CHEMICAL COMPOSITION, AGRONOMIC CHARACTERISTICS AND COST OF CORN (*Zea mays* L.) SPROUTS AS ANIMAL FODDER

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ABSTRACT

A study was conducted to determine the chemical composition, agronomic traits, and cost of production of 3d, 6d, 9d, and 12d corn sprouts. Corn seeds were steeped for 24hr and laid out in a 12 in x 24 in x 2 in a tray at a density of 10.7 kg/m^2. Watering was done 3x daily at 8 am, 12nn, and 4 pm. Production was repeated in 6 batches which served as replicates. Results were analyzed using one-way ANOVA in CRD with subsamples using the Proc Mixed procedure of SAS. Trend comparison was used and means were reported as LS means with standard error. Significance was declared if $P<0.05$ and trend if $0.05<P<0.10$ using Tukey's HSD test. Results showed a significant decrease in DM and NFC contents. Thus, there was a decrease in the DM yield of corn sprouts after 6d due to depletion of stored nutrients over time to support plant shoot growth. The decrease in DM led to an increase in CP, Ash, NDF, ADF, and GE from 3d to 12d due to metabolic interconversion of nutrients. Roots increased progressively from 3d to 12d in terms of length and number and so was the plant height. Leaves started to appear between 3d to 6d with a maximum of 3 leaves after 12d. Lastly, corn sprout production using low-cost technology resulted to an increase in cost per kilogram DM from 3d to 12d due to water usage and labor cost.

Key words: corn sprouts, fodder, composition, agronomic

INTRODUCTION

Cereal sprouts as animal feed have long been practiced by livestock farmers during the early 1600s. Historically, grains such as barley when left out in the field and wet, begin to germinate. Then, the sprouts are being fed as fodder for ruminants rather than wasted. Presently, sprouting of cereal grains as animal fodder has regained resurgence, particularly in countries challenged by water shortages, seasonality of high-quality forages, high prices of grains, the decline in arable land areas, and unpredictable changes in weather pattern (Hafla, 2014; Sneath and McIntosh, 2003). It also offers advantages, such as it can be grown completely free from pesticides, inorganic fertilizers, and interference of soil-borne adulterants and compounds that may be detrimental to the health of the ruminants (Soder *et*

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al., 2018). According to Rama *et al*. (2018) and Chavan and Kadam (1989), sprouting activities in seeds involve biochemical changes such as converting seed protein into amino acids, carbohydrates to soluble sugars, and lipids to essential fatty acids.

Moreover, the sprouting induces increasing enzyme levels from the seeds, increasing CP, EE, vitamins, minerals, and digestibility. Fazaeli *et al*. (2012) claimed a significant increase in CP, ash, EE, NDF, and ADF when barley was grown hydroponically until 8d. Also, sprouting reduces antinutritional factors (ANF) in seeds, such as decreasing levels of phytic acids, enzyme inhibitors, and oxalates.

Corn (*Zea mays* L.) has been recognized as the major cereal used in the livestock industry because of its palatability, high energy content, low fiber content, and other nutritional attributes. However, it is also known that corn has a nutritional limitation having low protein content and poor protein quality (Dei, 2017), which prompt nutritionists to use expensive protein supplements and even resort to synthetically produced amino acids in diet formulations. According to Prasanna *et al*. (2001), most of the protein in corn is zein, accounting for as much as 50-70% of the endosperm protein; however, devoid of lysine and tryptophan. These nutritional attributes of corn may be improved when it undergoes germination due to enzyme activation causing the mobilization of stored nutrients and the interconversion of metabolic products to support the developing plant shoot called sprouts (Rathjen *et al*., 2009).

There are many scientific and anecdotal claims of the benefits of feeding other sprouted cereals (mostly barley) in livestock. However, using corn sprouts as potential animal fodder has not been well elucidated in terms of chemical composition, agronomic yield and traits, and cost-benefits under the tropics' prevailing conditions; hence, this study was conducted.

MATERIALS AND METHODS

Whole (intact germ) feed grade yellow corn seeds were sourced from a reliable local supplier. Upon purchase, it was sundried to keep the moisture at 14% for better storage before germination. Then, the seeds were stored in a sealed plastic silo bin until it was used for germination. Prior to germination, known amounts of yellow corn seeds were washed with water to remove impurities and thereafter were steeped in a 0.1% hypochlorite solution to avoid fungal (Morgan *et al*., 1992) contamination until 24 hours room temperature to hasten the metabolic process in pre-germinated seeds. After soaking, the seeds were again washed repeatedly until all impurities were removed. Using a sprouting tray, 12 in (length) x 24 in (width) x 2 in depth, steeped seeds were spread uniformly at a seeding rate of 10.7 kg/m^2 with a thickness of 1.5–2 cm, then covered with a wet sack for one day to allow maximum germination of seeds. The sprouting trays were made of plastic material with holes at the bottom to drain excess water and thus preventing mold growth and rotting of seeds. The sprouting unit was designed as a 4-deck stair step with a height of 12 inches per layer to permit maximum growth of the sprouts. Watering without any nutrient supplement was done 3 times daily (8 am, 12 nn, and 4 pm) for 1-2 minutes until harvest. The covered facility where sprouting units were located was characterized by having good ventilation, with a limited provision of natural sunlight by strategically positioning the 4-level platform towards the early sunshine (between 8 am to 10 am) and allow maximum plant height before harvest. To ensure a constant supply of fresh corn sprouts, cleaned trays after sprout

harvest were seeded daily to continue cycles of corn sprout production.

Steeped seeds were harvested, laid out in uniform sized-trays. They were randomly assigned to each of the 4-deck stair steps sprouting unit layers to remove external variability following a completely randomized design (CRD). Day harvest (3d, 6d, 9d, and 12d) of corn sprouts served as treatments with a total of 6 batches as replicates.

To determine the chemical composition of each batch, fresh samples (about 500 g each from roots to tip) were taken per tray (replicate) per treatment, then oven-dried at 105 ^{o}C, ground to pass 1 mm mesh screen sieve and analyzed for %DM, %CP, %EE, and %Ash using standard AOAC (2006) methods. Also, %DM content on an as-fed basis was sampled from each tray and dried at 70^{o}C until constant weight. Moreover, detergent fiber fractions (%NDF and %ADF) were analyzed using Van Soest and Robertson (1980); the % NFC was calculated (NRC, 2001), and gross energy (cal/kg) was analyzed using Automatic Isoperibal Calorimeter, Parr Instrument (IL, USA).

Moreover, at each harvest day (3d, 6d, 9d, and 12d), the tray of corn sprout biomass (from the succulent top and intertwined dense mat composed of roots) was taken entirely to determine its agronomic yield and traits. For agronomic yield, percent harvest (herbage) yield (HY) was computed by dividing the final weight over the initial weight of seeds then multiplied by 100. Dry matter (DM) yield per kilogram of seed was computed by multiplying the % herbage yield to its analyzed DM content on an as-fed basis (70^{o}C). Lastly, for the DM yield per kg m^{2}, it was computed by multiplying the DM yield per kilogram to the relative size of the sprouting tray and was converted to a per square meter basis. In terms of agronomic traits, root length (cm) and plant height (cm) were measured using a metric ruler based on the origin of its tip. In contrast, several primary roots and leaves were counted manually. Costing was estimated by summing up all the production costs over the total DM (as-fed basis) yield.

Data were analyzed for homogeneity using Levene's test and normality using Wilk Shapiro's test, and transformations were derived as needed. The data were run using one-way analysis of variance (ANOVA) in CRD, with subsamples having harvesting days as fixed effect while batch as random effect. Trend comparison of the PROC mixed procedure of SAS (SAS Institute Inc., Cary, NC) was used to determine significance among harvesting days and all treatment means were reported as least square means with the corresponding standard error. Significance was declared if $P<0.05$, and data has a trend if $0.05<P<0.10$ using Tukey's HSD test.

RESULTS AND DISCUSSION

Chemical Composition

In Table 1, %DM on as-fed basis showed a quadratic decrease ($P<0.0035$), with 12d having the least DM (21.14%) as fed. For %CP, a linear trend ($P<0.0001$) was observed with the highest increase at 12d (14.97%) of sprouting days. An increasing trend was observed in %EE while linear increase ($P<0.0009$) was obtained for %Ash with increasing age (day) of corn sprouts. Meanwhile, based on detergent fiber fractions, %NDF and %ADF showed a quadratic increase when sprouted from 3d to 12d at $P<0.0123$) and $P<0.0001$, respectively, and this resulted in a %NFC skewed downward (quadratic, $P<0.0322$). Lastly, for GE content, the trend was linearly increasing ($P<0.0001$) over sprouting days in favor of 9d to 12d.

When seeds are steeped, water is imbibed and flows to the kernel through the

micropyle and enters the germ and scutellum to initiate germination. When kernels reached a minimum moisture content of 35% to 45% and are kept in temperature above 4°C, germination will proceed (Gooding *et al*., 2009). Imbibed water moves through the kernel and accumulates in the region between the pericarp and seed coat (Rathjen *et al*., 2009). When it reached the required moisture content, the seed starts the synthesis and release of gibberellic acid, abscisic acid, and ethylene. These plant hormones are responsible for releasing degrading enzymes specific for stored carbohydrates, protein, and lipids. The metabolic products from these processes provide a source of nutrients for the developing seed embryo. Expectedly, a reduction in the DM content occurs because of the enzymatic degradation of the stored nutrients in the seed endosperm.

In the current study, DM was gradually reduced over time. The metabolic degradation of stored nutrients could explain the seed endosperm. The hydrolysis of the stored nutrients leads to an increase in the concentration of soluble sugars, amino acids, fatty acids, and mineral fractions which explains the increasing trend of the CP, EE, ash, and GE contents. Dung *et al*. (2010) also reported that DM loss had led to a corresponding increase in the CP and mineral concentrations per unit DM. Besides synthesizing metabolic enzymes, actively dividing cells is theoretically highest during shoot growth, which would help explain the increase in CP content.

Additionally, it was claimed that sprouted grains resulted in increased protein quantity and quality. The metabolic products from nutrient mobilizations are consequently used up for the interconversions of simple nutrients to more complex nutrients over sprouting days. El-Morsy *et al*. (2013) reported that green fodder produced hydroponically has high ME, CP, and digestibility. However, as the shoot continuously develops, the reserved nutrients are gradually depleted. As for the crude ash, the increase might be attributed to the source of water, mainly deep-well. Thus, the differences should not be accounted for across sprouting days.

The relative proportion of reserve carbohydrates are being used extensively to fuel the metabolic process. This was depicted in this study when %NFC, which constitutes the soluble sugars including starch, gradually declined from 3d and after that. Conversely, the interconversion of carbohydrates would result in the synthesis of structural carbohydrates needed to support the young plant's physical growth. Cellulose and hemicellulose are the major constituents of cell walls. Hence, the concentration of NDF and ADF increased from 3d to 12d. These detergent fiber fractions are good sources of dietary fibers among ruminants and other foraging monogastric and poultry.

Agronomic Characteristics

Presented in Table 2 is the agronomic yield and traits of producing corn sprouts at different harvest times. Results showed the highest increase in % herbage yield (HY) was from 3d to 6d, then a moderate increase from 6d to 9d, and a slow increase thereafter (quadratic, $P<0.0030$). The increase in HY was around 2.5 folds at 6d versus more than 3 folds increase when sprouting continues until 12d. As for DM Yield (kg/m^2) of corn sprout, the trend was increasing after 3d but decreasing after 6d and after that (quadratic, $P<0.0001$. Lastly, root length had a quadratic increase ($P<0.0001$) while sprout height had a linear increase ($P<0.0001$) with the highest increase towards 6d. In terms of primary roots, root radicle had emerged even before 3d. The other root networks began to increase in number over the rest of the sprouting days (quadratic, $P<0.0001$). During sprouting of corn in trays,

Table 1. Chemical composition of different ages of corn sprout fodder (as fed basis).

Item[1]	Harvest Day[2]				SEM	Contrast, *P*-value	
	3d	6d	9d	12d		Linear	Quadratic
DM, %	50.44[a]	36.03[b]	28.09[c]	21.14[d]	0.53	<0.0001	0.0035
CP, %	8.64[d]	9.67[c]	11.14[b]	14.97[a]	0.08	<0.0001	0.3407
EE, %	3.08	3.07	3.55	3.60	0.07	0.0631	0.2539
Ash, %	1.57[c]	1.96[bc]	2.11[ab]	2.40[a]	0.04	0.0009	0.3164
NDF, %	3.48[d]	4.48[c]	9.49[b]	11.62[a]	0.04	<0.0001	0.0123
ADF, %	12.71[d]	23.90[c]	28.13[b]	35.79[a]	0.45	<0.0001	<0.0001
NFC, %	74.00[a]	61.41[b]	55.08[c]	43.25[d]	0.48	<0.0001	0.0322
GE, cal/kg	4177.80[b]	4209.94[b]	4267.86[a]	4291.42[a]	3.69	<0.0001	0.2208

[1]Chemical composition expressed as dry matter (%DM), crude protein (%CP), ether extract (%EE), % ash, neutral detergent fiber (%NDF), acid detergent fiber (%ADF), non-fibrous carbohydrates (%NFC), and gross energy (GE).
[2]Least square means per harvest day. Means of the same superscript are not significant from each other.

Table 2. Agronomic yield and traits of different ages of corn sprout fodder.

Item	Harvest Day[1]				SEM	Contrast, *P*-value	
	3d	6d	9d	12d		Linear	Quadratic
Herbage Yield, %	178.82[d]	258.79[b]	312.31[c]	322.52[a]	1.22	<0.0001	0.0030
DM Yield, kg/m^2	4.85[b]	5.01[a]	4.72[c]	3.67[d]	0.02	0.0035	<0.0001
Root length, cm	2.10[d]	6.55[c]	9.04[b]	9.90[a]	0.33	<0.0001	<0.0001
Sprout Height, cm	0.88[d]	9.26[c]	16.63[b]	22.95[a]	0.75	<0.0001	0.1433
No. of Roots	4.71[d]	5.84[c]	6.26[b]	7.48[a]	0.297	<0.0001	`0.0085
No. of Leaves	0.00[d]	1.70[c]	2.98[b]	3.38[a]	0.068	<0.0001	<0.0001

[1]Least square means per harvest day. Means of the same superscript are not significant from each other.

roots were intertwined, forming a dense mat of fiber networks, thus determining the number and size of adventitious roots were not taken. Lastly, leaves started to appear after 3d of steeping, almost tripled at 9d, and continued to increase after that (quadratic, $P<0.0001$).

Soaking of seeds and the rapid uptake of water is crucial for the germination of seeds and eventually producing fodder sprouts. The seed rate also affects the yield of the fodder, which varies according to the type of seeds (Sneath and McIntosh, 2003). Naik *et al*. (2012) has suggested a seeding rate for hydroponic maize fodder at 7.6 kg/m^2 for higher yields. However, it was not mentioned whether it was raw or steeped seeds. In the current study, the seeding rate was 10.7 kg/m^2 of the steeped seeds, which was adequately enough given the depth of the size of the sprouting trays. If seed density is high, there is a high risk of fungal growth in the root mat, which would likely be detrimental if fed as fodder sprouts (Naik *et al*., 2012). Based on the author's impression of the corn sprout experiment, there was no high incidence of fungal contamination throughout the duration of sprouting corn. The porosity of the tray, the pre-treatment of corn seeds with hypochlorite solution, the sun-drying of corn seeds, and storage in sealed silo bins were effective in the prevention of fungal growth in corn sprouts *in situ*.

Moreover, during sprouting, there was an increase in percent HY on a daily basis by as much as 2.50 to 3.20 folds from 6d-12d, while there was a consequent decrease in DM content. With the low-cost sprouting technology, as in this case, the results were quite inferior to those who ventured into commercial hydroponics technology where the yield can be multiplied to as much as 8 folds using other cereal grains (Naik *et al*., 2012; Fazaeli *et al*., 2012; Dung *et al*., 2010; Sneath and McIntosh, 2003). The high increase was likely due to rapid water imbibition during early sprouting days. The growth of plants continuously uses the reservoir of nutrients in the endosperm and depletes over time. This pointed out the decrease in DM yield and was aggravated by the continuous leaching of nutrients, especially when the sprouts were watered.

Leaching of nutrients exists because of enzymatic degradation (oxidation) of nutrients, especially in the hydrated kernel. The leaked solutes are proteins, amino acids, sugars, organic acids, and inorganic ions. Emam (2016) and Rathjen *et al*. (2009) explained that the activation of plant enzymes caused the solubilization of starch reserves in the endosperm. Its simple products are used to fuel the metabolic activities of the young plant. These substrates are respired to produce energy while giving off carbon dioxide and water. Loss of carbon dioxide contributes to the overall DM loss. Notably, a slower increase in percent HY was observed after 6d due to slow nutrient turnover in plants through limited photosynthesis.

According to Adjlane *et al*. (2016) and Sneath and McIntosh (2003), photosynthesis is not important for the metabolism of the young plant until the end of 5d when chloroplasts are activated. At this point, DM accumulation is not significant, and therefore, light is not required for sprouting cereal grains. However, the availability of light in the second half of the sprouting period encourages photosynthesis and the greening of the sprouts. At this period (6d to 12d), leaves start to double in number, increase in size, and surface area for possible photosynthesis. For this low-cost study, the sprout set-up was located strategically to allow light provision during early sunshine, which supported the continuous increase in HY, although a smaller increase compared to reports using hydroponic technology. Yield also continued to increase after 6d despite rapid nutrient depletion and leaching because the root network had already been established extensively, which aid in the water and leached nutrient retention. Without adequate nutrient replenishment, the yield increases at a slower

rate until leaves are at full photosynthetic activity. The roots can absorb nutrients from any source of media (soil or hydroponic). However, in the short growing cycle of sprouts, DM loss may range from 7% to 47% (Sneath and McIntosh, 2003).

Cost of Corn Sprout Production

This study adopted a 4-layer design laid in a stair-step deck arrangement (4 front and 4 back) to maximize the indoor space. Each layer was partitioned based on the planned seeding rate (10.7 kg/m^2), and the watering of corn sprouts was done manually. Based on the estimated production cost of corn spouts (Table 3), when the rental of trays, sprouting units, and seed costs were fixed, there was an incurred cost in producing corn sprouts. As the harvest day was extended from 3d to 12d, there was an increase in the price of corn sprouts per kg DM, which was attributed to an increase in water usage and labor cost.

The use of low-cost technology does not provide the full potential for corn sprout production's growing environment. For instance, there is a lack of a mechanism for the nutrient recycling process, limited watering frequency, variability in relative humidity and temperature, unavailability of a consistent light source for photosynthetic activity, and the like. Also, such technology underestimates the economy of scale, which can be attained when sprouts are produced at a large commercial scale, such as in hydroponic technology. This study has reported lower DM yield than previous studies using other cereal grains, mostly utilizing hydroponic technology. Therefore the total production cost appeared relatively expensive. Based on Table 3, as the harvest day was extended from 3d to 12d, there was an increase in the price of corn sprouts per kg DM basis. Mainly, it was due to incurred cost of water usage and labor cost. Nevertheless, the nutritional benefits provided by this fodder, specifically its dietary fiber and improvement in CP than with its seed counterpart, and many among others, the use of corn sprouts as an animal fodder has still huge potential as an alternative feed for foraging livestock and poultry.

Table 3. Total production cost of different ages of corn sprouts.

Item (Php)	Harvest Day			
	3d	6d	9d	12d
Materials and construction cost[1]	82.20	82.20	82.20	82.20
Seed cost[2]	200.00	200.00	200.00	200.00
Water usage[3]	2.10	4.20	6.30	8.40
Labor cost[4]	93.75	187.50	281.25	375.00
Cost of Production of Sprouts per Batch[5]	378.05	473.90	569.75	665.60
Cost of Production/ kilogram DM (as fed)[6]	20.96	25.41	32.48	48.81

[1]Projected rental for each batch of sprout produced assuming the fixed cost is Php 15,000.00 within 3 years depreciation.
[2]Estimated total cost of 20 kgs feed grade corn seed with 85% germination rate at Php 10.00/kg.
[3]Water usage at 1 m^3 per day for Php 0.70 per m^3.
[4]Daily routine including soaking of seeds, watering, and harvesting of sprouts at Php 31.25 per hour.
[5]Calculated as sum of items 1 to 4.
[6]Calculated as item 5 divided by total DM (as fed) yield per batch of corn sprout.

Sprouting corn seeds from 3d to 12d decreased DM and NFC but increased CP, Ash, NDF, ADF, and GE. These changes in the chemical composition are favorable for foraging livestock and poultry when corn sprouts are used as animal fodder. While sprouting time continues from 3d to 12d, water is continuously imbibed, causing increased percent HY. However, stored nutrients began to deplete after 6d due to leaching, and replenishment is very low until 12d due to limited photosynthesis. Hence, decreased DM yield was observed. Increased root length, plant height, and several roots and leaves were all supportive of the metabolic changes occurring in the different ages of corn sprouts. Extending the sprouting days in the context of low-cost technology resulted in an increased total production cost of corn sprouts on a DM basis. However, several benefits would likely outweigh such drawbacks. Future research may be directed to adopting hydroponics technology with the addition of nutrient solutions, preventing leaching of nutrients, and other biochemical assays to allow animal nutritionists to better utilize the corn sprout supplement to a specific age or physiological state of the animal.

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