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Postharvest quality of two sweet potato cultivars submitted to different harvest ages

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ABSTRACT

The quality of sweet potato roots is influenced by factors which precede harvest. Thus, the aim of this study was to correctly determine the harvest point and study the postharvest quality of two sweet potato cultivars harvested at different ages. The experiment was carried out at Universidade Federal de Roraima. The plants were grown from April to August, during rainy season, 2020. The harvest was carried out at 80, 95, 110, 125 and 140 days after planting (DAP). The tuberous roots were cleaned and the physicochemical traits of the pulp and peel were evaluated. Soluble solids, titratable acidity and SS/AT ratio were observed in greater quantity in the cultivar BD-02. The luminosity and chroma of the peel of the sweet potato roots were more intense in the cultivar BD-01 and the opposite was observed when characterizing the pulp of this cultivar. At 110 DAP, we verified the highest levels of reducing sugars and chroma of the peel, as well as lower values for the chroma of the pulp and °H of the peel. Thus, according to the results presented above, especially in relation to carbohydrate metabolism, productivity and dry matter accumulation, the cultivar BD-02, harvested at 110 DAP, showed the best postharvest traits under the experimental conditions presented in this study.

Keywords: *Ipomoea batatas*, convolvulaceae, physicochemical qualities, functional food.

RESUMO

Qualidade pós-colheita de duas cultivares de batata-doce submetidas a cinco idades de colheita

A qualidade das raízes de batata-doce é influenciada por fatores que antecedem a colheita. Assim, objetivou-se na execução deste trabalho a correta determinação do ponto de colheita e o estudo da qualidade pós-colheita de duas cultivares de batata-doce colhidas em diferentes idades de colheita. O experimento foi realizado nas dependências da Universidade Federal de Roraima. As plantas foram cultivadas de abril a agosto, durante o período chuvoso de 2020. A colheita foi realizada aos 80, 95, 110, 125 e 140 dias após o plantio (DAP). As raízes foram higienizadas e em seguida foram avaliadas as características físico-químicas da polpa e casca. Os sólidos solúveis, acidez titulável e relação SS/AT foram observados em maior quantidade na cultivar BD-02. A luminosidade e croma da casca das raízes tuberosas de batata-doce foram mais intensas na cultivar BD-01 e o inverso foi observado na caracterização da polpa da cultivar BD-01. Aos 110 dias após plantio (DAP) observou-se os maiores teores de açúcares redutores e croma da casca; menores valores de croma da polpa e °H da casca. Dessa forma, segundo os resultados acima apresentados, especialmente em função do metabolismo dos carboidratos e a observação da produtividade e o acúmulo de matéria seca, a cultivar BD-02, colhida aos 110 DAP, apresentou as melhores características pós-colheita nas condições experimentais aqui apresentadas.

Palavras-chave: *Ipomoea batatas*, convolvulaceae, qualidades físico-químicas, potencial funcional.

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Sweet potato (*Ipomoea batatas*), with a national production of about 850 thousand tons, presents an average productivity estimated in 14.2 t ha^{-1}. The main production regions of this vegetable in Brazil are the Northeast (317.3 thousand tons), South (252.9 thousand tons) and Southeast (214.0 thousand tons). The state of Rio Grande do Sul, showing a production of 175.0 thousand tons, is the largest producer, followed by São Paulo, 140.7 thousand tons. The Northern region, according to IBGE (2020), shows a production which does not exceed 20 thousand tons, which is carried out by native, indigenous and riverside populations: Roraima with an average production of 23.4 t ha^{-1} and the Amazon with 11.9 t ha^{-1} are the largest producers; this fact is due to some of the researches performed by local Institutions like EMBRAPA and Federal Universities. (IBGE, 2020).

This vegetable has becoming popular among the rural producers all over the world, due to its rusticity, being easy to adapt to the climate, showing shortterm production and drought tolerance (Andrade Júnior *et al.*, 2012; Silva *et al.*, 2015). Sweet potato tuberous roots are classified as functional food, due to its low glycemic index, high contents of B vitamins and calcium, being used in human and animal nutrition (Leonel & Cereda, 2002). Just like arrowroots (*Maranta arundinacea*) and cassava (*Manihot esculenta*), sweet potato is an important source of starch in human nutrition, in food, chemical and textile industries.

Propagation occurs through vines, usually from local productions, often not adapted to the growing region, which together with other phytotechnical factors, such as quality of propagules and inadequate nutrition, can result in low productivity index (Amaro *et al.,* 2019). Moreover, the physicochemical traits of tuberous roots are impaired when the management during the sweet potato cultivation is inadequate, such as harvest without taking into account tuberization period, the cultivation region and its meteorological conditions (Albuquerque *et al*., 2018).

Little information on physicochemical traits, varieties, regional adaptation of the crop under different production conditions, metabolic behavior in the field as well as in postharvest, variation and understanding on phenological quality attributes can be found in literature. This fact represents important barriers to sweet potato production. So, a cultivar can be productive and at the same time show nutritional low quality, consequently little demand for these tuberous roots can be verified.

Thus, the aim of this study was to determine the right harvest time and evaluate the postharvest quality of two sweet potato cultivars, harvested at different ages (80, 95 110, 125 and 140 DAP), grown in savannah of Roraima.

MATERIAL AND METHODS

The experiment was carried out at Universidade Federal de Roraima, Cauamé campus, Boa Vista-RR (75°16'35"S and 3°92'75"W). During the research the average minimum temperature was 26.6ºC and maximum 29.1ºC. The average daily radiation was 37.33 Kj/m^2 and the average rainfall 8.00 mm day^{-1}. These data were obtained using the daily evaluation in the local meteorological station.

The plants were grown under field conditions, during seven months. Three months for soil preparation and simultaneously vine multiplication in a protected environment, and five months for sweet potato management, from planting to harvest. The vines of the cultivars BD-01 and BD-02 were given by the producers, collected in the municipality of Boa Vista, Roraima, Brazil. According to Köppen, the climate of the region is Aw (Alvares *et al*., 2014), two very well-defined seasons, one rainy season (April-September) and a dry one (October-March) (Araújo *et al*., 2001). The soils at Cauamé campus (experimental area) are predominantly medium-textured, acid, showing low fertility. The chemical analysis of the soil fertility obtained before growing, on March 15, 2020, using simple random sampling at 0.20-m depth, showed the following results from nine collection points: pH (H_2O) = 4.4; $H^{+++}Al^{+++}$ = 2cmol$_c$ dm^{-3}; Ca^{++} = 0.7cmol$_c$ dm^{-3}; Mg^{++}= 0.3 cmol$_c$ dm^{-3}; P (Mehlich) = 8.1 mg dm^{-3}; K^+ = 0.08 cmol$_c$ dm^{-3}; organic matter = 10 g dm^{-3}; CTC = 3.08cmol$_c$ dm^{-3}; V = 35.06%. Cleaning and harrowing were carried out on April 1, 2020, followed by liming application of 2.5 t ha^{-1} of dolomitic limestone in the 0-20-cm deep soil layer. Chemical fertilization at planting was carried out on April 4, 2020, using 600 kg ha^{-1} of the formula 05-30-10 + 40 kg ha^{-1} of FTE BR-12, 15 days before planting the vines, mixing it with the windrowed soils, from 5 to 15 cm in depth. The top-dressing fertilization was carried out just once, 30 DAP of vines, applying 150 kg ha^{-1} of the NPK formula (20-00-20). The vines were produced in the experimental field at CCA-UFRR three months before the experiment installation. The vines were irrigated by micro-sprinkler tapes, with 0.8 KGF cm^2 flow and 15-cm spacing between sprinklers with two daily watering shift applications (morning and afternoon). Parent vines were produced to avoid advantages concerning vigor between the vines which were used in the establishment of the research.

The evaluated cultivars were BD-01, called by the producers "Roxinha" (abundant in the region) and BD-02, acquired from rural producers, due to its resistance to pests and good productivity (Figure 1), showing traits quite similar to Brazlândia roxa.

The experimental design used was randomized block, with four replicates, arranged in a 2 x 5 split plot scheme: the plots corresponded to sweet potato cultivars (BD-01 and BD-02); and, the

Figure 1. Visual characterization of sweet potato cultivars grown in savannah of Roraima, on the left cultivar BD-02 and on the right cultivar BD-01. Boa Vista, UFRR, 2020.

split-plots corresponded to harvest ages [80, 95, 110, 125 and 140 days after planting (DAP)]. Each experimental unit consisted of 1±0.150 kg of sweet potatoes, corresponding to about 4 to 5 units of the evaluated material.

Each block consisted of 38.4 m^2 (3.2 x 12.0 m), composed of ten experimental subplots of 8.0 m^2 (2.5 x 3.2 m), composed of 4 windrows, spaced 0.8 m, where five 0.3-m vines each were planted, taken from the plant tops, spaced 0.5 m, which corresponds to 20 plants per subplot and 25,000 plants ha^{-1}. Each experimental unit was composed of six central sweet potato plants of each subplot. The sweet potato vines were planted on May, 2020, during the rainy season (March to September), without irrigation supplementation. Incidence of pests and diseases, as well as weed management, were properly controlled according to the recommendation of work team, based on the study carried out by Silva *et al*. (1995).

Windrows were manually raised at 0.30-m height, with the aid of a hoe. We planted apical vines with leaves, harvested the day before and kept in the shade, showing eight to ten nodes, totaling a population of 100 plants per experimental plot. Plots and subplots were drawn through a random sample formulation, by the Office program, using the excel platform.

The plants were manually harvested at 80, 95, 110, 125 and 140 DAP. Disease-free roots, with no apparent damage, weighing between 150 and 400 g, were transported to the postharvest laboratory, at Escola Agrotécnica da Universidade Federal de Roraima – EAGRO-UFRR, being evaluated for the following postharvest traits:

a) Marketable and total root productivity, obtained from the direct weighing using an electronic scale, expressed in t/ha; b) Color, obtained evaluating the peel and pulp of raw sweet potatoes, in triplicates. The authors used the system L*, a* and b* of the International Commission of L'airclairage (CIEL), with two readings of the opposite sides in the middle region, with the aid of a colorimeter. Luminosity coordinate (L*), varies from zero (black) to 100 (white); C*, chroma, related to color intensity, ranges from zero (neutral or grayish colors) to 60 (vivid colors); and the hue angle (hº) which assumes a value of 0º for red, 90º for yellow, 180º for green and 270º for blue; c) Hydrogen potential (pH) was determined by direct reading of the crushed pulp with the use of a digital peagameter, calibrated at 4.0 and 7.0 buffer solution according to AOAC (2012); d) Titratable acidity was determined by titration with 0.1N NaOH solution and phenolphthalein indicator, expressed in g of citric acid/100 g of pulp, recommended by AOAC (2012); e) Soluble solids (SS) were determined using a digital refractometer (by reading), according to recommendations described by AOAC (2012), using macerated and homogenized pulp. The results were expressed in °Brix; f) SS/AT ratio was performed using total soluble solids/titratable acidity ratio (AOAC, 2012); g) Reducing and total sugars were evaluated using Lane-Eynon method, which is based on reducing a known volume of alkaline copper reagent (Fehling) to cuprous oxide. The results were expressed in percentage; h) Starch content was determined using Lane-Eynon method. Although starch does not present a reducing reaction, an energetic hydrolysis in a strongly acidic medium produces exclusively glucose, the result is expressed in percentage.

The obtained data were submitted to normality analysis (Shapiro-Wilk test), and then homogeneity of variance was evaluated using F-max test, followed by the variance analysis.

For qualitative variables, we used Tukey test at 5% probability, whereas for quantitative variables, when significant, unfolding and regression analyses were performed. The coefficients of the equations obtained in this study were tested by F test at 5% probability.

RESULTS AND DISCUSSION

The variance analysis, estimated by F test, showed significant differences between the cultivars for pH, soluble solids, titratable acidity and soluble solids ratio (Table 1). Considering this fact, the sweet potato cultivars showed significant difference for pH, 2.21%, in which BD-02 showed higher value, 6.34, whereas BD-01 showed lower value, 6.20. Therefore, both were classified as low-acid foods (>4.5). We can also consider that the results showed for the potatoes pH can be indirectly related to the tendency of titratable acidity to decrease over time, coinciding with the advance of plant physiological maturation. Thus, the lower pH of the tuberous roots of the cultivar BD-01 coincided with higher titratable acidity shown by this same cultivar, as well as higher pH observed in tuberous roots of cultivar BD-02 also coincided with the lower acidity observed.

Soluble solid content ranged from 9.40°Brix, in the cultivar BD-01, to 11.76°Brix, in the cultivar BD-02, showing that, despite the significant difference, both sweet potato cultivars showed adequate quality. According to Panja *et al*. (2016), the soluble solids can vary from 6.43 to 11.25°Brix.

In relation to SS/AT ratio, the

Table 1. pH, soluble solids (SS), titratable acidity (AT) and soluble solids/titratable acidity ratio (SS/AT) of two sweet potato cultivars grown in savannah of Roraima. Boa Vista, UFRR, 2020.

Cultivars	pH	Soluble solids (SS) (°Brix)	Titratable acidity (AT) (g of citric acid/100g)	SS/AT
BD-01	6.2b	9.40b	0.63a	14.92b
BD-02	6.3a	11.76a	0.45b	26.13a
Average	6.3	10.58	0.54	19.59
CV1 (%)	2.03	10.08	15.17	19.77
CV2 (%)	3.43	17.96	17.53	24.04

*Averages followed by the same lowercase letter in the column do not differ from each other, by F test (p≤0.05).

cultivar BD-02 obtained 80.06%, being superior to BD-01. In this context, Kalkmann (2011), studying the sweet potato cultivar Roxa comum, obtained 1.36 for SS/AT ratio, inferior to the obtained in this study; Soluble solids/titratable acidity ratio can be considered one of the most used traits to evaluate maturation index, in order to provide an appropriate concept of balance between these two variables, being even more representative than the isolated measurement of sugars or titratable acidity.

In relation to total and commercial productivity of the studied species (Figure 2B), we can conclude that the permanence of the plants in the field provided a positive linear effect for both evaluated parameters, so that the evaluated harvest ages, 80; 95; 110; 125; and 140 DAP presented respectively the following averages: total productivity 2,710; 7,240; 8,440; 14,860 and 16,650 kg ha^{-1} and commercial productivity 0.290; 3,050; 4,380; 10,350 and 12,120 kg ha^{-1}. This indicates that as harvest date is postponed, an increase in root productivity is noticed. The authors observed that the minimum total productivity was 2,710 kg ha^{-1} and the minimum commercial productivity was 0.290 kg ha^{-1} in harvest at 80 DAP. This result highlighted that these cultivars shall not be harvested at 80 DAP, when they are grown in savannah of Roraima, in the rainy season whithout irrigation. Dry mass content (Figure 2B) showed a significant decrease from 110 DAP. This can be linked to the intense metabolic activity in this period.

According to IBGE (2020), the Brazilian national average productivity of sweet potato roots was 14.2 t/ha and the state average productivity in Roraima, considerably higher than the national average, is 23.4 t/ha. The authors observed that the commercial productivity only surpassed the regional average, which is equivalent to 6.8 t/ha. Thus, we observed that the total productivity of sweet potato roots grown in savannah, state of Roraima, with conventional management and no irrigation, surpassed only the national average considering the harvest performed at 125 DAP (14.86 t/ha). Similarly, the commercial productivity of sweet potato roots harvested at 125 DAP (10.35 t/ha) only surpassed the regional average. We believe that the root productivity had been affected by temperature, associated with rainfall and solar radiation during the research. According to Villordon *et al*. (2010), these climatic elements influence highly the tuberous root productivity, especially in the beginning of tuberization, which occurrs from 40 to 70 DAP. When tuberization started, June 2020, the average maximum and minimum temperatures were 29.1ºC and 26.6ºC, respectively. Thus, after the beginning of tuberization, the productivity would be, directly, related to the capacity of the shoots in producing photoassimilates and translocate these photoassimilates to the tuberous roots (Villordon *et al*., 2010). So, the high levels of solar irradiation could have contributed positively to tuberous roots productivity. Moreover, in tuberization phase, the necessary rainfall is 500 mm, whereas for planting the average annual rainfall shall be from 750 to 1000 mm (Silva *et al*., 2015). During the research the temperature was appropriate for root tuberization, 26.9ºC (average). Rainfall decreased from June on, as well as some oscillations in solar radiation could be noticed. In general, the roots initiated tuberization during the months in which lower radiation and decreased rainfall were verified. This clearly explains the results obtained in this study and the data found in literature. Thus, these climatic factors, associated with a lack of irrigation, as mentioned by Mantovani *et al*. (2013), could have influenced negatively the commercial and total productivity of sweet potato roots cultivated in savannah of Roraima.

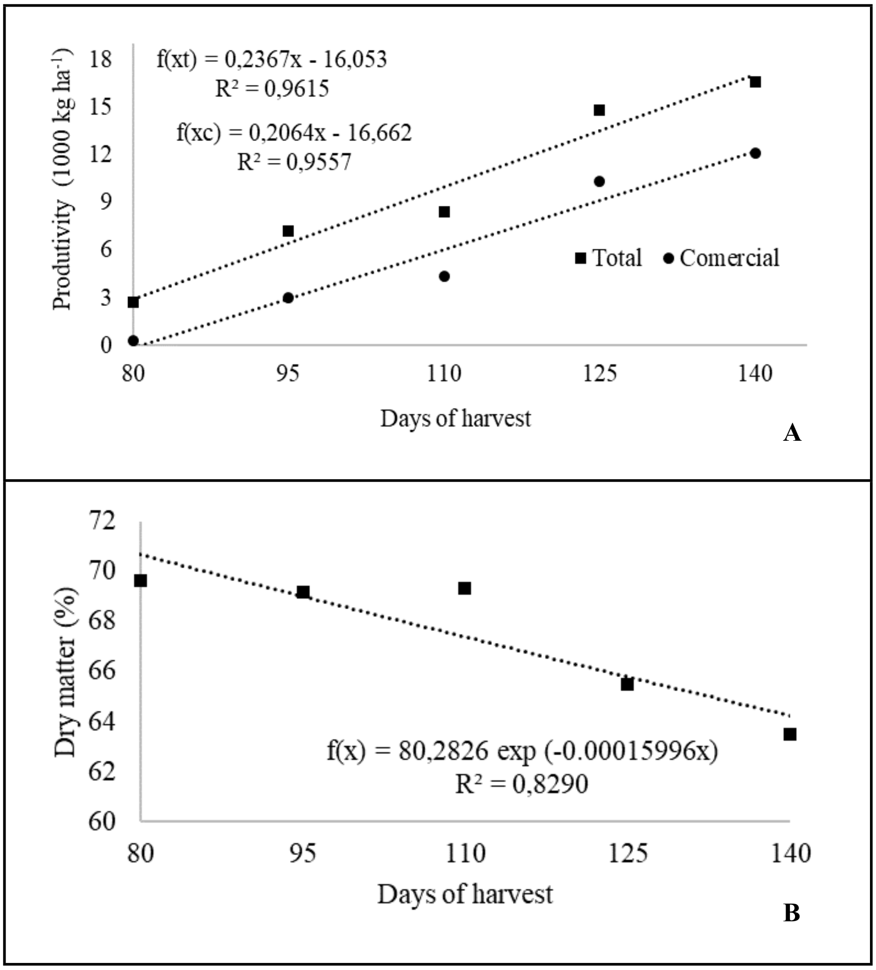

Figure 2. A= Total and commercial productivity (t/ha); B= dry matter (%) of sweet potato roots grown in savannah of Roraima in relation to harvest ages. Boa Vista, UFRR, 2020.

Besides, the influence of the cultivars, the soluble solids of tuberous roots were influenced by the harvest age (Figure 3A). At 95 and 110 DAP a reduction of 9.27% and 5.32%, respectively, in soluble solid contents compared with the result obtained at 80 DAP was observed. From 125 DAP, an increase in these contents was observed. This behavior, considering the soluble solid content in tuberous roots, harvested at 95 and 110 DAP is probably related to excess of water during the growing season.

Carbohydrate contents varied according to harvest age, considering that the total sugars (Figure 3B) showed positive linear increase during the harvest ages, at 80 DAP corresponded to 0.72% and at 140 DAP, to 2.92%. The constant accumulation of total sugars during the development of sweet potato roots could be associated with greater translocation of sucrose, since this is the main form of carbohydrate translocated in a plant, as reported by Wang *et al*. (2016), who observed a continuous increase of sucrose during the development of sweet potato tuberous roots.

The levels of reducing sugars (AR), Figure 3C, differed statistically with an increase of harvest age, showing a positive polynomial curve, with a difference of 23.53% between the levels of AR observed at 80 DAP and those observed at 140 DAP. This fact is important since the reducing sugars (glucose and fructose) are the main substrates of respiration and, as a result, tend to decrease during the ripening process, since glucose is used for oxidation in the respiratory process, via the Krebs cycle. Shekhar *et al*. (2015) reported AR contents equivalent to 2.6% in tuberous roots of white-fleshed sweet potato, results similar to those observed in this research. However, lower values were observed by Andrade

Table 2. Skin luminosity (L* C), skin chroma (Chroma C), pulp luminosity (L* P), hue angle of the pulp (°H P), pulp chroma (Chroma P) of two sweet potato cultivars grown in savannah of Roraima. Boa Vista, UFRR, 2020.

Cultivars	L* C	Chroma C	L* P	°H P	Chroma P
BD-01	42.99b	60.22a	84.65b	-70.86a	24.85a
BD-02	55.10a	53.42b	85.39a	-60.98a	20.85b
Average	49.05	56.82	85.02	-65.92	22.85
CV1 (%)	11.69	9.98	0.66	37.98	13.26
CV2 (%)	9.02	7.25	2.53	47.1	11.26

*Averages followed by the same lowercase letter in the column do not differ from each other, by F test (p≤0.05).

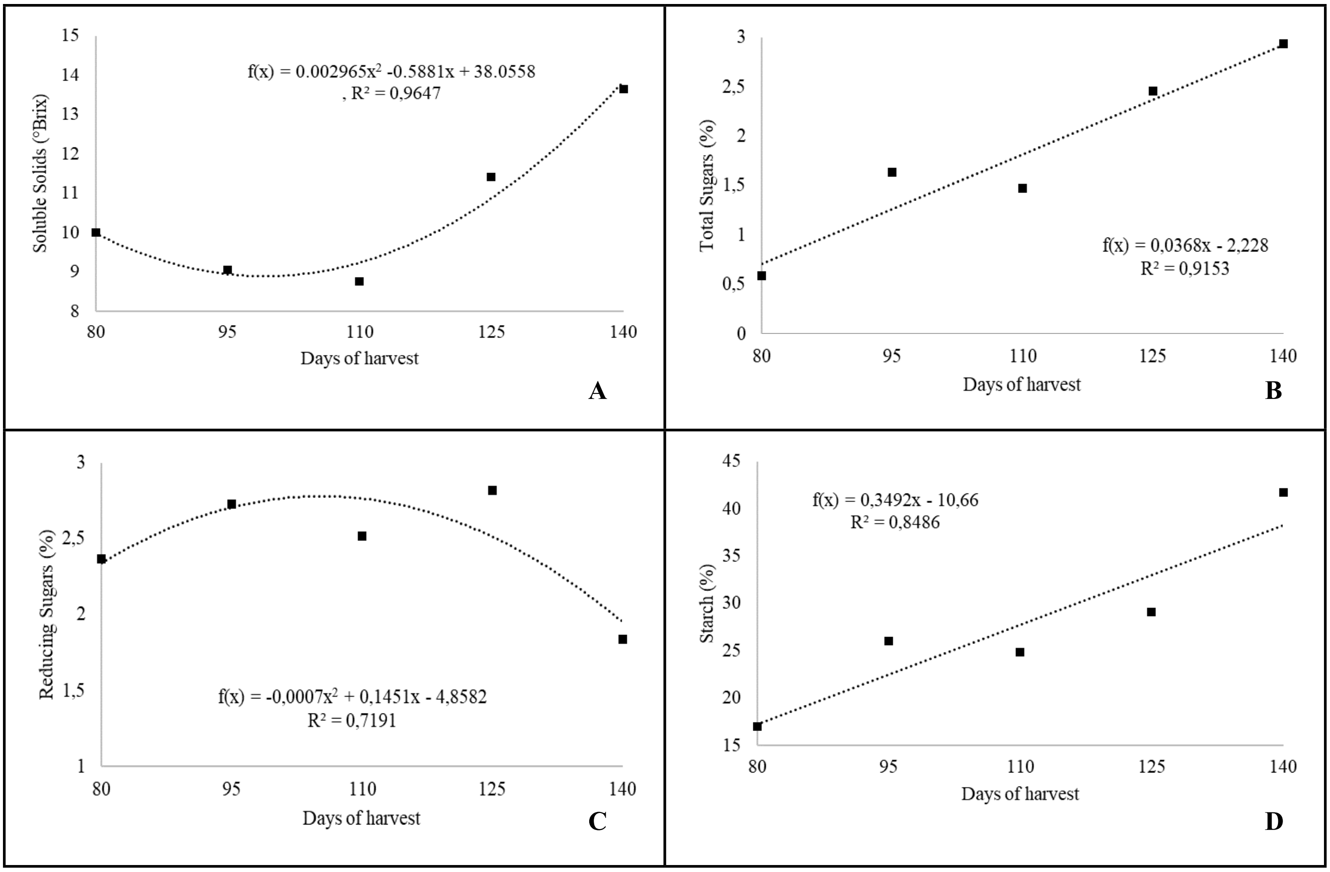

Figure 3. A= Soluble solids (°Brix); B= total sugars (%); C= reducing sugars (%); D= starch content (%) of sweet potato roots grown in savannah of Roraima in relation to harvest ages. Boa Vista, UFRR, 2020.

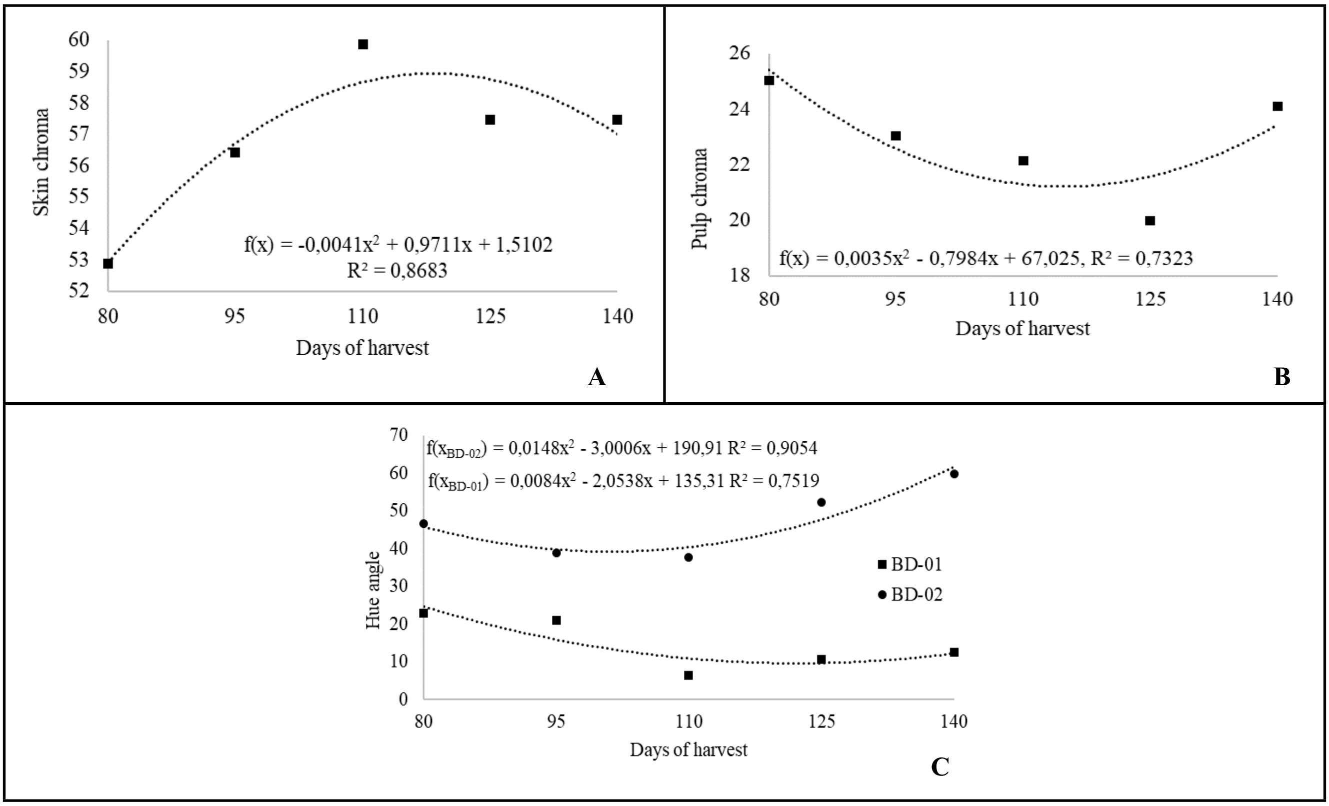

Figure 4. A= Values of skin chroma; B= Pulp chroma; C= hue angle of sweet potato roots grown in savannah of Roraima related to harvest ages. Boa Vista, UFRR, 2020.

Júnior *et al*. (2012), 1.09 for AR in sweet potato tuberous roots, whereas Leonel & Cereda (2002) verified 5.7% of AR, values higher than the one found in this study.

Starch contents (Figure 3D) observed in this research showed positive linear form, showing significant difference between them in relation to harvest age. Evaluating harvest ages, the author verified an increase of 121.27% in starch content of sweet potato tuberous roots from 80 to 140 DAP. This increase in starch content can be related to an increase in sucrose levels (total sugars), considering that this carbohydrate is able to potentiate starch synthesis. Considering this, Andrade Júnior *et al*. (2012), performing physicochemical analysis of sweet potato cultivars, observed that in Brazlândia Roxa the starch content was 18.4%, value similar to the one found in this research at 80 DAP. Leonel & Cereda (2002) noticed 14.72% of starch content in sweet potato tuberous roots and Oliveira *et al*. (2017) obtained average values from 21 to 25% for starch level at 150 DAP, values lower than the ones found in this research.

Luminosity, chroma and °H of the skin showed significant difference in the evaluated cultivars (Table 2). Significant difference was observed for luminosity and °H of the pulp. So, the cultivar BD-01 showed an average value ranging from 42.99 to 84.65, luminosity of the skin and pulp, respectively, whereas the cultivar BD-02 showed an average value of 55.10 for skin luminosity and 85.39 for pulp luminosity, showing that the cultivar BD-01 is darker than the cultivar BD-02. Given the above, Aina *et al*. (2009) observed skin luminosity of 15.6 in a red-skinned cultivar of sweet potato (cultivar Agriculture), values lower than the ones presented in this study.

In relation to chroma, the cultivar BD-01 showed values of 60.22 in the skin and 24.85 in the pulp: these values were also considered higher when compared with the ones observed in cultivar BD-02, showing that the cultivar BD-01 is more vivid than the cultivar BD-02. The influence of harvest age on the chroma of skin and tuberous root pulp did not show dependence on the studied cultivar, though. Thus, the chroma of the skin (Figure 4A) and pulp (Figure 4B) behaved inversely, so that over the harvest ages, from 80 DAP to 140 DAP, an increase of 7.83% in the chroma of the skin and a decrease of 6.67% in the chroma of the pulp could be noticed. Thus, at 95, 110 and 140 DAP the skin showed to be drier and the tuberous root pulp more humid. Such behavior can be associated with the loss of dry mass observed related to an increase in permanence of tuberous roots in soil and, being more pronounced after 110 DAP, and this loss may even be related to the tendency of reduction in reducing sugars (Figure 3C), consumed by the intense respiratory metabolism of the roots from this period on.

For the pulp hue angle, no significant difference was observed between the cultivars, which presented an average of 65.92, indicating a yellowish pulp color for both cultivars. Regarding the hue angle of the skin (Figure 4C), an interaction between the cultivars and the harvest ages was observed, so that the cultivar BD-01 presented a value from 24.77 to 12.42 of °H, at 80 and 140 DAP, respectively, indicating change from red to purple-red color. On the other hand, the cultivar BD-02 showed values from 45.58 to 60.91 of °H at 80 and 140 DAP, respectively, showing that the skin color changed from orange to yellow orange. Thus, the authors concluded that the cultivar BD-02 showed better response in relation to the evaluated parameters when comparing with the cultivar BD-01, especially with regard to soluble solids, titratable acidity, SS/AT ratio, luminosity and pulp chroma.

Therefore, taking into account, mainly, the carbohydrate metabolism and the interpretation of the results regarding the productivity and the dry matter production of the cultivated cultivars, the authors considered that the ideal time to harvest sweet potato tuberous roots would be at 110 DAP, the expected postharvest quality under rainfed conditions without irrigation in savannah of Roraima.

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