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The Use of Hydroponic Fodder in Animal Production Systems

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HIGHLIGHTS

- Forage production is essential for sustainable ruminant farming.
- Economic feasibility and dry matter cost remain uncertain.
- Hydroponic fodder systems offer land-efficient green feed production.
- This study evaluates the limitations of soilless forage systems.

Abstract

In general, roughage supply is one of the most important issues in large and small ruminant farming. Without roughage, ruminant farming is unthinkable. Purchasing roughage from outside sources is one of the obstacles to sustainable, economical production in ruminant farming. Roughage or feed prices generally begin to rise when milk prices fall. Hydroponic fodder production became popular in Türkiye in the early 2000s as an alternative for farms with insufficient land for roughage or no land at all. As of 2025, this topic has once again become a priority for farmers. The advantages of hydroponic fodder production include the ability to produce green barley year-round and repeat the process every eight days, as well as lower water consumption and labor requirements. However, it is also true that producing green barley using this method leads to nutrient losses. For instance, the cost of one kilogram of green barley dry matter is 3.4 times higher than that of barley grain dry matter, whereas the costs of energy and protein are 3.7 and 2.2 times higher, respectively. This article has been prepared to inform growers about the pros and cons of this method.

Keywords: Hydroponic Production; Fodder; Green Barley; Cost, Ruminants

1. Introduction

In ruminant farming, profitable production is impossible without forage production. This often-overlooked aspect can lead to certain metabolic diseases. The inability to rely on forage for breeding increases product costs, while the cost of treating any metabolic disorders that arise also impacts the cost of the product. Farms lacking sufficient land or pasture resources are not recommended for livestock farming, even with their own resources. Hydroponic fodder production is an innovative agricultural technology that has gained increasing importance due to the pressures exerted by rapid population growth, limited natural resources, and climate change on conventional agricultural systems. Based on the principles of soilless cultivation, this system

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enables plants to grow under controlled conditions in water enriched with nutrient solutions, thereby offering a sustainable alternative particularly in arid, semi-arid, and urban areas where feed shortages are prevalent (Hassen and Dawid 2022; Pastorelli et al. 2023). Recently, a commercial hydroponic fodder system advertised in Türkiye has been attracting growing interest from growers. The system is not significantly different from soilless tomato cultivation in greenhouses. The only difference is that barley doesn't require a large amount of nutrients to germinate and produce sprouts, and production is completed in a very short time. In hydroponic systems, green fodder is produced by rapidly germinating cereal grains such as barley, wheat, oats, and rye, which serve as a valuable feed resource due to their high digestibility and rich nutrient composition (Tranel 2013; Naik et al. 2015; Yahyaei and Talebi, 2024). This production method provides significant advantages over conventional feed production systems, particularly in terms of reduced land requirements and lower water consumption. The ability to produce large quantities of fresh fodder in a very limited space makes hydroponic systems a viable solution in regions experiencing land scarcity (Pastorelli et al. 2023). Furthermore, the possibility of year-round production contributes substantially to the sustainability of food and feed supply chains.

Forage obtained by harvesting barley, wheat, rye, oats, and corn while they are green is generally called green barley. Therefore, there's no harm in calling this soilless forage production system "commercial hydroponic fodder system ". In addition, the high content of protein, vitamins, minerals, and antioxidants in hydroponic fodder enhances animal nutrition and positively influences performance (Yahyaei and Talebi 2024). The contribution of hydroponic fodder to animal production is particularly evident in improvements in milk yield, live weight gain, and feed conversion efficiency. Studies indicate that incorporating such fodder into animal rations enhances digestibility and leads to significant increases in milk production (Cisneros-Saguilán et al. 2023; Bayskar et al. 2025). Moreover, characteristics such as low dry matter content and high fresh yield provide notable feeding advantages, especially for ruminants (Naik et al. 2015).

Some of the system's advantages are being promoted, particularly on agricultural television, and it's even being portrayed as a savior in solving the forage problem. Its most significant advantage is that it doesn't require large tracts of land. It appears that at least some of the forage needs of ruminant farms can be met this way. Meanwhile, information is also available online regarding the use of the produced material in non-ruminant horses. Advertisers generally strive to highlight the positive or advantageous aspects of the product. The absence of chemical fertilizers, pesticides, and similar inputs further makes hydroponic fodder a safer and more environmentally friendly alternative (Ghorbel et al. 2022; Hassen and Dawid 2022). However, the system also presents certain limitations, including high initial investment costs, the need for technical expertise, energy consumption, and risks related to mold and microbial contamination (Ghorbel et al. 2022; Pastorelli et al. 2023). Despite these challenges, hydroponic fodder production stands out as a sustainable alternative in the face of increasing feed demand and limited natural resources, offering numerous advantages. Notably, it ensures high productivity with minimal land use; whereas conventional fodder production may require approximately one hectare of land, hydroponic systems can achieve similar outputs within an area as small as 10 × 5 meters (Pastorelli et al. 2023).

What are the negative disadvantages of commercial hydroponic fodder systems for barley grass production, or more generally, of this system? What is the cost of one kilogram of dry matter produced? These questions remain unanswered. This article was prepared to answer at least some of the questions from growers, as no Turkish source was found on soilless forage production.

2. Advantages and Disadvantages of the System

Hydroponic fodder production systems represent an innovative and sustainable alternative to traditional forage cultivation methods. These systems enable the production of high-quality, fresh, and hygienic green feed throughout the year without the need for soil or large land areas. By using minimal water and labor, they significantly increase efficiency while reducing dependence on climatic conditions. Furthermore, soilless systems contribute to food security and environmental sustainability by ensuring continuous production and minimizing microbial contamination risks. Despite their high establishment costs, their productivity and repeatability make them an increasingly preferred method in modern livestock production. The advantages and disadvantages of the system are listed below.

2.1 Advantages

In this system, the daily forage yield grown in a 9 × 6 m area (Figures 1 and 2) can meet the same nutritional requirements as those of cattle grazing on a 1,200-decare area (Mooney 2005). Therefore, the system does not require land. Soilless production has an advantage over other feeds that are contaminated with microbes that can cause diseases in animals. Soilless production uses very little water. It is not dependent on rain or water. For example, Mooney (2005) reported that under normal land conditions, 80-90 liters of water are needed to produce one kilogram of forage, but in soilless production, 2-3 liters of water is sufficient for one kilogram of forage. According to Gallegos (2015), 800-1000 liters of water are needed to produce 1200 kg of sprouts per day, and this amount of sprouts is sufficient for 100 cattle or 500 sheep/goats. The repeatability of production throughout the year is another advantage. 25 cm of sprout can be produced in eight days. Eight kilograms of wet yield can be produced from one kilogram of barley grain in six to eight days, and this can be repeated at 10-day intervals (Figures 3-4). Labor requirements are minimal. It is possible to produce roughage even in winter.

Figure 1. External view of the system *(Naik et al. 2014)*

Figure 2. Inside view of the system *(Naik et al. 2014)*

Figure 3. Beginning of germination (Anonymous 2015a)

Figure 4. Sprouted barley heads (Anonymous 2015a)

Another important advantage of hydroponic fodder is its high nutritional value and digestibility. These feeds are rich in protein, vitamins (A, C, E, and B-complex), minerals, and antioxidants, thereby enhancing animal growth performance, milk yield, and feed conversion efficiency (Cisneros-Saguilán et al. 2023; Yahyaei and Talebi 2024). Indeed, it has been reported that supplementation with hydroponic fodder can increase milk yield by approximately 8–13% (Naik et al. 2015). Furthermore, the absence of chemical fertilizers and pesticides contributes to the safety and environmental sustainability of the product (Yahyaei and Talebi 2024).

Water-use efficiency is another notable advantage; in hydroponic maize production, only 1.5–3.0 liters of water are required to produce 1 kg of fresh fodder, which is particularly beneficial in regions experiencing water scarcity (Naik et al. 2015). In addition, low labor requirements, the possibility of vertical production, and the capacity for intensive production in small areas are among the key strengths of this system (Naik 2014; Ghorbel et al. 2022).

2.2 Disadvantages

The establishment cost of the facility is high. This disadvantage can be partially mitigated with greenhouse-like structures (Figure 5).

Figure 5. Greenhouse-like grain production facility (Naik et al. 2013)

Although hydroponic fodder production systems still require substantial initial capital investment due to the need for system installation, technical infrastructure, and specialized equipment, these systems also require continuous, albeit not intensive, labor, and their dependence on energy inputs during production may further increase operational costs over time (Ghorbel et al. 2022; Pastorelli et al. 2023).The system requires continuous, albeit not intensive, labor, and its dependence on energy inputs during production may further increase operational costs over time. In addition, the need for technical expertise and careful management of environmental parameters such as light, humidity, and nutrient solutions represents a critical constraint, as suboptimal conditions may reduce productivity and adversely affect product quality (Pastorelli et al. 2023). The potential presence of mold and its toxic metabolite, aflatoxin, poses significant risks to animal health and may also affect human health through transfer into animal products; nevertheless, treatment with 0.1% hypochlorite for one hour can effectively prevent fungal contamination without impairing germination (Sneath and McIntosh 2003), although the risk of microbial contamination remains an important biological limitation of the system (Ghorbel et al. 2022). From an economic perspective, the cost of dry matter is approximately 3.4 times higher than that of barley grain, while the metabolic energy cost per kilogram of dry matter is about 3.7 times higher and the crude protein cost is approximately 2.2 times higher compared to grain barley (Sneath and McIntosh 2003); furthermore, the necessity of immediate utilization of the produced fodder increases additional costs associated with labor, tools, and machinery. From a nutritional standpoint, the relatively low dry matter content of hydroponic fodder may limit its use as a sole feed source, particularly for monogastric animals (Cisneros-Saguilán et al. 2023), and the lack of standardized inclusion rates tailored to the requirements of different animal species further restricts its widespread adoption (Abdula 2022).

According to the literature cited above, hydroponic fodder production systems represent a highly efficient and environmentally sustainable approach that significantly contributes to the advancement of modern livestock production. Although the initial establishment and operational costs are relatively high and certain technical and biological constraints remain, their long term advantages, including high water use efficiency, improved hygiene, and the ability to ensure continuous year round production, make them a promising model for the future of feed production (Mooney 2005; Naik et al. 2015; Ghorbel et al. 2022; Pastorelli et al. 2023; Cisneros Saguilán et al. 2023; Yahyaei and Talebi 2024).

3. How is Production Done?

Grain production is generally accomplished by soaking cereal grains. Barley grain is typically used for this, and sprouting occurs approximately 5-8 days after soaking the grains in the trays. Pre-soaking is important for development and growth. A disinfectant water wash or soak is used to minimize the risk of mold. High-quality and productive sprout production is influenced by factors such as soaking time, grain quality, humidity, germination or sprout-promoting fertilizers, depth, grain density, and mold incidence. To produce grains with the highest yield and most usable nutrients, it is necessary to use clean, sound, intact, uncontaminated, untreated, and viable seeds. Cereal seeds germinate equally in both dark and light environments (Sneath and McIntosh 2003). Grain production does not require any special equipment; it can be easily carried out using trays, pans, or similar large containers. However, many commercial seed production systems have been developed that provide the conditions for the fastest and most rapid germination and sprouting. These systems control the facility's atmosphere by controlling temperature and air circulation. These facilities also require materials such as the system (seed pump), building, fertilizer tank, water, electricity, grain storage, transportation equipment, fertilizers, and disinfectants. In some countries, such as India, production is carried out in greenhouse-like structures due to their low cost (Naik et al. 2013).

4. Labor and Time Requirements

The operation of hydroponic fodder production systems involves several essential tasks to ensure efficient and hygienic production, including loading grains into trays, filling the soaking tank, preparing the nutrient solution, placing trays on shelves, monitoring germination daily, removing and emptying trays, washing and sterilizing equipment, cleaning the production area, and feeding the harvested fodder to animals. Overall, the system demands relatively low labor input, typically requiring 2–4 hours of work per day. For instance, a system producing approximately 1000 kg of fresh fodder daily (equivalent to 120–150 kg of dry matter) requires about two hours of labor, whereas production of 2000 kg per day may require around four hours (Anonymous, 2015a). Compared to conventional feed production methods, hydroponic systems offer a distinct advantage in terms of time and labor efficiency, as their production cycle is notably short, with fodder reaching harvest readiness within approximately 7–14 days (Naik 2014; Cisneros-Saguilán et al. 2023). This short cycle enables continuous year-round production, ensuring a stable feed supply and providing a significant advantage during periods of feed scarcity or market fluctuations, while also allowing for more controlled and predictable production planning. The labor and time requirements of hydroponic fodder production systems are relatively low compared to traditional methods, and their efficient workflow, minimal manpower needs, and high productivity make them an economically and environmentally advantageous option for sustainable livestock feed production. However, reduced labor demand does not eliminate the need for skilled management; continuous monitoring of environmental conditions such as light, humidity, and hygiene is essential, and failure to maintain these parameters may increase the risk of mold and microbial growth, thereby adversely affecting production quality (Ghorbel et al. 2022; Pastorelli et al. 2023). Therefore, although hydroponic systems require less physical labor, they necessitate a high level of technical expertise and careful operational control.

5. Changes in Nutrient Content During Barley Production

During germination and sprouting, seeds lose some dry matter as they use their reserves to generate the energy needed for growth. Later, sprouts can gain some dry matter through nutrient uptake and photosynthesis. Morgan et al. (1992) reported that during the short growth period (6–8 days), dry matter losses ranging from 7% to 47% can occur as seeds utilize their energy reserves for growth. Starting from the fourth day, as roots begin to spread, ash and protein contents in sprouts increase, with nitrate absorption contributing to the metabolism of nitrogenous compounds derived from carbohydrate reserves, thereby increasing crude protein levels (Table 1).

Table 1. Dry Matter, Ash and Crude Protein Contents of Barley on Days 4, 6 and 8 of Germination with Grain (Morgan et al. 1992)

Germination day	Dry matter (DM), %	Ash, g/kg DM	Crude protein, % DM
Original grain	100	21	10.1
Day 4	96	22	10.8
Day 6	91	31	13.7
Day 8	84	53	14.9

According to Table 1, prior to germination, the original barley grain contained 100% dry matter, 21 g/kg DM of ash, and 10.1% crude protein. During the 4th, 6th, and 8th days of germination, a notable decrease in dry matter was observed, accompanied by increases in ash and crude protein contents. Therefore, the germination process significantly alters the chemical composition of barley. The reduction in dry matter can be attributed to the conversion of carbohydrates into energy through respiration, whereas the increases in ash and protein contents are likely related to changes in nutrient concentration and enhanced enzymatic activity. Consequently, barley germination appears to enhance its nutritional value, particularly by increasing protein content while reducing dry matter.

Fazaeli et al. (2012) presented the changes that occur during the production of grain barley as conversion rates in Table 2.

Table 2. Changes occurring during the production of grain barley (as conversion rate*) (kg)

Traits	Days after germination		
	6	7	8
Fresh weight	4.93	6.65	7.21
Dry matter	0.95	0.95	0.96
Organic matter	0.94	0.95	0.95
Ash	1.23	1.26	1.40
Crude protein	1.19	1.20	1.36
True protein	0.68	0.67	0.65
Non-protein nitrogen	2.05	2.09	2.11
NDF	1.47	1.50	1.68
ADF	1.89	2.05	2.28
NFC (non-cellulose carbohydrate)	0.72	0.68	0.64
Water-soluble carbohydrate	1.81	1.59	1.72
Digestible organic matter	0.92	0.94	0.91
Metabolic energy	0.92	0.94	0.91

*The conversion ratio (CR) for each nutrient calculated as below:
CR= Nutrients contents in green fodder obtained per kg of barley grain / Nutrients contents per kg of barley grain

According to Table 2, as germination progresses, an increase is observed in fresh weight and certain nutrient contents; for instance, fresh weight rises from 4.93 kg on day 6 to 7.21 kg on day 8. Dry matter and organic matter remain relatively stable, ranging between 0.95 and 0.96 kg, while ash content and crude protein show an increasing trend. In contrast, true protein exhibits a slight decrease, from 0.68 kg to 0.65 kg. Fiber components also change during germination, with NDF (Neutral Detergent Fiber), and ADF (Acid Detergent Fiber) showing an upward trend, whereas NFC (Non-Fiber Carbohydrates) and water-soluble carbohydrate contents display fluctuations. Digestible organic matter and metabolic energy values remain largely stable, indicating that germination does not cause significant changes in energy value. In conclusion, the germination process substantially affects the nutrient composition and biochemical characteristics of barley, particularly inducing notable changes in protein and fiber contents.

6. Production Capacity

Approximately 2.5 kg of barley grain is placed in a tray measuring 70x30 cm and approximately 10 cm high (Figure 6). This amount of barley can produce approximately eight times the yield after eight days. Mooney (2005) reported that carbon dioxide injection doubles this yield. Under normal conditions, 20 kg of fresh grain can be produced from one tray. A facility with 100 trays can produce 2000 kg of fresh grain per day. Increasing the amount of grain placed in the trays slows down the recovery rate of the dry matter increase resulting from germination and also increases the risk of microorganism contamination (Morgan et al. 1992).

Figure 6. Plastic tray used in grain production (Anonymous 2015b)

7. Effects of Light and Temperature on Production

As previously stated, light is not required for grain germination. Sneath and McIntosh (2003) reported that light applied immediately after germination caused yellowing, while lighting applied two days before harvesting promoted photosynthesis. The same researchers stated that lighting was not very effective and that two days of illumination were sufficient. They also reported that increasing the light intensity from 1000 lux to 2000 lux was not very effective. Sneath and McIntosh (2003) reported that temperature and humidity are the two most important factors for grain germination. The required temperature is room temperature, and seeds can germinate between 12 °C and 30 °C. However, germination rates decrease at temperatures that drop to 12 °C or approach 30 °C. A temperature of 21 °C is generally maintained in soilless seed production.

8. Cost of Hydroponic Fodder Production

The cost of hydroponic fodder production is calculated by calculating the cost of dry matter entering and exiting the system. The same calculations can be made for energy, protein, and potential performance. Generally, when calculating cost: (1) Grain, (2) infrastructure (facilities, buildings, equipment, tanks, silos, shredders, etc.), (3) depreciation, (4) annual interest on invested capital, (5) labor costs, (6) ongoing expenses (electricity, gas, nutrients, disinfection materials), (7) repair, maintenance, and unexpected technical problems, and (8) risks (quality grain, germination success, mold, effects on performance) are taken into account (Sneath and McIntosh 2003). Based on these factors, the cost of producing 800 kg of 12% DM yield from 100 kg of grain in Figure 7 can be calculated as follows (Sneath and McIntosh 2003).

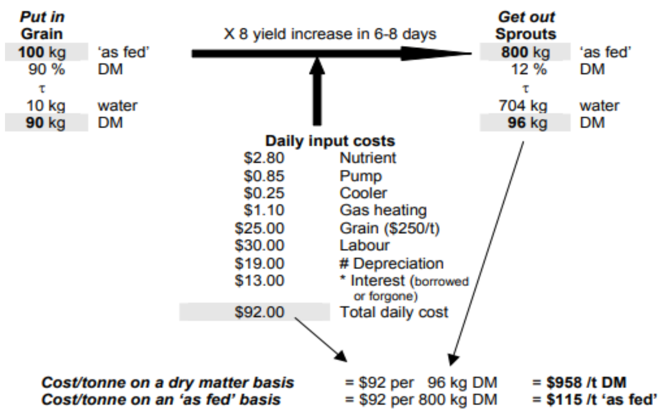

Figure 7. Costing sprouts production

According to Figure 7, a cost of $92 is incurred for 96 kg of dry matter. The cost of one ton of dry matter is $958/ton (92x1000/96=958). Similarly, the cost of 800 kg of fresh barley is $92, while the cost of one ton of barley is $115/ton. Assuming 90% dry matter, the cost of 1000 kg of barley is 250 x 1000/900 = $278. Therefore, the dry matter of fresh barley is 3.4 (958/278 = 3.4) times more expensive than barley.

9. Conclusion

Hydroponic fodder production systems offer an innovative and sustainable alternative to traditional forage cultivation, enabling the year-round production of fresh, high-quality, and hygienic green fodder with minimal land, water, and labor input. These systems play a crucial role in meeting the roughage needs of ruminants, particularly in farms with limited land or pasture resources, supporting animal nutrition and ensuring continuous feed availability. Consequently, hydroponic fodder systems emerge as a reliable and strategic solution for modern livestock production, providing efficiency, hygiene, and sustainability. Hydroponic fodder roughage production will be an alternative solution to the shortage of roughage production in the future years due to drought, which is inevitable as a result of global warming.

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