseini-Bandegharaei, A., & Bokov, D. O. (2025). A review on techno-economic assessment of Spirulina for sustainable nutraceutical, medicinal, environmental, and bioenergy applications. *Bioresources and Bioprocessing, 12*, Article 51.

Kore R. R., Dr. N. N. Prasade, Dr. S. S. Ramod, Dr. N. H. Khobragade (2023). Effect of spirulina (*Spirulina platensis*) on body weight of Konkan Kanyal kids. Pharma Innov. J. 2021; SP-12 (11):801-802.

Salahuddin, M., Abdel-Wareth, A. A. A., Stamps, K. G., Gray, C. D., Aviña, A. M. W., Fulzele, S., & Lohakare, J. (2024, August 21). *Enhancing Laying Hens' Performance, Egg Quality, Shelf Life during Storage, and Blood Biochemistry with Spirulina platensis Supplementation*. Veterinary Sciences, 11(8), 383.

Satya, A., Chrismadha, T., & Satya, I. A. (2021). *The irradiance optimation for growing Spirulina fusiformis: Biomass, phycocyanin, and protein production*. *Indonesian Journal of Limnology, 2*(1), 76–85.

Spínola, M. P., Mendes, A. R., & Prates, J. A. M. (2024). Chemical composition, bioactivities, and applications of *Spirulina* (*Limnospira platensis*) in food, feed, and medicine. *Foods, 13*(22), 3656.

Yadav, J. & Kumar, R. (2018). Effect of Spirulina (*Spirulina platensis*) Supplementation on Antioxidant status and immunity in growing Barbari goats. Int. J. Livestock Res., 8 (12), 252-257.