

Hydroponic Fodder Production for Smallholder Livestock: Yield, Nutritive Value and Economics

Goncalo Barros¹ ●, Georgios Theodorou² ●, Ruben Larranaga³ ●

¹ Senior Scientist, Department of Poultry Science, Alentejo Institute of Agrarian Sciences, Beja, Portugal. Email: g.barros@aias.pt | ORCID: 0000-0001-3159-8656

² Assistant Professor, Department of Livestock Production Management, Thessaly Plain Institute of Agriculture, Larissa, Greece. Email: g.theodorou@tpia.gr | ORCID: 0000-0001-0169-4815

³ Research Associate, Department of Livestock Production Management, Extremadura Centre for Dehesa Livestock Research, Plasencia, Spain. Email: r.larranaga@ecdrl.es | ORCID: 0000-0001-1820-1159

ABSTRACT

Hydroponic fodder, usually sprouted barley or maize grown for a few days on trays without soil, is promoted to smallholders as a way to turn a little grain and a little water into a large volume of green feed. This narrative review asks how much of that promise survives scrutiny. It draws on published work on the biochemistry of sprouting, on the nutritive value of germinated cereals, on water, energy and land use in soilless production, and on mycotoxins and microbial hazards, and it reports no new data. The central complication is a matter of arithmetic: the gain in fresh weight is largely water, while dry matter is lost to respiration, so the yield that matters to an animal is far smaller than the yield that is shown to a visitor. Claims about improved nutritive value mostly describe changes in proportions, not additions of nutrients. Costs of water, power, labour, seed and failed batches are seldom counted together, and warm humid trays favour mould, with mycotoxins a further concern for ruminants. Studies of animal response are few, short and often poorly reported. The review concludes that hydroponic fodder is a defensible tool in narrow circumstances, not a general answer to feed scarcity, and it sets out what a fair test would record.

Keywords: Hydroponic fodder; Sprouted barley; Dry matter; Nutritive value; Mycotoxins; Smallholder livestock; Narrative review

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1. Introduction

Anyone who has spent a dry season with livestock knows how quickly green feed becomes the limiting resource. Pasture thins, crop residues are dry and low in nitrogen, and concentrate is priced out of reach for many households. A method that promises a tray of fresh green fodder every few days from a handful of grain and a little water is bound to attract attention. Feed is the largest single cost in milk production in most systems [1], and smallholders face the pressure of mixed crop and livestock farming on land also needed for food

[2, 3].

Hydroponic fodder is the name usually given to cereal or legume seed that is soaked, germinated on trays under a light spray of water and harvested after a short growing period as a mat of roots, seed remnants and young shoots. Barley and maize are the usual choices. The method is promoted as space-saving, water-saving and independent of season, and advertisements tend to quote one figure above all others: the ratio of harvested fresh weight to seed weight.

That figure is where the difficulty begins. A tray of green fodder weighs a great deal because it is full of water, and what an animal needs is dry matter, energy and nutrients. During sprouting the seed uses its own reserves to grow, so dry matter is lost even as fresh weight rises [4, 5]. A system can therefore look highly productive on a scale and be unremarkable, or worse, when judged on the nutrients delivered. Claims about nutritive value, about water and energy, and about animal response each carry their own uncertainty, and mould and mycotoxin risk adds a safety dimension that is rarely mentioned in promotional material. The aim is a fair account of what is known and what is merely repeated.

This is a narrative review. It brings together published work on the biochemistry of sprouting, the composition of sprouted cereals, resource use in soilless production, mycotoxins in feed and the design of feeding trials, and it deliberately reports no new data. Where evidence for smallholder livestock is thin, which is often, we say so and describe what a convincing test would need to record, rather than quoting figures we could not check against their sources. The tone is sceptical without being dismissive.

2. Literature Review

2.1 What Hydroponic Fodder Is, and Why It Appeals

The practical idea is old: germinate seed, harvest the green mat, feed it fresh. Commercial units with controlled lighting and temperature are now marketed alongside simple racks in a shaded shed, and the word hydroponic suggests a precision that the simpler systems do not have. The seed does most of the work from its own reserves; the water mainly keeps the tray moist and carries away heat. Studies of green fodder grown this way have examined yield and water use for several forage crops [6], and reviews of cereal sprouts describe the changes in composition at length [4, 7].

The appeal to a smallholder is easy to understand: a small shed replaces hectares of fodder crop, and the product looks fresh and green. It also fits the argument that livestock should make better use of land that could grow food directly [8, 9]. What the feed is worth is a different matter from how it looks.

2.2 What Happens to the Seed During Sprouting

Germination is a metabolic event. Water uptake activates enzymes that break down starch and storage protein into simpler compounds for the

growing embryo, and respiration burns part of the stored carbohydrate for energy [5]. Reviews describe falling starch, rising enzyme activity, changes in amino acid and vitamin profile and a reduction in some antinutritional factors, the size of each depending on grain, temperature, light and time [4, 7, 10]. These effects are real, and explain why sprouted grain has a following in human nutrition.

For a feed, however, the same events read differently. Starch is the main energy source in barley and maize, and the carbohydrate burned in respiration is energy the animal will not receive. A comparison of barley grain with sprouted barley, including in sacco digestibility, is the kind of evidence needed to judge the net effect [11]. The compositional changes are shifts in proportion as one fraction shrinks, not nutrients created from nothing. This is why the same system can look excellent in one report and unremarkable in the next.

2.3 Fresh Weight, Dry Matter and the Yield Question

The distinction between fresh and dry weight is the hinge on which most claims turn. Fresh sprouted fodder is mostly water, and a dairy animal has a limit to how much bulky, wet feed it can eat in a day, so a high fresh yield may not translate into more nutrient intake [12]. Table 1 sets the two readings side by side. The point of the table is not that sprouting is useless, but that a statement of yield without a statement of dry matter says very little.

Table 1. Two ways of reading the yield of sprouted fodder.

Attribute	Fresh-weight view	Dry-matter view
Total yield	Large gain over seed weight, mostly water [4, 6]	Flat or lower than seed weight [4, 11]
Starch and sugars	Not visible in the tray	Consumed by the growing seedling [5, 7]
Protein	Appears richer	Share rises as other fractions fall; total may not [7]
Fibre	Not obvious	Rises with root mat and shoots [13]
Intake limit	Bulky, little energy per kilogram	Energy per kilogram of feed as fed is low [12]
Price per kilogram	Looks cheap	Dearer per kilogram of dry matter

Note: Qualitative comparison. The size of each change depends on species, seed quality, duration and management, so no figures are given.

Fibre matters here too. The root mat and stem add structural carbohydrate, commonly described as

neutral detergent fibre [13], so as starch declines and fibre rises the feed becomes less energy dense per kilogram of dry matter than the seed it came from. For a ruminant that is not necessarily a disadvantage, but it undercuts the idea of sprouted grain as a concentrated supplement.

2.4 Nutritive Value for Ruminants and Other Livestock

A ruminant meets its requirements through rumen fermentation and intestinal digestion, and published requirement tables remain the reference for judging whether a ration is short of anything [14]. Replacing dry grain with sprouted grain changes what reaches the rumen: starch availability falls and fermentable fibre rises, which matters most in rations that depend on grain for energy. Where the basal ration is already adequate, a change in the form of the supplement should have only a small effect.

Work on supplementing grazing cows offers a useful parallel. Animals eat less pasture when given more concentrate, so a supplement does not add its full nutrient content to the diet, and the extent of this substitution depends on pasture and supplement [15]. Green fodder fed on top of a ration should behave the same way, so the effective gain will be less than the tray suggests.

2.5 Water, Energy and the Wider Resource Debate

The argument for water saving is usually made by comparing the litres used per kilogram of fresh green fodder with those needed for field-grown forage, and studies of hydroponic fodder have indeed reported favourable water use efficiency on that basis [6]. Two cautions apply. The comparison changes once water is expressed per kilogram of dry matter, and it ignores the water embedded in the seed itself, which was grown in a field. Global assessments show that the water footprint of animal products is dominated by feed production rather than by drinking water [16], so a tray system that depends on bought grain inherits that footprint.

Energy is the less discussed side of the ledger. Soilless production of vegetables has been reported to use less land and water than conventional production but considerably more energy [17], and the same logic applies, in lighter form, to any enclosed fodder unit that needs lighting, fans or cooling. At the scale of the planet the issue is how much cropland feeds animals rather than people [18, 19], and sprouting edible grain for livestock puts the system squarely in the feed-food debate [8, 20].

2.6 Moulds, Mycotoxins and Microbial Hazards

Sprouting conditions are close to ideal for fungi: trays are warm, wet and rich in sugars released from the seed, and the dense mat traps moisture. Toxin-producing fungi are a familiar problem in cereals and feed generally [21, 22], and reviews make clear that mycotoxins are chemically diverse, with effects from reduced intake to reproductive and liver disorders [23]. Surveys of feedstuffs show that contamination is common, though the share affected differs between toxins and regions [24]. A frequently quoted figure for the share of the world's crops affected has itself been questioned [25], a reminder to treat headline numbers with care.

Ruminants are sometimes described as more tolerant of mycotoxins because rumen microbes degrade some of them, but the protection is partial and varies by toxin [26]. Zearalenone is oestrogenic and relevant to breeding animals [27], ochratoxin A has been studied in livestock production [28], and aflatoxin and some other toxins can pass into milk [29, 30]. Sprouts raise a separate concern, because seeds can carry bacterial pathogens that multiply during germination [31]. The main hazards and the checks that follow are collected in Section 4.4.

3. Materials and Methods

3.1 Scope and Question

The review asks how much usable feed a hydroponic fodder system delivers, how its nutritive value compares with the grain it starts from, what it costs once all inputs are counted, what hazards it introduces and what the animal response literature shows, all under smallholder conditions of few animals, limited capital and family labour.

3.2 Literature Assembly

The review draws on peer-reviewed work in five areas: sprouting biochemistry, ruminant nutrition and supplementation, resource use in soilless and livestock systems, mycotoxins and microbial hazards, and the design and statistics of animal studies. Sources were chosen for relevance and standing, and some because they illustrate a general principle, such as substitution when supplements are fed or the effect of small samples on reliability.

We did not run a formal systematic search and we do not claim a complete census of the literature. This is a narrative synthesis, which means selection is open to the reviewers' judgement, and

readers should treat the account as an informed reading and not as an exhaustive count. Dedicated studies of hydroponic fodder in livestock are fewer than the volume of promotional material would suggest.

3.3 Appraisal Framework

To judge how far a claim can be trusted, we used a short set of questions. Is yield stated on a dry-matter basis? Is the composition of the fodder fed reported, and is it compared with the seed? Were all inputs, including labour and energy, priced? Was the basal ration described? Was the unit of analysis the unit that was actually fed? Were sample size and duration adequate to support the conclusion? Reporting standards for animal studies provided the template for the last three questions [32, 33]. Table 2 lists the cost components we looked for.

4. Results

4.1 How Much Feed Does a Tray Deliver?

The first finding is arithmetic. Sprouting converts a modest mass of dry seed into a much larger mass of wet fodder, but the dry matter in that fodder is no greater than, and generally lower than, that of the seed that went in [4, 5]. Figure 1 shows the pattern as a schematic: the tall fresh-weight bar is mostly water, while the dry-matter bar is about the height of the seed bar or a little shorter. No numbers are implied, since the ratio depends on species, seed quality, time and management.

Table 2. Cost components to record in a hydroponic fodder account.

Component	What to record	Often omitted?
Seed	Grain type, price paid, losses in storage	Rarely
Structure	Shed, trays, shelving, lining, expected life	Often
Water	Volume, source, pumping or carrying; drainage	Often
Energy	Lighting, fans, cooling, pumps, timers	Very often
Labour	Hours to soak, sow, water, harvest and wash trays, at local wage	Very often
Failed trays	Share lost to mould, heat, pests or neglect	Often
Grain saved	What would otherwise have been fed, on a dry-matter basis	Rarely stated

Note: The last column gives the authors' reading of how often advisory material leaves the item out of a stated saving.

This matters for every claim downstream. A farmer who divides harvest weight by seed weight sees a

multiple, and a promoter who quotes it is not wrong, only silent about water. Dried samples would give a much smaller figure, one that could fall below one. Comparisons of sprouted and unsprouted grain therefore need to state their basis, and results given only on a fresh basis cannot be taken as evidence of more feed.

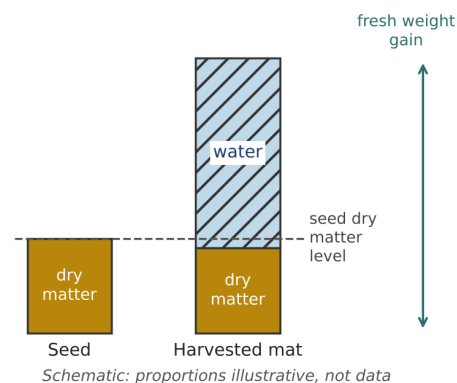


Figure 1. Fresh weight and dry matter of sprouted grain compared with the seed (schematic, proportions illustrative, not data).

4.2 Nutritive Value: Proportions Versus Totals

Several reviews report that sprouting increases the concentration of protein in the dry matter and improves the availability of some vitamins and minerals while lowering certain antinutritional factors [5, 7, 10]. The mechanism is plausible and well described in the cereal literature. Starch is consumed faster than protein, so protein forms a larger share of what is left, and enzymatic changes in the seed can improve the availability of some minerals.

A rise in percentage protein, however, is not a rise in protein delivered. If dry matter shrinks and protein stays roughly constant, the concentration increases without any gain in total protein, and the feed has become less energy dense. A ration short of rumen-degradable nitrogen may benefit; a ration short of energy may be made worse. In sacco work on sprouted barley illustrates the direction of change [11] but does not settle the question for a farm ration. The bioactive compounds and vitamins that attract attention in human nutrition [10] are likely to matter little for animals on a balanced ration.

4.3 What a Fair Cost Account Includes

Advertising for hydroponic units often highlights a cost saving, usually the difference between the price of the grain and that of the conventional feed it replaces. A full account looks different. Seed is the largest recurring item, and it is edible grain, often purchased. Structure, trays and shelving must be paid for and replaced. Water has to be sourced and drained, and energy appears

wherever lighting, fans or cooling are used [17]. Table 2 lists the items and how often our reading suggests advisory material omits them.

Labour is the item most often left out and probably the one that matters most to a household. Trays must be soaked, sown, watered, harvested and washed every day, and the work cannot be postponed without losing a batch. A mouldy tray is a total loss of its seed, water and labour. The denominator matters as well: cost per kilogram of fresh fodder looks cheap because of the water, while cost per kilogram of dry matter is a much sterner test. A saving that disappears when labour is priced is not a saving a hired worker would ever see.

Finally, what is being replaced must be defined. If the fodder displaces purchased concentrate, the comparison is with the concentrate price; if it displaces a free crop residue, there may be no saving at all. Because feed is such a large share of production cost [1], small errors in the feed account can reverse a conclusion.

4.4 Mould, Mycotoxin and Hygiene Risk

The hazards fall into two broad groups: those that come in with the seed and those that develop on the tray. Seed that carries toxin-producing fungi from the field or the store brings that burden into the system, and sprouting does not remove it [23, 24]. Trays then provide conditions in which moulds can grow further, so that the fodder fed to the animal may be worse than the seed [21, 26]. Table 3 lists the hazards and the checks that follow from them.

Table 3. Hazards in sprouted fodder and the checks that follow from them.

Hazard	Why it arises	Check
Mould on the root mat	Warm, humid, nutrient-rich trays [31]	Inspect daily; discard affected trays
Mycotoxins already in seed	Field or storage fungi on the grain [23, 24]	Buy clean seed; test where possible
Mycotoxins formed on trays	Moulds grow on seed and mat [21, 26]	Short cycles, airflow, hygiene
Carry-over to milk	Transfer of some toxins to dairy products [29, 30]	Keep suspect fodder from lactating animals
Bacterial contamination	Seeds can carry pathogens that multiply in sprouting [31]	Clean seed, clean trays, clean water
Mixed signs in animals	Effects of low-level exposure are hard to spot [22]	Record feed refusal and health events

Note: Hazards are those described in the cited literature on mycotoxins and sprouts; no occurrence rates are implied for any farm.

Practical measures are mostly about hygiene and judgement: clean seed, trays and water, moving air, short cycles and daily inspection for discoloration or odour. None of this guarantees safety, because mycotoxins can be present without visible mould, so testing of seed belongs in the cost of operating the system. Lactating animals deserve particular caution because some toxins can reach milk [29, 30].

4.5 Evidence on Animal Response

The part of the literature that most farmers care about, how animals perform when sprouted fodder replaces or supplements part of the ration, is also the weakest. Controlled studies are few, and many are short, small and sparse in describing the ration and the fodder, so it is hard to tell whether a reported effect came from the fodder, from a difference in total nutrient supply, or from chance [34, 35]. Figure 3 gives our qualitative reading of how well each strand of the topic is documented; it is a judgement, not a count.

Statistical problems compound the difficulty. When animals share a pen the pen is the unit that was fed, and treating each animal as a replicate overstates precision [35]. Small studies yield estimates that swing widely and, when significant, tend to exaggerate effects [34, 36]; reporting intervals and effect sizes would help readers judge magnitude [37]. In dairy work the lactation curve itself produces apparent changes in yield unrelated to treatment [38].

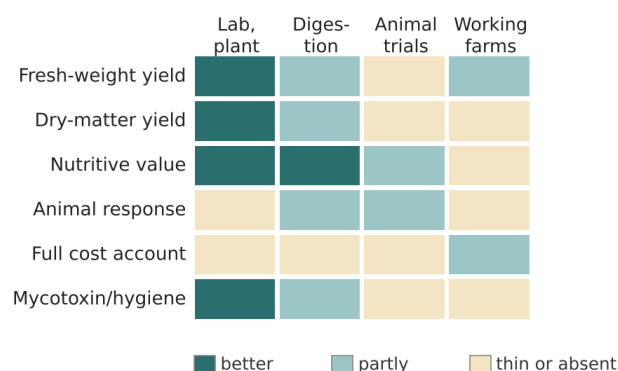


Figure 3. Authors' qualitative reading of how well each claim is documented (not data).

Put plainly, the literature supports a cautious statement. Sprouted grain is digestible and animals eat it, but there is little convincing evidence that, in a smallholder shed, it improves growth or milk yield beyond what the same grain would do if fed dry, and even less that it does so at acceptable cost. Read this way, a null result from a small trial is not evidence that nothing happens.

5. Discussion

5.1 Interpretation and Practical Reading

The main finding of this review is conditional. Hydroponic fodder can supply fresh green feed where none is otherwise available, and for confined animals or those with high needs for fresh forage that has real value. What the evidence does not support is the general claim that it multiplies feed from a little grain and water, because the multiplication is in water and dry matter is conserved at best. Such differences look small on any single day, but they accumulate over a season.

The second conditional is economic. Whether the system lowers cost depends on what is replaced, how labour is valued and how often trays fail. A household with spare family labour, cheap water and good seed may find the numbers acceptable; one whose tray-tender could be earning elsewhere may not. Writing the account down, every input priced, is the most useful step before buying racks and trays.

A third point concerns safety. Feeding a product that is grown wet and warm and eaten fresh carries a mycotoxin and hygiene risk that the dry grain does not [22, 26]. The risk is manageable, but it needs attention every day, and more so for lactating and breeding animals.

Three findings would change this reading. A well-designed trial showing a clear performance benefit on a dry-matter-equivalent basis would shift the biological argument. A cost account showing a saving after labour and energy are priced would shift the economic one. And evidence that routine monitoring keeps toxin levels low in real smallholder sheds would ease the safety concern.

5.2 Limitations

This is a narrative review and shares the limitations of that design. Selection of sources is subjective, and a systematic search might have found studies we have not discussed. We have pooled no results and avoided quoting numbers whose provenance we could not verify; readers needing quantitative guidance should consult the primary papers.

The review also draws on evidence from other settings: human nutrition studies of sprouted grains, general mycotoxin surveys, soilless vegetable production and trials on supplementing grazing cows. Their relevance to a village fodder shed is plausible but not certain, and largely non-peer-reviewed extension material was not weighed heavily.

5.3 Where Hydroponic Fodder May Fit

Figure 2 sets out the questions a farm should answer in sequence. Is there a real feed gap that cheaper options, such as conserved forage or crop residues, cannot close? Is clean seed available at a price that leaves room for the account to work? Is water reliable and labour genuinely free? Can the unit be kept clean and monitored? Only when all answers are yes does the method deserve a pilot.

Even then, a pilot should allow a fair judgement: a small group fed the sprouted fodder compared with a similar group fed the same dry matter as grain, with the same basal ration and milk or growth recorded over a sufficient period. This is no substitute for a formal trial, but it is far better than an impression formed from the tray. A farmer reading a trial report needs the answer to a plain question: would this have worked in my shed?

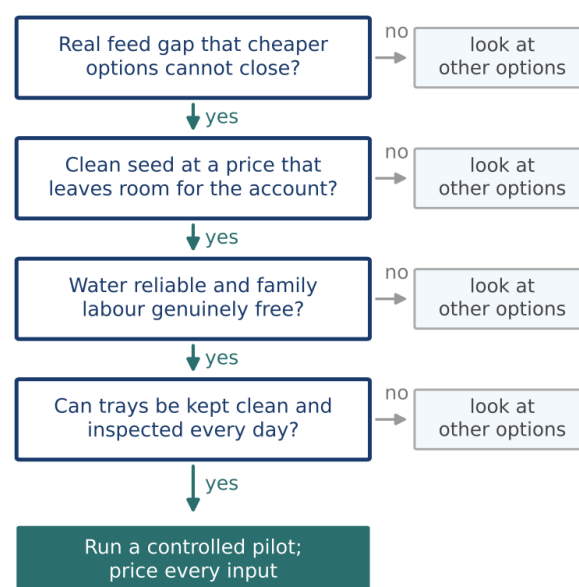


Figure 2. Decision sequence for deciding whether hydroponic fodder suits a farm (schematic, not data).

5.4 Directions for Future Work

Three needs stand out. First, dry-matter yield, nutrient content and digestibility should be reported together, with the seed as comparator, for the grains and conditions smallholders actually use. Second, trials with adequate animal numbers and appropriate units of analysis, reported against recognised standards [33], are needed to test whether the sprouted product beats the grain. Third, integrated cost and hazard studies in working units, including mycotoxin testing and pricing of labour and energy, would replace the assumptions that now decide most investment. Nothing in this reading argues against sprouting grain; it argues for measuring what happens when the sprouts are fed.

6. Conclusion

Hydroponic fodder is a real option and a modest one. The headline gain in fresh weight is mostly water, dry matter is lost during sprouting, claims of better nutritive value mostly describe changes in proportion, and the cost of water, energy, labour and failed batches is seldom counted in full. Mould and mycotoxin risk is built into the method and needs daily management. The evidence on animal response is thin, short and often poorly reported. These points apply with equal force to any novel feed, not only to this one.

For the practitioner the message is practical rather than discouraging: measure dry matter, price every input, buy clean seed, inspect the trays daily and compare against a plain grain control before committing capital. Researchers can supply the trials and cost studies that would let these judgements rest on evidence. Reviews of this kind are more useful when they say where the evidence stops than when they smooth it over.

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9. Conflict of Interest

The authors declare no conflict of interest.

10. Author Contributions

G.B. conceived the review and wrote the sections on feed safety and hygiene. G.T. wrote the sections on nutritive value and trial design. R.L. wrote the sections on feed economics and resource use. All authors revised the manuscript and approved the final version.

11. Ethics Statement

This is a review of published literature. No animals were used and no ethical approval was required.

12. Data Availability

No new data were generated. All sources are cited in the reference list.

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