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Utilisation of Hydroponic Feed Technology in Livestock Feeding in Ethiopia - A Review

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Abstract

In Ethiopia, production of sufficient green fodder and grain to feed the livestock population has become a big challenge. This is due to limited land allocation for cultivation, lack of irrigation facilities and natural disaster. To overcome this problem, hydroponics fodder production technology is an innovative, emerging, efficient, and promising way to produce sufficient quality feed in livestock farms. In this paper, we have tried to explain the utilization of hydroponics feed technology in livestock feeding, with more emphasis on Ethiopia. *When used effectively, a hydroponic fodder system can guarantee livestock farmers a source of sufficient and abundant fodder, particularly in regions with limited grazing pasture, frequent droughts, and other climate-related issues.* Moreover, it is advantageous in terms of nutritional benefit and economic value, constant feed supply year-round, marginal land use, reduced labor requirement, and natural feed for animals. In situations where conventional green feed cannot be grown successfully, hydroponic feed can be produced by farmers for feeding their animals using low-cost devices. Feeding hydroponically produced feed increases the digestibility of the nutrients in the ration; this could contribute to an increase productivity of animals. Generally, hydroponic technology offers a significant potential for improving livestock feeding in Ethiopia. This technology is particularly valuable due to its ability to produce a readily available, highly palatable and digestible feed source rich in protein, vitamins, and minerals, which can significantly enhance animal health. Based on different research reports, hydroponic use has brought significant improvements in livestock production and has a significant positive impact on pastoral households' ability to generate additional income in Ethiopia. According to some authors, reports show all supplemented hydroponics produced better bodyweight gains and feed conversion efficiencies than the control in lambs. Moreover, past research findings have shown that the addition of hydroponic fodder to chicken rations was found to have a positive effect on the production performance. In Ethiopia there is a vigor in the adoption of this technology, and few farmers have been practicing this technology. However, there is a big gap and no adequate compiled information that clearly indicates the importance of hydroponics fodder production for sustainable livestock production. *According some research report hydroponic fodder production practice was low due to lack of awareness among extension workers, farmers, and service providers, high cost of seed, and labor shortage* and the adoption rate was found less than global average.

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Introduction

Due to dietary shifts, urbanization, and population increase, there is a steady rise in the demand for animal products worldwide. In Ethiopia, the livestock sector is a cornerstone of the agricultural economy, contributing significantly to livelihoods, food security, and national income. However, the high price and limited supply of high-quality feed ingredients and complex feeds are two of the main issues facing livestock production. Due to restricted supply and rivalry with human food systems, conventional feed resources are getting more and more expensive.

The improvement of feed availability and appropriate feeding management are important strategies to address the issues in livestock feed production. Investigating alternate feed sources such as "hydroponics fodder," which means "working with water," which grows fodder plants in nutrient-rich water without soil. The only things given to the producing plants are moisture and nutrition. Hydroponic growing systems produce a greater yield over a shorter period of time in a smaller area than traditionally-grown crops. This alternative technology viable for landless farmers for fodder production. It is a vertical growing process allows the production of large volume of hydroponics fodder in small area. One kg seed produces 6-8kg yields of fodder within 6- 8 days in green house or small shade (Anonymous, 2015). To produce 1kg of fresh hydroponics fodder about 2-3 (if water is not reused) liters of water is required (Naik *et al.,* 2013).

In just 50 square meters, hydroponics can produce over 600 kg of fodder per day for seven days. Fodder feed systems allow any size animal operation to grow their own feed year-round in a compact growing area, with minimal labor. All of the vital nutrients, vitamins, and minerals required for the best possible production of meat, milk, and eggs are included in the fodder, which is regarded as a complete animal ration. Regardless of the weather, hydroponics is a year-round growing method that yields a steady supply of high-quality plant material. Using hydroponics technology to produce the quality green fodder would be a revolutionary step in country's green fodder production.

The hydroponic growing process involves both structural and chemical changes. Proteins, carbohydrates, and lipids are hydrolyzed into their simpler components when enzymes inside the grain are activated. The quantities of fatty acids, soluble carbohydrates, and amino acids rise as a result of this hydrolysis (Chavan and Kadam, 1989). Minerals and bioactive enzymes are abundant in hydroponic feed (Dung *et al.,* 2010; Naik *et al.,* 2014). With sprouting time, the levels of crude protein and fatty acids rose linearly (Peer and Leeson, 1985). Sprouting eliminate ANF found in the grain. According to Naik *et al.,* (2015), hydroponic feeds are excellent sources of chlorophyll, which enhances chicken performance and makes the feed more palatable, digestible, and enjoyable for the birds.

Overview of hydroponic fodder technology

Hydroponic fodder technology is a sustainable method of growing green fodder without use of soil as medium. The system, utilizes nutrient-rich water to grow crops like barley, oats, wheat, etc, from seed. It provides a high-quality, easily digestible green fodder that benefits ruminant and poultry for, enhanced milk and egg production, and health of the animal. Economically, it reduces costs related to traditional fodder production, transportation and storage needs while ensuring a year-round supply independent of season and location. Environmentally, it is more resource-efficient, utilizes less water, land, and energy when compared to that of the conventional soil-based fodder farming systems.

Definition and concept of hydroponic fodder

Hydroponics is the technique of growing fodder using a water-based nutrient solution without soil, using water or nutrient-rich solutions instead. This soilless cultivation method is also known as hydroponics, derived from the Greek words "hydro" (water) and "ponics" (working). Hydroponic fodder production is a cost-effective and efficient way to produce feed, especially in areas with limited land or water resources. Hydroponic production systems are used by small farmers, hobbyists, and commercial enterprises. Through hydroponics it is easier and quick to produce nutritive green fodder.

Principles of Hydroponic Fodder Production

Hydroponics grows cereal grains with necessary moisture, nutrients, and the absence of a solid growing medium. The root mat and sprouting shoot are collected and given to the animals. Within 7-10 days, germination responds to the moisture and nutrients provided, producing bright green shoots that are 200 to 300 mm long and have interwoven roots (Naik *et al.,* 2011). With varying chemical and structural changes during the growing stages, different cereal grains can be used to produce fodder (Naik *et al.,* 2011). The breakdown of

nutrients into their more basic forms requires the activation of enzymes. The amount of sprouted and high-quality fodder depends on a number of factors, including grain variety, quality, and treatments such nutrient availability, pH, water quality, soaking period, etc. (Girma and Gebremariam, 2018). It is the science of growing plants in nutrient-rich solutions instead of soil. Water, nutrients, and sunlight are the three things that plants need to thrive (Swain and Sahoo, 2020). A simple method of supplying all these nutrients without soil in a regulated environment to maximize plant growth is hydroponics. In order to provide dairy animals with wholesome, high-quality green feed, hydroponic technology has been tested on a variety of crops, including maize, sorghum, barley, and oats (Swain and Sahoo, 2020). In addition, for best growth, hydroponics can be used to produce paddy seedlings, wheatgrass, etc. in seven days. In contrast to traditionally grown fodder, which only contains the stem and leaves, hydroponic fodder includes grass with grains, roots, stems, and leaves (Sneath and Mclntosh, 2011).

Importance of hydroponic fodder

Feeding livestock is a critical factor in the livestock industry and the search for more efficient and sustainable methods is ongoing. One of the most promising advancements in this field is the use of hydroponic fodder. Hydroponic fodder is rich in essential nutrients and vitamins, which translates into a more balanced diet for the livestock and making it an excellent supplement in their diet and enhanced production and productivity. It's a sustainable alternative to traditional fodder production, especially in areas with limited resources.

Nutritional Benefits for Livestock

Enhancing Performance and Health

One of the most significant advantages of hydroponic fodder is its positive impact on the health and performance of livestock. Its production and utilization are significantly benefiting animal industries by providing highly nutritious feed. The fodder produced is rich in essential vitamins, minerals, and amino acids. It enhances milk yield and quality due to higher levels of crude protein, moisture, and vitamins supplied to animals in feeds of hydroponic fodder compared to those of traditional forages (Niemenak *et al.,* 2020). Dairy cows fed with hydroponic fodder tend to experience an increase in milk production. This is due to the high nutritional quality of the fodder, the superfood that provides dairy cows with the necessary nutrients for optimal milk production. The result is a benefit for both milk producers and end consumers. Studies on the improvement of milk production through hydroponic fodder feeding show improvement than animals fed cereal grains, hay, or silage. Hydroponic fodder increases milk yield by 10.07% in dairy cows (Salo, 2019). Canadian dairy farmers also indicate the increase in feed intake of their cows after feeding hydroponic fodder and improve their milk yield by 3.6kg per day over the lactation period. Moreover, farmers from South Africa reported a drop of 3.6 liters of milk after a leave off of 6.8 kg fed per day (Shit, 2019; Mooney, 2005). Some studies reported that supplementation about 5-10 kg fresh hydroponics fodder per cow per day increases milk production (8-13%) by increases in the digestibility of the nutrients.

Hydroponic fodder improves the Bodyweight fain of lambs, and this is realized due to having high bioactive enzymes and ingredients that improve livestock performances. Moreover, increased body weight also reflects microbial activity in rumen and enhanced nutrient digestibility (Shit, 2019). In beef cattle, average increase in Bodyweight is achieved through feeding hydroponic fodder than maize similarly, birds and other animals (Tudor *et al.,* 2011; Ata, 2016).

In poultry, including hydroponic fodder in broiler diets often improves feed intake and nutrient utilization of broilers, leading to better body weight gain, which translates to higher carcass yield. The increased protein and essential fatty acids supply from the hydroponic fodder leads to improved egg production and meat quality, while minimizing contamination risks from aflatoxin. Many studies suggested that supplementation of hydroponic fodder can improve egg-laying performance due to its high content of bioavailable nutrients, such as vitamins, enzymes, and trace minerals. Some studies indicate that hens fed hydroponic fodder maintain peak egg production for a longer period compared to hens fed conventional diets. The immune-boosting properties of antioxidants and chlorophyll in hydroponic fodder contribute to healthier layers, indirectly supporting consistent egg production. The calcium and trace mineral content in hydroponic fodder contributes to better eggshell strength, reducing breakage rates. Studies have shown that improved shell thickness due to better nutrient availability and utilization in layers fed fodder. Fodder can also lead to a modest increase in egg weight due to enhanced protein and energy metabolism. The carotenoids in fodder impart a deeper

yellow or golden hue to the egg yolk, thereby improving visual appeal. Higher levels of vitamins (e.g., Vitamin A and E) and omega-3 fatty acids have been observed in the yolk, benefiting the nutritional quality of eggs, particularly for children.

Digestibility of Livestock

Another important aspect is the digestibility of hydroponic fodder. Hydroponic grass offers high digestibility for livestock (90%), compared to traditional pasture. Thanks to this palatable fodder, due to its taste, color, and texture, livestock can focus on activities such as reproduction, fattening, or milk production. This results in better nutrient absorption and reduced waste production, benefiting both the animals and the environment. In sheep, the digestibility of hydroponic fodder leads to faster weight gain and reduced digestive disorders (Rodrigues *et al.,* 2021). Even if there is a loss in the dry matter content of sprouted barley fodder, their digestibility has an advantage. In the rumen, the digestibility of the sprouts is higher than the cracked grain. However, comparing the digestibility of shoot and root sprouts, shoots quickly degrade in the rumen. Therefore, ruminant animals prefer leafy than steamy (Gebremedhin, 2007).

Economic benefit of Hydroponic fodder

Traditional fodder production requires a major investment for the purchase of land, in addition to investment in agricultural machinery, equipment, infrastructure required for pre- and post- harvesting, including handling, transportation and conservation of fodder. It also requires labour, fuel, lubricants, fertilizers, insecticides, pesticides, and weedicides.

On the other hand, hydroponic fodder production requires only seed and water as production inputs with modest labour inputs. Hydroponic fodder production provides significant economic benefits for livestock farming. Hydroponic fodder cultivation can take place in smaller spaces compared to traditional grazing. This is particularly valuable in areas where land is scarce or expensive.

The ability to produce feed in a smaller area allows livestock farmers to expand their operations without acquiring more land. Furthermore, it only takes 7-8 days in hydroponic systems to grow from seed to feed, compared to 45-60 days in conventional systems. The feed cost/kg milk is significantly decreased (by 25 to 30%) and the net profitability is significantly increased when fodder is grown in a low-cost hydroponic system (Naik *et al.,* 2013; FAO, 2015; Rachel Jemimah *et al.,* 2015).

With the ability to grow vertically and in controlled environments, hydroponic systems require less land area, making it suitable for urban and space-limited areas to produce fodder with much-reduced cost of acquiring land. Furthermore, the initial investment in hydroponic cultivation equipment can be quickly amortized through long-term savings. The system allows year-round cultivation of green feeds and reduces dependency on fluctuating commercial feed resources. This technology has gained traction due to its efficiency, sustainability, and economic advantages. As traditional farming faces challenges such as land scarcity, water shortages, and climate variability, hydroponics offers a promising solution for meeting the growing demand for livestock feed in a cost-effective and environmentally friendly manner. Hydroponic farming uses significantly less water than conventional methods, with water being recirculated in the system, resulting in cost savings and better water management. The system could save up to 90% more water than conventional soil-based agriculture.

Hydroponic fodder Production in Ethiopia

In Ethiopia, the adoption of hydroponics as a means of producing green fodder is gaining importance to address green fodder scarcity for livestock feed. Since its adoption in 2020 farmers are increasingly growing crops like barley, maize, and legumes as hydroponic fodder (Ayele and Melaku, 2022). This has been supported by the government and partners. Experiences gained so far showed accelerated growth of fodder, addressing critical feed shortages in urban and peri-urban areas (Oumer *et al.,* 2021). Some feeding trial carried out showed that inclusion of hydroponic fodder in the daily ration of livestock feed gave significantly increases production performance. According to Agegnehu *et al.,* (2021) the adoption of this technology increased milk yield and egg production in the country. Research indicates that the inclusion of green fodder in broiler diets can positively affect carcass yield, increase the weight of edible parts, and enhance carcass quality by improving meat texture, fat content, and overall appearance (Gaber *et al.,* 2019). However, the adoption of this technology was found to be less than the global average and this was related to a lack of awareness among extension workers, farmers, and service providers.

Utilization of Hydroponic Fodder for Feeding Ruminant Animal in Ethiopia

Hydroponic fodder has several benefits for ruminant animal specifically for dairy and sheep, making it an excellent supplement in their diet, such as for enhanced milk, improved feed digestibility, and health. These uses make hydroponic fodder a sustainable and efficient option for enhancing productivity and profitability in animal farming. The level of fodder supplementation in dairy cows should be tailored based on several factors, including animal type, body weight, milk production, age, breed types, and the quality of diet offered. The supplementation levels should be adjusted as part of a balanced diet, ensuring that other feed components, such as dry basal diet, concentrates, and minerals, are adequately provided to meet the overall nutritional requirements of the animal.

According to many research reports, the utilization of hydroponic feed technology can increase milk production and dairy productivity, especially in areas where seasonal drought is extended in Ethiopia. Kidane *et al.,* (2022) study confirmed that beneficiary households are producing more milk due to the green feed production and hence are getting a higher and significant daily income out of it. The author reported that hydroponic use has brought significant improvements in both cattle and goat milk production. Similarly, Bedeke *et al.,* (2024) found that hydroponic fodder production has a significant positive impact on pastoral households' ability to generate additional income. The findings demonstrated that a number of parameters, which warrant careful attention, were highly correlated with the impacts of adopting hydroponic fodder. The study's findings also showed that cooperative membership was favorably and significantly affecting the adoption of hydroponic fodder. The authors recommended that for the study area, pastoralists' cooperatives need to be strengthened to support farmer-to-farmer knowledge sharing. Additionally, a lot of work needs to be done to capacitate their financial and human resources by offering incentives so that they can serve as the center for agricultural technology transformation. Some studies on the improvement of milk production through hydroponic fodder feeding show more improvement than animals fed cereal grains, hay, or silage. Hydroponic fodder increases milk yield by 10.07% in dairy cows (Salo, 2019). Moreover, farmers from South Africa reported a drop of 3.6 liters of milk after a leave-off of 6.8 kg fed per day (Shit, 2019). Feeding hydroponic barley fodder (2.5 to 5 kg/calves/day) to calves results in increased dry matter intake, nutrient digestibility, and improved growth rate of the Hariana male calves (Verma *et al.,* 2015). Hydroponic maize fodder should be used for heifer feeding in situations where conventional feed is not available or cannot be grown due to adverse conditions (Naik *et al.,* 2016). Hydroponics maize fodder has a beneficial effect on growth performance and digestible nutrients in Gir calves, and it can replace up to 75% of crude protein in concentrate mixture (Jediya *et al.,* 2021). Calf starter replaced with hydroponic maize fodder (50-75% on a DM basis) has no adverse effect on the growth performance and nutrient digestibility of cross-bred calves (Rani *et al.,* 2019). Similarly, feeding hydroponics maize fodder as a partial substitute for calf starter (7% on a protein basis) can improve dry matter intake and daily body weight gain and lower the cost of production (Rajkumar *et al.,* 2018).

Regardless of hydroponic technology adoption as animal feed in Ethiopia Assefa *et al.,* (2018) reported that hydroponic fodder production practice was low (6.9%) due to lack of awareness, high cost of seed, and labor shortage. However, greater proportion (56.7%) of dairy cattle owners having experience of using hydroponic fodder witnessed that it improved milk production, calf growth, and animal's body condition. The high cost of seeds contributes to the low use of hydroponic fodder production in the research locations, despite awareness of its advantages. However, if the technology is shown to be economical and boost milk output without endangering the health of the animals, farmers will want to get involved in production. In contrast to urban respondents who doubt the technology's viability, a sizable portion of peri-urban respondents (83.2%) view hydroponic fodder production as a promising opportunity that is ready to expand if the technology is affordable and has been shown to boost milk production without endangering animal health. Although majority of the required facilities for hydroponic fodder production exists in the study area, seed cost and information on the effect of the fodder on productivity and health of animals limited its wider adoption and use. The author recommended that, future research should focus on identifying cost effective technologies and knowledge on effect of feeding such fodder on animal productivity and health. Kidane *et al.,* (2022) study confirmed that hydroponic technology has brought significant improvements in cattle production in the study area and producers are getting a higher income from it, and they recommended that this technology should be scaled up to other farmers.

Table.1 Comparison of the nutritional composition of hydroponic fodder and conventionally grown fodder.

Nutrient	Hydroponic Fodder (Global)	Traditional Fodder (Global)	Hydroponic Fodder (Ethiopia)	Traditional Fodder (Ethiopia)
Protein (%)	20.5	15.0	18.0	14.5
Fiber (%)	9.5	10.2	10.0	11.0
Vitamin C (mg/kg)	150	75	130	70
Calcium (g/kg)	6.2	4.5	5.8	4.2

Source: Kumar *et al*., 2021

Table.2 Hydroponic fodder production in Ethiopia

Parameter	Ethiopia (2023)	Global Average
Adoption Rate (%)	15	40-50
Average Farm Size (m²)	50	200-300
Feed Production (kg/day)	40	150-300
Water Use Efficiency (L/kg of fodder)	2.0	1.2

Source: Belay and Alemayehu, 2022; Tessema and Shenkute, 2022.

Mekonnen *et al.,* (2019) evaluated the feasibility of using hydroponically grown barley and oats forage as a supplement to natural pasture hay for sheep feeding and reported that all supplemented treatments had higher total DM intakes than the control, and all supplements produced marked substitution effects for pasture hay. All supplemented treatments produced better bodyweight gains and feed conversion efficiencies than the control. The author further stated that partial budget analysis showed that the highest net return was obtained from hydroponic supplementation, and the result indicated that feeding any of the supplements produced a positive financial outcome. Hydroponically grown oats forage could have the potential to replace a commercial concentrate for supplementing sheep on native pastures.

Hydroponic feed improves the body weight gain of lambs. This is realized due to having high bioactive enzymes and ingredients that improve livestock performances. Moreover, the increase in body weight also reflects microbial activity in the rumen and enhanced nutrient digestibility.

The result suggests that hydroponic options could be adopted by farmers, as hydroponic fodder production and utilization could be a possible option for boosting small ruminant production by smallholder farmers. For this intensive forage production strategy to be effectively used in the country, an option could be the production of hydroponic green forage by larger livestock producers as well as farmer-led commercial cooperatives.

Utilization of Hydroponic Fodder in poultry Feed in Ethiopia

The integration of hydroponically produced green fodder into poultry diets has emerged as an innovative approach to enhance production performance. Hydroponic systems offer a sustainable, space-efficient method of growing nutrient-dense fodder, which can improve overall chicken health, growth performance, and feed conversion efficiency. Green fodder is rich in essential nutrients such as vitamins, minerals, and amino acids, which are crucial for optimal muscle development and carcass quality.

At Bishoftu Agricultural Research Center, a trial showed that layer chickens fed 15% hydroponic fodder had significantly higher body weight and egg production, alongside lower feed consumption and production costs compared to other diets. Economic analysis indicated that up to 10% hydroponic fodder can be safely included in layer rations (unpublished data).

The program also delivered training for a total of 15 poultry producers from small, medium, and large scale on hydroponic fodder. The majority of the poultry producers are optimistic about the adoption and perception of this technology. The farmers are told that we are late to hear this big news about how to utilize non-conventional feed resources with low cost. This technology gave confidence to the participant farmers to utilize this alternative feed for sustainable chicken

production. Thus, there seems to be a great potential for using hydroponic technology for fodder production in chicken farming to reduce the feed cost. One farmer from Bishoftu town expressed that hydroponics is a wonderful technology; our worries about the production of conventional fodder by spending money, labor, and dependency on rain and irrigation have been reduced.

The related research work done results somewhere else also similar to this report. Including 25-30% hydroponic fodder in geese hens' diets improved hatching yields and egg production rates, as well as nutritional quality (Danis Khaziev *et al.,* 2021). Similarly, Abouelezz *et al.,* (2019) found laying Japanese quails on a diet with hydroponic barley had better egg production and fertility compared to those on a standard diet. Laying hens foraging on green feed materials access more amino acids, metabolizable energy, and calcium for eggshell development and yolk color, regardless of supplementary feed type. Studies suggest hydroponic fodder positively impacts egg yield and quality.

The addition of hydroponic fodder to broilers' rations was found to have a positive effect on the growth performance of the birds. For example, a feeding trial conducted by Baye *et al.,* (2024) on three-week-old chicks showed that the inclusion of 10.5 % hydroponic barley fodder in the daily ration of chicks fed for the first 21 days. The author found that there was a positive correlation between hydroponic barley fodder and the carcass yield of broiler chickens.

The author tried to demonstrate that the increment of body weight as the increased level of hydroponic barley supplementation may be due to the high nutritional value of the fodder, as it contains higher protein and energy, and it is a good source of vitamins and minerals as a result of sprouting. The authors further stated that an increased level of hydroponic barley fodder supplementation was also associated with an increase in the weight of drumstick, back, breast, thigh, and edible offal portions.

There is a gradual increment of dressing percentage as the hydroponic barley fodder supplementation increased. Alewi *et al., (*2016) reported that the mortality rate was not significantly different among all treatment groups. Research indicates that the inclusion of green fodder in broiler diets can positively affect carcass yield, increase the weight of edible parts, and enhance carcass quality by improving meat texture, fat content, and overall appearance (Gaber *et al.,* 2019). The positive effect of the hydroponic barley fodder on carcass yield of the broilers may be due to the accession of the protein content of the barley as a result of sprouting (Abouelezza *et al.,* 2019).

Conclusion

Hydroponics is an agro-technology that may be made using low-cost materials that offer animals more nutritious, tasty, and digestible fodder and has a lot of potential to alleviate feed shortages and increase livestock productivity in Ethiopia. This technology is particularly valuable due to its ability to produce a constant supply of high-quality and nutritious fodder throughout the year, especially in the areas facing frequent droughts and limited grazing land. However, the adoption of this technology in Ethiopia was found less due to a lack of awareness among extension workers, farmers, and service providers.

Conflict of Interests

The authors declare that they have no competing interests.

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