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# Production and quality of hydroponic corn fodder cultivated in various substrates and harvested at different times

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**ABSTRACT.** In the adaptation of the hydroponic cultivation technique, fodder species can be obtained from germination to seedling cultivation, to obtain fresh green food of superior quality, to supplement animal feed. Thus, this experiment aimed to evaluate productive and qualitative aspects of hydroponic corn fodder produced on different organic substrates (rice husk, coffee husk, sugarcane bagasse, and corn straw) in two cultivation periods (up to the 10 and 15th days after sowing). This was a 5 x 2 factorial completely randomized experimental design, with four replications, totaling 40 experimental plots. Sugarcane bagasse and coffee husk did not promote the aerial development of corn seedlings in hydroponic fodder cultivation, considering that they were green materials and had not been subjected to prior composting. The substrates tested showed significantly higher substrate dry biomass and total dry matter (DM) production than the control hydroponic fodder (no substrate). Cultivation of hydroponic corn fodder up to the 10th day after sowing resulted in higher total DM production. Hydroponic fodder obtained from rice husk showed higher DM, neutral detergent fiber, and acid detergent fiber contents, for harvesting after 15 days of cultivation, differing significantly from the control treatment. Hydroponic fodder from coffee husk substrate had higher lignin and ash contents, showing lower nutritional quality of the food.

**Keywords:** cultivation time; fresh biomass; agricultural waste; germination.

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## Introduction

Hydroponics is an emerging technology commonly adopted for growing vegetables in agricultural production. The technique consists of cultivating plants without soil, in which nutrients are dissolved in water and made available to the root system of the plants in sufficient proportions for plant production, draining the excess for recycling within the system. Recently, it has been investigated as an option for producing green fodder for animal feed, as a complementary alternative to livestock production.

Hydroponic fodder is the result of cultivating viable seeds of cereals normally supplied in animal feed, such as corn (Rocha et al., 2014), millet (Müller et al., 2006), sorghum (Santos et al., 2015), barley (Alemnew & Mekuriaw, 2023), among others. The production of hydroponic green fodder is based on the cultivation of germinated cereal seeds and basically consists of the supply of water or a solution with an additional nutritional load for the production of green plants, in a short time (Camacho, 2019; Organización de las Naciones Unidas para la Agricultura y la Alimentacion [FAO], 2001; Gutiérrez & Maucieri et al., 2019). Therefore, hydroponic fodder has high nutritional value due to the conversion of complex compounds into simpler forms necessary for activating enzymes in the germination process. This technique stands out for producing plants with a high fresh biomass yield and excellent nutritional quality. Furthermore, as the cultivation time lasts until the initial formation, from 10 to 25 days (Almeida et al., 2021), the food is high in protein and vitamins and highly digestible, promoting the absorption of nutrients (Girma & Gebremariam, 2018).

Several factors influence the efficiency of hydroponic fodder production, including the cultivation time. For corn, harvesting is recommended from the 12th day after sowing, or in priority cases, between the 7 and 10$^{th}$ day, as this timing offers higher nutritional value. However, earlier harvesting may lead to lower overall yield (FAO, 2001). Late harvests can result in a reduction in both the total biomass and nutritional quality of the fodder produced, which is supplied to animal feed in its entirety: aerial part, root system, and any ungerminated seeds. For hydroponic millet fodder, harvesting at 20 days yields lower amounts of fresh and dry biomass. This decrease is primarily due to the depletion of seed reserves and the competition between larger plants, compared to harvesting at 10 days (Müller et al., 2006). Regarding hydroponic wheat, Herrera-Torres et al. (2010) recommend harvesting on the 10th day to achieve optimal nutritional value and production yield.

In livestock production, ruminants stand out for taking advantage of low-quality feed, such as by-products or agricultural waste, transforming them into high-value products like meat and milk, and reducing feed costs. Some organic substrates can be used for hydroponic green fodder production to increase the biomass and fibers of the feed. However, certain substrates can change the nutritional value and acceptance of the obtained feed. Therefore, depending on the characteristics of the substrates, they must be evaluated for the possibility of affecting the germination or plant nutrition processes. In this case, the substrate must be low-cost, and palatable, ensure the germination of the cereal, retain moisture adequately to promote the oxygenation necessary for root respiration, and provide mechanical support to the plants. The pH of the substrate should range from 5.2 to 7.0, and it should have a low salt concentration, which can be measured by electrical conductivity, ideally between 1,000 and 2,000 μS $cm^{-1}$ (FAO, 2001). As organic substrates, there are studies with chopped elephant grass (Pícollo et al., 2013), chopped sugarcane bagasse (Fonseca et al., 2021), rice husk (Rocha et al., 2014), coffee husk (Píccolo et al., 2013), chopped signal grass (Silva et al., 2023) and fermented whole açaí seeds (Fonseca et al., 2021). Hydroponic fodder is suggested as a supplementary food source, particularly during shortage periods, representing an alternative to the traditional pasture production system (FAO, 2001). Thus, the experiment aimed to evaluate productive and qualitative aspects of hydroponic corn fodder grown on different organic substrates, in two cultivation periods.

## Material and methods

The experiment was conducted from March 26 to April 10, 2023, in the municipality of Ariquemes, state of Rondônia, on a rural property located on line C65, Km 15, at the geographic coordinates: 9°54'11.4"S and 62°54'03.3"W.

This was a 5 x 2 factorial completely randomized design, with 4 replications, totaling 40 experimental units. The main factor was the organic substrates: rice husk (*Oryza sativa*) (RHS), coffee husk (*Coffea canephora*) (CHS), sugarcane bagasse (*Saccharum officinarum*) (SBS), corn straw (*Zea mays*) (CSS), and the control (no substrate) in the hydroponic corn fodder cultivation. Two cultivation periods were adopted as a secondary factor: up to the 10 and 15$^{th}$ days after sowing (DAS).

The SBS, obtained from fresh sugarcane, and the CSS, from green bracts of corn, were chopped in an electric fodder harvester. Subsequently, the materials were dried in a forced air oven at 55°C for 72 hours. They were then processed in an electric shredder to particles between 1 and 5 mm. Rice husk and coffee husk were used without processing, additional drying, or composting.

Corn grains, genotype JM 2M91, obtained from a local farmer, were used for hydroponic cultivation of corn fodder. The following parameters were measured: germination (96.50%), purity (90.30%), 1,000-grain weight (384.11 g), and moisture content (11.40%, on a wet basis), according to Brasil (2009).

For sowing, corn grains were subjected to triple washing in water and treated with a 1% sodium hypochlorite solution for 30 minutes. Afterwards, the solution was discarded and the grains were washed again with water. Subsequently, the material was subjected to osmotic conditioning, which consisted of immersion in water for 24 hours, replenishing water after 12 hours of hydration, and drainage for sowing (FAO, 2001), which occurred on March 27, 2023. During the experimental period, the plots were arranged in a covered environment (under shade), and a digital data logger recorded the temperature and relative humidity data (Figure 1).

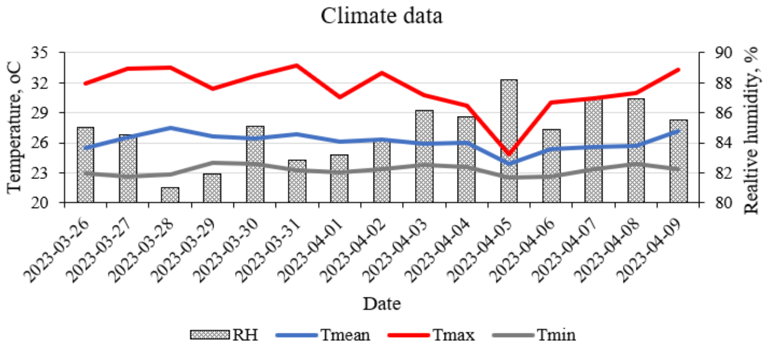


**Figure 1.** Temperature and relative humidity during the hydroponic corn fodder cultivation period (15 days).

Round plastic dishes with a diameter of 0.30 m and a height of 0.4 m were used to sow the experimental units. The substrates were layered in the experimental units at a thickness of 0.02 m. This was followed by a uniform distribution of hydrated corn at a density of 3.6 kg $m^{-2}$, which was then covered by another 0.02 m layer of pre-soaked substrate, taking into account the water-holding capacity determined for each substrate type. The substrate mass used in the experimental units consisted of 2.30, 3.90, 4.50, and 4.10 kg $m^{-2}$, on a dry matter basis, respectively, RH, CH, SB, and CS. In the control treatment, which did not use any substrate, the corn grains were simply distributed at 3.6 kg $m^{-2}$.

To maintain suitable moisture levels in the substrates for corn cultivation, around 60% of the holding capacity, was determined according to Brasil (2009). The daily water requirements for the substrates were 4.5, 5.7, 14.5, and 11.6 L $m^{-2}$, respectively, RHS, CHS, SBS, and CSS. The control treatment received 1.3 L $m^{-2}$ of water daily. The daily volume of water was distributed in three irrigations: at 8 am, 12 pm and 5 pm.

For all treatments, up to the 2$^{nd}$ DAS, irrigation was performed only with water. From the 3$^{rd}$ day until the final treatment, a nutrient solution indicated for hydroponic corn fodder production was used. The commercial product consists of two sachets with a water-soluble nutrient formulation. Formulation 1 contains N (9.3%), Fe (0.139%), $K_2O$ (35.7%), Mn (0.045%), $P_2O_5$ (9.4%), S (2.7%), B (0.045%), Cu (0.029%), Mo (0.008%) and Zn (0.018%). Formulation 2 contains N (13.0%), Ca (10%) and Mg (3.7%). To prepare the nutrient solution, 3.7 g of each formulation was separately dissolved in 5 liters of water, and, subsequently, solutions 1 and 2 were homogenized, totaling 10 liters of nutrient solution.

The water used came from a dug well. Characteristics of the solution obtained from the substrates soaked in water for 12 hours and the nutrient solution are listed in Table 1. Total hardness was determined by titration with EDTA; and turbidity, conductivity, and potential of hydrogen (pH), respectively, were determined using a turbidimeter, conductivity meter, and benchtop pH meter.

**Table 1.** Physicochemical characterization of the aqueous extract of the substrates and the experimental nutrient solution.

| Variable | Turbidity (NTU) | Hardness (mg $L^{-1}$) | Conductivity (µS $cm^{-1}$) | pH |
|---|---|---|---|---|
| RHS | 19.6 | 1.6 | 499.7 | 6.7 |
| SCC | 240.8 | 6.6 | 4.6 | 6.4 |
| SBC | 42.1 | 14.1 | 1,299.0 | 4.6 |
| SPM | 92.0 | 5.0 | 651.1 | 4.2 |
| Nutrient solution | 1.4 | 6.9 | 479.0 | 6.8 |

Irrigation was suspended in the harvests on the 10 and 15$^{th}$ days of cultivation, respectively, on the 9 and 14$^{th}$ days. At the end of the experimental period (on the 10 and 15$^{th}$ DAS), using a ruler, the height of the aerial part of the fodder was measured from the substrate to the apex of the leaves, and expressed in meters. A sample of 0.15 x 0.15 m was taken from the experimental units to determine the fresh yield of aerial biomass and substrate biomass (consisting of substrate, ungerminated grains, and roots). The aerial part (leaves) was cut with scissors, weighed, and packaged separately. The substrate biomass was weighed and packaged in kraft paper. The aerial and substrate samples were pre-dried in a forced air oven at 55°C for 72 hours, using method G-001/2 (Detmann et al., 2021). After pre-drying, the yield of aerial and substrate biomass was determined, considering: initial fresh biomass (IFB) and final fresh biomass (FFB). Based on the dry matter (DM) content, the aerial dry biomass (ADB), substrate dry biomass (SDB), and total production (TDP) of the hydroponic corn fodder (aerial biomass + substrate biomass) were determined.

For chemical analysis, the samples (aerial biomass and substrate) were homogenized and ground in a Wiley knife mill, with a 1 mm mesh sieve. As proposed by Detmann et al. (2021), the following were determined: dry matter (DM), method G-003/1; ash (AS), method M-001/2; ether extract (EE), method G-004/1; neutral detergent fiber (NDF) and acid detergent fiber (ADF), methods F-001/2 and F-003/2, respectively; and lignin (LIG), method F-006/1.

Using the SISVAR software (Ferreira, 2019), data were subjected to analysis of variance and, when significant, the differences between the means were compared by Tukey's test, at a significance level of 5%.

## Results and discussion

For final fresh biomass (FFB), dry biomass of the growing substrate and roots (BSS), and total dry production (TDP) of hydroponic corn fodder, the analysis of variance identified an isolated effect of the substrate (S) and growing period (P) (Table 2). Aerial dry biomass (ADB) and height (HAP) of hydroponic corn fodder showed an interaction between S and P, characterizing interdependence between the factors.

**Table 2.** Summary of the analysis of variance for initial (IFB) and final (FFB) fresh biomass of substrate and corn grains, dry biomass of the growing substrate and roots (SSB), aerial dry biomass (ADB), total production (TDP) and height (HAP) of hydroponic corn fodder produced in different substrates and growing periods.

| Variable | Substrate (S) | Cultivation period (P) | S × P | CV[1], % | Mean |
|---|---|---|---|---|---|
| | | -------------- F- value -------------- | | | |
| IFB, kg m$^{-2}$ | 852.658** | --- | --- | 5.28 | 12.23 |
| FFB, kg m$^{-2}$ | 243.264** | 68.359** | 1.140$^{ns}$ | 6.66 | 12.82 |
| SSB, kg DM m$^{-2}$ | 139.858** | 42.549** | 0.727$^{ns}$ | 6.62 | 3.13 |
| ADB, kg DM m$^{-2}$ | 594.348** | 57.696** | 24.122** | 13.39 | 0.09 |
| TDP, kg DM m$^{-2}$ | 126.248** | 35.025** | 1.131$^{ns}$ | 6.60 | 3.22 |
| HAP, m | 1150.967** | 73.590** | 19.820** | 8.71 | 0.14 |

[1] CV: coefficient of variation. ** and $^{ns}$, significant at 1% and non-significant, respectively, by the F-Test.

The substrate treatments coffee husk (CHS) and sugarcane bagasse (SBS), at 10 and 15 days of cultivation, did not promote the emergence of corn seedlings, as evidenced by the absence of HAP and ADB (Table 3). Although SBS and CSS presented acidic pH, respectively, 4.6 and 4.2 (Table 1), they do not indicate a negative effect on germination. In the initial stages of corn germination, Wellmann et al. (2023) reported a significant reduction in the pH of the medium surrounding the seeds. The authors state that a pH below 4.5 promotes the initial growth of the radicle and plumule, as it ensures flexibility of the plant cell wall, in which turgor is prevalent. Furthermore, ecologically, acidification can be considered beneficial as it is a defense mechanism of the seed (rich in starch, proteins, and lipids) and susceptible to infestation by bacteria and fungi.

**Table 3.** Mean values of aerial dry biomass (ADB) and height (HAP) of hydroponic corn fodder cultivated in different substrates and the control, in two cultivation periods.

| Cultivation substrates | ------------- Cultivation periods (days) ------------- | |
|---|---|---|
| | 10 | 15 |
| | ------------------- (ADB, kg m$^{-2}$) ------------------- | |
| Rice husk (RHS) | 0.20 aB[1] | 0.31 aA |
| Coffee husk (CHS) | 0.00 d | 0.00 d |
| Sugarcane bagasse (SBS) | 0.00 d | 0.00 d |
| Corn straw (CSS) | 0.06 cB | 0.09 cA |
| Control | 0.12 b | 0.14 b |
| | ------------------- (HAP, m) ------------------- | |
| Rice husk (RHS) | 0.31 aB | 0.39 aA |
| Coffee husk (CHS) | 0.00 d | 0.00 d |
| Sugarcane bagasse (SBS) | 0.00 d | 0.00 d |
| Corn straw (CSS) | 0.18 bB | 0.24 bA |
| Control | 0.14 cB | 0.16 cA |

[1] Means followed by different letters in the same column (lowercase) and the same row (uppercase) differ significantly ($p < 0.05$) from each other by Tukey's test.

The plant substrate obtained from fresh sugarcane, without extracting the juice, was quickly dried and processed into tiny particles. This increased the surface area, with a predominance of micropores in the material; therefore, greater water holding capacity. Furthermore, the high electrical conductivity in the substrate solution, 1,299 µS cm$^{-1}$ (Table 1) indicates reduced oxygen in the medium, which is essential for seed germination. This situation was observed during an experimental period in which fermentative degradation of the material impaired corn emergence. Fonseca et al. (2021) evaluated crushed açaí seeds as a substrate for the production of hydroponic corn fodder and recorded an increase in the temperature of the cultivation medium, as a consequence of the fermentation of the material, since the substrate moisture provided anaerobic microenvironment conditions.

Studies on the use of coffee husks indicate some level of inhibition in certain plants due to compounds with allelopathic effects, such as caffeine, tannins, and caffeic acid (Braga & Pasin, 2020; Lima et al., 2017; May et al., 2011; Píccolo et al., 2013). In the case of CSS, obtained by dry process (dried coffee cherry), the aqueous extract of coffee husks may have caused an allelopathic effect, inhibiting the germination of corn seeds due to the presence of caffeine, an alkaloid predominant in the *Coffea canephora* variety (Caracostea et al., 2021). Baqueta et al. (2017) state that coffee husks have the potential for caffeine extraction. Moura et al. (2022), when testing concentrations of aqueous extracts of coffee residues, recorded inhibition of germination and dry mass accumulation of corn seedlings. Therefore, for hydroponic corn cultivation, the contact of the substrate with seeds impaired seeding's emergence and aerial production (Table 3).

The rice husk substrate (RHS) showed a significant effect, with ADB and HAP higher than the control treatment, including for harvesting carried out at 15 days of cultivation (Table 3). Rice husk is a material with irregular morphology, porous and with grooves, with diameters ranging from 10 to 20 µm (Penha et al., 2016), with low volumetric density, characterizing an adequate aeration environment for the root system of seedlings (Zorzeto et al., 2016), and did not show a predisposition to decomposition during the cultivation periods.

The SBS showed IFB and FFB significantly higher than the other substrates and the control. As for FFB, the substrates obtained from fresh material (SBS and CSS) characterized a loss of mass over IFB, in this order, equivalent to 12.23 and 1.60% (Table 4), characterizing seed deterioration. Control, RHS, and CSS resulted in increased FFB, proportional to 67.22, 34.68 and 1.77%, respectively.

**Table 4.** Mean values of initial (IFB) and final (FFB) fresh biomass, substrate dry biomass (SSB), and total production (TDP) of hydroponic corn fodder cultivated in different substrates.

| Variable | RHS | CHS | SBS | CSS | Control |
|---|---|---|---|---|---|
| IFB, kg $m^{-2}$ | 8.91 d[(1)] | 11.84 c | 21.34 a | 15.58 b | 3.60 e |
| FFB, kg $m^{-2}$ | 12.00 c | 12.05 c | 18.73 a | 15.33 b | 6.02 d |
| SSB, kg MS $m^{-2}$ | 3.52 ab | 3.70 a | 3.57 a | 3.24 b | 1.61 c |
| TDP, kg MS $m^{-2}$ | 3.81 a | 3.70 a | 3.57 ab | 3.31 b | 1.74 c |

[(1)] Means followed by different letters in the same row differ significantly ($p < 0.05$) from each other by Tukey's test.

For dry biomass of the substrate (SSB) and total production (TDP), there was a prominent effect of RHS, CSS, and SBS on the control treatment (Table 4). For CSS and SBS, TDP was obtained exclusively from SSB, as shown in Table 3, due to the absence of ADB.

The 10-day cultivation period resulted in higher TDP, SSB and FFB, compared to the 15-day cultivation (Table 5). Therefore, the shorter cultivation period (10 days) provides higher production, optimizing the production system, as it reduces the "lead time".

**Table 5.** Mean values of final fresh biomass (FFB), dry biomass of substrate (SSB) and total production (TDP) of hydroponic corn fodder obtained in two cultivation periods.

| Variable | -------------- Cultivation periods (days) -------------- | |
|---|---|---|
| | 10 | 15 |
| FFB, kg $m^{-2}$ | 13.94 a[(1)] | 11.71 b |
| SSB, kg DM $m^{-2}$ | 3.34 a | 2.91 b |
| TDP, kg DM $m^{-2}$ | 3.42 a | 3.02 b |

[(1)] Means followed by different letters in the same row differ significantly ($p > 0.05$) from each other by Tukey's test.

Regarding the qualitative factors of hydroponic corn fodder, for the variables ash (AS) and lignin (LIG), the analysis of variance evidenced an exclusive effect of the substrate (Table 6). For dry matter (DM), ether extract (EE), neutral detergent fiber (NDF), and acid detergent fiber (ADF), there was an interaction between S and P, characterizing a mutual dependence between the factors

**Table 6.** Summary of the analysis of variance for dry matter (DM), crude protein (CP), ash (AS), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (LIG) of hydroponic corn fodder cultivated in different substrates and cultivation periods.

| Variable | Substrate (S) | Cultivation period (P) | S × P | CV[(1)], % | Mean |
|---|---|---|---|---|---|
| | | -------------- F-value -------------- | | | |
| DM, % | 41.957** | 0.704$^{ns}$ | 4.396** | 9.20 | 25.80 |
| AS, %DM | 216.935** | 1.613$^{ns}$ | 1.153$^{ns}$ | 7.98 | 5.07 |
| EE, %DM | 67.262** | 2.960$^{ns}$ | 3.551* | 9.97 | 3.40 |
| NDF, %DM | 332.072** | 35.834** | 10.985** | 4.11 | 45.30 |
| ADF, %DM | 472.122** | 9.880** | 15.138** | 6.17 | 25.72 |
| LIG, %DM | 22.334** | 0.183$^{ns}$ | 1.903$^{ns}$ | 21.29 | 1.74 |

[(1)] CV: coefficient of variation, **, * and $^{ns}$: significant at 1%, 5%, and non-significant, respectively, by F-test.

The treatments of hydroponic corn fodder cultivated with RHS, SSC, and the control, on the 10th day of cultivation, presented higher dry matter (DM), differing significantly from SSB and CHS (Table 7). For hydroponic corn fodder cultivation up to the 15th day, RHS differed significantly from the other substrates and the control, which exhibited lower DM content. The treatments of hydroponic corn fodder obtained from SBS and CSS, showed reduced DM, both for cultivation at 10 and 15 days (Table 7), characterizing the effect of degradation of the organic matter of the substrates, since there was no emergence of corn seedlings (Table 2).

**Table 7.** Mean values of dry matter (DM), ether extract (EE), neutral detergent fiber (NDF), and acid detergent fiber (ADF) of hydroponic corn fodder cultivated in different substrates and the control, in two cultivation periods.

| Cultivation substrates | Cultivation periods (days) | |
|---|---|---|
| | 10 | 15 |
| | (DM, %) | |
| RHS | 29.08 aB[1] | 35.31 aA |
| CHS | 30.39 aA | 26.93 bB |
| SBS | 19.24 b | 18.81 c |
| CSS | 21.02 b | 21.75 c |
| Control | 27.69 a | 27.76 b |
| | (EE. %DM) | |
| RHS | 2.74 bA | 2.17 cB |
| CHS | 2.53 bB | 3.09 bA |
| SBS | 4.69 a | 4.37 a |
| CSS | 2.88 b | 2.77 bc |
| Control | 4.65 aA | 4.16 aB |
| | (NDF. %DM) | |
| RHS | 53.05 aB | 62.30 aA |
| CHS | 51.29 ab | 49.42 b |
| SBS | 38.71 cB | 45.15 cA |
| CSS | 49.01 b | 51.55 b |
| Control | 25.64 d | 26.91 d |
| | (ADF. %DM) | |
| RHS | 32.44 bB | 39.88 aA |
| CHS | 39.72 a | 38.30 a |
| SBS | 19.42 dB | 22.95 bA |
| CSS | 25.29 cA | 21.49 bB |
| Control | 7.81 e | 9.95 c |

[1]Means followed by different letters in the same column (lowercase) and the same row (uppercases) differ significantly ($p < 0.05$) from each other by Tukey's test.

Between the cultivation periods, the RHS treatment at 15 days of growing showed higher DM content (Table 7). Rice husk is an inert material, resistant to degradation, and ensures porosity and adequate moisture to the root system of seedlings, which results in a higher DM increase. Nevertheless, as observed by Campêlo et al. (2007), the nutritional quality of rice husk is questionable because it has a high silicon content (90% in ash), which is an important inhibitor of fiber digestion in bulky feed. Coffee husk (from dry processing of grains, like rice husk), on the other hand, reduced the DM of the fodder with the extension of the production cycle (Table 7), evidencing an allelopathic inhibition of crop development. For the other substrates and the control, there was no effect from cultivation periods.

Comparing the ether extract (EE) content of the control, except for SBS, the other substrates showed a dilution effect on the nutrient content, both for cultivation at 10 and 15 days (Table 7). RHS and control had a reduction in the EE content for hydroponic corn fodder in cultivation at 15 days, respectively, proportional to 20.80 and 10.53%. For hydroponic corn fodder with CHS, the increase in the EE content for cultivation at 15 days was equivalent to 22.14%. Nevertheless, the EE levels obtained in foods are not limiting, as they do not exceed 7% of dry matter (National Research Council [NRC], 2001), with the potential to impair animal intake, either due to regulatory mechanisms that control food intake or due to the limited capacity of ruminants to oxidize fat, which is insoluble in water (Bosa et al., 2012).

For hydroponic corn fodder cultivation on the $10^{th}$ day, RHS and CSS promoted NDF significantly higher than in the control fodder, equivalent to 51% (Table 7). In cultivation at 15 days, hydroponic corn fodder with RHS had higher NDF, differing from the other treatments. Therefore, the values obtained in the present study meet the recommendations of Van Soest (1965), in which NDF levels below 70% do not affect food intake by ruminants, as it characterizes good nutritional value of the fodder, favoring animal performance and productivity (Alencar et al., 2010). Thus, plant production (hydroponic corn fodder) characterizes a dilution effect of the components of structural carbohydrates, such as cellulose, hemicellulose, and lignin of the substrates tested. Only hydroponic corn fodder from RHS and SBS treatments showed an effect from cultivation times (Table 6 ou 7). The increase in NDF for cultivation at 15 days in hydroponic corn fodder cultivated with RHS and CHS, respectively, was proportional to 17.44 and 16.64% (Table 7). Specifically for hydroponic corn fodder from RHS, this increase is due to the substrate (Campêlo et al., 2007), containing a high silica content (Penha et al., 2016) and to the maturity of the seedling due to later harvest (Müller et al., 2006). In turn, for hydroponic corn fodder from SBS, as no ADB production was recorded (Table 2), the advancement in the cultivation cycle evidenced degradation of the organic matter of the substrate and seeds (by fermentation), highlighting the structural components of the plant tissue of the substrates. Mahmud and Anannya (2021) emphasized the composition of structural tissues of sugarcane bagasse, which varies depending on the cultivar or age of the plant, with proportions of 26-47% cellulose, 19-33% hemicellulose, and 14-23% lignin.

The ADF contents (Table 7) are in line with the digestibility of the feed, indicating low levels of lignified components, favoring the digestibility and use of the ingested fodder (Oliveira et al., 2010). Fodder ADF with values around 30% is considered ideal for animal intake (Mertens, 1994). For cultivation at 10 days, hydroponic corn fodder obtained from CHS presented higher ADF, differing significantly from the other substrates and the control. The control hydroponic corn fodder presented reduced ADF, equivalent to 19.66% of that found for CHS (Table 7). At 15 days, hydroponic corn fodder from RHS and CHS treatments presented similar ADF but differed significantly from the other treatments. The control fodder showed a lower value, proportional to 25.98% of that obtained in CHS. For evaluations between cultivation periods, hydroponic corn fodder from RHS and SBS, ADF values increased with cultivation time, evidencing the high fiber content of the substrates. For hydroponic corn fodder cultivated with CSS, there was a reduction in the ADF content for cultivation at 15 days, characterizing the availability of the hemicellulose of the material.

**Table 8.** Mean values of ash (AS) and lignin (LIG) of hydroponic corn fodder cultivated in different substrates and the control.

| Variable | RHS | CHS | SBS | CSS | Control |
|---|---|---|---|---|---|
| AS, %DM | 6.54 b | 7.88 a | 4.21 c | 4.15 c | 2.59 d |
| LIG, %DM | 1.72 b | 2.54 a | 1.68 b | 1.92 b | 0.82 c |

(1)Means followed by different letters in the same row differ significantly ($p < 0.05$) from each other by Tukey's test.

Hydroponic corn fodder cultivated with CSS had higher AS and LIG contents, differing significantly from the other treatments (Table 8). Comparing the control hydroponic corn fodder with the hydroponic corn fodder cultivated with CSS, there was an increase equivalent to 204.25 and 209.76%, respectively, in the AS and LIG contents. Thus, for the production of hydroponic corn fodder, CSS enhances the LIG content, as indicated by the high content of this component in the substrate, adapting to the ADF content, in cultivation at 10 days (Table 7 ou 8).

## Conclusion

For the production of hydroponic corn fodder using green substrates, prior composting of the material is essential, as it characterizes fermentation and anaerobiosis in the cultivation substrate and impairs corn germination.

The coffee husk substrate inhibited the germination and development of corn seedlings for hydroponic fodder production.

The cultivation of hydroponic corn fodder presents a higher yield of fresh and dry matter for harvesting after ten days of cultivation.

The rice husk substrate presents favorable characteristics for cultivation, as it increases the production of dry matter of hydroponic corn fodder.

The neutral detergent fiber and acid detergent fiber contents of hydroponic corn fodder cultivated with rice husk do not limit ruminant intake.

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