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Original scientific article

Morphological and physicochemical characterisation of mizuna microgreens grown on cellulose-based substrates

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A B S T R A C T

Peat is one of the most commonly used substrates for microgreens production, but new trends are leading to its replacement with more sustainable substrates or mixtures in various proportions. This study aimed to investigate the replacement of peat substrate with a new cellulose-based substrate, named ARBOCEL®, in mizuna microgreens production, as well as different formulations of peat and ARBOCEL® substrates. For growing mizuna microgreens, the following substrate formulations were used: 100% peat substrate (P); substrate containing 50% ARBOCEL® and 50% peat (50A:50P); substrate containing 70% ARBOCEL® and 30% peat (70A:30P); 100% ARBOCEL® (A). The results showed that microgreens grown on ARBOCEL® (A) had slightly different morphological properties compared to those grown on peat or on the mixture of ARBOCEL® and peat. Moreover, microgreens grown on substrates containing different proportions of peat and ARBOCEL® (50A:50P and 70A:30P) exhibited improved morphological characteristics compared with those grown exclusively on ARBOCEL® (A), including greater weight of microgreens, leaf length and width, and root height. Microgreens grown exclusively on ARBOCEL® and those grown on ARBOCEL®–peat mixture substrates showed lower moisture content than those grown entirely on peat, which is understandable due to the physicochemical properties of cellulose. Visual ratings were also higher in these samples than those grown entirely on ARBOCEL®. In conclusion, the use of ARBOCEL®, either alone or combined with peat, is a viable option for sustainable microgreen production and contributes to addressing ecological concerns. However, future studies are necessary to evaluate the phytochemical profile of mizuna microgreens grown on ARBOCEL®.

Keywords: mizuna microgreens, peat, ARBOCEL®, morphological properties, physicochemical properties

И З В О Д

Тресет је најчешће коришћени супстрат за производњу микробиља; међутим, нови трендови воде ка његовој потпуној замени одрживијим супстратима или њиховим мешањем у одређеним пропорцијама. Циљ овог истраживања је био испитивање могућности замене тресета новим супстратом на бази целулозе, ARBOCEL®, као и утицаја различитих формулација супстрата са различитим уделом тресета и ARBOCEL®-а на производњу микробиља мизуне. За гајење микробиља, коришћене су следеће формулације супстрата: 100% тресет (P); супстрат који садржи 50% ARBOCEL® и 50% тресета (50A:50P); супстрат који садржи 70% ARBOCEL® и 30% тресета (70A:30P); 100% ARBOCEL® (A). Резултати овог истраживања су показали да је микробиље мизуне гајено на ARBOCEL®-у (A) имало нешто другачије морфолошке карактеристике у односу на оно гајено на тресету или на различитим формулацијама супстрата са ARBOCEL®-ом и тресетом. Поред тога, микробиље гајено на супстратима који су садржали различите пропорције ARBOCEL®-а (50A:50P и 70A:30P) показало је побољшане морфолошке карактеристике у поређењу са микробиљем гајеним искључиво на ARBOCEL®-у (A), и то у погледу појединачне масе, дужине и ширине листова, као и висине корена. Такође, оцене визуелног квалитета су биле више код ових узорака у односу на оне гајене искључиво на ARBOCEL®-у. На крају, употреба ARBOCEL®-а, било самостално или у комбинацији са тресетом, представља одрживу опцију за производњу микробиља и доприноси решавању еколошких изазова. Међутим, будућа истраживања су неопходна ради испитивања фитохемијског профила микробиља мизуне гајеног на ARBOCEL®-у.

Кључне речи: микробиље мизуне, тресет, ARBOCEL®, морфолошке карактеристике, физичко-хемијске карактеристике

1. Introduction

Microgreens are an emerging trend in horticultural production and human nutrition; they are also called vegetable confetti and are considered a functional food, with specific characteristics regarding growing period, substrate, growing system, and morphological properties (Gunjal et al., 2021). This class of plants has a simple morphology reflected in its edible and non-edible parts; the edible parts are the stem, cotyledonary leaves, and true leaves, while the only non-edible part is the root (Partap et al., 2023). Besides advantages such as a short growing period and ease of production, microgreens have a unique aroma, flavour, and texture, and, most importantly, contain various bioactive compounds (Abaajeh et al., 2023). Some of these bioactive compounds include phenolic compounds, vitamins, minerals, glucosinolates, betalains, and chlorophylls (Belošević et al., 2024). The content of the mentioned bioactive compounds in microgreens can be several times higher than in the mature plant, and their content is positively associated with health benefits; therefore, microgreens are considered nutrient-rich and healthy food (Bhaswant et al., 2023). Among the various families used in microgreens production, the Brassicaceae family stands out as one of the most popular, particularly with mustards, which have a high content of bioactive compounds, such as phenolic compounds, pigments, minerals, and vitamins (Kyriacou et al., 2021).

On the other hand, uncontrolled exploitation of agricultural land and peat has caused progressive soil degradation, leading to a decline in essential nutrients required for plant growth, while the effects of traditional agriculture negatively impact the environment and contribute to global warming (Dubey et al., 2024). In these conditions, microgreens offer a viable alternative for ensuring year-round food production on various substrates. Growing microgreens in vertical farming depends on various factors, but the growing substrate is the most important. There are many substrates used for microgreens production as replacements for peat, sourced from various origins and with different properties. However, the most frequently grown microgreens are cultivated in soilless systems, which include vermiculite, perlite, coconut coir dust, etc. (Bhaswant et al., 2023). Several studies have investigated the effects of various light sources and combinations of growing media on mustard microgreens, examining their impact on growth, morphology, physicochemical properties, and phytochemicals content (Jones-Baumgardt et al., 2019; Kong, Masabni, and Niu, 2023; Flores et al., 2024; Syahriana et al., 2025). The media studied include cellulose, mixtures of peat and perlite, mixtures of peat, compost, coir, and perlite, rockwool, mixtures of vermiculite, cocopeat, and sand, among others, as well as modern hydroponic systems using pads of polyethylene terephthalate fibres (Kopsell et al., 2012). Till now, no studies have used ARBOCEL® for microgreens production. ARBOCEL® is a cellulose fibre derived from a natural and renewable source. ARBOCEL® is also a non-toxic, biodegradable product that does not cause environmental concerns (Bărbuță and Harja, 2008), and its positive physicochemical properties make it suitable as a substrate for growing microgreens.

Some articles have investigated the effect of using cellulose-based substrates (cellulose sponge) on the morphological, physicochemical, and phytochemical properties of microgreens and have demonstrated improvements in these properties. However, until now, ARBOCEL® has not been used for this purpose. Taking into account the above, the aim of this study was to investigate the effect of replacing peat substrate with a new cellulose-based substrate, ARBOCEL®, on the morphological and physicochemical properties of mizuna microgreens.

2. Materials and methods

2.1. Materials

The experiment was conducted at the local Plantica company in Belgrade, where mizuna microgreens were grown in plastic trays with three replicates (three trays per treatment). The seed density for the production of mizuna microgreens was 6 seeds/cm^2. Peat substrate was purchased from Klasmann–Deilmann GmbH (Geeste, Germany) (the peat substrate was enriched with NPK – nitrogen, phosphorus, and potassium fertilisers), while mizuna microgreen seeds were obtained from Plantica for microgreen production. ARBOCEL® FIF 400 cellulose was purchased from Effecta Feed d.o.o. (Novi Sad, Serbia). ARBOCEL® is a fine powder produced from natural cellulose by wet processing, fine grinding, sieving, and classification. The particles were white, with a powder structure, an average fibre length of approximately 2,000 µm, a maximum loss on drying of 8%, oxide ash (850 °C, 4 h) of about 0.3%, a pH value in a 5% suspension of 5.5–7.5, and a bulk density of 25–50 g/L (in accordance with DIN EN ISO 60). In this study, four different formulations were used for growing microgreens, as shown in Table 1.

Table 1.
Different substrate formulations for growing microgreens

	Substrate			
	P	50A:50P	70A:30P	A
Ingredient	100% peat substrate	50% ARBOCEL® + 50% peat substrate	70% ARBOCEL® + 30% peat substrate	100% ARBOCEL®

The preparation of the substrate involved measuring the required amounts of peat and ARBOCEL®, followed by mixing and homogenising the ingredients. The prepared substrate was then arranged on the growing medium and watered with distilled water. The growing medium was a plastic container with a specified growing area (12x8 cm). Mizuna seeds were sown in the medium, watered, and left in the dark until sprouting. Microgreens were grown in a vertical farming system under controlled conditions, including the use of a fan, artificial lights, and regulated temperature. The temperature at the cultivation site was 20°C, with humidity at 80%. Microgreens were harvested with scissors 10 days after germination.

2.2. Morphological properties

After harvesting, microgreens were used to determine morphological properties. Morphological properties were measured on 10 randomly selected microgreens per plastic tray according to Gunjal et al. (2024), with some modifications. The following morphological parameters were recorded: height of microgreens (cm), height of root (cm), width of stem microgreens (cm), weight of a single microgreen (mg), weight of 10 microgreens (mg), leaf length of microgreens (cm), and leaf width of microgreens (cm).

Measurements were taken using a ruler and a laboratory analytical balance. Images of mizuna microgreens grown on different substrate formulations, prepared for the determination of morphological properties, are showed in Figure 1.

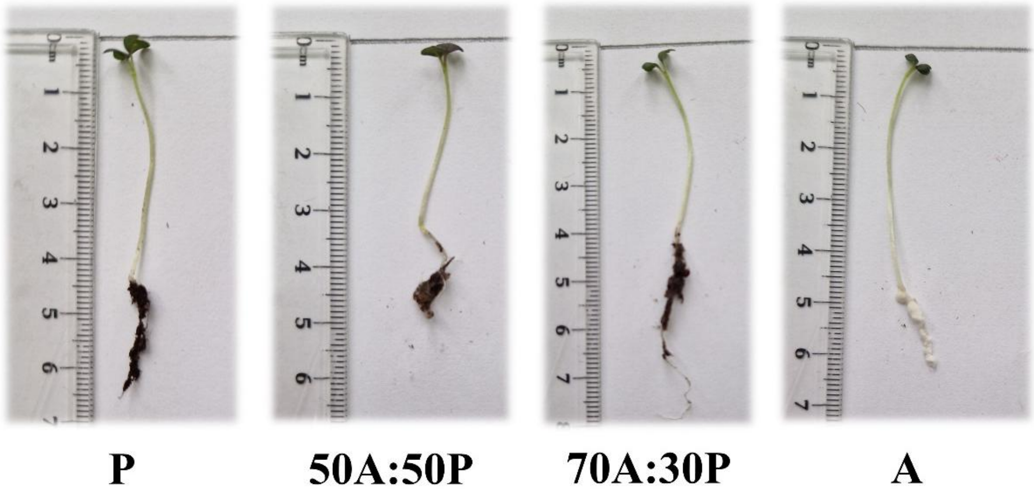

Figure 1. Images of mizuna microgreens grown on different substrates

2.3. Dry weight and moisture content

Dry weight (DW) and moisture content (MC) were measured using the standard gravimetric method (AOAC, 2005) by drying the sample at 105 °C until a constant mass was achieved, according to the following equations:

$$\boldsymbol{DW}\ (\%) = \frac{Weight\ of\ the\ dry\ microgreens}{Weight\ of\ initial\ microgreens} \times 100$$

$$\boldsymbol{MC}\ (\%) = 100 - \boldsymbol{DW}$$

2.4. Visual quality rating

The visual quality rating of microgreens was assessed by trained evaluators using a 1–5 rating scale, following Li et al. (2023). In this scale, a score of 1 indicates seedling growth covering 20% or less of the growing surface; 2 indicates 20–40% coverage; 3 indicates 40–60% coverage; 4 indicates 60–80% coverage; and 5 indicates over 80% coverage with healthy plant growth.

2.5. Statistical analysis

The results of morphological and dry weight results were expressed as mean values ± standard deviation (n = 3), while significant differences between means were determined by one-way ANOVA using the Duncan post-hoc test (IBM SPSS ver. 25 statistical software, SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Morphological properties

Morphological characteristics are important indicators of growth, development, and productivity in a wide range of plant species (Ćirković, 2025), while in microgreens, morphology and visual appearance are considered primary indicators of microgreens quality. Figure 2 presents the height and weight of the microgreens investigated in this study.

The global trend in microgreens production involves replacing peat with alternative substrates, as peat is considered unsustainable due to its slow renewability and high level of exploitation, which raises ecological concerns (Min Allah et al., 2023). In this study, microgreens grown in ARBOCEL® (A) reached a greater height (4.73 ± 0.39 cm) than those grown in the control substrate (P) (4.63 ± 0.70 cm), but the difference was not significant ($p < 0.05$). Our study reported slightly higher values compared to Kong, Masabni, and Niu (2023), who used rockwool to grow mustard microgreens, particularly regarding morphological properties. Similar results were observed in a study by Min Allah et al. (2023), who used peat and an alternative jute substrate for the production of mustard microgreens. The study found that microgreens grown on peat and those grown on the alternative substrate had similar morphological properties related to height, as the difference was not significant as in our study. However, in our study, mizuna microgreens grown on ARBOCEL® had higher values for height than those in the mentioned study, which may be due to the favourable characteristics of the ARBOCEL® substrate for growing microgreens. Also, these findings are consistent with the study by Dhaka et al. (2023), who used a mixture of coco peat, vermiculite, and sand for growing microgreens. In contrast to our study, Polash et al. (2019) obtained better results for the height of mustard microgreens, but they used different substrates to grow the microgreens, such as tissue media (tissue paper with water), foam media (foam with water), soil media, and a mixture of soil and cow dung. Comparable results with peat were obtained for the width of stem microgreens, with values ranging from 0.89 ± 0.14 mm (70A:30P) to 0.99 ± 0.09 mm (50A:50P). Also, similar results were observed in the study by Kyriacou et al. (2020), where selected microgreens grown on cellulose sponge had heights comparable to those in our study.

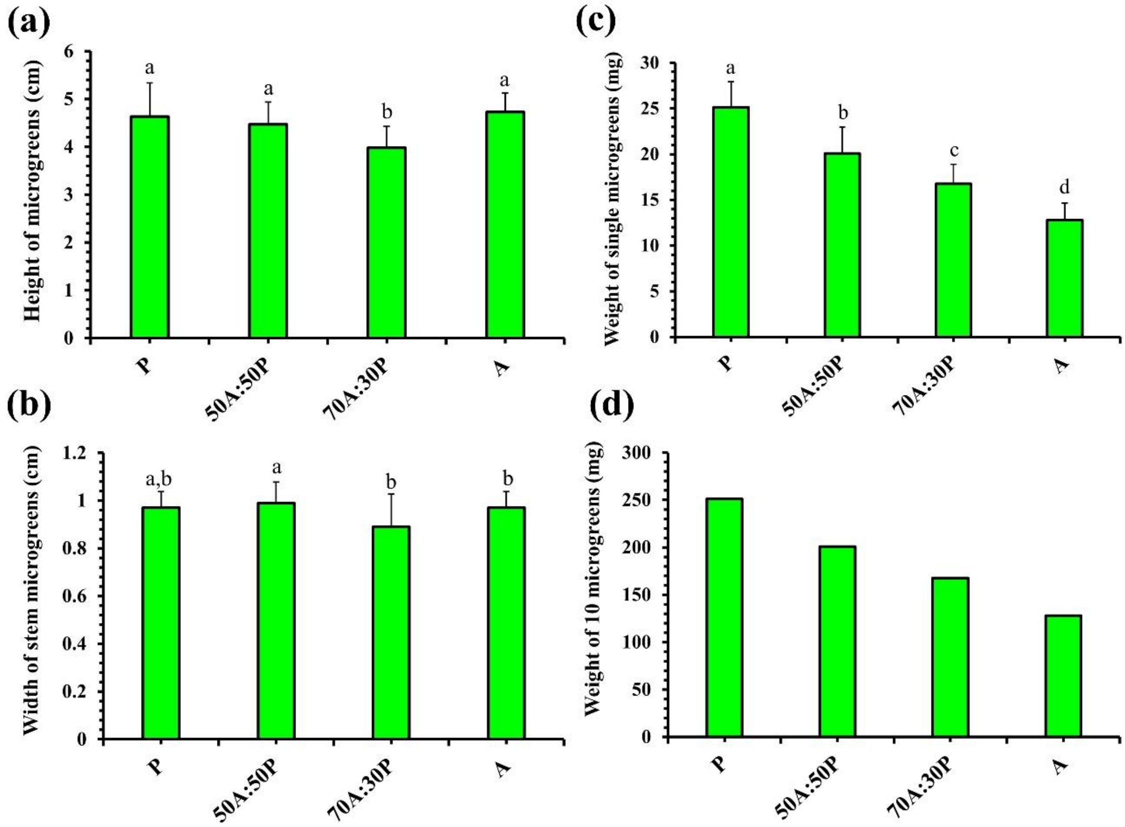

Figure 2. Morphological characterisation of mizuna microgreens grown in different substrates. The results are expressed as mean ± standard deviation. Different lowercase letters indicate a significant difference between the microgreens. Where: (a) Height of microgreens, (b) Width of stem microgreens, (c) Weight of single microgreens, and (d) Weight of 10 microgreens. Abbreviations: P – mizuna microgreens grown on 100% peat substrate; 50A:50P – mizuna microgreens grown on a substrate containing 50% ARBOCEL® and 50% peat; 70A:30P – mizuna microgreens grown on a substrate containing 70% ARBOCEL® and 30% peat; A – mizuna microgreens grown on 100% ARBOCEL®

Regarding the weight of mizuna microgreens, better results were obtained when microgreens were grown in peat rather than ARBOCEL®, with results ranging from 12.79 ± 1.86 mg (A) to 25.11 ± 2.82 mg (P). Kyriacou et al. (2020) made a similar observation, noting that microgreens had higher yields when grown on peat moss compared to cellulose sponge. In our study, mizuna microgreens grown on a peat substrate showed the highest weight, followed by those grown on substrates containing 50% ARBOCEL® (20.08 ± 2.87 mg), 70% ARBOCEL®, and 100% ARBOCEL®. Moreover, it can be concluded that mizuna microgreens grown on the 50A:50P substrate formulation exhibited more promising results for morphological properties than those grown on the 70A:30P substrate formulation, and that mixing different substrate proportions led to improved morphological properties. This is understandable because the peat contained a high level of organic matter, which positively affected the fresh weight of microgreens (Nur and Gofar, 2023). Moreover, Nur and Gofar (2023) reported that mustard microgreens grew better on loose compost substrate and soil–compost or cocopeat–compost mixtures, likely due to the improved porosity and water retention provided by the organic matter, while a deficit of nutrients can decrease the height and weight of seedlings (Polash et al., 2019).

The continuation of the morphological parameters refers to the part of microgreens that is not edible, the root, while the edible part is the leaf. Figure 3 presents the root height and the leaf length and width of the microgreens investigated in this study.

The leaf length and width of microgreens are morphological parameters that did not show significant differences among treatments. The mizuna microgreens grown on substrate P showed the greatest length and width, while those grown on the other formulation substrates had similar values without significant differences. Our study showed similar results to the study by Suwegiono et al. (2025), who investigated the effect of different growing media on the growth and yield of mustard microgreens and did not find significant differences among media in relation to leaf properties. On the other hand, roots are an important part of microgreens morphology, as they provide the plant with adequate water and nutrients, while the substrate plays a role in ensuring proper root development. The lowest root height was produced by mizuna microgreens grown on A (1.42 ± 0.37 cm), while the best values for this parameter were obtained by microgreens grown on 70A:30P (3.33 ± 0.48cm). The combination of peat and ARBOCEL® provided better results for root height, which may indicate a better-developed root system. Similar results were reported by Nur and Gofar (2023), who found that combining different substrates provides the most favourable morphological characteristics for the root length of mustard microgreens. In our case, this is understandable because ARBOCEL® is purified cellulose obtained from plant raw material and does not contain organic matter related to nitrogen, phosphorus, or potassium that plants can use for development. Moreover, similar results were obtained by Kyriacos et al. (2020), when a substrate based on cellulose sponge provided a poor environment for microgreens roots due to low air capacity and a high relative content of micropores. Therefore, the results obtained in our study show that it is desirable to combine ARBOCEL® with a substrate containing organic matter to improve the investigated morphological properties of mizuna microgreens. The observed differences in certain morphological properties between microgreens grown on peat substrate and those grown on ARBOCEL® substrate may originate from the physicochemical properties of the substrates. However, the addition of fertiliser has a minor effect because the seed provides microgreens with adequate nutrition for the development of the young crop, although this does not exclude the potential benefit of using light fertilisers (Treadwell et al., 2020; Dubey et al., 2024).

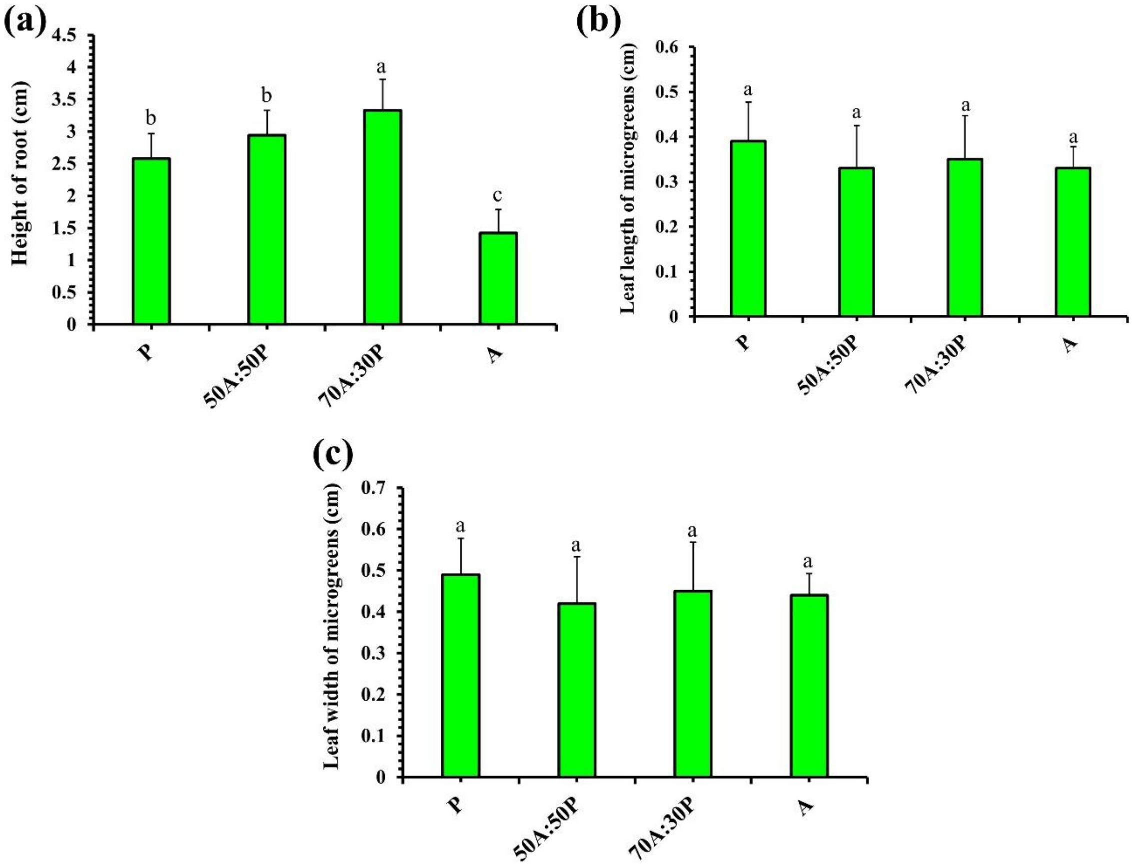

Figure 3. Morphological characterisation of mizuna microgreens grown in different substrates. The results are expressed as mean ± standard deviation. Different lowercase letters indicate a significant difference between the microgreens. Where: (a) Height of root, (b) Leaf length of microgreens, and (c) Leaf width of microgreens. Abbreviations: P – mizuna microgreens grown on 100% peat substrate; 50A:50P – mizuna microgreens grown on a substrate containing 50% ARBOCEL® and 50% peat; 70A:30P – mizuna microgreens grown on a substrate containing 70% ARBOCEL® and 30% peat; A – mizuna microgreens grown on 100% ARBOCEL®

3.2. Physicochemical properties

The moisture content of mizuna microgreens grown on different substrate formulations is shown in Table 2. There are several factors that can affect the moisture content in microgreens, including environmental conditions, cultivation methods, harvesting, storage conditions, and the growing substrate (Gunjal et al., 2024). The high moisture content in mizuna microgreens is expected; the microgreens contain a higher amount of water and a lower amount of carbohydrate. For this reason, these microgreens are preferable for inclusion in a healthy diet (Polash et al., 2019). Moisture content in microgreens ranged from 91.63±0.04 % (A) to 94.31±0.23 % (P). Microgreens grown in ARBOCEL® had a lower moisture content and higher dry matter than microgreens produced on peat. This difference can be explained by the structure of the substrates used in this study. Namely, cellulose substrates have more micropores, which leads to reduced root growth and increased dry weight, in contrast to decreased moisture content (Paglialunga et al., 2023), as can be seen in the results for root height (Figure 3). Kyriacou et al. (2020) had a similar observation that microgreens of coriander, kohlrabi, and pak choi had higher dry matter (lower moisture content) when grown on cellulose sponge compared to peat moss. However, comparisons between published studies can be difficult due to differences in environmental conditions, substrate structures, and harvest stages.

Table 2.
Moisture content of mizuna micorgreens grown on different substrate formulations

Microgreens	Substrate	Moisture content (%)
Mizuna microgreens	P	94.31±0.23^{a}
	50A:50P	92.96±0.25^{b}
	70A:30P	91.71±0.22^{c}
	A	91.63±0.04^{c}

* Different lowercase letters indicate significant differences between samples, as determined by the Duncan test, $p < 0.05$. Abbreviations: P – mizuna microgreens grown on 100% peat substrate; 50A:50P – mizuna microgreens grown on a substrate containing 50% ARBOCEL® and 50% peat; 70A:30P – mizuna microgreens grown on a substrate containing 70% ARBOCEL® and 30% peat; A – mizuna microgreens grown on 100% ARBOCEL®.

3.3. Visual rating quality

The visual quality rating of mizuna microgreens grown on different substrate formulations is shown in Table 3. Visual rating differed among mizuna microgreens grown on various substrate formulations.

Table 3.
Visual quality rating of mizuna micorgreens grown on different substrate formulations

Microgreens	Substrate	Visual rating (%)
Mizuna microgreens	P	5
	50A:50P	4.5
	70A:30P	4.5
	A	3^{c}

* Abbreviations: P – mizuna microgreens grown on 100% peat substrate; 50A:50P – mizuna microgreens grown on a substrate containing 50% ARBOCEL® and 50% peat; 70A:30P – mizuna microgreens grown on a substrate containing 70% ARBOCEL® and 30% peat; A – mizuna microgreens grown on 100% ARBOCEL®.

The best visual rating was obtained for mizuna microgreens grown on P (5), while the lowest score was for those grown entirely on A (3). This may be a consequence of slightly poor germination of mizuna microgreens grown on A, which was visually noticeable (Figure 4). In contrast, microgreens grown on substrates with different proportions of peat and ARBOCEL®(4.5) had better seedling coverage than those grown entirely on A, indicating a better appearance.

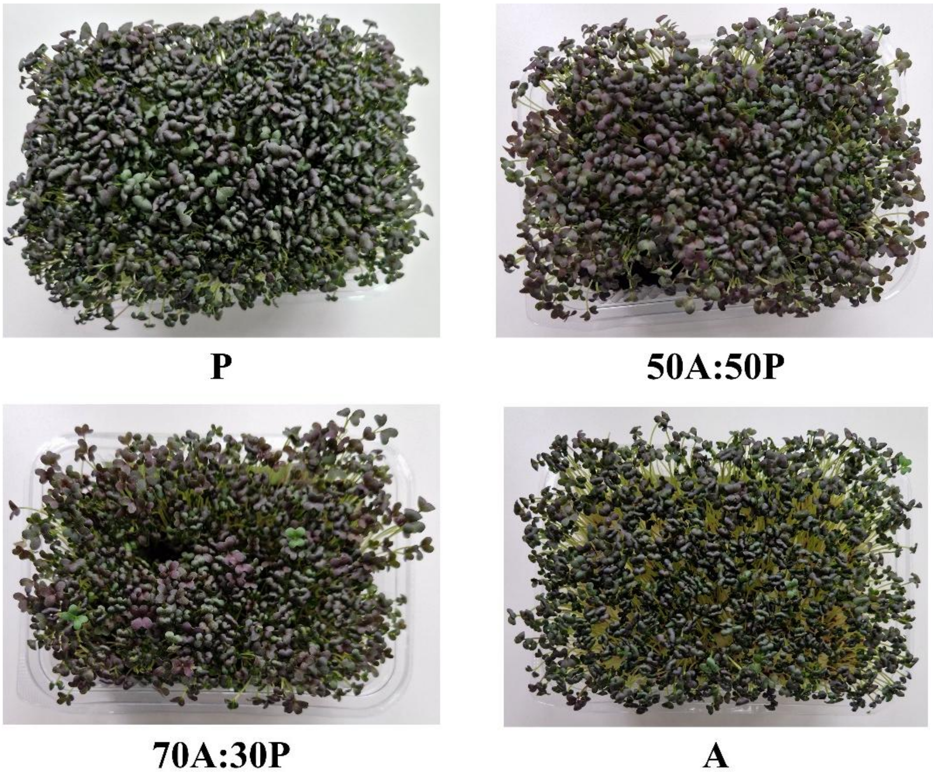

Figure 4. Top-view images of mizuna microgreens grown on different substrates. Abbreviations: P – mizuna microgreens grown on 100% peat substrate; 50A:50P – mizuna microgreens grown on a substrate containing 50% ARBOCEL® and 50% peat; 70A:30P – mizuna microgreens grown on a substrate containing 70% ARBOCEL® and 30% peat; A – mizuna microgreens grown on 100% ARBOCEL®

Conclusion

This study investigates a new cellulose-based substrate, ARBOCEL®, for microgreen production, as a replacement for peat substrate. Although mizuna microgreens exhibited better morphological properties when grown on peat, microgreens grown on ARBOCEL® also showed suitable morphological properties. Moreover, microgreens grown on substrates with different proportions of peat and ARBOCEL®(50A:50P and 70A:30P) showed better morphological properties than those grown entirely on ARBOCEL®(A) in terms of weight, leaf length and width, root height, etc. Microgreens grown entirely on ARBOCEL® and those grown on substrates with different proportions of ARBOCEL® had lower moisture contents than those grown entirely on peat. Visual ratings were also higher in these samples than in those grown entirely on ARBOCEL®. In conclusion, although better results were achieved with peat substrate related to morphology, using ARBOCEL® substrate or a mixture with peat in microgreen production represents a promising alternative to peat, supports sustainable agriculture, and helps address ecological concerns. Further research is needed to evaluate the phytochemical characterisation of mizuna microgreens grown on ARBOCEL® and similar substrates.

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Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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