BIOSCIENCE JOURNAL

CONTRIBUTION OF THE CARBONIZED RICE HUSK ADDED TO THE SUBSTRATE IN THE PRODUCTION OF VEGETABLE SEEDLINGS

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How to cite: ZANÃO JÚNIOR, L.A., et al. Contribution of the carbonized rice husk added to the substrate in the production of vegetable seedlings. *Bioscience Journal*. 2022, **38**, e38029. https://doi.org/10.14393/BJ-v38n0a2022-54050

Abstract

The carbonized rice husk (CRH) is an agro-industrial residue with great potential for use in mixtures with other substrates for the production of vegetable seedlings. Thus, the purpose of this study was to evaluate the effect of the addition of CRH to the commercial substrate for the production of greenhouse seedlings. The evaluated vegetables were lettuce, broccoli and mustard, cultivated in polystyrene foam (Styrofoam®) trays. Five treatments were evaluated: 100% of the commercial substrate (CS); 25% of CRH + 75% of CS; 50% of CRH + 50% of CS; 75% CRH + 25% CS; and 100% CRH, in a completely randomized design with twelve replicates. The substrates were evaluated for their physical and chemical characteristics. The morphometric evaluations were: number of leaves per plant, plant height, shoot fresh matter yield, root length, and shoot and root dry matter yield. The data were submitted to regression analysis, and the homogeneity of the variance between the experiments was confirmed by the Cochran test. With the addition of CRH to the substrate, there was an increase in total porosity and P content and a reduction in density, water holding capacity, cation exchange capacity, electrical conductivity, and N, K, S, Ca and Mg contents. The carbonized rice husk added to the commercial substrate is a viable alternative for the production of lettuce, broccoli and mustard seedlings. The quality of the vegetable seedlings was higher when there was a 25% CRH + 75% CS mixture.

Keywords: Broccoli. Initial growth. Lettuce. Mustard. Organic residue.

1. Introduction

Rice husk is an agro-industrial residue generated by the processing of rice (*Oryza sativa*), which is one of the most cultivated and consumed cereals in the world (Walter et al. 2008).

Brazil produced 10,653.8 tons of rice in the 2018/2019 crop (CONAB 2019). After processing, the rice husk represents 20% of the total weight of the production (Foletto et al. 2005).

While on the one hand, Brazil has significant rice production, on the other hand the residue from its processing causes environmental concern. Given the availability of the waste that is generated annually, the search for alternatives for the use of this raw material becomes necessary. One of the alternatives is the use of carbonized rice husk in conjunction with the commercial substrate, mainly for the production of vegetable seedlings.

Among the seedlings that are produced on a large scale, the families *Brassicaceae* (broccoli and mustard) and *Asteraceae* (lettuce) stand out. The first two species have the highest economic relevance (Miguel-Wruck et al. 2010) and the third is the most consumed leafy vegetable crop in the country (Freitas et al. 2013a).

For the production of quality seedlings, it is important for the substrate to present good chemical and physical characteristics for the initial development of the plants.

Therefore, the substrates should be able to support the plant, retain moisture, and allow aeration in the root system. It should also be free of phytopathogens and weeds. In addition, they should be easy to handle, long-lasting, and with high availability and low cost for acquisition (Fernandes et al. 2006; Trani et al. 2007; Farias et al. 2012). Furthermore, it should present good cation exchange capacity (CEC), hydrogenation potential (pH) near neutral values, and low salinity to provide a nutrient supply necessary for the development of seedlings (Lima et al. 2006).

Carbonated rice bark has many of these characteristics, as it presents slow biodegradation, high porosity to facilitate drainage, reduced weight, absence of nematodes and phytopathogens, slightly alkaline pH, low salinity, and moisture retention (Vieira and Pauletto 2009; Freitas et al. 2013b; Castoldi et al. 2014).

Normally, a single substrate is not able to meet all the needs of the species to be produced, thus making necessary the combination of substrates, at adequate doses, and with chemical components and physical characteristics that complement each other (Gomes and Silva 2004; Pagliarini et al. 2015).

Carbonized rice husk has been physically and chemically characterized in combinations with other components added to the commercial substrate and has been found to provide greater porosity to the final substrate, improving the quality of lettuce seedlings (Castoldi et al. 2014; Simões et al. 2015; Watthier et al. 2017), broccoli (Lopes et al. 2012), and mustard (Souza et al. 2017).

Thus, the purpose of this study was to evaluate the effects of the addition of carbonized rice husk to the commercial substrate, in different proportions in the production of lettuce, broccoli and mustard seedlings.

2. Material and Methods

Location and implementation of the experiment

The study was carried out in a greenhouse, with an oblong arch structure and high-density milky polyethylene cover with anti-UV activation, with 15 m in length, 7 m in width, and 3 m in ceiling height. The greenhouse was located at the Rural Development of Paraná (IDR-Paraná), Santa Tereza do Oeste, PR, Brazil, latitude 25º03’08” S and longitude 53º37’59” W.

Two experiments were conducted – the first one from May to June 2015 and the second from July to August 2015. The greenhouse temperature was measured daily throughout the experimental period with daily mean temperatures of 27°C, minimum daily mean of 22.1°C, and maximum daily mean of 31.1°C.

Preparation of carbonized rice husk and substrates

The carbonization of the rice husk was carried out according to the methodology proposed by the National Horticultural Research Center (Medeiros 1998). The substrate was formed by the mixture of carbonized rice husk (CRH) and the commercial substrate Tropstrato® (CS), which were homogenized manually. Five treatments were evaluated: 100% CS; 25% CRH + 75% CS; 50% CRH + 50% CS; 75% CRH + 25% CS; and 100% CRH.

Prior to the installation of the experiment, the substrates were prepared with four replicates for each treatment, which were evaluated for physical and chemical characteristics.

The physical and chemical characteristics of the substrates (pH, density (wet Ds and dry Ds), cation exchange capacity (CEC) and electrical conductivity (EC)) were evaluated by the official methods of Normative Instruction No. 17, of May 21, 2007 (MAPA 2007), and water holding capacity was kept at 10 cm (WHC10), according to Normative Instruction No. 31, of October 23, 2008 (MAPA 2008) (Table 1).

The soluble contents of phosphorus (P), potassium (K), sulfur (S), ammoniacal nitrogen ($N-NH_4^+$), nitric nitrogen ($N-NO_3^-$), calcium (Ca), magnesium (Mg), boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were determined after the extraction with water at low concentration by the 1:1.5 method (v/v) (Sonneveld 1988) (Tables 2 and 3, respectively).

Experimental design and sowing of vegetable species

The experimental design was fully randomized, with three replicates, each replicate represented by 12 plants. The lettuce seeds used were the Elisa cultivar, with 100% germination, Ramoso Santana broccoli cultivar, with 99.9% germination, and Lisa mustard cultivar, with 98% germination.

Sowing of the species was carried out in expanded polystyrene trays of 128 cells. Each tray consisted of 36 plants of each plant species. One seed per cell was seeded at 0.5 cm depth. Seedling emergence occurred, on average, on the seventh day after sowing.

Irrigation of plants

The frequency of irrigation occurred two to three times a day to maintain the moisture content in the field capacity. Two fertigation processes were performed, one on the 20th day and another on the 30th day after sowing (DAS) of the species. The fertigation steps were performed with 2 mL L^{-1} of liquid fertilizer (in %): N = 5.9; P_2O_5 = 1.70; K_2O = 5.6; Ca = 3.70; Mg = 0.8; Zn = 0.01; Mn = 0.03; B = 0.01; Cu = 0.01; Ni = 0.002; Fe = 0.04; Mo = 0.002, replacing irrigation on the day they were performed.

Evaluation of plants

The evaluation of the plants occurred at 37 DAS for lettuce, 38 DAS for broccoli, and 41 DAS for mustard. The number of leaves, plant height, fresh matter yield, and shoot dry matter yield, dry matter yield, and root length were evaluated.

A digital caliper was used to determine plant height. The distances from the surface of the substrate to the apex of the plant were measured.

For the other evaluations, the plants were removed from the trays, separated from the substrates and washed in running water. First, the length of the main root was measured, and the shoot fresh matter yield of the plants was quantified. Following this step, the shoot and root system of the plants were stored in individualized paper bags and taken to the oven at 60°C until reaching constant weight, to determine the dry matter yield.

Statistical analysis

The data were submitted to analysis of variance. Regression equations were adjusted for the variables evaluated as a function of the proportion of CRH added to the commercial substrate, and the coefficients were tested up to 5% probability by the t-test.

The models tested for the variables under study were linear, square root, and cubic root. The models were chosen based on the significance of the regression coefficients, biological significance, and coefficient of determination. The Assistat application was used (Silva and Azevedo 2016).

The results of each variable of the two experiments were analyzed together because the homogeneity of the variance between the experiments was confirmed by the Cochran test (Gomez and Gomez 1984).

3. Results and Discussion

Substrate analysis

The pH was not influenced by the addition of carbonized rice husk (CRH) to the commercial substrate (CS) and ranged from 6.5 to 6.8. According to Schmitz et al. (2002), when the pH is between 6 and 7, greater nutrient availability occurs in the mineral substrate (Table 1).

Table 1. Physical and chemical characteristics of the substrates formulated from the mixture of carbonized rice husk and commercial substrate in different proportions.

Substrate	pH	Wet Ds	Dry Ds	WHC 10	WHC 10	CEC	EC	TP
		--------kg m^{-3}------		% v/v	% m/m	$mmol_c\ kg^{-1}$	$dS\ m^{-1}$	%
0% CRH + 100% CS	6.5	737.4	426.5	53.0	123.6	584.5	1.30	80.3
25% CRH + 75% CS	6.5	596.3	357.4	42.5	116.4	490.3	1.02	82.8
50% CRH + 50% CS	6.6	445.4	284.1	30.7	103.7	424.6	0.72	85.1
75% CRH + 25% CS	6.6	294.4	210.8	18.9	91.0	322.5	0.42	86.8
100% CRH	6.8	143.5	137.5	7.1	78.3	255.1	0.12	87.9
Statistical model	ns	L*	L	L	L	L	L	L
R^2	ns	0.99	0.99	0.99	0.99	0.98	0.98	0.98

ns = not significant at 5% probability by the t-test; L* = linear model significant at 5% probability by the t-test; CRH = carbonized rice husk; CS = commercial substrate; Wet Ds = wet density; Dry Ds = dry density; WHC = water holding capacity at 10 cm; CEC = cation exchange capacity; EC = electrical conductivity; TP = total porosity.

There was a linear reduction in density (Ds) and water holding capacity at 10 cm (WHC 10) with an increase in the amount of CRH added to the substrate. In order to reduce the water content of the substrates, it is necessary to reduce the water content of the substrates (Carrijo et al. 2004; Modolo et al. 2011). Klein et al. (2002) also observed higher porosity in the substrate when there was addition of CRH in commercial substrates.

According to Allaire et al. (2004), the substrates composed of material with a greater particle size as the CRH present lower WHC. Nevertheless, in substrates with higher water holding capacity, the aeration spaces are reduced, and there may be a lack of oxygen for the development of the plant roots.

In relation to Ds of the substrate, there was a reduction with the addition of CRH given that the material was light. The values of Ds ranged from 137.5 to 426.5 kg m^{-3}. According to Cardoso et al. (2010), the Ds of a substrate is the relationship between mass and volume and is a physical property to be considered, as the smaller the vessel diameter, the smaller the Ds of the substrate used.

Martinez (2004) states that for the production of seedlings, the ideal Ds varies between 100 and 300 kg m^{-3}. For vessels with diameters smaller than 20 cm, substrates with Ds of 200 to 400 kg m^{-3} and substrates with Ds above 600 kg m^{-3} are suggested for use in vessels larger than 30 cm in diameter.

With the increase in the CRH addition, there was a reduction in cation exchange capacity (CEC) and electrical conductivity (EC). CEC is higher in substrates with mineral components such as vermiculite, soil, and decomposed organic material. Since CRH is composed mostly of silica, the higher the amount added, the lower the CEC of the substrate formed.

With the increase in the addition of CRH, there was a linear reduction in the EC of the substrates. The EC evaluates the degree of salinization of a substrate, i.e., the concentration of ionized salts in the solution. According to Sodré et al. (2005), it is recommended that substrates marketed for most plants have values of at most 1.8 dS m^{-1}. The EC of the substrates of this study ranged from 0.12 to 1.3 dS m^{-1}. Low EC values indicate low levels of nutrients in the substrate.

Unlike Ds, WHC, CEC and EC, there was an increase in total porosity (TP) with an increasing amount of CRH added to the substrate. For substrates, TP values of 75-90% are sought for better aeration, water infiltration and drainage, according to Kämpf (2000). Thus, all substrates evaluated have adequate TP.

According to Fermino (2002), the larger the Ds, the smaller the TP, by the approximation of the particles to each other, increasing the proportion of micropores and increasing the WHC.

Zorzeto et al. (2014) evaluated four substrates (coconut coir, two types of pine bark (Lupa and Vida Verde), and stabilized rice husk) and two mixtures (50% CRH + 50% coconut coir, 50% CRH + 50% pine bark) for the plants and observed that both CRH and coconut coir presented high porosity, with values above 50%. In turn, the pine bark presented low porosity coupled with the high capacity of water holding.

There was a significant effect of the addition of CRH on the soluble contents of the macronutrients of the substrates. The soluble contents of K, S, N, Ca and Mg decreased linearly with increasing amount of carbonized rice husk added to the commercial substrate (Table 2).

Table 2. Soluble macronutrient contents of substrates formulated from the mixture of carbonized rice husk and commercial substrate in different proportions.

Substrate	P	K	S	N-NH_4^+	N-NO_3^-	Ca	Mg
	mg L^{-1}						
0% CRH + 100% CS	0.5	308.6	28.9	65.0	245.6	235.7	120.7
25% CRH + 75% CS	1.3	240.2	23.1	52.3	180.4	184.5	98.8
50% CRH + 50% CS	2.3	145.3	14.3	32.5	99.8	100.8	59.1
75% CRH + 25% CS	3.6	70.4	9.4	19.9	46.7	48.9	23.9
100% CRH	5.7	6.5	4.5	9.3	6.7	10.3	5.7
Statistical model	L*	L	L	L	L	L	L
R^2	0.96	0.99	0.99	0.99	0.98	0.98	0.98

L* = linear model, significant at 5% probability by the t-test; CRH = carbonized rice husk; CS = commercial substrate.

Comparing the lowest with the highest CRH dose added to CS, there was a reduction of 61% in K content, 97% in S content, 71% in ammoniacal nitrogen content, 81% in nitric nitrogen content, 97% in Ca content, and 94% in Mg content. The inverse occurred for the P contents, which increased by 83% when comparing the lowest with the highest dose of carbonized rice husk added to the commercial substrate.

Thus, when adding CRH to the substrate, fertilizer or applications of nutrient solutions should be added for the adequate nourishing of the plants, especially in relation to the adequate supply of macronutrients.

The soluble contents of the micronutrients were not influenced by the addition of CRH to CS (Table 3). The mean micronutrient contents in the substrates were: 0.1 mg L^{-1} B, Fe and Mn; < 0.01 mg L^{-1} Cu, and 0.03 mg L^{-1} Zn. This information is useful for the nutritional management of plants grown on substrates formed by the CRH/CS mixture.

Table 3. Soluble micronutrient contents of substrates formulated from the mixture of carbonized rice husk and commercial substrate in different proportions.

Substrate	B	Cu	Fe	Mn	Zn
	mg L^{-1}				
0% CRH + 100% CS	0.1	<0.01	0.2	0.1	0.05
25% CRH + 75% CS	0.1	<0.01	0.1	0.1	0.03
50% CRH + 50% CS	0.1	<0.01	0.1	0.1	0.05
75% CRH + 25% CS	0.1	<0.01	0.2	0.2	0.03
100% CRH	0.1	<0.01	0.2	0.2	0.04
Statistical model	ns	ns	ns	ns	ns

ns = not significant at 5% probability by the t-test; CRH = carbonized rice husk; CS = commercial substrate.

Agronomic analyses

For the production of lettuce, broccoli and mustard seedlings, the number of leaves per plant, plant height, shoot fresh matter yield, root length and shoot and root dry matter yield had higher values when the substrate was added to about 25% CRH (Figure 1).

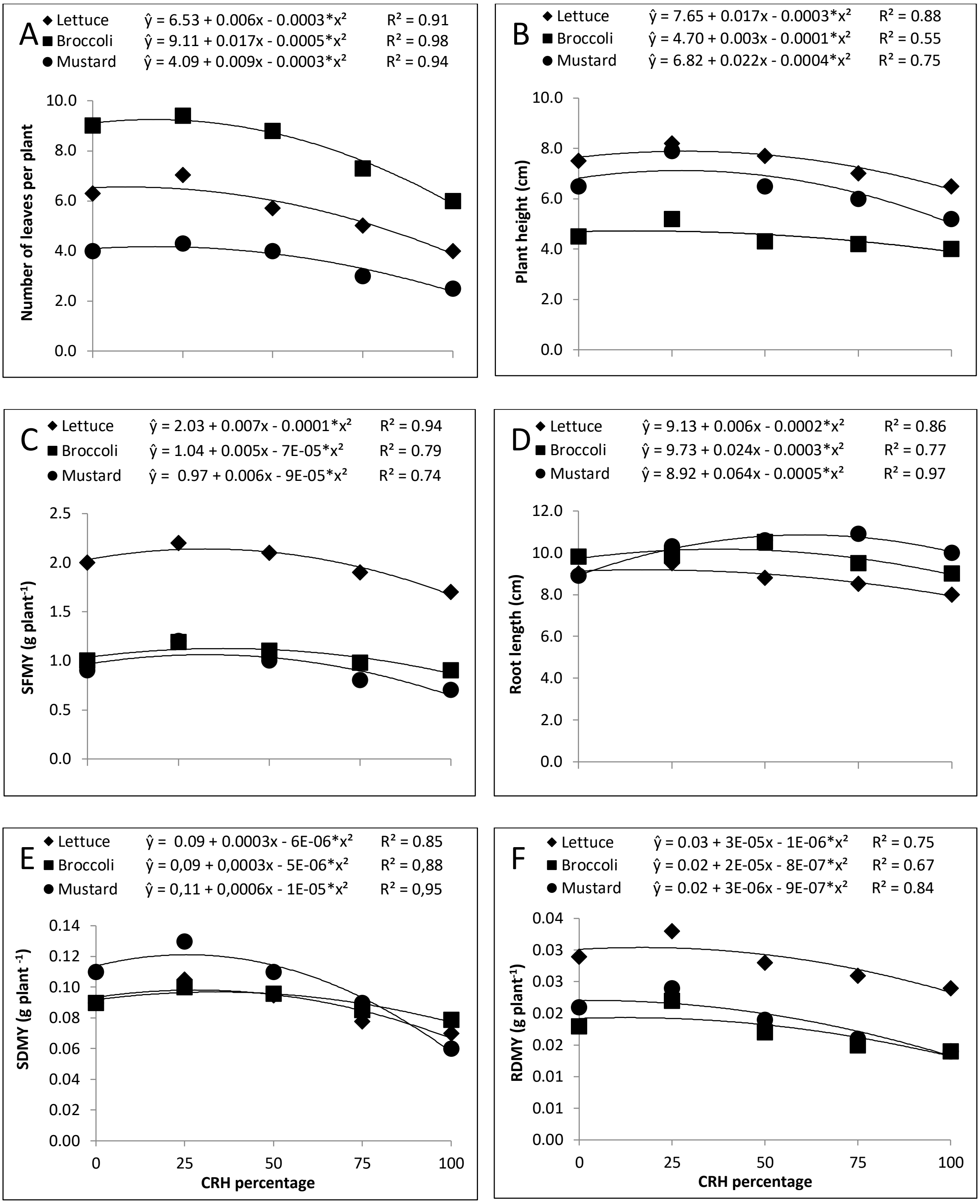

Figure 1. A – number of leaves per plant; B – plant height; C – shoot fresh matter yield (SFMY); D – root length; E – shoot dry matter yield (SMDY); and F – root dry matter yield (RMDY) as a function of the carbonized rice husk and commercial substrate in different proportions used as substrate for lettuce, broccoli and mustard plants. * = significant at 5% by the t-test.

Milec et al. (2007) studied the influence of the vermicompost of cattle and pig manure, carbonized rice husk and commercial substrate Germina Plant® on broccoli seedlings (cv. Santana) and verified that for plant height and root dry matter yield, the best values were also obtained with 25% CRH and 75% cattle manure vermicompost.

In turn, Gonçalves et al. (2000) reported that suitable substrates for the propagation of seedlings of native species can be obtained from the mixture of 70-80% of sugarcane bagasse, eucalyptus bark and vermicompost, with 20-30% of CRH and boiler ash to increase the macro and microporosity of the substrate.

Watthier et al. (2017) analyzed the characteristics of the substrates of China wood compost, CRH and vermicompost in the production of lettuce seedlings and observed that the substrate with 15% CRH + 75% China wood compost + 10% vermicompost provided quality lettuce seedlings.

Simões et al. (2015) concluded that the combination of CRH, coconut coir, kapok stem compost and chopped palm stipe are viable for the development of lettuce seedlings, producing seedlings with a higher quality index.

In this study, less developed plants were obtained with the use of pure CRH, without addition of commercial substrate. The addition of CRH increased the macroporosity of the substrate and reduced the water holding capacity available for vegetable seedlings. These results corroborate the findings of Klein et al. (2002), Allaire et al. (2004), Carrijo et al. (2004), and Modolo et al. (2011).

On the other hand, in commercial substrates, fertilizers are added, and this fact may have contributed to the greater development of lettuce, broccoli, and mustard seedlings. From the preliminary results, additional research can be suggested to evaluate these substrates under a controlled irrigation system with addition of fertilizer.

4. Conclusions

With the addition of CRH to the substrate, there was an increase in total porosity increased and P content and a reduction in density, water holding capacity, cation exchange capacity, electrical conductivity, and N, K, S, Ca and Mg contents. The carbonized rice husk added to the commercial substrate is a viable alternative for the production of lettuce, broccoli and mustard seedlings. The quality of the vegetable seedlings was higher when there was a 25% CRH + 75% CS mixture.

Authors' Contributions: ZANÃO JÚNIOR, L.A.: conception and design, acquisition of data, analysis and interpretation of data, drafting the article; ANDRADE, E.A.: acquisition of data, analysis and interpretation of data, drafting the article; PEREIRA, N.: acquisition of data, analysis and interpretation of data drafting the article; KAZUE, L.T.: acquisition of data, analysis and interpretation of data, drafting the article; SECCO, D.: acquisition of data, drafting the article; CARVALHO-ZANÃO, M.P.: conception and design, analysis and interpretation of data, drafting the article. All authors have read and approved the final version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Ethics Approval: Not applicable.

Acknowledgments: This study was financed in part by the CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico -Brasil). The authors are also grateful to the Western Paraná State University (UNIOESTE) for the infrastructure support.

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Received: 15 December 2020 | **Accepted:** 21 July 2021 | **Published:** 24 May 2022