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ORIGINAL RESEARCH ARTICLE

Lettuce culture in semi-hydroponics with a normal nutrient solution and using treated wastewater

Sónia Rodrigues[1], Fátima Carvalho[1], Adelaide Almeida[1], Idália Guerreiro[1], Ana Prazeres[2], Mariana Regato[1*]

[*1] *Instituto Politécnico de Beja-Escola Superior Agrária de Beja, Rua Pedro Soares, Beja, Portuga. E-mail: mare@esab.ipbeja.pt*

[2] *Centro de Biotecnolgia Agrícola e Agro-Alimentar do Alentejo (CEBAL), Rua Pedro Soares Beja 7800, Portuga.*

ABSTRACT

This work aimed to evaluate the effects of using three different substrates in the semi-hydroponic culture of lettuce (*Lactuca sativa* L.) using two different nutrient solutions. A first trial was performed with a nutrient solution rich in macronutrients and micronutrients suitable for lettuce culture, and a second trial with a nutrient solution with pretreated wastewater from effluents of a cheese factory. The experimental design was in randomized blocks with three repetitions and three substrates were used: perlite, coconut fiber, and expanded clay, in both trials. The following parameters were observed: number of leaves, diameter of the cabbage, fresh and dry weight of the aerial part, chlorophyll index and mineral composition of the lettuce. For the first trial, the highest result for the number of leaves (20 leaves), fresh weight (142.0 g) and dry weight (7.2 g) of the aerial part was obtained in the plants growing on perlite. In the second trial, the highest result for the number of leaves (28 leaves), diameter of cabbage (26.7 cm), fresh weight (118.8 g) and dry weight (9.5 g) of the aerial part were achieved by the plants that were grown in coconut fiber. The nutrient solutions were analyzed after each irrigation cycle to verify the possibility of their discharge into the environment. Several parameters were analyzed: pH, conductivity, redox potential, nitrates, nitrites, ammoniacal nitrogen, chlorides, hardness, calcium, phosphates, sodium, potassium, chemical oxygen demand (COD) and magnesium. Ammoniacal nitrogen was found to be the only nutrient that can limits the discharge of nutrient solutions into the environment. It was also proven that the plants, besides obtaining the nutrients necessary for their development in the semi-hydroponic system with the nutrient solution with pretreated residual water, also functioned as a purification system, allowing the said nutrient solution to be discharged into the environment at the end of each cycle.

Keywords: Substrates; Cheesecloth; Fresh and Dry Weight; Cabbage Diameter

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1. Introduction

The reuse of wastewater in agriculture is of great importance to meet the increasing needs of water use that this practice requires; to reduce the pollution of water resources caused by effluents and to increase the economic benefits for producers due to the reduction of fertilizer application[1], since some of the treated effluents are rich in nitrogen, phosphorus, organic matter, etc., and can be used as fertilizers[2]. However, there must be a precise knowledge of its chemical composition, so that there is no contamination of crops or groundwater, since this may be slightly different from the water normally used for irrigation[3].

Irrigation with wastewater also has direct benefits for farmers and the environment, as it reduces energy costs and thus minimizes carbon emissions, and is also a water scarcity mitigation measure[4].

Lettuce can be grown in several culture systems without soil. The hydroponic system called NFT (Nutrient Film Technique) has achieved prominence in the production of this vegetable, being the system of choice among the various systems available, for its effectiveness in production and for being one of the most practical in terms of use[5].

The use of wastewater, as a nutrient solution in an NFT system, led to the formation of larger leaf area and consequently a higher fresh weight content in the lettuce crop[6]. Studies on the effect of fertigation with treated wastewater from dairy and slaughterhouse industries indicated that this technique had a significant contribution to the increase in the average productivity of lettuce grown under glasshouse conditions[7].

2. Material and methods

Two greenhouse trials were conducted in the Horticultural Center of the Beja Agricultural College, with the objective of evaluating the effects of using three different substrates on the semi-hydroponic culture of lettuce (*Lactuca sativa* L.) in an NFT (Nutrient Film Technique) system, using two nutrient solutions and three substrates: expanded clay, perlite, and coconut fiber.

It was also the objective of these trials to evaluate the performance of the hydroponic system in removing nutrients from the nutrient solutions in order to allow their discharge into the aquatic environment.

In the first trial (from November to January) a normal nutrient solution was used for this crop (SNAS) and in the second trial (from March to May) a nutrient solution obtained from a cheese factory wastewater effluent, pre-treated through basic chemical precipitation + natural neutralization processes, which allowed the partial removal of organic matter, total suspended solids, fats and some nutrients (SNART). The cultivar used in both trials was the potato variety "Loura de Paris".

The NFT system used consisted of a laminar nutrient flow technique, composed of a tank where the nutrient solution was placed, a pumping system, cultivation channels, and a return system to the tank. The nutrient solution was pumped into the channels and drained by gravity, forming a thin sheet of nutrient solution that watered the roots.

The experimental design used in both trials was a randomized block design with three replications.

The same methodology was used in both trials, that is, the lettuce seedlings were transplanted into small polyethylene pots, perforated at the base, with 4 cm diameter at the base and 7 cm diameter at the top, and a height of 8 cm. A total of 27 pots were used, 9 for each type of substrate.

The nutrient solution was circulated every 15 minutes (15 minutes circulating and 15 minutes not circulating) during the daytime period, from 07:00 am to 07:00 pm. During the night, two 15-minute irrigations were performed, one at 11:00 pm and another at 3:00 am.

The pump used in the system had a flow rate of 10.4 liters per minute.

The solution was renewed every two weeks, according to the protocols described by Moraes and Martinez cited by Genúncio *et al.*[8].

The number of leaves was counted and the diameter of the cabbage and the chlorophyll index of the lettuce were measured throughout the crop cycle. After harvest, the following parameters were also observed: fresh and dry weight of the aerial part, and leaf mineral composition.

The nutrient solutions were analyzed after each irrigation cycle (every 15 days), in order to verify the possibility of their discharge into the environment. Several parameters were analyzed: pH, electrical conductivity, redox potential, nitrates, nitrites, ammoniacal nitrogen, chlorides, calcium, phosphates, sodium, potassium, magnesium and COD (chemical oxygen demand).

At the end of each cycle, the average removal efficiency for each of the monitored parameters was also evaluated according to the following expression: % removal = [(Ci-Cf)/Ci]x100, where Ci is the initial average concentration and Cf is the final average concentration.

3. Results and discussion

For the first trial, where the standard nutrient solution (SNAS) was used, it was found that there were no statistically significant differences between substrates for the number of leaves and chlorophyll index.

The fresh weight and dry weight of the aerial part and the diameter of the cabbage showed significant differences between the substrates, the highest values being found with the perlite substrate, although the diameter of the cabbage did not show differences with respect to coconut fiber (**Table 1**).

The results for perlite are probably due to the ease of circulation of the nutrient solution in the substrate, and the fact that it allows moisture and oxygen to flow freely to the roots.

Regarding the mineral composition of lettuce, it was found that in coconut fiber, the leaves had the highest value of phosphorus (0.87%), in expanded clay the highest values of potassium (0.74%) and sulfur (0.22%) and in perlite the highest content of boron (22.31 mg·kg^{-1}) (**Table 2**).

The results obtained are not enlightening to determine which of the substrates allows for a more nutrient-rich mineral composition of the plant.

In the second trial, in which the nutrient solution from the cheese factory effluent (SNART) was used, there were significant differences between substrates for the parameters: fresh and dry aboveground, number of leaves and diameter of cabbage, with coconut fiber showing the highest values (**Table 3**).

Table 1. Effect of substrate on aboveground fresh and dry weights (SNAS)

Substrates	Fresh weight of the aerial part (g)	Dry weight of the aerial part (g)	Diameter of cabbage (cm)
Expanded clay	94.2 c	5.1 c	26.1 b
Perlite	142.0 a	7.2 a	28.2 a
Coconut Fiber	133.5 b	6.4 b	28.8 a

Table 2. Average potassium, phosphorus, sulfur, and boron contents in the aboveground part of lettuce (SNAS)

Substrates	P (%)	K (%)	S (%)	B (mg·kg^{-1})
Expanded clay	0.74	6.83	0.22	21.83
Perlite	0.75	6.55	0.21	22.31
Coconut fiber	0.87	6.61	0.14	21.55

Table 3. Effect of substrate on fresh and dry weights of aerial part, # of leaves and diameter of cabbage (SNART)

Substrates	Fresh weight of aerial part (g)	Dry weight of aerial part (g)	Number of Leaves	Diameter of cabbage (cm)
Expanded clay	30.3 c	3.2 c	17.1 c	18.4 c
Perlite	61.8 b	6.3 b	25.2 b	21.9 b
Coconut fiber	118.8 a	9.5 a	28.7 a	26.7 a

The type of substrate influenced and had effects on the productivity of the lettuce crop in both trials. In contrast, Carneiro *et al.*[9] did not find any influence of substrates on the weight of dry matter of the aerial part and the number of leaves, in the evaluation of five different substrates in the culture of cucumber.

When SNAS was used, the substrate that presented the highest results in most of the parameters was perlite, while with the use of SNART, it was with coconut fiber that the best results were obtained. Farias *et al.*[10], also obtained higher results in coconut fiber in hydroponic culture in NFT of arugula when they used the substrates, carbonized rice husk and coconut fiber.

Visually it could be seen that in both trials, the substrate with more difficulty in retaining the nutrient solution was the expanded clay. On the contrary, coconut fiber retained the most water and nutrients, which proved to be an advantage in the second trial, since it was performed in the spring-summer period, a warmer season and with a greater need for water. This may be one of the reasons why better results were obtained for coconut fiber in the SNART trial.

The substrate composition influenced the analyzed parameters, possibly due to the pore space and water holding capacity presented in the different substrates[11].

It is thus clear that the choice of substrate is very important when using certain nutrient solutions in the semi-hydroponic system.

In addition to verifying the possibility of producing lettuce using a nutrient solution from a pretreated wastewater, there was also interest in observing whether the lettuce produced in the NFT hydroponic system would have a dual function: withdraw the nutrients from the SNAS and SNART solutions in sufficient quantity to develop and, simultaneously, by withdrawing these nutrients, function as a tuning system for the solutions, allowing their discharge into the environment at the end of each cycle.

Usually hydroponic systems reuse the nutrient solution by continuous nutrient replacement.

In **Table 4**, we can observe the chemical composition of the SNAS nutrient solution at the entrance and exit of the system, as well as the percentage of removal of the elements that constituted it. It can be seen that there were removals in the order of 50% for phosphates, potassium and sodium. Nitrogen in nitric (20.2%) and ammoniacal (49.3%) form was removed, as well as calcium in a percentage of only 8.1%.

Looking at **Table 5**, we see that the pH has risen from 7.3 to 7.8, the electrical conductivity has decreased, as has the redox potential and the SAR.

Table 4. Characterization of the SNAS at the input and output of the system and the % removal

Analyzed Parameters	SNAS input (average values)	SNAS output (Average values)	% Removal
Nitrates (mg·L^{-1})	111.1	88.7	20.2
Nitrite (mg·L^{-1})	0.0	0.4	-
Ammoniacal Nitrogen (mg·L^{-1})	20.3	10.3	49.3
Chlorides (mg·L^{-1})	36.5	43.8	-
Calcium (mg·L^{-1})	157.0	144.9	8.3
Phosphates (mg·L^{-1})	9.5	4.6	51.6
Sodium (mg·L^{-1})	110.5	49.1	55.6
Potassium (mg·L^{-1})	135.1	66.8	50.6

Table 5. Variation of SNAS parameters at system input and output

Analyzed Parameters	SNAS input (average values)	SNAS output (average values)	Parameter variation
pH	7.3	7.8	+0.5
Conductivity (mS·cm^{-1})	1.6	1.5	-0.1
COD (mg·L^{-1} O_2)	38.8	55.5	-
Redox Potential (mV)	113.4	111.4	-2
SAR	5.6	2.5	-3.1

Analyzing the behavior of the SNART nutrient solution at the entrance and exit of the system (**Table 6**), it is verified that there was a high removal of nitrates, nitrites and ammoniacal nitrogen. Sodium and chlorides were also removed, but in a smaller percentage (15.2% and 12.1%, respectively), potassium showed a removal value of 41.8%. There was also a removal of 23.9% of organic matter (**Table 7**).

Regarding the variation of the other parameters analyzed (**Table 7**), there was an increase in pH and redox potential and a decrease in electrical conductivity and SAR.

The percentages of removal, in principle will be related to the quantities of nutrients absorbed by the plants, but may also be due to evapotranspiration phenomena[12].

To verify the possibility of discharge of these solutions into the hydric environment, or their use as irrigation water, the parameters analyzed were compared with the stipulations of the Decree-Law 236 of August 1, 1998 (**Table 8**).

Regarding the possibility of using the nutrient solutions at the output of the system as irrigation water, the SNAS presents a nitrate content higher (88.7 mg·L^{-1}) than the maximum recommended value (50 mg·L^{-1}), contrary to the SNART, which presents a much lower value (3.8 mg·L^{-1}), therefore, this parameter is not limiting for its use as irrigation water. However, the SNART presents a very high chloride content (291.7 mg·L^{-1}) compared to the maximum recommended value of 70 mg·L^{-1}. If we consider the maximum allowable values there is no limitation for both solutions to be used as irrigation water (**Table 8**).

With regard to the discharge of solutions into the environment after leaving the system, it can be seen that only the nitrate content becomes a limiting factor for SNAS, and SNART does not present any limitation related to this parameter (**Table 8**).

Thus, we can conclude that the wastewater from cheese factories, after treatment, allowed the development of lettuce in a semi-hydroponic system and that at the end of each cycle it can be discharged into the environment, thus solving a worrying problem, which is the large amount of by-product from cheese factories, which are discharged into the environment without treatment, constituting a major source of pollution.

Table 6. Characterization of SNART at the inlet and outlet of the system and the % removal

Analyzed Parameters	SNART input (average values)	SNART output (average values)	% Removal
Nitrates (mg·L^{-1})	8.1	3.8	53.1
Nitrite (mg·L^{-1})	0.2	0.1	50.0
Ammoniacal Nitrogen (mg·L^{-1})	19.8	4.3	78.3
Chlorides (mg·L^{-1})	331.8	291.7	12.1
Calcium (mg·L^{-1})	90.2	121.7	-
Phosphates (mg·L^{-1})	0.6	1	-
Sodium (mg·L^{-1})	229.5	194.7	15.2
Potassium (mg·L^{-1})	128.1	74.6	41.8

Table 7. Variation of SNART parameters at system input and output

Analyzed Parameters	SNART input (average values)	SNART output (average values)	Parameter variation
pH	7.4	7.7	+0.3
Conductivity (mS·cm^{-1})	1.7	1.4	-0.3
COD (mg·L^{-1} O_2)	65.9	50.1	-23.9
Redox Potential (mV)	67.3	97.1	+29.8
SAR	16.1	9.9	-6.2

Table 8. Comparison of SNAS and SNART at system output with DL 236/98

Analyzed Parameters	SNAS output (average values)	SNART exit (average values)	Water irrigation (DL 236/98) MRV	Irrigation water (DL 236/98) MPV	Wastewater discharge (DL 236/98) ELV
pH	7.8	7.7	6.5–8.4	4.5–9.0	6.0–9.0
Conductivity (mS·cm^{-1})	1.5	1.4	1	-	-
Redox Potential (mV)	111.4	97.1	-	-	-
Nitrates (mg·L^{-1})	88.7	3.8	50	-	50
Nitrite (mg·L^{-1})	0.4	0.1	-	-	-
Ammoniacal Nitrogen (mg·L^{-1})	10.3	4.3	-	-	10
Chlorides (mg·L^{-1})	43.8	291.7	70	-	-
Calcium (mg·L^{-1})	144.9	121.7	-	-	-
Phosphates (mg·L^{-1})	4.6	1	-	-	10
Sodium (mg·L^{-1})	49.1	194.7	-	-	-
Potassium (mg·L^{-1})	66.8	74.6	-	-	-
COD (mg·L^{-1} O2)	55.5	50.1	-	-	150
SAR	2.5	9.9	8	-	-

MRV—Maximum Recommended Value
MPV—Maximum permissible value
ELV—Emission limit value

4. Conclusions

According to the results obtained and the conditions under which the tests were carried out, the following conclusions can be drawn.

With the use of the nutrient solution called SNAS, the fresh weight and dry weight of the aerial part obtained higher values with the perlite substrate.

When the SNART nutrient solution was used, the fresh and dry weight of the aerial part, the total number of leaves and the diameter of the cabbage presented the highest values in the coconut fiber substrate, perhaps because it is the substrate with the highest water retention capacity and consequently the highest capacity to retain nutrients.

Expanded clay, according to the results obtained, is not a suitable substrate for growing in semi-hydroponics compared to coconut fiber and perlite.

The NFT hydroponic system with the lettuce crop proved to have a double action, in addition to the plants withdrawing the nutrients in sufficient quantity to develop, it worked as a system for tuning the SNART, so that it could be discharged into the environment at the end of each cycle without causing pollution.

Conflict of interest

The authors declare that they have no conflict of interest.

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