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Utilization of Hydroponics for Green Fodder Production

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ARTICLE ID: 048

Introduction

The increase in livestock production have increased nutrient requirement of animals. Productive and reproductive performance of animals increase through feeding green fodder. Subsequently, feeding green fodder improve livestock products. For instance, provision of hydroponic fodder to dairy animal leads to sustainable economic development of dairy production and it is a fact that deficiency happens if dairy animals feed without including green fodder in their ration.

Livestock production in India and other countries in Asia are limited due to insufficient production. Nevertheless, the main problems in producing green fodder emanates from reducing land size for fodder cultivation, labor requirements, shortage of water and elevated cost of fertilizers. Moreover, lack of constant quality green fodder throughout the years magnifies restricts of sustainable dairy farming.

Now a day's scarcity of land has been shown as a great constraint of forage production for ruminant animals. The ruminant animals cannot always be dependent on cereal grains like that of monogastric animals. Having these and other problems in mind, alternative technologies like the hydroponics found critical. Using this technology as livestock feed leads to improvement of livestock performance. Cultivation of wider range of land creates an opening to hydroponics method of forage production for livestock. One of the progressive technologies in agriculture is hydroponics which satisfies the nutrient demand of livestock. This technology gives a grantee for sustainable forage production and with suitable price. It is a technique of growing crops like barley without use of chemicals and artificial growth agents. It is characterized by short growth period with around 7-10 days and need of a small piece of land for production. It has extraordinary protein, vitamins, fiber and mineral contents with their healthy beneficial effects on animals.

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Therefore, this technology is an important agricultural technique currently used in many countries. Hydroponic green fodder need suited growing condition for better forage grain germination with short period of time in special growing rooms. Fresh forages are developed from wheat, oat, barely and other grains. Even if there is variation in development of different forage grains, the average fresh forage mat reaches 15 to 30cm height, 7 to 9kg and 0.9 to 1.1kg dry matter. In production of hydroponics there is a recommendation to use water efficiently.

Hydroponic Feed Value on Livestock Production

Definition of hydroponic feeds

In definition hydroponics comes from two Greek words 'hydro' and 'ponics' which means water and working respectively. This is growing of a plant without soil. It is also called sprouted grain/fodder. It needs a short period to grow and develop in green house under controlled environment. Green house is a media for plant growth with at least partially controlled environmental conditions. However, for operational purpose, the structure/media should be large enough.

Development of hydroponic forage is without soil but with the use of water. In green house there is a possibility to use nutrient rich solutions for a short duration. However, this nutrient solution is not a must and only tap water can be used. The fodder is like a mat with probably a height of 20-30 cm consisting of roots, seeds and plants. It is indicated as highly palatable, digestible and nutritious for animals. There is increment in milk production of 8-13% with the use of hydroponic fodder. This is a best alternative technology to use for dairy animals with low cost materials in places where conventional green fodder production is limited.

Principles of hydroponic fodder production

Hydroponics is growing of cereal grains with necessary moisture, nutrient and absence of solid growing medium. The sprouted shoot and root mat is harvested and fed to animals. Germination is a response for the supplied moisture and nutrient and produce 200 to 300mm long forage green shoot with interwoven roots within 7 to 10 days. Different cereal grains can be used for fodder production with varied chemical and structural changes throughout the growing processes. Enzyme activation is found necessary for hydrolysis of nutrients to their simpler forms. Grain variety, quality, treatments like nutrient supply, pH, water quality, soaking time *etc* are influencing factors for the amount of sprouted and quality fodder.

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Importance of hydroponic feeds

Hydroponics avoids problems shown in conventional methods of fodder production. This is realized through use of small piece of land with vertical growing process that permits production of a large volume of hydroponic fodder on a fraction of area needed by conventional fodder production and thus increases stocking capacity of livestock. It is indicated that 600kg maize fodder per day is produced in 50 square meters area. However, for a production of the same amount of fodder 1hectare of land is required in conventional method of production. Water required for hydroponic fodder production is less due to water recycling activities. Therefore, 1kg of maize hydroponic fodder is produced in 7 days with 1.5 litre (if water is reused) or 3 litres (if water is not reused). The water which is not reused can be utilized for garden near the production unit. For production of around 600kg of hydroponic fodder, only one person suffices. Moreover, fodder can be produced without soil preparation, constant weed removal, fencing, post-harvest loss and per daily requirement. There are also more advantages like production of fodder free of antibiotics, hormones, herbicides or pesticides, no damage from insects which leads to low maintenance requirement.

One of the characteristics of hydroponic fodder is its high growth with no competition for nutrients and higher yield. Since there is no soil nutrient loss, no crop rotation is needed. In here, weeds are minimal as the media is sterile and closed. The hydroponic fodder is with high moisture content and dust free. The operational systems like irrigation, cooling and lighting systems are controlled and maintained with low cost. This produces quality succulent green feed throughout the year. The feed is highly palatable, nutritious and free from contamination than commercial feed. This leads to low requirement of concentrate feeds. Therefore, this technology is found conducive for almost all livestock animals. Hydroponic feed is a natural product which is produced without the use of any hormone, growth promoter and chemical fertilizer. There is no also pesticide or fungicide, dust and any toxic that could contaminate the products of livestock.

Nutritive value of hydroponic fodders

Hydroponic fodder from cereal grains deviate in their nutrient content. When starch content decrease, both organic matter and dry matter content decreased. Sprouting catabolize starch in to soluble sugar biochemical purpose of the plant. However, ether extract of

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hydroponic fodder increases due to increment of structural lipids and chlorophyll as the plant grows. There is also increment in linoleic acid concentration with sprouting. Development of structural carbohydrates increases crude fiber, neutral detergent fiber and acid detergent fibers but decreases nitrogen free extract. Sprouting process increase total ash content associate with decrease in organic matter. Root growth which increases the mineral uptake increase the mineral content of the sprout from day four. This ash content increases more as nutrient solution is used than water. Hydroponic fodder show superiorities from common non-leguminous fodders in terms of crude protein, organic matter, ether extract and nitrogen free extracts. However, during sprouting the gross energy, metabolizable energy and total digestible nutrient content decreases. This is due to energy up take during respiration of the plant.

Conventional fodders are less nutritious than hydroponic fodders. Nutrient deviation occurs during sprouting which increase in crude protein, ether extract, nitrogen free extract but decrease in crude fiber, total ash and insoluble ash. In planet earth the most enzyme rich plants are hydroponic fodder sprouts. Enzyme active of the sprouts are at most highest level from germination to seven days age. They are rich with anti-oxidants especially in the form of β-carotene. In terms of palatability, hydroponic fodder preforms outshine. There is no nutrients wastage as the shoots and roots of the plant consumed together. Dairy animals take 25kg/day with low concentrate and straw level. Improvement in digestibility of feed is evident with supplementation of hydroponic fodder in dairy cows.

Digestibility/Degradability

Even if there is a loss in dry matter content of sprouted barley fodder there is being an advantage in their digestibility. In rumen the digestibility of the sprouts is higher than cracked grain. However, comparing the digestibility of shoot and root sprouts, shoots easily degrade in the rumen. Therefore, ruminant animals prefer leafy than stemmy.

Energy

Hydroponic sprouts and processed grains are both nutritious and digestible feeds. Sprouting of grains changes the starch to sugar. On dry matter bases the energy value of sprouts are less than grains with gross energy loss of 2%.

Protein

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Animal performance is high dependent on critical element which is protein. Thus there is a need to analyze the feed value of the fodder. In sprouts crude protein, ash and all other minerals except potassium are highly concentrated on a dry matter bases than barley grains. The increase in dry crude protein content is due to loss in dry matter content particularly carbohydrate. Moreover, nutrient absorption also facilitates the metabolism of nitrogenous compounds which lead to increase the crude protein content. Nutrient solutions improve the crude protein level of the hydroponic fodder than using tap water.

Vitamins

Hydroponic fodder is especially rich in vitamin C and E. Sprouting improve the vitamin content of the grain. However, the increase in individual vitamins is too small that its practical use in addressing nutritional requirement of cereal-based diets makes little difference on the feed value.

Minerals

In hydroponic fodder, root growth helps for mineral up take which in turn changes the ash and protein contents swiftly from day four on wards. Absorption also facilitate metabolism of nitrogenous compounds and thus increase the crude protein level. The type of irrigated water for the hydroponic fodder changes the mineral content. However, through the process of chelating sprouting make minerals more available.

Anti-nutritional factor versus hydroponic feed

Seed coat and germ of plant seeds has phytic acid. The main effect of this phytic acid is through forming of insoluble with minerals like calcium, iron which cause ineffective absorption in the blood. In experimental animals, provided a diet with high phytic acid and poor in mineral content led to mineral deficiency symptoms. Sprouting decrease the level of phytic acid. Moreover, enzymes during germination eliminate other detrimental substances. The digestive enzymes in sprouts help as biological catalysts in protein, fat and carbohydrate digestions. Sprouts have hundred times more enzymes than fruits and thus the physiological activity of vitamins, minerals and trace elements depend on enzyme activity. It is indicated that from germination to seven days, it is the period of greatest enzyme activity of the sprouts. If the cereal grains are away of germination, enzymes remain in active due to the inhibitors. These inhibitors avoid seed deterioration for years. However, inhibitors like *trypsin inhibitor* in

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soyabeans should be heated, cooked and grinded for inactivation prior to feeding of livestock. Luckily, germination and sprouting also neutralize the inhibitors and enhance the beneficial plant digestive enzymes.

Effect of hydroponic feed on livestock productivity

Because hydroponic fodders are highly succulent, their intake varied between 15 to 25, 0.25 to 2.0, 1.5 to 2.0 and 0.1 to 0.2 kg/animal/day in large ruminants, small ruminants, adult pigs and rabbits respectively or 1.0 to 1.5% of body. Saidi and Abo Omar (2015) reported that hydroponic barley fodder (HBF) had no effect on feed intake, body weight change, milk yield, and milk composition; however, HBF had positive effects on ewe's health, mortality, conception rate and abortion. Hydroponic fodders are highly digestible, palatable and relished by the animals. Feeding vitamin-rich hydroponic green barley fodder did not increase bioavailability of nutrients for fattening calves. There was no effect of the fodder on average daily gain (ADG), but feed cost was increased by 24%. Rachel Jemimah et al. (2015) found no adverse effects on ADG and feed conversion ratio (FCR) in goat kids and rabbit kittens fed hydroponic horse gram or sunn hemp fodder replacing 50% of a concentrate mixture. A 90-day feeding trial on 3-month-old weaned Awassi ram lambs showed that feeding hydroponic barley fodder improved ($P<0.05$) feed intake, ADG and FCR significantly compare to those fed a ration containing barley grains.

Milk production

Studies on improvement of milk production through hydroponic fodder feeding shows improvement than animals fed cereal grains, hay or silage. Hydroponic fodder increase milk yield by 10.07% in dairy cows. Canadian dairy farmers also indicate the increase in feed intake of their cows after feeding of 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.

Reddy et al. (1988) observed significant increases in the digestibility of nutrients in lactating cows fed hydroponic fodder compared to those fed Napier bajra (NB-21) green fodder. Feeding of a total mixed ration (TMR) containing either hydroponic maize fodder (HMF) or Napier bajra hybrid green fodder (NBH) for 68 days to lactating dairy cows did not have any significant effect on digestibility of nutrients, except that the digestibility of CF and NFE was higher ($P<0.05$)

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in the HMF fed group (Naik et al., 2014). The daily milk yield was 8.0-14.0% higher in animals fed TMR containing hydroponic maize or barley fodder than those fed conventional green. Naik et al. (2017b) further reported that feeding of hydroponic maize fodder by replacing 50% maize grains in the concentrate mixture did not have any adverse effect on nutrient utilization and performance of low yielding lactating cows. Besides increased milk yield, conception rate, herd health and longevity were also improved (Naik et al., 2015). Furthermore, it must follow that improved animal health stemming from higher quality hydroponic fodder will reduce veterinary costs.

Hydroponic fodder heavily infested with *Aspergillus clavatus* should not be fed to dairy/beef cattle. Animals may develop posterior ataxia, knuckling of fetlocks, dragging of hind legs, high stepping in the hind limbs, stiff gait, tremors, progressive paresis, hypersensitivity, recumbency, clonic convulsions, decreased milk yield and possibly death .

Meat production

Hydroponic fodder 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 rumen and enhanced nutrient digestibility. In beef cattle average increase of 200g is achieved through feeding the hydroponic fodder than maize. Similarly 8% improvement is reported in birds and other animals. Feeding hydroponic fodder to beef cattle resulted in leaner meat containing more omega-3-fatty acids and vitamins.

Major disadvantages of hydroponics

Loss in total dry matter: A number of studies reported that sprouting resulted in 7-47% loss in DM from the original seed after sprouting for a period of 6-7 days of growth, mainly due to respiration during the sprouting process. Seed soaking activates enzymes that convert starch stored in endosperm to a simple sugar, which produces energy and gives off carbon dioxide and water, leading to loss of DM with a shift from starch in the seed to fiber and pectin in the roots and green shoots.

Availability of nutrients: Sneath and McIntosh (2003) showed that sprouted barley fodder was 3.4 times more expensive per kg of DM than the original barley grains. Similarly ME (cents/MJ), CP ($/kg DM) and FCR (feed cost/kg live weight gain) were 3.7, 2.2 and 2.5 times costlier using

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hydroponic fodders than the original grains, respectively; confirming the earlier report of Appleman (1962) who found that hydroponic oat and barley grass may be 2.1 and 3.8 times costlier than rolled oats and barley in terms of food energy. Decades of research and farmer experience indicate that the costs associated with hydroponic fodder production are 2 to 5 times those of the original grain.

Economics of hydroponics

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. Hydroponics minimises post-harvest losses, with no fuel required for harvesting and post harvesting processes. Moreover, in hydroponic systems it takes only 7-8 days to develop from seed to fodder while it takes 45-60 days under traditional systems. However, the initial investment required for setting up hi-tech, sophisticated, automated commercial hydroponic fodder production systems, with environmental control, plus operational costs are much higher than traditional soil-based fodder production farming. Such hydroponic systems require much more specialized equipment and technical knowledge than is required in traditional farming. Mold is highly likely and thus prevention or treatment could further involve investment. Therefore, even if there are benefits of feeding hydroponic fodder, the benefits are usually outweighed by the costs (Tranel, 2013; Reddy, 2014).

The feed cost/kg milk was higher when animals were fed maize fodder produced from a hi-tech hydroponic system, mostly due to higher cost of hydroponic fodder production [INR 4.0 to 4.50/kg] than green fodder produced by traditional farming (INR 1.50/kg). However, farmers of the Satara district of Maharashtra found that the cost of milk production of hydroponic fodder was reduced remarkably to INR 2.0-3.50 per kg in a low cost shade net system with home-grown or locally purchased seeds. Accordingly when fodder was produced in low cost hydroponic system, the feed cost/kg milk was reduced remarkably (25 to 30%) and net profitability was improved considerably.

Conclusions

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One of the agro-technology which could be developed locally with low cost materials and is more nutritious, palatable and digestible fodder for livestock is hydroponics. Hydroponics is a smart alternative technology against scarcity of land and impeding climate changes. Now a day's several countries are practicing it for their sustainable livestock production. Developing seed culture and new activities in hydroponics reduce production cost and helps for cooperatives to produce and sell. Thus, it is very vital to use hydroponic fodder for livestock which is with low cost and highly nutritive. This technology has a solution to avoid scarcity of green feed special in dry seasons and urban areas having a shortage of land for forage production. Having a characteristic of high intake palatable and digestible properties, this technology is best chosen than cereal grains and other concentrate feeding. Progressive modern farmers can also adapt this technology for their dairy animals to enhance productivity. Therefore, further research and development endeavors should be carried out for its further utilizations.