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Original Article

Production, biometrics and physicochemical analysis of bell pepper fruits fertilized with biochar from different residues[1]

Produção, biometria e análise físico-química de frutos de pimentão adubado com biocarvão de diferentes resíduos

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HIGHLIGHTS:
Biochar doses promote, except for skin thickness, higher biometric averages of bell pepper fruits.
Doses influence the physicochemical characteristics; biochars influence titratable acidity and soluble solids.
Only soluble solids are influenced by the interaction between doses and biochars.

ABSTRACT: Bell pepper, a crop of nutritional importance, stands out for its vitamin C content. Given the need for sustainable agricultural practices, the present study explored the use of biochars derived from regional waste as an alternative in bell pepper cultivation. In this context, the present study aimed to evaluate the effect of biochars from poultry litter, coconut fiber, and rice straw on the biometric and physicochemical characteristics of bell pepper fruits, on fruit production per plant and on fruit yield. The experiment was performed in the field in a randomized block design, in a 5 × 3 + 1 factorial scheme, referring to five doses of biochar (0, 3, 6, 9, and 12 t ha^{-1}) and three types of biochar (coconut fiber, poultry litter, and rice straw) with four repetitions, plus an additional treatment (mineral fertilization). Biometric variables (fruit length and diameter, skin thickness, number of fruits, fruit mass) and physicochemical variables of the fruits (soluble solids, titratable acidity, pH, vitamin C, and ash content), production and yield of the fruits were evaluated. The production of bell pepper fruits was not influenced by biochars, but the doses of biochars influenced all variables analyzed with the exception of skin thickness. Vitamin C and soluble solids contents were higher in treatments with biochar and lower with mineral fertilizer. Biochar produced from rice straw had the greatest influence on fruit acidification.

Key words: *Capsicum annuum* L., fertilization, post-harvest, poultry litter, coconut fiber, rice straw

RESUMO: O pimentão, cultura de importância nutricional, destaca-se por seu valor de vitamina C. Diante da necessidade de práticas agrícolas sustentáveis, o estudo explorou o uso de biocarvões derivados de resíduos regionais como alternativa na cultura de pimentão. Nesse contexto, objetivou-se avaliar o efeito de biocarvões provenientes de cama de frango, fibra de coco e palha de arroz, nas características biométricas e físico-químicas de frutos de pimentão verde, na produção de frutos por planta e na produtividade. A pesquisa foi conduzida em campo no delineamento em blocos casualizados, em esquema fatorial 5 × 3 + 1, referentes a cinco doses de biocarvão (0, 3, 6, 9 e 12 t ha^{-1}) e três tipos de biocarvão (fibra de coco, cama de aviário e palha de arroz) com quatro repetições, mais um tratamento adicional (adubação mineral). Foram avaliadas variáveis biométricas (comprimento e diâmetro dos frutos, espessura da casca, número de frutos, massa do fruto) e físico-químicas dos frutos (sólidos solúveis, acidez titulável, pH, vitamina C e teor de cinzas), produção e produtividade dos frutos. A produção de frutos de pimentão verde não foi influenciada pelos biocarvões, porém as doses de biocarvões influenciaram todas as variáveis analisadas com exceção da espessura da casca. Os teores de vitamina C e de sólidos solúveis foram maiores nos tratamentos com biocarvões e menores com adubação mineral. A maior influência na acidificação dos frutos foi com o biocarvão produzido com palha de arroz.

Palavras-chave: *Capsicum annuum* L., adubação, pós-colheita, cama de aviário, fibra de coco, palha de arroz

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Introduction

Bell pepper (*Capsicum annuum* L.), a fruit from the Solanaceae family, rich in antioxidants, lycopene, ascorbic acid, and carotenoids, is valued for its culinary properties and high nutritional content (Mohi-Alden et al., 2022). Bell pepper cultivation is demanding regarding soil fertility, which requires the application of both organic and mineral fertilizers to suit its specific needs (Jeque et al., 2022). However, given the high costs of fertilization and the search for sustainability in agricultural production systems, it is necessary to use products and adopt alternative techniques that guarantee yield with less environmental impact and that are economically viable (Rezende et al., 2022).

An alternative organic fertilizer option to be used in crop production has been biochar, a carbonaceous product produced through pyrolysis of organic waste (Hu & Wei, 2023). Its final characteristics depend on the original raw material and the conditions of the production process (James et al., 2022).

In the State of Paraíba, due to the economic importance of poultry farming and the cultivation of coconut and rice, a considerable amount of waste is generated, such as poultry litter, coconut fiber, and rice straw. Biochars, produced from these residues, contribute to a greater environmental balance due to the reduction in the use of chemical fertilizers. Furthermore, it improves the physical and chemical properties of soils, reducing soil density, increasing porosity, field capacity, permanent wilting point, and water available to plants, increasing pH, cation exchange capacity (CEC), base saturation (V%), as well as the retention of phosphorus and potassium in sandy soils, promoting improvements in fertility (Martins Filho et al., 2019; Chaves et al., 2020; Guarnieri et al., 2021). In this context, the bell pepper crop will probably react well to the application of biochars in the soil, since agricultural benefits are well described in several studies using crops such as maize, beet, radish, 'Biquinho' pepper, and beans, fertilized with biochars. Plant responses, due to the application of biochar to the soil, related to plant biometrics, production and/or fruit yield, vary depending on the diversity of materials used and pyrolysis conditions in biochar production (Silva et al., 2017). However, there is little information regarding the composition and physical and physicochemical characteristics of bell pepper fruits.

Therefore, the present study aimed to evaluate the effect of biochars from poultry litter, coconut fiber, and rice straw on the biometric and physicochemical characteristics of bell pepper fruits, on fruit production per plant and on fruit yield.

Material and Methods

The experiment was performed under field conditions in the experimental area belonging to the Center for Agricultural and Environmental Sciences (CCAA), Campus II of the State University of Paraíba (UEPB), Lagoa Seca, Paraíba, Brazil (7° 09' S; 35° 52' W) in the period from October 2021 to February 2022 with the climate information presented in Figure 1.

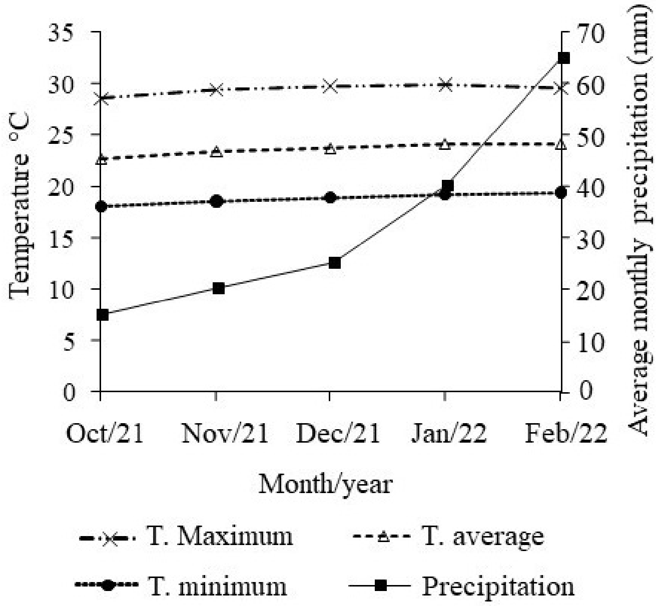


Figure 1. Climatic information for the municipality of Lagoa Seca, Paraíba, Brazil, from October 2021 to February 2022

The soil used in the experiment was an Ustults collected in the arable layer (0-0.20 m depth) with the following physical-chemical characteristics according to the methodology proposed by Donagema et al. (2011): 841.7 g kg^{-1} of sand; 83.6 g kg^{-1} of silt, and 74.7 g kg^{-1} of clay, bulk density = 1.38 kg dm^3; particle density = 2.70 kg dm^3; total porosity = 48.87%; pH = 6.25; P = 9.3 mg dm^{-3}; OM = 12.45 g dm^{-3}; Ca = 2.77 $cmol_c$ dm^{-3}; Mg = 1.50 $cmol_c$ dm^{-3}; Na = 0.06 $cmol_c$ dm^{-3}; K = 0.33 $cmol_c$ dm^{-3}; H + Al = 1.33 $cmol_c$ dm^{-3}; and cation exchange capacity = 5.99 $cmol_c$ dm^{-3}.

Biochars from poultry litter, coconut fiber, and rice straw were produced in a "drum" type oven at the Centro de Ciências Agrárias e Ambientais (CCAA), Campus II, UEPB according to Silva et al. (2022). For the pyrolysis process, a 200 L iron drum was used containing a wood oven thermometer with a 5 cm rod to monitor the temperature variation inside the oven and, inside, 20 L iron containers where poultry litter, coconut fiber, and rice straw were individually accommodated, as well as *Mimosa caesalpiniifolia* firewood for burning. The poultry litter used was purchased from CCAA, the coconut fiber in the municipality of Mataraca, PB, and the rice straw in the Sertão region of Paraíba. After production, the biochar samples were chemically analyzed according to the Manual of Official Analytical Methods for Fertilizers and Correctives (BRASIL, 2017) (Table 1).

The experimental design used was randomized blocks, arranged in a 5 × 3 + 1 factorial scheme referring to five doses of biochar (0, 3, 6, 9, and 12 t ha^{-1}, based on the results of Mendes et al. (2021) and three types of biochar (coconut fiber, poultry litter, and rice straw)) with four replications plus an additional treatment corresponding to the cultivation of bell pepper with mineral fertilizer (basal dose: 30, 120, and 20 kg ha^{-1} of N, P_2O_5, and K_2O, respectively, and in top dressing: 90 and 20 kg ha^{-1} of N and K_2O, respectively, using ammonium sulfate, single superphosphate, and potassium chloride), totaling 64 experimental units. Each plot consisted of three Yolo Wonder bell pepper plants. The doses of biochar were incorporated

Table 1. Chemical characterization of biochar from poultry litter, rice straw, and coconut fiber pyrolyzed in a "drum" type oven

Types of biochar	pH	M	N	P_2O_5	K_2O	Ca	Mg	C	C/N
		(%)							
Poultry litter	12.00	1.60	0.40	2.60	1.90	7.30	0.60	12.30	31.50
Rice Straw	7.66	3.57	0.65	0.72	0.87	0.29	0.23	35.34	54.37
Coconut Fiber	9.45	3.22	0.50	0.33	3.20	0.52	0.35	59.26	118.50

M - Moisture

into the soil in the period prior to transplanting the seedlings. During the experimental period, plants grown with biochar treatments did not receive mineral fertilizer.

The bell pepper seedlings were prepared in polystyrene trays, distributing three seeds per cell and using, to fill the trays, earthworm humus substrate with the following composition: pH = 7.0; EC = 2.34 dS m^{-1}; P = 827.67 mg dm^{-3}; K^+ = 643.50 mg dm^{-3}; Na^+ = 0.37 $cmol_c$ kg^{-1}; H + Al = 0.25 $cmol_c$ kg^{-1}; Ca^{2+} = 12.35 $cmol_c$ kg^{-1}; Mg^{2+} = 13.86 $cmol_c$ kg^{-1}; CEC =28.48 $cmol_c$ kg^{-1} and OM = 196.54 g kg^{-1}.

The seedlings were protected with shade net and irrigated twice a day, using a watering can, keeping the substrate moist. The one-month-old seedlings were transplanted to the field at a spacing of 1.0 × 0.4 m, 1.0 m apart. Thinning was carried out when the seedlings had six true leaves, leaving 1 plant per hole. An espalier-type staking system was set up, with plastic ribbons placed horizontally, 0.15 m apart in the direction of the planting row, which, depending on the growth of the plant stems, were tied together.

The irrigation system used was drip, with one dripper per plant, Katif model, with a flow rate of 3.75 L h^{-1}, with quantification based on evaporation readings from the Class A Pan and precipitation in the period, adopting a pan coefficient (Kp) of 0.75. The irrigation depth was applied daily, and all treatments were irrigated with the same depth (100% ETc). The water used for irrigation was collected from a reservoir close to the experimental area.

Daily the bell peppers were harvested manually, from 56 to 96 days after transplanting the seedlings to the field, and the fruits were then stored in a refrigerator at 7 °C. At the end of the harvest, the fruits were subjected to determination of the following biometric variables: length and diameter of the fruits, skin thickness, number of fruits, fruit mass, production per plant, and fruit yield. Also, physicochemical variables of the fruits were analyzed in triplicate, namely: soluble solids (°Brix), titratable acidity (% citric acid), pH, vitamin C, and ash content following the analytical standards of IAL (2008) at 30 days after harvest.

The data obtained were subjected to analysis of variance ('F' test). When significant p-values were observed ($p \leq 0.01$; $0.01 \leq p \leq 0.05$), regression analysis was performed for biochar doses and comparison of means using the Tukey test for biochars. An analysis of orthogonal contrasts was performed when a significant effect was found between the factors and the additional treatment. All statistical analyses were carried out with the aid of the Sisvar statistical program (Ferreira, 2011).

Results and Discussion

According to the analysis of variance, only the individual factor biochar doses significantly influenced the length and diameter of the fruits, number of fruits, fruit mass, production per plant, and fruit yield of bell pepper. There was no influence of individual factors or the interaction between factors (doses × types of biochar) on skin thickness.

Regarding fruit length (Figure 2A), the data were described by the quadratic polynomial regression model, with a maximum value of 67.18 mm being estimated with a dose of 7.63 t ha^{-1} of biochar. This treatment, when compared to the additional treatment (49.97 mm), i.e. mineral fertilization, promoted a significant increase of 34.44% in fruit length ($p \leq 0.01$). Values similar to those obtained in the present work were found by Carvalho et al. (2013) when evaluating nitrogen doses in the development of bell pepper crop under controlled conditions, where a value of approximately 6 cm was observed for this variable, with the greatest length being obtained when the soil did not receive nitrogen fertilization.

The estimated maximum fruit diameter was 58.27 mm, obtained with a dose of 7.67 t ha^{-1} of biochar (Figure 2B), approximately 24% higher than the value obtained with mineral fertilizer (46.99 mm). A similar result was observed by Costa et al. (2019), when evaluating the efficiency of potassium sources and fertilizers in the nutrition of pepper plants under an organic system, as they found an average fruit diameter of 53.92 mm when using wood ash as a source.

Fruit length and diameter are important characteristics due to consumer market demand, as consumers opt for large fruits. According to CEAGESP fruit classification standards and considering the maximum estimated values for the fruit length and diameter variables, bell peppers fertilized with biochar are classified in class 6 (6 to 8 cm in length) and subclass 4 (4 to 6 cm in diameter), while bell peppers fertilized with mineral fertilizer were classified in class 4 (4 to 6 cm in length) and the same subclass. Thus, under the conditions of the present study, although bell peppers are a vegetable that responds well to the application of NPK, it is possible to observe that bell peppers fertilized with biochar have more attractive characteristics (length) to consumers at the time of marketing when compared to bell peppers fertilized with NPK. This result demonstrates, in a more striking way, the potential of biochar.

The data for the number of pepper fruits as a function of increasing biochar doses (Figure 2C) were described by the positive linear regression model, with a maximum value of approximately 6 fruit units at the maximum dose of biochar, which corresponds to a 100% increase compared to the treatment without biochar and the mineral treatment (≈ 3 fruits).

This was probably due to the release of biochar nutrients into the soil, improving soil fertility and plant nutrition. Likewise, Costa et al. (2019), when working with potassium sources and fertilizers in the nutrition of pepper plants,

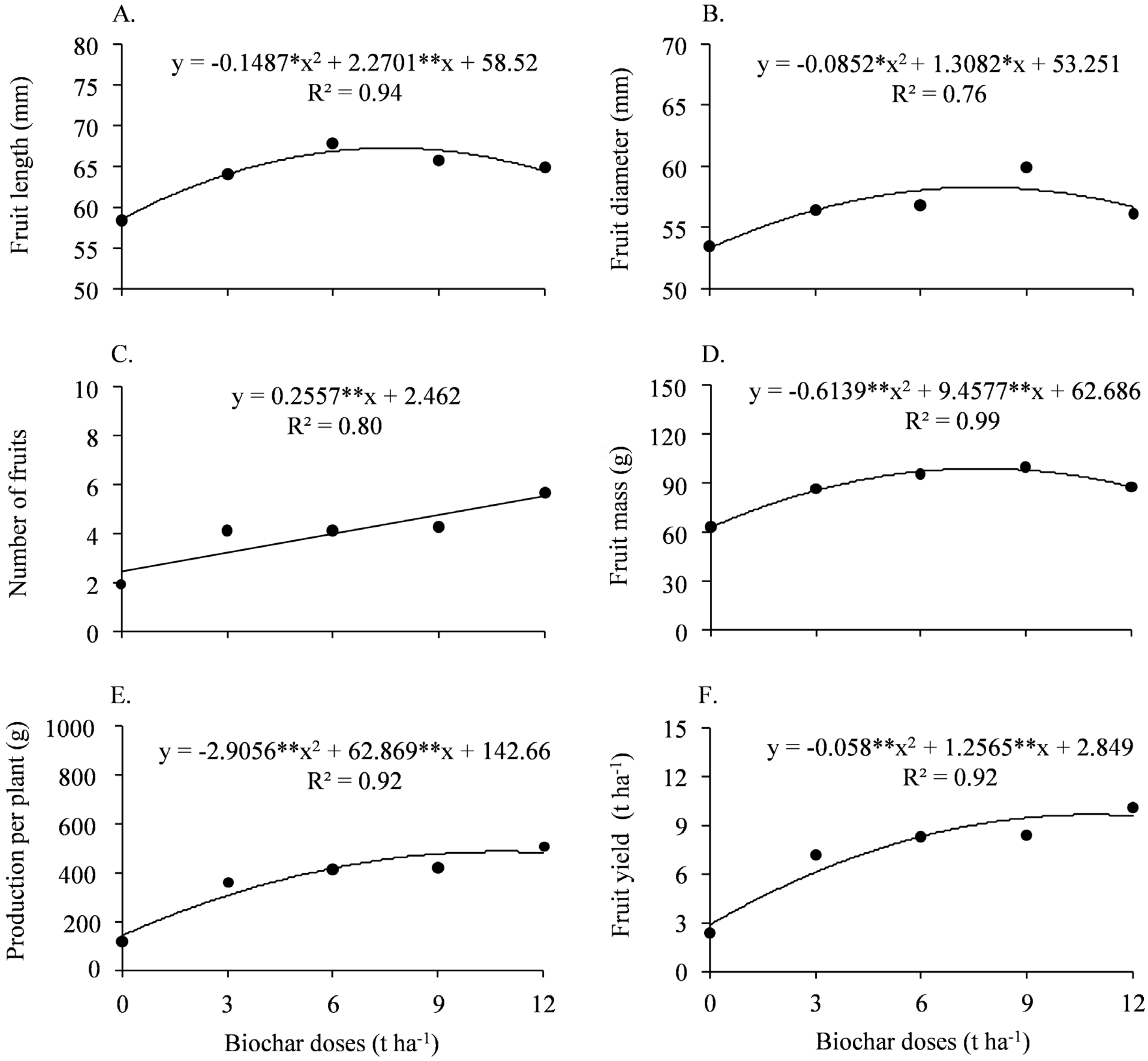


Figure 2. Length (A) and diameter (B) of fruits, number of fruits (C), fruit mass (D), production per plant (E) and fruit yield of bell pepper as a function of biochar doses

obtained superior results for this variable in the treatment with wood ash (28.75 units) with harvests carried out at 95, 114, and 130 days after sowing (DAS). It is important to highlight that, in the present study, the bell peppers were harvested at 86 to 126 days after sowing. The number of fruits produced per plant can show a relative variation in crops depending on management and cycle length and constitutes a parameter of great relevance to obtaining satisfactory yield levels.

The data for fruit mass as a function of biochar doses (Figure 2D) were described by the quadratic polynomial regression model, with the maximum estimated value being 99.11 g with a dose of 7.7 t ha^{-1} of biochar, equivalent to an increase of 78.25% when compared to the mass of the fruit from the additional treatment (55.6 g), where mineral fertilizer was used. Similar values were observed by Hachmann et al. (2017), who used organic compost (cattle manure and vegetable waste) and found a value of 73.38 g for the variable average pepper weight.

The increase in fruit mass may be associated with the availability of nutrients with the application of biochar. According to Chaves et al. (2020), poultry litter biochar has considerable levels of nutrients in its composition, mainly phosphorus and potassium, and a high cation exchange capacity, increasing the availability of these nutrients to plants when added to the soil. Furthermore, the nutrients potassium and phosphorus have fundamental roles in the biochemical and physiological processes of plants related to the growth and development of fruits (Olmo & Villar, 2018).

The data of production per plant were described by the quadratic polynomial regression model (Figure 2E), indicating the highest estimated production of 482.74 g under the dose of 10.12 t ha^{-1} of biochar, a higher value (230.19%) than that verified with the use of mineral fertilizer (146.2 g). Regarding yield (Figure 2F), the data were described by the quadratic polynomial regression model, with a maximum value of 9.65 t ha^{-1} being estimated with a dose of 10.83 t ha^{-1} of biochar, 232.75% higher than that observed in the treatment with the application of mineral fertilizer (2.9 t ha^{-1}). It is possible to observe that the number of fruits per plant contributed to the yield result, that is, the greater the number of bell pepper fruits, the greater the yield. This may occur probably due to the chemical composition of biochars (Table 1), partially meeting the nutritional requirements of bell peppers. It is worth highlighting that the low production seen in plants that received mineral fertilization may be associated with viruses, due to the presence of insect vectors such as whiteflies (*B. tabaci*) and aphids (*M. euphobiae*). The presence of these vectors was also verified in plants that received biochars, but with a lesser incidence of the disease. The main symptoms observed were: darkening of apical leaflets, reduction in leaf area, curvature of the stem, presence of chlorotic and necrotic rings on leaves and fruits, with a halt in plant growth (Figure 3).

Results different from those of this work were observed by Ribeiro et al. (2000), who found that the application of organic fertilizer in the absence of mineral fertilizer promoted an additional gain of 3.5 t ha^{-1} compared to the control, while in the presence of mineral fertilizer this additional gain was 7.0 t ha^{-1}. In the literature it is possible to find several authors, such as Taiwo et al. (2007) and Costa et al. (2019), reporting that better plant development and increased yield are achieved when mineral fertilizer is associated with organic fertilizer, compared to just these fertilizers alone.

However, Almeida et al. (2021), when evaluating the agronomic production of five bell pepper cultivars (three red and two yellow) in a greenhouse, fertilized only with aged cattle manure, observed average length (97.4 mm), diameter (18.20 cm) and number of fruits (52) data that were much higher than the data in the present work. This is probably justified by crop management (cultivation in a field with incidence of viruses) and differences between cultivars, that is, bell peppers are normally smaller than yellow and red peppers.

On the contrary, the number of fruits per plant (35), average weight (61.10 g) and average length of yellow pepper fruits (58.10 mm), cultivated with mineral fertilizers (Nascimento et al., 2020) were lower than the data from Almeida et al. (2021), obtained under organic fertilization, and higher than the data of green peppers using mineral fertilizers in the present work, that is, on average, 3 fruits per plant, average weight of 55.6 g

Figure 3. Underdeveloped bell pepper plant with mosaic symptoms and viral symptoms causing concentric rings on the leaves

and 50 mm in length. This mineral fertilization significantly influenced the length and diameter of fruits, fruit mass, production, and yield of bell pepper fruits.

Regarding the physicochemical characteristics of bell pepper fruits, there were individual effects of the biochar factor for titratable acidity ($p < 0.05$) and of the dose factor for vitamin C, pH, titratable acidity, all at $p \leq 0.01$. The interaction between factors significantly influenced ($p \leq 0.01$) only soluble solids (°Brix). A significant effect of factors versus additional treatment (mineral fertilization) was also observed for vitamin C, titratable acidity and soluble solids.

The doses of biochar significantly influenced the vitamin C content, which may be associated with the greater water and nutrient retention capacity promoted by biochar, contributing to a favorable environment for the physiological development of the fruit. The vitamin C data were described by the quadratic polynomial regression model, with a maximum value of 64.55 mg $100g^{-1}$ being estimated with a dose of 6.57 t ha^{-1} of biochar (Figure 4A). This concentration was higher (40.02%) than that obtained with the use of additional treatment (46.1 mg $100g^{-1}$). However, these levels were lower than the usual value of vitamin C in bell peppers, that is, 84 mg $100g^{-1}$, and those observed by Rinaldi et al. (2008), which ranged from 73.64 to 203.53 mg $100g^{-1}$ for the Magali and Paloma varieties, respectively.

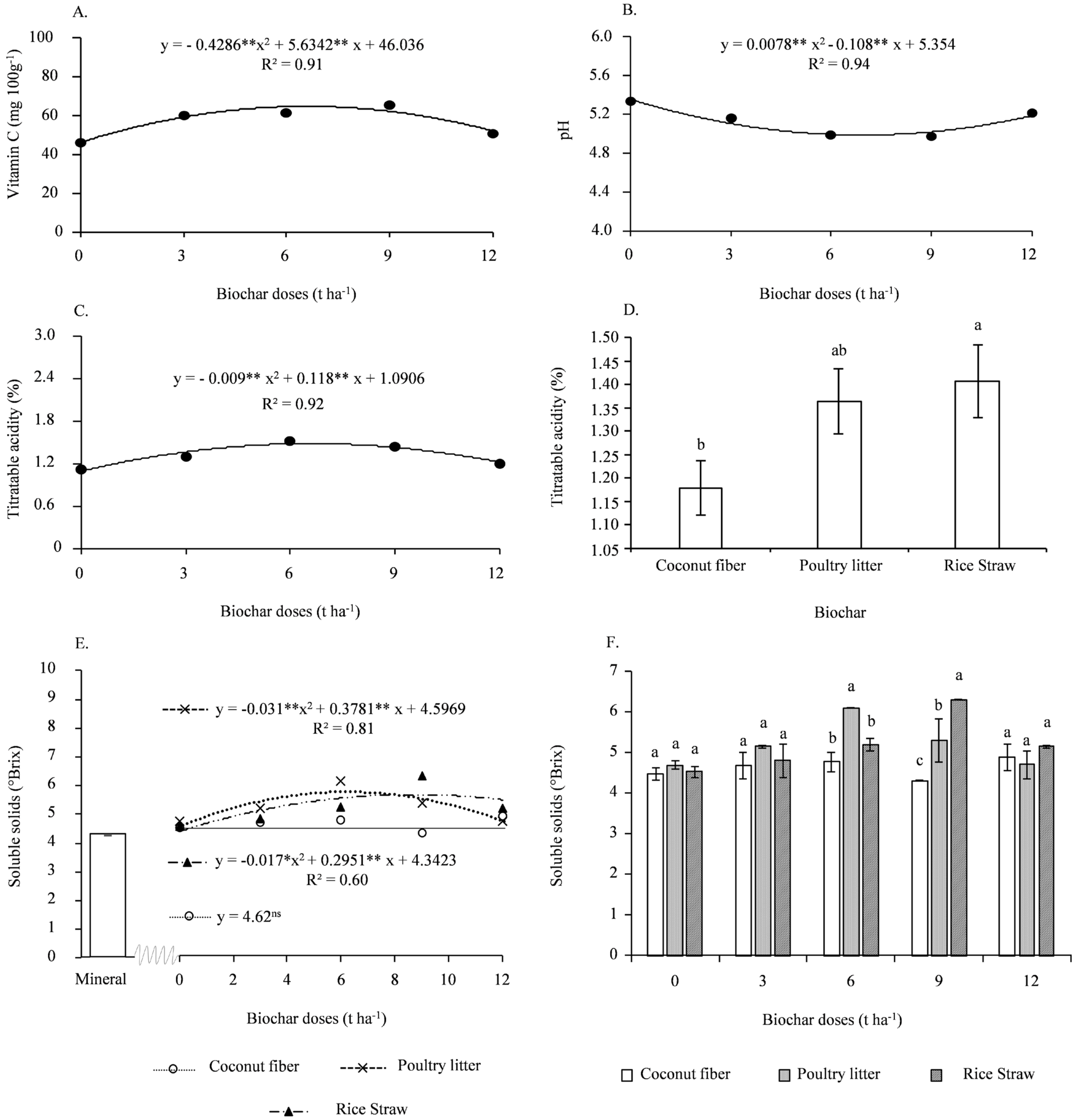
In general, the pepper fruit is a product quite rich in vitamin C; however, it is the most unstable of the vitamins as it is sensitive to physical-chemical agents and climatic conditions, cultural practices, maturation point, fertilizer management, methods of harvest and post-harvest treatment to which the plant is subjected.

The lower levels of vitamin C than those observed in the literature may also be related to the storage time of the fruits, which, in the present study, corresponded to 30 days, above the 12 days considered an ideal period for storage (Rinaldi et al., 2008).

According to Machado et al. (2017), vitamin C levels differ between different varieties of bell pepper. These authors, evaluating the physicochemical and antioxidant composition of varieties of bell pepper, observed that the green bell pepper, the most commonly consumed by the Brazilian population, has one of the lowest levels of vitamin C among those evaluated, 62.5 mg $100g^{-1}$, followed by cream (73.6 mg $100g^{-1}$), red (99.2 mg $100g^{-1}$), and yellow (109.8 mg $100g^{-1}$).

Hydrogen potential (pH) is an essential indicator regarding the durability of peppers (Braga et al., 2013). In view of this, as the pH value decreases, the fruit will be more acidic and will be more resistant to deterioration and contamination by microorganisms harmful to human health, in addition to having greater durability than fruits with a neutral pH (Borges et al., 2015). However, if the fruit has a high acidity content, it may be less accepted by consumers.

In the present work, the pH values in fruits subjected to different doses of biochar presented a maximum estimate of approximately 5.35 at a dose of 0 t ha^{-1} of biochar, following the quadratic polynomial regression model (Figure 4B). These fruits were slightly less acidic when compared to those obtained with mineral fertilizer, whose pH corresponded to 5.2. Similar



Biochar bars with the same letter (Figure D) and within the same dose (Figure F) do not differ from each other by the Tukey test and vertical bars represent the standard error of the mean (n=3).

Figure 4. Individual effect of biochar doses for vitamin C (A), pH (B) and titratable acidity (C); and effect of biochar types for soluble solids (D) and interaction between biochar doses and biochar types for soluble solids (E and F).

values were observed by Pedó et al. (2014) when evaluating the physicochemical characterization of pepper cultivars subjected to different sources and doses of organic fertilizer, whose pH varied from 5.03 to 5.06. Costa et al. (2019), in a study evaluating the efficiency of potassium sources and fertilizers in the nutrition of pepper plants, found pH ranging from 4.00 to 4.47, therefore being more acidic than those found in the present study.

The data on titratable acidity as a function of biochar doses (Figure 4C) were described by the quadratic polynomial regression model, with its maximum estimated value being 1.48% of citric acid at a dose of 6.5 t ha^{-1}. As for the additional treatment (mineral fertilization), the titratable acidity corresponded to 0.5%, a lower value (54.12%) even when compared to that obtained in the treatment without biochar, that is, 1.09% citric acid.

The titratable acidity of bell pepper fruits increased until the application of 6.55 t ha^{-1} of biochar, whose maximum value corresponded to 1.48% (Figure 4C). This increase is justifiable because to maintain the C:N ratio in plants fertilized with organic fertilizer, the extra C is used in the production of organic acids such as citric and malic acids, which increase the acidity of the fruit (Taiwo et al., 2007).

The titratable acidity (Figure 4D) was also influenced by biochars; rice straw biochar was responsible for the highest acidity (1.41%), but without differing from poultry litter (1.36%). The lowest average was obtained with the use of coconut fiber biochar (1.18%).

It is likely that the chemical composition of rice straw and poultry litter biochars influenced their results, since they contained 0.65 and 0.4% nitrogen and the highest phosphorus contents, 0.72 and 2.6%, respectively.

Using biochar from orchard pruning biomass in the production and quality of tomato fruits, Simiele et al. (2022) attributed the gains in fruit quality to the high phosphorus and nitrogen contents in the roots of plants fertilized with biochar.

Regarding the soluble solids content (Figure 4E), data related to biochar from poultry litter and rice straw were described by the quadratic polynomial regression model. For poultry litter biochar, the maximum estimated value was 5.75 °Brix at a dose of 6.1 t ha^{-1}, while rice straw biochar led to a maximum estimated value of 5.62 °Brix at a dose of 8.67 t ha^{-1}. Coconut fiber biochar did not significantly influence the content of this variable, whose average value was 4.62 °Brix. Plants that received mineral fertilization produced fruits with 4.3 °Brix, which is statistically lower than those of fruits harvested from plants fertilized with 3, 6, and 9 t ha^{-1} of poultry litter biochar and 6, 9, and 12 t ha^{-1} of rice straw biochar. The higher incidence of viruses in plants fertilized with NPK influenced these results (data not shown), because the presence of pathogens can harm the development of the crop and compromise production in its entirety (Oliveira et al., 2008).

Regarding the effect of biochars at each applied dose (Figure 4F), only with the use of 6 and 9 t ha^{-1} there was a significant difference in °Brix content between biochars; the highest averages were observed using poultry litter and rice straw biochars, respectively.

Soluble solids content is a characteristic that represents water-soluble compounds, such as sugars, vitamins, acids, amino acids, and some pectins, in addition to being considered an index of quality (Braga et al., 2013). Reference values for bell peppers are not provided by an identity and quality standard, as it is a natural product that suffers variations in its physicochemical patterns due to the influence of parameters such as climate, soil, water availability, time of year, region of cultivation and variety. However, values close to those found in this study were also found by Machado et al. (2017) in research conducted under similar conditions to this study.

Under the conditions of the present study, bell peppers produced under biochar fertilization had higher concentrations of soluble solids and are, therefore, more suitable for fresh consumption than those produced with mineral fertilization due to the flavor and sweetness of the vegetable. It is also important to consider that the Yolo Wonder cultivar has fruits with a crunchy texture and higher sugar content (Borges et al., 2022).

The ash content did not follow a normal distribution and, even after applying the Kruskal Wallis test, no significant difference was found between the treatments.

In general, the use of biochars has proven to be a promising alternative for pepper cultivation, offering benefits in terms of both production and fruit quality.

Conclusions

1. The production of bell pepper fruits was not influenced by the type of biochar; however, the doses of biochars influenced all variables analyzed with the exception of skin thickness.

2. The levels of vitamin C and soluble solids were higher in treatments with biochar, varying depending on the doses used, and were lower with mineral fertilization.

3. The doses of biochar acidified the bell pepper fruits, with the biggest influence of the biochar produced from rice straw.

4. In general, a dose of 6 t ha^{-1} of biochar is the most suitable for growing bell peppers, promoting higher amounts of vitamin C, titratable acidity, and soluble solids in the fruits.

Contribution of authors: Laysa Gabryella de Souza Laurentino: participation in the research design, literature review, analysis and interpretation of data, preparation of the manuscript. Josely Dantas Fernandes: participation in the research design, conducting the experiment in the field; collection of data, statistical analysis, analysis and interpretation of data, preparation of the manuscript. Lúcia Helena Garófalo Chaves: participation in the research design; analysis and interpretation of data, preparation of the manuscript. Antonio Fernandes Monteiro Filho: conducting the experiment in the field, collection of data. Elida Barbosa Corrêa: fruit analysis, analysis and interpretation of data. Deise Souza de Castro: conducting the experiment in the field, collection of data, fruit analysis

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