academicJournals

Vol. 16(49), pp. 2289-2298, 6 December, 2017
DOI: 10.5897/AJB2017.16083
Article Number: 79087C066966
ISSN 1684-5315

http://www.academicjournals.org/AJB

African Journal of Biotechnology

*Full Length Research Paper*

# Evaluation of productivity of sweet potato genotypes for first and second generation bioethanol production

**Daniel José Silva Viana[1], Silvânia Saldanha da Silva Pinto[2], Karen Paola Fróes Dias[3], David Lee Nelson[3], Lílian de Araújo Pantoja[3], Nísia Andrade Villela Dessimoni Pinto[4], Valter Carvalho de Andrade Junior[5] and Alexandre Soares dos Santos[2*]**

[1]Department of Biology, Federal University of the Jequitinhonha and Mucuri Valleys, Diamantina, MG, Brazil.
[2] Department of Basic Sciences, Federal University of the Jequitinhonha and Mucuri Valleys, Diamantina, MG, Brazil.
[3]Institute of Science and Technology, Federal University of the Jequitinhonha and Mucuri Valleys, Diamantina, MG, Brazil.
[4]Department of Nutrition, Federal University of the Jequitinhonha and Mucuri Valleys, Diamantina, MG, Brazil.
[5]Department of Agronomy, Federal University of the Jequitinhonha and Mucuri Valleys, Diamantina, MG, Brazil.

Received 24 May, 2017; Accepted 17 August, 2017

**The increased supply of ethanol fuel and its spread as an alternative to fossil fuels depend on the exploration of biomasses that can be regarded as alternatives to sugarcane and maize. In this study, the agricultural productivity and the potential for production of ethanol from roots and the aerial portion of twenty sweet potato genotypes were evaluated. The roots and branches were harvested 180 days after planting. Starch, hemicellulose, cellulose, lignin and soluble sugars from sweet potato roots or branches were determined and expressed as percentage of dry matter produced per hectare. The genotype UFVJM 28 stood out for the production of root and branches (fresh material), yielding 43.5 and 31.7 t ha$^{-1}$, respectively. The roots of the Palmas, Batata Mandioca, Cariru Vermelha and UFVJM 45 genotypes had the highest total soluble sugar concentrations, between 4.1 and 5.4%. The enzymatic digestibility for starch contained in the roots ranged from 58.2 to 91.2%, and when related to the cellulose contained in the branches, it ranged from 14.2 to 42.4%. The estimates for the production of ethanol from the roots ranged between 1120 and 4940 L ha$^{-1}$. The estimated production of bioethanol from sweet potato branches of the genotypes varied from 240 to 995 L ha$^{-1}$. Considering the combined use of roots and branches, at least four sweet potatoes genotypes presented a potential for ethanol production greater than 4000 L ha$^{-1}$ in a 180-day cycle.**

**Key words:** *Ipomoea batatas*, ethanol, biofuels, second generation ethanol, starch.

## INTRODUCTION

The sweet potato (*Ipomoea batatas* (L.) Lam) is one of the most widely cultivated plant crops in the world. The plant root is the main product; it is used both for human consumption and animal feed. The sweet potato stands out for its ease of cultivation, hardiness, adaptability to different types of soil and climate, high drought tolerance, short production cycle and low production cost (Andrade Júnior et al., 2012). In 2014, 104.4 million tons of sweet

potato roots were produced worldwide, and China accounted for 68% of the world production (FAO, 2016). According to FAO (2016), the average worldwide productivity of sweet potatoes was only 13 tons per hectare in 2014, reaching 45.5 tons per hectare in Ethiopia. In general, the low agricultural productivity of this crop is associated with a low technification index and the lack of adoption of appropriate cultivation practices (Widodo et al., 2015). The mean starch content of fresh sweet potato roots is 20%, and it may range between 9.8 and 27.5% or between 40.0 and 83.1% on a dry weight basis (Dangler et al., 1984; Suarez et al., 2016). Because of its significant starch content, the sweet potato is also being evaluated as an alternative to sugarcane and maize for the production of ethanol (Ziska et al., 2009; Masiero et al., 2014). The literature has presented projections and case studies that report a productivity between 1250 and 8839 L of ethanol per hectare per year (Ziska et al., 2009). The great challenge for the incorporation of this starchy biomass for ethanol production is the selection of super-productive varieties with high starch contents. Two crops per year are likely, and saccharification of the starch should be accomplished by a small investment and positive energy balance. In addition, genotypes that are adapted to climatic and soil diversity in different regions of the globe must be selected. The use of the aerial portion of the sweet potato plant for the production of ethanol is also possible through use of the technology employed for second-generation ethanol production (Aditiya et al., 2016). However, few studies exist that address this perspective.

There are many varieties of sweet potato, with different sizes, shapes, textures, colors and compositions. Although extremely productive, some are not suitable for marketing. Even among the varieties already selected to satisfy the food market, there are considerable losses caused by rot, mechanical injury, sprouting, formation defect or pest damage and they are responsible for the lack of compliance with commercial specifications (Ray and Tomlins, 2010; Parmar et a., 2017). Because of these characteristics, one can envisage the simultaneous allocation of sweet potatoes to the food market and to biofuel industries, with economic advantages for the producer.

To furnish information that could facilitate the use of sweet potatoes as an alternative biomass for the ethanol fuel production chain, this study evaluated the agricultural productivity of twenty genotypes of *Ipomoea batatas* under the soil and climatic conditions of the Alto Vale do Jequitinhonha, central Minas Gerais State, Brazil, and estimated the productivity of ethanol, considering the carbohydrate contents of the roots and branches and the use of the whole plant.

## MATERIALS AND METHODS

### Cultivation of sweet potatoes

The sweet potato genotypes studied were Brazlândia Branca, Brazlândia Rosada, Batata Mandioca, Marmel, Cariru Vermelha, Palmas, Cambraia, Princesa, Tomba Carro I, UFVJM 45, UFVJM 20, UFVJM 46, UFVJM 23, UFVJM 48, UFVJM 01, UFVJM 04, UFVJM 06, UFVJM 14, UFVJM 21, and UFVJM 28. The planting of sweet potato genotypes was conducted in the city of Diamantina, MG, Brazil, a town with an average altitude of 1219 m, at 18°31'31"S and 43°51'19"W, and a Cwb climate according to the Köppen classification, characterized as humid temperate with a dry winter and rainy summer. The experiment was conducted in a randomized block design with 20 treatments and 4 repetitions, totaling 80 plots of 3.9 $m^3$ each. The spacing used was 1.0 m between rows (ridges) and 0.30 m between plants. Each plot contained 13 plants. The seedlings from clones maintained in the germplasm bank of the Federal University of the Vales do Jequitinhonha and Mucuri (UFVJM) were produced from branches with eight nodes, collected and planted for rooting in a greenhouse for 30 days in a commercial substrate (Bioplant - Bioplant Agrícola Ltda). The seedlings were distributed in trays containing 72 cells. Planting was accomplished in March 2014, and the harvest occurred in September of the same year after 180 days of cultivation. Fertilization, covering and other cultural practices employed were those recommended by Filgueira (2008). The area for the planting was plowed and fenced, after which the soil was formed into rows. The area was irrigated with a sprinkler every day in the morning during the first three months and then three times a week.

### The production parameters

The productivity of fresh roots and branches per plot was expressed in tons per hectare. The percentage dry matter in the roots and branches of the genotypes was obtained after crushing the biomass in a Croton knife mill (TE - 625 – Tecnal - Brazil) with a No. 10 mesh screen and drying in a forced-air oven at 65°C (TE - 394/3 – Tecnal - Brazil) to constant weight. The productivity of the dry matter from the roots and branches was also expressed in tons per hectare. All the data were submitted for analysis of variance and the Scott-Knott test was applied to the means at $p < 0.05$.

### Determination of carbohydrates present in the roots and branches of the sweet potato

About 400 g per plot of roots and branches of each genotype was analyzed. Fresh, sliced roots and fresh branches were dried in a forced-air oven (TE - 394/3 – Tecnal - Brazil) at 60°C for 96 h and ground in a Croton knife mill (TE - 625 – Tecnal - Brazil) with a No. 10 mesh screen. The samples were then labeled and placed in

*Corresponding author. E-mail: alexandre.soares@ufvjm.edu.br. Tel: +55 38 35321200.

plastic pots for further analysis. Total soluble sugar content of the roots was analyzed by the anthrone-sulfuric acid method (McCready et al., 1950); glucose concentration was determined by the enzymatic-colorimetric GOD-POD method (Trinder, 1969); reducing sugars were analyzed by the method proposed by Miller (1959); and the amount of starch in the roots was determined by the colorimetric enzymatic method described as follows. Dried and crushed root samples (2.0 g) were weighed in 2.0-mL polypropylene microtubes to which were added 500 µl of distilled water and 10 µl of alpha-amylase (Liquozyme® Novozymes). The tubes were incubated in a water bath at 90°C for a period of 30 min. The bath temperature was lowered to 60°C, 10 µl of amyloglucosidase (Spirizyme® Novozymes) was added, and the mixture was incubated for 1 h. The enzyme hydrolyzate was completed to 100 ml with distilled water, and the glucose released was determined as described earlier. The starch content was calculated on the basis of the conversion of the glucose to its equivalent in starch, multiplying the first value by 0.9, and then expressed as percentage of starch on a dry matter basis. Standard corn starch (Megazyme) was used as a reference to validate the method. The hemicellulose, cellulose and lignin contents of the aerial portions of the plants were quantified according to the gravimetric method proposed by Van Soest (1967). The concentration of total soluble sugars was determined by the anthrone-sulfuric acid method (McCready et al., 1950). All analytical determinations were performed in triplicate.

**Calculation of the projected yields of alcohol from each genotype**

On the basis of the carbohydrate (starch, soluble sugars, hemicellulose and cellulose) contents of the roots and branches of the sweet potato genotypes and the dry biomass yield per hectare, the theoretical production of ethanol per hectare was estimated. A 90% yield for the conversion of carbohydrates into alcohol was considered for the purpose of estimation. Equation 1 was used for the projection of ethanol production from sweet potato roots ($EP_{roots}$). For the projection of ethanol production from the branches ($EP_{branches}$), Equation 2 was used. The total estimated ethanol production per hectare of planted area, considering the use of both the roots and the branches, was calculated by summing the values obtained from the two previous equations.

$$EP_{roots} = \frac{(S \times 1.1 \times 0.511) + (T_R \times 0.511)}{0.789} \times 0.9 \quad (1)$$

$$EP_{branches} = \frac{(C_H \times 1.1 \times 0.511) + (T_B \times 0.511)}{0.789} \times 0.9 \quad (2)$$

where EP is the estimated ethanol production in liters per hectare; S is the kilograms of starch per hectare; $T_R$ is the kilograms of total soluble sugars from roots per hectare; $T_B$ is the kilograms of total soluble sugars from aerial portion per hectare; $C_H$ is the kilograms of cellulose and hemicellulose per hectare; (1.1) is the factor for the conversion of starch, cellulose or hemicellulose into monosaccharides; (0.511) is the theoretical yield for the fermentative conversion of monosaccharides into ethanol; (0.789) is the density of ethanol; and (0.9) is the yield adopted for the conversion of total carbohydrates into ethanol.

**Enzymatic digestibility of sweet potato starch**

The enzymatic digestibility assay of starch present in the roots of sweet potato genotypes was evaluated using commercial enzymes and conducted according to the following method: 0.5 g of dried and crushed sweet potatoes, 3.5 ml of 100 mM acetate buffer, pH 4.0, 10 µl of alpha-amylase (AGXXL® - Novozymes) and 10 µl of amyloglucosidase (Spirizyme® - Novozymes) were transferred to glass tubes with screw caps and incubated in a water bath at 60°C for 15 min. The tubes were transferred to a water bath at 100°C for 5 min for denaturation of the enzymes; the contents of each tube was completed to 100 ml with distilled water and glucose concentrations were determined by the GOD-POD method, as described earlier. The enzymatic digestibility ($ED_{starch}$) was calculated according to Equation 3.

$$ED_{starch} = \frac{G \times 0.9}{S} \times 100 \quad (3)$$

where G is the amount of glucose released after enzymatic hydrolysis of dried roots, in grams; S is the amount of starch contained in dried root sample, in grams; and 0.9 is the factor for conversion of glucose to starch.

**Enzymatic digestibility of cellulose in sweet potato branches**

Enzymatic digestibility of cellulose in the aerial portions of sweet potato plants was conducted in two stages. The first step involved the pre-treatment of dried and ground samples, which were immersed in 4% sulfuric acid (w/v) with a solid:liquid ratio of 1:4 and held at 121°C in an autoclave for 30 min. After the pretreatment, the insoluble fraction was washed with water to remove sulfuric acid and recovered by vacuum filtration through Whatman No. 1 filter paper. The residue was dried to constant weight at 65°C in an oven with forced air circulation and reserved for the second stage of the assay. In the second step, 0.5 g of the pretreated and dried material was placed in glass tubes with screw caps to which were added 4.4 ml of 50 mM bicarbonate buffer, pH 5.0, and 100 µl of cellulolytic preparation (Celluclast® - Novozymes). The reaction medium was incubated at 50°C for 24 h. After digestion, the tube contents were completed to 100 ml with distilled water, and the glucose concentration was determined according to the methods already described. The enzymatic digestibility of cellulose ($ED_{cellulose}$) was calculated according to Equation 4.

$$ED_{cellulose} = \frac{G \times 0.9}{C} \times 100 \quad (4)$$

where G is the amount of glucose release after enzymatic hydrolysis of dried branches, in grams; C is the amount of cellulose contained in dried branch sample, in grams; and 0.9 is the factor for conversion of glucose to cellulose.

## RESULTS AND DISCUSSION

The best results for agricultural productivity in this study, expressed in terms of total material (Table 1), were obtained with the Cariru Vermelha, UFVJM 21, Tomba Carro I, and UFVJM 28 genotypes. These genotypes were not statistically different from one another. The mean productivity was 36.6 t $ha^{-1}$. Azevedo et al. (2015) obtained mean productivities of 13.8 and 7.3 t $ha^{-1}$ for the

**Table 1.** Agricultural productivity in total material (PTM), dry matter content (DM) and agricultural productivity in dry matter (PDM) of the roots from the different sweet potato genotypes studied.

| Genotypes | PTM (t ha$^{-1}$) | DM (%) | PDM (t ha$^{-1}$) |
|---|---|---|---|
| Batata Mandioca | 25.92 ± 5.30$^{b}$ | 29.98 ± 2.04$^{a}$ | 7.83 ± 1.91$^{a}$ |
| Brazlândia Branca | 9.88 ± 5.81$^{b}$ | 28.39 ± 4.56$^{a}$ | 2.62 ± 1.22$^{b}$ |
| Brazlândia Rosada | 24.71 ± 12.37$^{b}$ | 24.23 ± 2.93$^{a}$ | 6.22 ± 3.38$^{b}$ |
| Cambraia | 14.99 ± 3.05$^{b}$ | 26.31 ± 1.90$^{a}$ | 3.93 ± 0.77$^{b}$ |
| Cariru Vermelha | 32.36 ± 11.14$^{a}$ | 28.21 ± 3.28$^{a}$ | 8.89 ± 2.33$^{a}$ |
| Marmel | 22.30 ± 4.19$^{b}$ | 27.87 ± 4.08$^{a}$ | 6.32 ± 2.14$^{b}$ |
| Palmas | 18.35 ± 9.26$^{b}$ | 27.56 ± 2.08$^{a}$ | 5.04 ± 2.46$^{b}$ |
| Princesa | 19.82 ± 1.81$^{b}$ | 27.49 ± 2.80$^{a}$ | 5.48 ± 1.01$^{b}$ |
| Tomba Carro I | 35.78 ± 11.06$^{a}$ | 27.56 ± 4.34$^{a}$ | 9.61 ± 2.15$^{a}$ |
| UFVJM 01 | 20.66 ± 10.36$^{b}$ | 26.55 ± 1.52$^{a}$ | 5.59 ± 3.13$^{b}$ |
| UFVJM 04 | 20.72 ± 12.74$^{b}$ | 27.09 ± 1.82$^{a}$ | 5.72 ± 3.79$^{b}$ |
| UFVJM 06 | 21.43 ± 9.34$^{b}$ | 27.14 ± 0.16$^{a}$ | 5.82 ± 2.55$^{b}$ |
| UFVJM 14 | 21.89 ± 17.19$^{b}$ | 27.79 ± 4.37$^{a}$ | 5.72 ± 3.74$^{b}$ |
| UFVJM 20 | 14.42 ± 3.34$^{b}$ | 28.49 ± 2.33$^{a}$ | 4.15 ± 1.19$^{b}$ |
| UFVJM 21 | 34.67 ± 14.11$^{a}$ | 27.27 ± 3.15$^{a}$ | 9.31 ± 3.25$^{a}$ |
| UFVJM 23 | 18.53 ± 3.62$^{b}$ | 25.48 ± 4.34$^{a}$ | 4.76 ± 1.38$^{b}$ |
| UFVJM 28 | 43.48 ± 12.68$^{a}$ | 25.91 ± 3.03$^{a}$ | 11.07 ± 2.42$^{a}$ |
| UFVJM 45 | 12.30 ± 4.51$^{b}$ | 29.55 ± 2.03$^{a}$ | 3.59 ± 1.17$^{b}$ |
| UFVJM 46 | 15.94 ± 3.54$^{b}$ | 29.48 ± 2.92$^{a}$ | 4.75 ± 1.49$^{b}$ |
| UFVJM 48 | 19.23 ± 7.57$^{b}$ | 27.37 ± 1.57$^{a}$ | 5.22 ± 1.87$^{b}$ |
| CV (%) | 38.61 | 9.11 | 37.90 |
| Mean | 22.37 | 27.48 | 6.08 |

*Means followed by the same lower case letter in the columns do not differ by the Scott-Knott test at $p < 0.05$.

Tomba Carro I and UFVJM 28 genotypes, respectively, cultivated in the municipality of Diamantina, MG, Brazil (18°12'01"S, 43°34'20"W and altitude of 1387 m) and harvested five months after planting in December 2007. The main differences between the cultivation conditions used by Azevedo et al. (2015) and those used in the present study were the planting season, the age of the plant at harvest and the use of irrigation. The use of irrigation and the later harvesting period probably favored the increase of productivity in the present study.

As for the dry matter content of the roots (Table 1), a range from 24.2 to 29.9% and an average of 27.5% was observed for the genotypes, and they did not differ significantly from one another. Shumbusha et al. (2014) evaluated the dry matter content of sweet potato clones in Uganda and encountered values between 23.5 and 35.2%. Regarding the productivity of the roots expressed as dry matter (Table 1), Batata Mandioca, Cariru Vermelha, UFVJM 21, Tomba Carro I, and UFVJM 28 contained the highest statistically equivalent levels, with an average of 9.3 t ha$^{-1}$.

As for the agricultural productivity of the branches from the sweet potato genotypes (Table 2), there were significant differences for all the variables. Agricultural productivities in terms of total plant material from the more productive genotypes were 31.7 (UFVJM 28) and 26.7 t ha$^{-1}$ (UFVJM 46) (Table 2). The average dry matter content of all the genotypes was 14.8%, with emphasis on the UFVJM 48, Cariru Vermelha, UFVJM 28, UFVJM 14, UFVJM 06, UFVJM 45, and UFVJM 46 genotypes (Table 2). The branches of the UFVJM 28 genotype furnished the highest yield of dry matter (5.7 t ha$^{-1}$). Andrade Júnior et al. (2012), evaluating the production of branches of sweet potatoes for use as animal feed, reported the production of 1.4 to 3.5 tons of dry mass per hectare for seven genotypes originating in the region of the Vale do Jequitinhonha (Minas Gerais, Brazil).

There were significant differences between genotypes with regard to the concentrations of starch and soluble sugars (Table 3). The mean starch content of the genotypes was 54.2%. There were no significant differences between the starch yields for Cariru Vermelha, UFVJM 21, Tomba Carro I, and UFVJM 28 genotypes, and the highest productivities were obtained for these genotypes, between 4.9 and 6.5 tons of starch per hectare. Waluyo et al. (2015) reported yields between 0.9 and 7.4 tons of starch per hectare of sweet potato clones classified as promising for bioethanol production in

**Table 2.** Agricultural productivity of total plant material (PTM), dry matter content (DM) and agricultural productivity in dry matter (PDM) of branches from the different sweet potato genotypes studied.

| Genotype | PTM (t ha$^{-1}$) | DM (%) | PDM (t ha$^{-1}$) |
|---|---|---|---|
| Batata Mandioca | 19.34 ± 8.63$^{b}$ | 12.82 ± 1.12$^{b}$ | 2.51 ± 1.28$^{c}$ |
| Brazlândia Branca | 16.76 ±10.05$^{c}$ | 13.50 ± 0.83$^{b}$ | 2.21 ± 1.26$^{c}$ |
| Brazlândia Rosada | 21.30 ± 2.44$^{b}$ | 13.76 ± 2.78$^{b}$ | 2.92 ± 0.62$^{b}$ |
| Cambraia | 15.50 ± 5.40$^{c}$ | 14.15 ± 1.18$^{b}$ | 2.16 ± 0.71$^{c}$ |
| Cariru Vermelha | 16.50 ± 4.28$^{c}$ | 15.66 ± 1.14$^{a}$ | 2.61 ± 0.78$^{c}$ |
| Marmel | 13.17 ± 1.97$^{c}$ | 13.56 ± 1.30$^{b}$ | 1.79 ± 0.40$^{c}$ |
| Palmas | 13.37 ± 5.10$^{c}$ | 14.52 ± 1.55$^{b}$ | 1.92 ± 0.73$^{c}$ |
| Princesa | 15.33 ± 3.87$^{c}$ | 14.93 ± 1.60$^{b}$ | 2.24 ± 0.42$^{b}$ |
| Tomba Carro I | 22.74 ± 5.02$^{b}$ | 15.06 ± 1.26$^{b}$ | 3.39 ± 0.65$^{b}$ |
| UFVJM 01 | 22. 89 ± 6.34$^{b}$ | 13.78 ± 1.09$^{b}$ | 3.10 ± 0.71$^{b}$ |
| UFVJM 04 | 15.18 ± 6.45$^{c}$ | 14.30 ± 1.28$^{b}$ | 2.11 ± 0.77$^{c}$ |
| UFVJM 06 | 19.76 ± 6.90$^{b}$ | 16.57 ± 2.17$^{a}$ | 3.17 ± 0.75$^{b}$ |
| UFVJM 14 | 21.04 ±11.55$^{b}$ | 15.63 ± 1.43$^{a}$ | 3.29 ± 1.86$^{b}$ |
| UFVJM 20 | 15.73 ± 3.93$^{c}$ | 13.92 ± 2.50$^{b}$ | 2.25 ± 0.92$^{c}$ |
| UFVJM 21 | 20.91 ± 3.73$^{b}$ | 14.03 ± 0.75$^{b}$ | 2.94 ± 0.60$^{b}$ |
| UFVJM 23 | 11.86 ± 1.11$^{c}$ | 14.09 ± 0.86$^{b}$ | 1.66 ± 0.08$^{c}$ |
| UFVJM 28 | 31.68 ± 8.94$^{a}$ | 17.84 ± 5.22$^{a}$ | 5.66 ± 2.20$^{a}$ |
| UFVJM 45 | 21.42 ± 6.84$^{b}$ | 17.51 ± 2.95$^{a}$ | 3.64 ± 0.91$^{b}$ |
| UFVJM 46 | 26.70 ± 3.36$^{a}$ | 15.6 2± 1.30$^{a}$ | 4.18 ± 0.60$^{b}$ |
| UFVJM 48 | 10.27 ± 2.44$^{c}$ | 15.37 ± 1.45$^{a}$ | 1.56 ± 0.30$^{c}$ |
| Mean | 18.57 | 14.83 | 2.76 |
| C.V % | 28.07 | 12.76 | 33.41 |

Means followed by the same lower case letter in the columns do not differ by the Scott-Knott test at $p < 0.05$.

Indonesia. Oliveira et al. (2017) related starch yields from 4.0 to 6.6 t ha$^{-1}$ in a study with six sweet potato genotypes targeted as raw material for bioethanol.

The highest total soluble sugar concentrations were obtained with the Palmas, Batata Mandioca, Cariru Vermelha, and UFVJM 45 genotypes. There were no significant differences among them, and the concentrations ranged from 4.1 to 5.4%. Adu-Kwarteng et al. (2014) found total soluble sugar concentrations in sweet potato genotypes higher than those found in this work, ranging from 7.4% for the Sauti genotype to 10.3% for the Otoo genotype five months after planting. These sugars, consisting mainly of sucrose, can easily be converted to ethanol during fermentation.

There were no significant differences between the genotypes with respect to the different carbohydrate fractions present in the branches of the sweet potato genotypes evaluated (Table 4). However, the average hemicellulose content found in the twenty genotypes (13.7%) was greater than the average value recorded for the cellulose content (8.9%). The concentration of soluble sugars found in Brazlândia Branca and Tomba Carro I genotypes was at least 25% higher than the values recorded for the other genotypes (Table 4). The lignin contents of the sweet potato branches ranged from 1.5 to 4.0%, with no significant differences (Table 4). However, the average value of the lignin found in this study (2.6%) was lower than the values recorded for some lingo-cellulosic biomasses that exhibit a potential for the production of second generation ethanol, such as wheat straw, with 13 to 15% lignin, and bagasse from sugarcane, containing 23 to 32% lignin (Saini et al., 2015). Lignin is a key limiting factor in the saccharification of lignocellulosic feedstocks (Van der Weijde et al., 2016).

Although there were no significant differences in the quantities of cellulose and hemicellulose found in the branches of the sweet potato genotypes studied, there were significant differences in the concentrations of these carbohydrate fractions multiplied by the agronomic yield (dry matter per hectare). The highest hemicellulose productivities in the aerial portion by planted area, between 0.45 and 0.74 t ha$^{-1}$, were observed for the UFVJM 14, UFVJM 28, UFVJM 45 and UFVJM 46 genotypes (Table 5). The highest cellulose productivities in branches per planted area, 0.62 and 0.52 t ha$^{-1}$, were obtained for the UFVJM 28 and UFVJM 46 genotypes, respectively. The highest yields of soluble sugars from the branches by planted area, 0.067 and 0.073 t ha$^{-1}$,

**Table 3.** Levels of starch and total soluble sugars (TSS) in the dry matter of sweet potato roots from the different genotypes studied and their yields per hectare.

| Genotype | Starch (%) | TSS (%) | Starch (t ha$^{-1}$) | TSS (t ha$^{-1}$) |
|---|---|---|---|---|
| Batata Mandioca | 49.37 ± 1.69$^{b}$ | 4.25 ± 2.03$^{a}$ | 3.87 ± 0.97$^{b}$ | 0.34 ± 0.20$^{a}$ |
| Brazlândia Branca | 54.75 ± 7.76$^{a}$ | 2.34 ± 1.72$^{b}$ | 1.50 ± 0.90$^{b}$ | 0.05 ± 0.02$^{b}$ |
| Brazlândia Rosada | 57.05 ± 1.48$^{a}$ | 3.25 ± 1.37$^{b}$ | 3.52 ± 1.90$^{b}$ | 0.22 ± 0.18$^{b}$ |
| Cambraia | 53.66 ± 0.48$^{a}$ | 2.18 ± 0.82$^{b}$ | 2.11 ± 0.43$^{b}$ | 0.08 ± 0.03$^{b}$ |
| Cariru Vermelha | 55.71 ± 2.65$^{a}$ | 4.08 ± 0.90$^{a}$ | 4.94 ± 1.29$^{a}$ | 0.37 ± 0.12$^{a}$ |
| Marmel | 44.39 ± 12.15$^{c}$ | 2.78 ± 0.23$^{b}$ | 2.92 ± 1.60$^{b}$ | 0.17 ± 0.04$^{b}$ |
| Palmas | 52.72 ± 0.88$^{b}$ | 5.45 ± 1.57$^{a}$ | 2.65 ± 1.30$^{b}$ | 0.25 ± 0.10$^{a}$ |
| Princesa | 53.04 ± 0.74$^{b}$ | 3.31 ± 0.96$^{b}$ | 2.91 ± 0.57$^{b}$ | 0.18 ± 0.05$^{b}$ |
| Tomba Carro I | 56.60 ± 0.31$^{a}$ | 3.23 ± 0.80$^{b}$ | 5.45 ± 1.24$^{a}$ | 0.30 ± 0.05$^{a}$ |
| UFVJM 01 | 51.56 ± 1.88$^{b}$ | 2.66 ± 0.52$^{b}$ | 2.92 ± 1.70$^{b}$ | 0.16 ± 0.11$^{b}$ |
| UFVJM 04 | 51.02 ± 0.94$^{b}$ | 3.86 ± 1.98$^{a}$ | 2.93 ± 1.95$^{b}$ | 0.21 ± 0.14$^{b}$ |
| UFVJM 06 | 50.25 ± 1.05$^{b}$ | 3.75 ± 0.74$^{a}$ | 2.94 ± 1.33$^{b}$ | 0.23 ± 0.13$^{b}$ |
| UFVJM 14 | 56.33 ± 1.34$^{a}$ | 3.94 ± 0.72$^{a}$ | 3.26 ± 2.22$^{b}$ | 0.21 ± 0.13$^{b}$ |
| UFVJM 20 | 53.70 ± 0.53$^{a}$ | 2.54 ± 0.57$^{b}$ | 2.23 ± 0.65$^{b}$ | 0.11 ± 0.05$^{b}$ |
| UFVJM 21 | 56.82 ± 1.13$^{a}$ | 2.15 ± 0.11$^{b}$ | 5.27 ± 1.79$^{a}$ | 0.20 ± 0.07$^{b}$ |
| UFVJM 23 | 54.03 ± 0.73$^{a}$ | 1.61 ± 0.69$^{b}$ | 2.57 ± 0.73$^{b}$ | 0.07 ± 0.02$^{b}$ |
| UFVJM 28 | 59.05 ± 1.53$^{a}$ | 2.79 ± 0.51$^{b}$ | 6.56 ± 1.56$^{a}$ | 0.32 ± 0.13$^{a}$ |
| UFVJM 45 | 56.47 ± 1.27$^{a}$ | 4.38 ± 0.18$^{a}$ | 2.02 ± 0.65$^{b}$ | 0.16 ± 0.05$^{b}$ |
| UFVJM 46 | 61.21 ± 0.87$^{a}$ | 3.80 ± 0.66$^{a}$ | 2.90 ± 0.89$^{b}$ | 0.18 ± 0.04$^{b}$ |
| UFVJM 48 | 56.18 ± 2.50$^{a}$ | 2.72 ± 0.37$^{b}$ | 2.94 ± 1.08$^{b}$ | 0.15 ± 0.06$^{b}$ |
| Mean | 54.20 | 3.25 | 3.32 | 0.20 |
| CV (%) | 6.23 | 32.39 | 39.33 | 49.37 |

Means followed by the same lower case letter in the columns do not differ by the Scott-Knott test at $p < 0.05$.

**Table 4.** Hemicellulose (HC), cellulose (CL), lignin (LG) and total soluble sugars (TSS) in the dry matter of branches from the different sweet potato genotypes.

| Genotype | HC (%) | CL (%) | LG (%) | TSS (%) |
|---|---|---|---|---|
| Batata Mandioca | 12.38 ± 2.36$^{a}$ | 8.21 ± 3.72$^{a}$ | 1.77 ± 0.49$^{a}$ | 0.43 ± 0.01d |
| Brazlândia branca | 11.71 ± 1.48$^{a}$ | 9.33 ± 1.22$^{a}$ | 2.26 ± 0.28$^{a}$ | 1.60 ± 0.05$^{a}$ |
| Brazlandia rosada | 11.92 ± 2.25$^{a}$ | 9.01 ± 2.08$^{a}$ | 3.11 ± 2.01$^{a}$ | 0.97 ± 0.03$^{c}$ |
| Cambraia | 14.32 ± 4.37$^{a}$ | 8.01 ± 1.85$^{a}$ | 2.46 ± 0.79$^{a}$ | 1.33 ± 0.03$^{c}$ |
| Cariru Vermelha | 13.79 ±3.60$^{a}$ | 7.24 ± 4.01$^{a}$ | 2.04 ± 0.29$^{a}$ | 1.12 ± 0.04$^{c}$ |
| Marmel | 14.96 ± 3.02$^{a}$ | 10.19 ± 3.71$^{a}$ | 3.05 ± 2.14$^{a}$ | 0.80 ± 0.03$^{c}$ |
| Palmas | 14.06 ± 2.29$^{a}$ | 7.96 ± 5.02$^{a}$ | 3.29 ± 0.66$^{a}$ | 0.79 ± 0.06$^{c}$ |
| Princesa | 13.83 ± 3.90$^{a}$ | 7.98 ± 2.81$^{a}$ | 4.04 ± 3.29$^{a}$ | 1.05 ± 0.08$^{c}$ |
| Tomba Carro I | 14.60 ± 3.47$^{a}$ | 6.43 ± 3.01$^{a}$ | 3.54 ± 2.70$^{a}$ | 1.99 ± 0.14$^{a}$ |
| UFVJM 01 | 11.30 ± 2.36$^{a}$ | 6.08 ± 2.00$^{a}$ | 2.44 ± 0.37$^{a}$ | 1.31 ± 0.04$^{c}$ |
| UFVJM 04 | 14.09 ± 3.53$^{a}$ | 8.49 ± 2.00$^{a}$ | 2.30 ± 0.66$^{a}$ | 0.64 ± 0.02$^{c}$ |
| UFVJM 06 | 16.14 ± 5.25$^{a}$ | 10.11 ± 2.84$^{a}$ | 2.85 ± 0.96$^{a}$ | 0.61 ± 0.03$^{c}$ |
| UFVJM 14 | 13.53 ± 2.23$^{a}$ | 11.18 ± 6.17$^{a}$ | 2.16 ± 1.05$^{a}$ | 0.77 ± 0.04$^{c}$ |
| UFVJM 20 | 14.91 ± 1.47$^{a}$ | 9.73 ± 4.43$^{a}$ | 2.51 ± 0.94$^{a}$ | 0.73 ± 0.08$^{c}$ |
| UFVJM 21 | 12.94 ± 2.47$^{a}$ | 8.61 ± 1.97$^{a}$ | 2.63 ± 0.68$^{a}$ | 0.72 ± 0.06$^{c}$ |
| UFVJM 23 | 8.91 ± 2.65$^{a}$ | 9.86 ± 3.66$^{a}$ | 2.41 ± 0.37$^{a}$ | 0.85 ± 0.04$^{c}$ |
| UFVJM 28 | 13.22 ± 3.32$^{a}$ | 11.19± 2.46$^{a}$ | 2.30 ± 0.53$^{a}$ | 1.29 ± 0.08$^{c}$ |
| UFVJM 45 | 17.47 ± 1.72$^{a}$ | 9.12 ± 2.00$^{a}$ | 2.99 ± 0.85$^{a}$ | 1.29 ± 0.28$^{b}$ |
| UFVJM 46 | 15.81 ± 2.97$^{a}$ | 12.46 ± 4.25$^{a}$ | 2.29 ± 0.93$^{a}$ | 1.31 ± 0.05$^{c}$ |

**Table 4.** Contd.

| | | | | |
|---|---|---|---|---|
| UFVJM 48 | 14.64 ± 0.85[a] | 7.08 ± 3.10[a] | 1.50 ± 0.80[a] | 1.06 ± 0.02[c] |
| Mean (%) | 13.73 | 8.9 | 2.61 | 1.06 |
| CV (%) | 22.16 | 32.54 | 48.23 | 10.52 |

Means followed by the same lower case letter in the columns do not differ by the Scott-Knott test at $p < 0.05$.

**Table 5.** Productivity of hemicellulose (HC), cellulose (CL) and total soluble sugars (TSS) in the dry matter of branches from different sweet potato genotypes.

| Genotypes | HC (t ha$^{-1}$) | CL (t ha$^{-1}$) | TSS (t ha$^{-1}$) |
|---|---|---|---|
| Batata Mandioca | 0.32 ± 0.18[c] | 0.17 ± 0.05[b] | 0.011 ± 0.005[d] |
| Brazlândia branca | 0.26 ± 0.14[c] | 0.21 ± 0.12[b] | 0.035 ± 0.007[c] |
| Brazlândia rosada | 0.35 ± 0.05[c] | 0.27 ± 0.10[b] | 0.028 ± 0.006[c] |
| Cambraia | 0.31 ± 0.12[c] | 0.17 ± 0.07[b] | 0.029 ± 0.003[c] |
| Cariru Vermelha | 0.35 ± 0.08[c] | 0.20 ± 0.16[b] | 0.029 ± 0.011[c] |
| Marmel | 0.27 ± 0.06[c] | 0.19 ± 0.10[b] | 0.014 ± 0.005[d] |
| Palmas | 0.26 ± 0.08[c] | 0.13 ± 0.07[b] | 0.015 ± 0.005[d] |
| Princesa | 0.32 ± 0.09[c] | 0.17 ± 0.05[b] | 0.024 ± 0.009[c] |
| Tomba Carro I | 0.50 ± 0.12[b] | 0.21 ± 0.11[b] | 0.067 ± 0.021[a] |
| UFVJM 01 | 0.35 ± 0.07[c] | 0.19 ± 0.07[b] | 0.041 ± 0.008[b] |
| UFVJM 04 | 0.30 ± 0.13[c] | 0.18 ± 0.09[b] | 0.014 ± 0.004[d] |
| UFVJM 06 | 0.51 ± 0.13[b] | 0.31 ± 0.04[b] | 0.019 ± 0.002[d] |
| UFVJM 14 | 0.45 ± 0.25[a] | 0.37 ± 0.25[b] | 0.025 ± 0.002[c] |
| UFVJM 20 | 0.33 ± 0.14[c] | 0.19 ± 0.06[b] | 0.016 ± 0.002[d] |
| UFVJM 21 | 0.38 ± 0.09[c] | 0.25 ± 0.08[b] | 0.021 ± 0.001[c] |
| UFVJM 23 | 0.26 ± 0.02[c] | 0.16 ± 0.06[b] | 0.014 ± 0.001[d] |
| UFVJM 28 | 0.74 ± 0.25[a] | 0.62 ± 0.26[a] | 0.073 ± 0.005[a] |
| UFVJM 45 | 0.64 ± 0.16[a] | 0.33 ± 0.08[b] | 0.047 ± 0.005[b] |
| UFVJM 46 | 0.65 ± 0.06[a] | 0.52 ± 0.21[a] | 0.055 ± 0.009[b] |
| UFVJM 48 | 0.23 ± 0.05[c] | 0.11 ± 0.06[b] | 0.017 ± 0.006[d] |
| Mean (%) | 0.38 | 0.25 | 0.03 |
| CV (%) | 30.83 | 41.37 | 26.99 |

Means followed by the same lower case letter in the columns do not differ by the Scott-Knott test at $p < 0.05$.

were obtained for the Tomba Carro I and UFVJM 28 genotypes, respectively. The highest productivity of total carbohydrates (cellulose, hemicellulose and total soluble sugars) in the aerial portion by planted area, 1.4 t ha$^{-1}$, was observed for UFVJM 28.

The estimated ethanol yields per hectare obtainable from the Cariru Vermelha, UFVJM 21, Tomba Carro I and UFVJM 28 genotypes varied from 3810 to 4940 L ha$^{-1}$. These values are higher than those achieved for the production of ethanol from maize, the main starchy raw material used by the biofuel alcohol industry, with a productivity between 2800 and 3800 L ha$^{-1}$ (Duvernay et al., 2013; Ziska et al., 2009).

The productivity of sweet potatoes can vary greatly with the chosen genotypes, cultivation and soil and climatic conditions. Santana et al. (2013) identified sweet potato genotypes that were grown in Tocantins, a semi-humid tropical region of Brazil, yielded up to 181.6 L of ethanol per ton of roots and furnished a productivity of 3122 to 10007 L ha$^{-1}$. Waluyo et al. (2015) worked with sweet potato clones in Indonesia and obtained estimated ethanol yields ranging from 3320.1 to 5364.5 L ha$^{-1}$ from the roots. Oliveira et al. (2017) estimated ethanol productivities from 2667 to 4379 L ha$^{-1}$ for six sweet potato genotypes cultivated in Sergipe state, a tropical semiarid region of Brazil.

In addition to the production of ethanol estimated from the use of roots, the best projection for alcohol yield obtained from the branches, 995 L ha$^{-1}$, was calculated for the UFVJM 28 genotype. Considering the projections

**Table 6.** Theoretical projection of ethanol yield from the roots and branches of different sweet potato genotypes.

| Genotype | Ethanol from roots (L ha$^{-1}$) | Ethanol from branches (L ha$^{-1}$) | Total Ethanol (L ha$^{-1}$) |
|---|---|---|---|
| Batata Mandioca | 3030 ± 810$^{b}$ | 370 ± 50$^{j}$ | 3400 ± 800$^{c}$ |
| Brazlândia Branca | 1120 ± 660$^{b}$ | 330 ± 80$^{l}$ | 1450 ± 650$^{c}$ |
| Brazlândia Rosada | 2690 ± 1480$^{b}$ | 440 ± 80$^{h}$ | 3130 ± 1470$^{c}$ |
| Cambraia | 1580 ± 310$^{b}$ | 350 ± 40$^{k}$ | 1930 ± 310$^{c}$ |
| Cariru Vermelha | 3810 ± 990$^{a}$ | 390 ± 40$^{i}$ | 4200 ± 980$^{b}$ |
| Marmel | 2230 ± 1180$^{b}$ | 320 ± 40$^{l}$ | 2550 ± 1190$^{c}$ |
| Palmas | 2080 ± 980$^{b}$ | 290 ± 30$^{m}$ | 2370 ± 990$^{c}$ |
| Princesa | 2220 ± 410$^{b}$ | 350 ± 10$^{k}$ | 2570 ± 420$^{c}$ |
| Tomba Carro I | 4130 ± 900$^{a}$ | 510 ± 20$^{f}$ | 4640 ± 900$^{b}$ |
| UFVJM 01 | 2210 ± 1310$^{b}$ | 380 ± 40$^{i}$ | 2590 ± 1300$^{c}$ |
| UFVJM 04 | 2250 ± 1490$^{b}$ | 350 ± 60$^{k}$ | 2600 ± 1490$^{c}$ |
| UFVJM 06 | 2270 ± 1040$^{b}$ | 600 ±40$^{d}$ | 2870 ± 1030$^{c}$ |
| UFVJM 14 | 2500 ± 1680$^{b}$ | 580 ± 190$^{e}$ | 3080 ± 1690$^{c}$ |
| UFVJM 20 | 1680 ± 310$^{b}$ | 400 ± 80$^{i}$ | 2080 ± 510$^{c}$ |
| UFVJM 21 | 3930 ± 1330$^{a}$ | 460 ± 60$^{g}$ | 4390 ± 1320$^{b}$ |
| UFVJM 23 | 1900 ± 520$^{b}$ | 300 ± 10$^{m}$ | 2200 ± 520$^{c}$ |
| UFVJM 28 | 4940 ± 1210$^{a}$ | 995 ± 20$^{a}$ | 5930 ± 1200$^{a}$ |
| UFVJM 45 | 1560 ± 500$^{b}$ | 690 ± 40$^{c}$ | 2250± 500$^{c}$ |
| UFVJM 46 | 2210 ± 660$^{b}$ | 840 ± 150$^{b}$ | 3050 ± 660$^{c}$ |
| UFVJM 48 | 2220 ± 820$^{b}$ | 240 ± 30n | 2460 ± 830$^{c}$ |
| Méan | 2520 | 450 | 2980 |
| CV (%) | 39.20 | 35.53 | 33.17 |

Means followed by the same lower case letter in the columns do not differ by the Scott-Knott test at $p < 0.05$.

for the yield of ethanol from the roots and branches obtained with the UFVJM 28 genotype, a productivity of 5930 L ha$^{-1}$ in a six-month cycle was estimated (Table 6). In the best scenario, the estimated production for this genotype could reach 11860 L ha$^{-1}$ year$^{-1}$. The productivity of sugarcane can vary from 40 to 70 tons per hectare, depending on the country. Some specific varieties are able to reach 150 tons of sugarcane per hectare under experimental conditions (Morais et al., 2015). Considering a mean of 82 L of bioethanol per ton of processed sugarcane (Boddey et al., 2008), a maximum of 3279 to 12300 L ha$^{-1}$ year$^{-1}$ could be produced. The average ethanol yield per hectare in Brazil is 6280 L ha$^{-1}$ year$^{-1}$ (Boddey et al., 2008). This ethanol productivity is lower than the highest values estimated in this study.

In addition to the carbohydrate content present in the roots and branches of the genotypes, the digestibility of starch or cellulose present in these biomasses is relevant to the choice of biomass or technology to be used in the saccharification process of polysaccharides. The digestibility experiment using dried and crushed roots of sweet potato genotypes (Table 7) indicated a digestibility between 58.2 and 91.2%. The highest digestibility values, between 79.9 and 91.2%, were observed for the Brazlândia Rosada, Princesa, UFVJM 14, UFVJM 28, and UFVJM 45 genotypes. Whereas the digestibility trial was undersized to allow differentiation between biomasses, the outstanding clones are extremely susceptible to enzymatic saccharification, an intrinsic step in the production of ethanol from starchy raw materials.

The digestibility assay of the cellulosic fraction of the dry matter from the branches of the sweet potato genotypes selected was based on the estimated yield of ethanol (Table 6) or the compositional characteristics (Table 4) provided before the pretreatment with dilute inorganic acid. After the acid pretreatment, the percentage of cellulose in the insoluble material recovered increased (Table 8) as a natural consequence of the removal of the hemicellulose fraction (Carvalho et al., 2015). After enzymatic digestion of the pretreated material, the cellulose content in the recovered insoluble material decreased by different degrees that depended on the genotype (Table 8). The insoluble residue recovered after enzymatic digestion of the branches from the Palmas genotype contained the smallest amount of cellulose (Table 8). The digestibility assay of each material, which was based on the amount of glucose released after enzymatic action, yielded higher values for Marmel, Palmas, and UFVJM 28 genotypes (Table 8), whose digestibility values were close to 40%. The UFVJM 46 genotype, despite having the highest yield of branches,

**Table 7.** Digested starch and enzymatic digestibility of starch in the roots from the sweet potato genotypes.

| Genotype | Digested starch (% g/g) | Digestibility (%) |
|---|---|---|
| Batata Mandioca | 34.45 ± 2.84[b] | 69.76 ± 3.35[c] |
| Brazlândia Branca | 39.20 ± 4.68[b] | 71.60 ± 7.01[c] |
| Brazlândia Rosada | 46.35 ± 4.50[a] | 81.24 ± 3.97[b] |
| Cambraia | 37.32 ± 2.77[b] | 69.55 ± 5.02[d] |
| Cariru Vermelha | 38.06 ± 3.47[b] | 68.33 ± 2.60[d] |
| Marmel | 33.62 ± 5.50[b] | 75.73 ± 1.96[c] |
| Palmas | 34.34 ± 4.83[b] | 65.13 ± 7.47[d] |
| Princesa | 48.40 ± 0.32[a] | 91.25 ± 1.46[a] |
| Tomba Carro I | 36.54 ± 2.26[b] | 64.56 ± 3.79[d] |
| UFVJM 01 | 38.00 ± 2.83[b] | 73.70 ± 3.20[c] |
| UFVJM 04 | 30.56 ± 2.97[c] | 59.90 ± 4.72[e] |
| UFVJM 06 | 29.26 ± 4.91[c] | 58.22 ± 2.47[e] |
| UFVJM 14 | 45.00 ± 3.20[a] | 79.88 ± 6.24[b] |
| UFVJM 20 | 35.10 ± 2.18[b] | 65.36 ± 4.63[d] |
| UFVJM 21 | 35.32 ± 3.94[b] | 62.16 ± 4.00[e] |
| UFVJM 23 | 36.19 ± 4.02[b] | 66.97 ± 7.51[d] |
| UFVJM 28 | 49.31 ± 6.79[a] | 83.51 ± 6.90[b] |
| UFVJM 45 | 46.70 ± 3.55[a] | 82.69 ± 2.48[b] |
| UFVJM 46 | 36.71 ± 2.03[b] | 59.97 ± 3.99[e] |
| UFVJM 48 | 42.82 ± 5.33[a] | 76.21 ± 6.22[c] |
| Mean (%) | 38.66 | 73.81 |
| CV (%) | 9.47 | 6.81 |

Means followed by the same lower case letter in the columns do not differ by the Scott-Knott test at $p < 0.05$.

**Table 8.** Content of cellulose after acid pretreatment ($CL_{PT}$), cellulose content after enzymatic saccharification ($CL_{SC}$) and enzymatic digestibility (ED) from branches of selected sweet potato genotypes.

| Genotype | $CL_{PT}$ (%) | $CL_{SC}$ (%) | ED (%) |
|---|---|---|---|
| Marmel | 23.72 ± 0.28[b] | 14.25 ± 0.01[b] | 39.60 ± 3.20[a] |
| Palmas | 19.64 ± 0.33[c] | 2.09 ± 0.01[e] | 42.41 ± 21.01[a] |
| UFVJM 14 | 26.98 ± 0.91[a] | 13.79 ± 0.01[c] | 28.63 ± 1.33[b] |
| UFVJM 28 | 27.09 ± 0.72[a] | 4.80 ± 0.10[d] | 41.06 ± 6.60[a] |
| UFVJM 46 | 25.00 ± 0.29[c] | 20.31 ± 0.01[a] | 14.24 ± 2.71[b] |
| UFVJM 48 | 21.00 ± 1.32[c] | 14.18 ± 0.01[b] | 18.36 ± 4.28[b] |
| Mean (%) | 23.90 | 11.57 | 30.72 |
| CV (%) | 3.34 | 0.37 | 30.47 |

Means followed by the same lower case letter in the columns do not differ by the Scott-Knott test at $p < 0.05$.

along with the UFVJM 28 genotype, was recalcitrant to enzymatic attack and its digestibility was only 14.2%.

## Conclusion

The genetic variability of the evaluated genotypes was marked by differences in the agricultural productivity and the carbohydrate contents. UFVJM 28 was shown to be the most productive sweet potato genotype in terms of starch, total soluble sugars, cellulose and hemicellulose quantities produced per planted area. The highest digestibilities for the starch contained in the roots and for the cellulose contained in the branches were also obtained for the UFVJM 28 genotype. These characteristics resulted in a higher estimated ethanol yield, 5930 L

$ha^{-1}$, in a 180-day production cycle, or 11860 L $ha^{-1}$ $year^{-1}$ if two contiguous cycles were considered. The possibility of utilizing the branches of the sweet potatoes represented an increase of up to 20% in the estimated production of bioethanol. Disregarding the cost of producing the ethanol from sweet potatoes, which was not evaluated here, the genotype highlighted earlier seems to be as promising, or more promising, than corn or sugar cane when they began to be used as raw material for fuel ethanol production.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENTS

Financial support was furnished by the Fundação de Amparo de Pesquisa do Estado de Minas Gerais (FAPEMIG). An undergraduate research scholarship was granted by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ). D. L. Nelson was the recipient of a PVNS fellowship furnished by the Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior (CAPES).

### REFERENCES

Aditiya HB, Mahlia TMI, Chong WT, Nur H, Sebayang AH (2016). Second generation bioethanol production: A critical review. Renew Sust. Energ. Rev. 66:631-653.

Adu-Kwarteng E, Sakyi-Dawson EO, Ayernor GS, Truong V-D, Shih FF, Daigle K (2014). Variability of Sugars in Staple-Type Sweet Potato (*Ipomoea batatas*) Cultivars: The Effects of Harvest Time and Storage. Int. J. Food Prop. 17:410-420.

Andrade Júnior VC de, Viana DJS, Pinto NA, Ribeiro KG, Pereira RC, Neiva IP, Azevedo AM, Andrade PC de R (2012). Características produtivas e qualitativas de ramas e raízes de batata-doce. Hortic. Bras. 30:584-589.

Azevedo AM, Andrade Júnior VC, Fernendes JSC, Pedrosa CE, Oliveira CM (2015). Desempenho agronômico e parâmetros genéticos em genótipos de batata-doce. Hortic. Bras. 33:084-090.

Boddey RM, Soares LHB, Alves BJR, Urquiaga S (2008). Bio-Ethanol Production in Brazil. In: Pimentel, D, ed. Biofuels, Solar and Wind as Renewable Energy Systems. Springer Netherlands, Heidelberg, Germany. pp. 321-356.

Carvalho DM, Sevastyanova O, Penna LS, Silva BP da, Lindström ME, Colodette JL (2015). Assessment of chemical transformations in eucalyptus, sugarcane bagasse and straw during hydrothermal, dilute acid, and alkaline pretreatments. Ind. Crops Prod. 73:118-126.

Dangler JM, Locascio SJ, Halsey LH (1984). Sweet potato for biomass. *Biomass* 4:253-261.

Duvernay WH, Chinn MS, Yencho GC (2013). Hydrolysis and fermentation of sweet potatoes for production of fermentable sugars and ethanol. Ind. Crops Prod. 42:527-537.

FAO (2016). Food and Agriculture Organization of the United Nations - Statistics Division. Available in: http://www.fao.org/faostat/en/#data/QC. Accessed Sept 20, 2016.

Filgueira FAR (2008). Novo manual de olericultura: agrotecnologia moderna na produção e comercialização de hortaliças.' (Ed. UFV: Viçosa)

Masiero SS, Peretti A, Trierweiler LF, Trierweiler JO (2014). Simultaneous cold hydrolysis and fermentation of fresh sweet potato. Biomass Bioenergy 70:174-183.

McCready RM, Guggolz J, Silviera V, Owens HS (1950). Determination of Starch and Amylose in Vegetables. Anal. Chem. 22:1156-1158.

Miller GL (1959) Use of Dinitrosalicylic Acid Reagent for Determination of Reducing Sugar. Anal. Chem. 31:426-428.

Morais LK, Aguiar MS, Albuquerque e Silva P, Câmara TMM, Cursi DE, Júnior ARF, Chapola RG, Carneiro MS, Bespalhok Filho JC (2015) Breeding of Sugarcane. 'Industrial Crops'. (Eds VMV Cruz, DA Dierig) (Springer New York: New York, NY) pp. 29-42.

Oliveira MAS, Blank AF, Alves RP, Arrigoni-Blank MF, Maluf WR, Fernandes RPM (2017). Performance of sweet potato clones for bioethanol production in different cultivation periods. Hortic. Bras. 35:057-062.

Parmar A, Hensel O, Sturm B (2017). Post-harvest handling practices and associated food losses and limitations in the sweetpotato value chain of southern Ethiopia. NJAS Wagen. J. Life Sci. 80:65-74.

Ray RC, Tomlins KI (2010). Sweet potato: post-harvest aspects in food, feed and industry. Nova Science Publ: New York.

Saini JK, Saini R, Tewari L (2015). Lignocellulosic agriculture wastes as biomass feedstocks for second-generation bioethanol production: concepts and recent developments. 3 Biotech 5:337-353.

Santana WR, Martins LP, Silveira MA, Santos WF, Gonçalves RC, Souza FR, Resplandes GRS, Lima MM (2013). Identificação agronômica de genótipos de batata-doce em banco de germoplasma para fins industriais de etanol carburante. Tecnol. Ciên. Agropec. 7:31-34.

Shumbusha D, Tusiime G, Edema R, Gibson P, Adipala E, Mwanga ROM (2014). Inheritance of root dry matter content in sweet potato. Afr. Crop Sci. J. 22:69-78.

Suarez MH, Hermández AIM, Galdón BR, Rodríguez LH, Cabrera CEM, Mesa DR, Rodríguez-Rodríguez EM, Romero CD (2016). Application of multidimensional scaling technique to diferentiate sweet potato (*Ipomoea batatas* (L.) Lam) cultivars according to their chemical composition. J. Food Compost. Anal. 46:43-49.

Trinder P (1969) Determination of blood glucose using an oxidase-peroxidase system with a non-carcinogenic chromogen. J. Clin. Pathol. 22:158-161.

van der Weijde T, Torres AF, Dolstra O, Dechesne A, Visser RGF, Trindade LM (2016). Impact of different lignin fractions on saccharification efficiency in diverse species of the bioenergy crop Miscanthus. Bioenergy Res. 9:146-156.

Van Soest PJ (1967). Use of detergents in the analyses of fibrous feeds. 2. A rapid method for the determination of fiber and lignin. J. Assoc. Off. Anal. Chem. 46:829-835.

Waluyo B, Roosda AA, Istifadah N, Ruswandi D, Karuniawan A (2015). Identification of fifty sweetpotato (*Ipomoea batatas* (L.) Lam.) promising clones for bioethanol raw materials. Energy Procedia 65:22-28.

Widodo Y, Wahyuningsih S, Ueda A (2015). Sweet potato production for bio-ethanol and food related industry in Indonesia: Challenges for sustainability. Procedia Chem. 14:493-500.

Ziska LH, Runion GB, Tomecek M, Prior SA, Torbet HA, Sicher R (2009). An evaluation of cassava, sweet potato and field corn as potential carbohydrate sources for bioethanol production in Alabama and Maryland. Biomass Bioenergy 33:1503-1508.