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Use of Some Forage Plants Produced by Hydroponic System in Ruminant Animal Nutrition

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ABSTRACT

Green fodder plants have an important place in animal nutrition in terms of meeting the nutritional needs of animals and increasing their appetite. Especially in dairy cattle breeding, green feeds are needed for milk yield and quality. In meeting the green feed needs of ruminant animals, the scarcity of agricultural areas, water use, environmental and climatic factors have negative effects on agricultural production. The tendency to soilless agriculture is increasing due to the lack of transportation of green feeds, which cannot be sustained in production throughout the year, and the high prices of green feed. For this purpose, it is thought that the elimination of the negative conditions related to the environment and soil will be occurred by hydroponic production, the continuity of green feed production can be ensured throughout the year and feed costs can be reduced. However, the digestibility and feed efficiency of the products to be obtained by green feed production with the hydroponic system will be increased. Meat, milk yield and quality, animal performance and health will, also, be positively affected by the increase in feed utilization.This review was aimed to give information about the use of cereals with a high germination rate grown by hydroponic systems as green feed in animal nutrition and their disadvantages.

Hidroponik Sistemle Üretilen Bazı Yem Bitkilerinin Ruminant Hayvan Beslemesinde Kullanımı

MAKALE BİLGİSİ

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ÖZ

Hayvanların besin madde gereksinmelerini karşılama ve iştah artırma açısından yeşil yem bitkileri, hayvan beslemede önemli bir yer teşkil etmektedir. Özellikle süt sığırı yetiştiriciliğinde süt verimi ve kalitesi için yeşil yemlere gereksinim duyulmaktadır. Ruminant hayvanların yeşil yem ihtiyaçlarının karşılamasında tarım alanlarının azlığı, su kullanımı çevre ve iklim faktörleri tarımsal üretimi olumsuz etkilemektedir. Yıl boyunca üretimde devamlılığı sağlanamayan yeşil

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Anahtar Kelimeler

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yemlerin hem yıl boyunca ulaşımının olmaması hem de yeşil yem fiyatlarının yüksek olmasından dolayı topraksız tarıma yönelim artmaktadır. Bu amaçla hidroponik üretim ile çevreye ve toprağa bağlı olan olumsuz şartların ortadan kaldırılmasıyla yıl boyunca yeşil yem üretiminin devamlılığı sağlanabilmekte ve yem masraflarının azaltılabileceği düşünülmektedir. Bununla birlikte, hidroponik sistemle yapılacak yeşil yem üretimiyle elde edilecek ürünlerin sindirilebilirliği ve yemden yararlanma oranı artacaktır. Yemden yararlanmanın artmasıyla et, süt verimi ve kalitesi, hayvanın performansı ve sağlığı da olumlu etkilenebilecektir. Bu derlemede, hidroponik sistemle yetiştirilen çimlenme hızı yüksek tahılların yeşil yem olarak hayvan beslemede kullanılması ve dezavantajları hakkında bilgi verilmesi amaçlanmıştır.

Introduction

Industrialization and population growth in our country have caused unplanned urbanization, and, consequently, agricultural areas have gradually decreased. According to the data of TURKSTAT (2021), the total agricultural area of Türkiye, including meadow and pasture areas is 38,063 thousand hectares (Anonymous, 2022). The decrease in agricultural areas has led to the emergence of important problems in animal and plant production. Land scarcity, water shortage, labor in growing green fodder crops (such as sowing, picking, weeding and harvesting), fertilizer requirement, long growing period and unsuitable environmental conditions are among the factors that limit the production of quality green fodder throughout the year (Naik et al., 2013a). Because of such constraints, it can be said that hydroponic production will contribute more to the production of quality green feed than conventional one.

Animal and plant production are closely related to each other, and especially for the sustainability of animal production, it is necessary to give importance to plant production. The yield and quality of forage crops, which have an important place in animal husbandry, are affected by the amount and width of cultivation areas, the structure of the soil, and the climatic conditions of the region. Therefore, forage crop production based on agricultural lands is adversely affected by these factors and yield decreases. The decrease in forage crop production causes feed prices to increase (Kumar and Cho, 2014).

On the other hand, the freshwater crisis causes a global problem. Every year, 87% of freshwater is used in agricultural production, and, therefore, the crisis deepens and threatens environmental quality, sustainable livelihoods, and economic development in arid and semi-arid regions (Kumar and Cho, 2014). With both the freshwater crisis and the gradual decrease in agricultural areas, feed prices have increased, and accordingly, the price of animal products has increased. Thus, the food needs of people cannot be fully met. Thanks to hydroponic production, food and feed cultivation in unsuitable climate and degraded soil conditions ensure the sustainability of agriculture and animal husbandry without being affected by the disadvantages of soil-based agriculture and the water crisis (Bildirici, 2021). The continuity of green fodder plants can be ensured by hydroponic production to tolerate the price increase due to the unavailability of green fodder during the year depending on the seasons. In addition, hydroponically produced green fodder crops are important to improve the use and digestion of

low-quality roughage (Devendar et al., 2020).

The absence of a solid layer that supports plant roots in the hydroponic production system distinguishes it from traditional agriculture. In addition, in this system, the nutrient solution needed by the plant can be applied at once (Bingol, 2019; Karadag et al., 2020). In hydroponic systems, water use efficiency in agricultural production is increased, and it allows the plant to grow away from diseases/harms and for higher quality and yields (Al-Karaki and Al-Momani, 2011; Al-Karaki and Al-Hashimi, 2012; Bingol, 2019). Water use is 70% less in hydroponic production compared to traditional agriculture (Cho, 2011). The hydroponic system is associated with the germination of grains. In this stage, higher metabolic energy, crude protein and digestibility can be obtained from grains (Atan et al., 2022). In this kind of production, the nutrient solution is used, or cultivation can be done without using the nutrient solution. If a nutrient solution is to be used, it is applied to the roots of the plant with the help of capillary pipes from the bottom or by spraying technique (Karadag et al., 2020). In the case of using the nutrient solution, it, also, causes a high yield to be obtained since all nutrient requirements of the plant will be considered (Gul, 2008; Hazar, 2013).

Especially in small family farms, factors such as little or insufficient land for planting forage crops, water shortage, lack of quality forage seeds, labor requirement, fertilizer requirement, lack of certain quality feed throughout the year and long growth period of forage crops (45-60 days) cause the search for alternative forage crops (Gebremedhin et al., 2015). Soilless green fodder is defined as very tasty sprouts, whose height varies between 15-20 cm, by the germination of cereal grains (barley, maize, etc.) produced using water with mineral nutrient solution (FAO, 2001). For hydroponic production, the use of nutrient solutions is not mandatory, and tap water can also be used (Naik et al., 2015). The quality criteria of the irrigation water are determined according to the total concentration of soluble salts, the sodium absorption rate, the concentrations of special ions such as boron, and the (bi)carbonate concentration that is more than the sum of calcium and magnesium in the irrigation water used in crop production. Although these quality parameters vary depending on the type of plant, it is thought that they may be important in hydroponic production (Anonymous, 2021). In addition, since toxic chemicals are not used in the place where this production system is used, there are no substances that may adversely affect animal and human health (Kilic, 2016). It is known that feed raw materials are grown with this method. In this way, the protein, fiber, vitamin and mineral contents of crop were positively affected, and, consequently, feed quality improved (Lorenz, 1980; Reddy et al., 1988; Snow et al., 2008; Ata, 2016).

Feed Raw Materials Produced in the Hydroponic System and Preparation Conditions

Seeds of forage plants to be used in hydroponic technique should be easy to find, considering the geographical location and climatic conditions. In particular, the seed to be grown in this system must be clean, sound or undamaged, and free from pests (Kumar et al., 2018). Crop yield in hydroponic production may vary depending on factors such as the type and quality of the seed, harvest time, seed rate, seed processing, water quality, pH, the nutrient solution used, light, temperature, humidity, condition of a clean and hygienic greenhouse (Trubey et al., 1969; Sneath and McIntosh, 2003; Fazaeli et al., 2011; Naik et al., 2015).

In addition to the selection of feed raw materials and seed preparation, the seed rate to be used

in soilless production also affects yield. The seed rate of 7.6 kg/m^2 can be used in corn grown as one of the hydroponic feed raw materials, which varies according to the seed type (Naik, 2013a). It was reported as 6.6 kg m-2 for the highest green forage yield in barley grass produced by hydroponic system (Karaşahin, 2017). The high rate of seed produced in the hydroponic system increases the risk of microbial contamination affecting the growth of the sprouts (Naik, 2013a).

The beginning of germination and the process of visible roots may vary according to plants' seeds. Germination of maize and cowpea seeds starts after 1-2 days and roots can be seen after 2-3 days (Sneath and McIntosh, 2003). Until the end of the 5th day, chloroplasts are activated in the metabolism of the seedlings, and there is no need for light for sprouting. The germination period of the grains is 7 days on average and it is harvested on the 8th day. Delaying the harvest in this production system increases the possibility of mold growth in green feed, thus causing a decrease in feed quality (Kumar et al., 2018). However, it causes mold problems in the aquatic environment of germination or excessive moisture in the hydroponic system (Güler, 2019; Böbrek, 2022). For this reason, to prevent water from accumulating in a certain place, either the trays should be kept under running water to flow or the trays should be adjusted with a 1-2% slope (Güler, 2019). Otherwise, it should be kept in mind that mold growth in feeds reduces feed consumption, negatively affects performance and yield, and may cause deaths (Böbrek, 2022).

This production system can be done not only with the device but also in field conditions or the greenhouse. While barley and maize seeds can germinate within 4 hours under greenhouse conditions, sprouting occurs within 1-2 days after the seeds are placed in a tightly packed bag in land conditions (Naik et al., 2015). In addition to all these, attention should be paid to the DM (dry matter) content of the feed raw material produced in the hydroponic system (Dung et al., 2010). Since water absorption and nutrient reserves in the seed endosperm play a role in enzymatic activities (oxidation) during sprouting, a decrease in DM content occurs (Naik et al., 2015). Since the enzyme activity changes with the germination of the grains produced with the hydroponic system, the total protein increases. They reported that the increase in the enzyme level with the germination of grains may cause the conversion of starch to sugar, a decrease in DM, and an increase in CP, EE, cellulose, mineral and vitamin content (Sarıçiçek et al., 2018). Since the phytase enzyme is formed with germination, the negative effect of phytic acid decreases (Karasahin, 2016; Girma and Gebremariam, 2018). In addition, germination and sprouting neutralize inhibitors in cereal grains and develop beneficial digestive enzymes (Shipard, 2005). It is also known to the hydroponic system improves amylase and urease activity and nitrogen retention, as it positively affects food digestibility (Farghaly et al., 2019). The prolongation of the germination period decreases the protein and dry matter content and increases the ash, crude oil and cellulose contents (Kilic, 2016). In the hydroponic system, the grains produce green grass in a period of 7 days by meeting the germination and growth needs such as heat, light, moisture in the soilless environment (Guler, 2019). In the hydroponic system, grains such as corn, barley, wheat, oat and rye can be preferred because their germination is high (Kilic, 2016; Dogrusöz, 2020). It was reported that pre-soaking for 12-24 hours, temperature of 18-22 (22 ±1)°C, relative humidity of 65-70%, lighting for 12-14 hours and watering twice a day were applied for germination of barley seeds (Peer and Leeson, 1985; Kilic, 2016). However, in the study of Güler (2019) for barley germination, it was reported that

16-35º C temperature and 20-66% finish and initial humidity values were used. For corn seeds, pre-soaking for 24 hours, temperature of 20 °C, humidity of 60% were applied (Karaşahin, 2017).

Effects on Animal Performance

The nutritious root part of the cereals grown with hydroponic production system positively affects the immune system, saliva production, and pH buffering properties of the rumen in ruminant animals. Furthermore, because the grain's crude protein and dry matter digestibility rise with sprouting, milk yield (8.7-10%), milk fat content (14%), meat yield, carcass quality, daily live weight gain, and growth rate are all increased (Sharif et al., 2013; Kilic, 2016; Antunes et al., 2018; Farghaly et al., 2019). This process increased the digestibility of crude protein and dry matter, especially when poor-quality roughage was used with feed obtained by hydroponic production system, thus, increasing the dry matter intake of ruminants (Devendar et al., 2020). The performance and health of animal can be positively affected since the forage plants with a long growth period will sprout in a shorter time with hydroponic production (Mohsen et al., 2015).

*Effects on body weight and meat qu*ality

Kilic (2016) (cited URL, 2016) reported that hydroponically grown green feeds had low ADF and NDF contents with higher soluble sugar and starch contents, positively affecting rumen fermentation and providing continuous energy. However, it was reported that some feeds grown in this system should have given as concentrate, as it would reduce the dry matter consumption of some grains such as barley grown hydroponically (Farghaly et al., 2019).

It was reported that daily live weight gain will be higher when barley grown with hydroponic production is used with low-quality hay in the diet of cattle (Tudor et al., 2003). On the other hand, it was reported that barley grown hydroponically increased carcass yield and quality, as increased the total cholesterol and α-tocopherol in calves (Antunes et al., 2018).

In sheep, feed consumption, live weight gain, milk yield, and milk composition were not affected by feeding of barley grown by hydroponic system compared to feeding of wheat produced hydroponically (Saidi and Omar, 2015). In addition, it was reported that 50% of sorghum and barley placed in the hydroponic system increased feed efficiency, growth performance, and carcass quality of sheep (Devendar et al., 2020). In lambs, it was reported that the use of maize grown with the hydroponic system increased digestibility and live weight gain about 40% (Cantón-Castillo, 2020). Therefore, although the amount of hydroponic production is driven according to the capacity of animal farms, its use in animal feeding reduces the cost of feed and provides the opportunity to make more profitable livestock.

Effects on milk yield and composition

Quality green feed should be given regularly for sustainable successful dairy cattle (Naik et al., 2012a). Green fodder obtained by hydroponic production system has a positive effect on milk yield and quality, as it contains total digestible nutrients and highly degradable protein in the ration (Sneath and Mclntosh 2003, Naik et al., 2011,2012b,2013b, 2014).

The use of hydroponic barley in the diet of ruminant animals increased milk yield about 3.9%, while hydroponic corn increased milk yield about 13.7% (Heins et al., 2016; Naik et al., 2014). However, the use of hydroponic barley at a rate of 50% in the ration may affect milk fat negatively (Grigor'ev et al., 1986). Kaouche-Adjlanea et al. (2016) reported that hydroponic barley (10 kg) supplementation in dairy cattle ration increased milk yield without affecting nutrient contents of milk. Salo (2019) stated that the addition of hydroponic cereals to cow ration increased milk production and improved butter quality. Šidagis et al. (2014) stated that barley sprouts increased milk yield and milk fat content, but this increase was statistically insignificant. Pandey and Pathak (1991) reported that the use of only hydroponic barley in lactation dairy cattle rations was limiting in high milk yielding cows, and milk yield increased if it was supplemented with concentrated feeds. Hayati et al. (2018) reported that when hydroponic barley was added to the ration at 37%, 66% and 100%, dry matter intake decreased in Saanen goats, while blood cholesterol and total protein concentrations increased. The researchers,also, reported that the difference in milk composition was statistically insignificant and 66% hydroponic barley feeding would result in more than 37% milk yield. Therefore, the use of hydroponic green fodder plants in the ration caused an increase in milk yield as it is associated with high degradable protein and total digestible nutrient content (Naik et al., 2014, Helal, 2015).

Abd Rahim and Omar (2015) reported that the effect of using hydroponic barley green feed on milk protein and milk fat in dairy goat ration was not statistically significant. Apart from that, Heins et al. (2016) reported that the use of hydroponic barley in dairy cattle rations caused a decrease in milk-fat ratio and yield. They reported that the use of hydroponic corn had no effect on milk yield, fat content, milk quality, feed consumption and live weight gain, but improved the health status of the animals, increased the rate of conception and decreased the mortality rate (Barlett et al. 1938, Chinnam, 2015; Saidi and Omar, 2015).

Disadvantages and Solutions of Hydroponic Production

Although the hydroponic system has advantages such as being able to be used on lands that are not suitable for conventional agriculture, water efficiency, preventing unnecessary fertilization, increasing feed and food yield, changing the chemical structure of the soil and preventing soil degradation, it, also, has some disadvantages. These disadvantages can be listed as the expensive installation of the system, the need for technical knowledge, the constant monitoring of the installed system and the correct selection of the nutrient solution or seed to be used (Bingöl, 2019). In addition, the main problem is that chemical fertilizers cause pollution of the surrounding ecosystems and groundwater due to the discharge of waste nutrient solutions (Kumar and Cho, 2014). In the hydroponic system, it is recommended to treat and reuse the mixed wastewater with nutrient solution preference for seed germination and plant growth (Son et al., 2020; Egbuikwem et al., 2020).

Another way to prevent the disadvantage caused by the content of the nutrient solution is to prefer tap water that does not contain nutrient solution in soilless production. However, attention should be paid to electrical conductivity (EC), pH, dissolved oxygen and temperature for adequate management of nutrients in tap water to be used in hydroponic production (Son et al., 2020). It should be kept in mind that to produce fodder plants in the hydroponic system,

there will be no shortage of seeds in perennial plants, and in annual plants, it is necessary to use seeds again after the production is over. For this reason, forage crops such as alfalfa, which are used both traditionally and whose seeds are important, are not produced hydroponic instead, it is recommended to use grains to close the roughage gap in hydroponic production.

Conclusion

In recent years, the decrease in agricultural areas, deterioration of ecological balance, climate changes and water scarcity have caused significant problems in animal nutrition. For these reasons, the use of soilless agriculture in animal husbandry is becoming increasingly important. With hydroponic production, which is one of the soilless farming systems, dependence on the environment and climate is reduced, and disease-free and highly digestible green feeds can be obtained throughout the year. Therefore, it can be said that the germination rate with hydroponic production is different from traditional green fodder production of high-quality grains (such as barley, maize, wheat and oats). In short, while traditional green fodder is produced at certain times of the year, green fodder production with hydroponic system is preferred to ensure that grains such as alfalfa and sainfoin, which are not generally used as green fodder, can be used as green fodder in animal nutrition. Some grains with a high germination rate (such as barley, corn and wheat) are preferred for the production of green fodder plants in the hydroponic system.

Generally, green feeds obtained by hydroponic method are more palatable, more easily digestible and richer in nutritional contents than those of other feed stuffs. In the grass of some forage crops produced hydroponically, nutritional contents such as carbohydrates, proteins, vitamins and minerals become more beneficial, meat and milk yields are increased, and animal health is positively affected. For this reason, it is thought that the use of annual forage crops such as barley and corn as green fodder in animal feeding can be a solution to the roughage shortage.

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