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Lettuce production in aquaponic and hydroponic systems

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Abstract. Besides soil cultivation, there are other alternative methods such as the aquaponic and the hydroponic technology.

In our research, four lettuce varieties ('Edina', 'Május királya', 'Lollo Rossa', and 'Lollo Bionda') were compared by the use of different systems. In hydroponics, the direct nutrient supply resulted higher leaf weight. In addition, multiple values of nitrate (269.50–406.50 mg kg-1) were measured in this system compared to the aquaponic system (23.25–170.00 mg kg-1). The 'Lollo Rossa' stood out with higher element content (Zn, B, and Mg) in both cultivation methods.

In conclusion, it can be stated that higher nutrient content in hydroponics resulted higher leaf weight, but nitrate values were also higher in this unit. Aquaponic technology can be used to produce high-quality (low-nitrate) lettuce with the 'Lollo Rossa' and 'Lollo Bionda' varieties.

Keywords: soilless cultivation method, variety, nitrite, nitrate

1. Introduction

Lettuce (*Lactuca sativa* L.) is a well-known plant among leaf vegetables. It belongs to the family of *Asteraceae*. The lettuce is rich in nutrient elements for it contains essential elements such as minerals and organic substances [3]. The leafy green vegetables also contain vitamin C, beta-carotene, fibre, folate, and phytonutrients. It can be part of a well-balanced diet since it does not contain cholesterol and is naturally low in calories [2].

Earliness in vegetable forcing has a great importance due to the advantages of high sale prices in the early season. The length of the growing season is

determined primarily by the characteristics of the variety, the environmental factors (light, temperature), and the cultivation technology [6].

Besides traditional soil cultivation, there are other alternative methods such as aquaponics and hydroponic gardening (soilless cultivation). Aquaponics is a closed recirculation ecosystem, which is a combination of aquaculture and hydroponics [7]. It is an integrated bio-system where the plants and the fish live in a symbiotic relationship. Wastewater from fish farming contains nitrogenous compounds, especially ammonia, which could be hazardous for fish, even in paucity. Additionally, toxicity depends on the temperature and pH of the water [5]. Therefore, it is a sustainable vegetable farming technique which uses natural biological cycles to supply nitrogen and minimizes the use of non-renewable resources.

Several mediums exist for producing hydroponic crops, for instance: floating raft, nutrient film technique (NFT), rockwool, perlite, or pine bark. On the other hand, there are some critical management requirements to maintain the water quality and the bio-filter nitrification [8]. In hydroponic systems, fertilizers are used to provide nutrients for the vegetables. The root of the plant takes up nutrients from the water in the tank [1].

This cultivation method is able to provide vegetable crops in good quality throughout the year. Furthermore, using this method, the vegetation period can be shortened to 30 days compared to conventional cultivation, which needs to match a longer period (nearly 60 days) for production. These alternative methods are widely used for growers who have limited growing field for vegetable production [4].

2. Materials and methods

The experiment was conducted at the University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Institute of Horticultural Science. The aquaponic system belongs to the Department of Animal Husbandry.

For the evaluation, two head-forming (‘Edina’ and ‘Május királya’) and two leaf-forming (‘Lollo Rossa’ and ‘Lollo Bionda’) lettuce were examined in two different soilless cultures (hydroponic and aquaponic).

Sowing into seed tray took place on 14 March 2017. Clay balls were used to fix the root of the plants in both systems. *Pétisol* nitrogen plus fertilizer (18:9:12 NPK + 0.1% microelement) was applied in 0.1% concentration into the Intermediate Bulk Container (IBC) by hydroponic technology. At that time, the pH of the water was 8.05, the temperature was 20.3 °C, and the EC value was 0.96 mS/cm.

In aquaponic production, catfish (*Ameiurus nebulosus*) were cultivated as they adapt to harsh environmental conditions, and they have the ability to tolerate the low oxygen concentration and the range of water salinity.

At the time of transplanting (20 April 2017), the water parameters were the following in the aquaponic system: the temperature of the water was 20.5 °C, the pH was 7.99, and the EC value was 1.01 mS/cm. The transplants were with 5–6 leaves, and the spacing was 25 × 25 cm in the growing area. For the experiment, we used 25 plants/variety.

3. Results and discussions

In springtime cultivation, the head weight (g/plant) and the root weight (g/plant) of the lettuce were measured 5 weeks after transplanting. The head weight of the lettuce is an important factor from the aspect of profitability.

It can be clearly seen in *Table 1* that in the hydroponic system the head weights of varieties were higher than in the case of the aquaponic cultivation method.

Table 1. The head weight (g/plant) and root weight (g/plant) of different varieties

Growing method	Variety	Head weight (g/plant)	Root weight (g/plant)
Aquaponic system	**'Edina'**	109.04 ± 13.13	20.93 ± 0.81
	'Lollo Rossa'	128.98 ± 15.23	44.13 ± 2.39
	'Lollo Bionda'	97.28 ± 13.59	50.27 ± 9.06
	'Május királya'	131.32 ± 16.79	61.36 ± 6.75
Hydroponic system	**'Edina'**	190.13 ± 10.09	39.84 ± 4.93
	'Lollo Rossa'	170.77 ± 10.22	54.32 ± 6.41
	'Lollo Bionda'	185.59 ± 19.36	70.31 ± 8.47
	'Május királya'	152.99 ± 22.17	56.13 ± 5.55

In the hydroponic system, one of the head lettuce, 'Edina', showed the highest value (190.13 ± 10.09 g), while the two leaf lettuce ('Lollo Rossa' and 'Lollo Bionda') showed nearly equal values (170.77 ± 10.22 g and 185.59 ± 19.36

g). In the aquaponic system, again one of the head lettuce (‘Május királya’) showed the highest value (131.32 ± 16.79 g).

Evaluating the nitrate and mineral element content in water (*Table 2*), we can state that there was a higher nitrate and nitrite content (31.20 and 1.43 mg l^{-1}) in the hydroponic system. In both growing systems, high calcium (191.00 and 231.00 mg l^{-1}) content was measured. Potassium and sulphur content were several times higher in the aquaponic than in the hydroponic system.

Table 2. Nitrate, nitrite, and mineral element content (mg l^{-1}) in water samples

Parameter mg l^{-1}	**Hydroponic**	**Aquaponic**
Nitrate	31.20	0.14
Nitrite	1.43	0.06
B	0.26	0.10
Ca	191.00	231.00
Cu	0.80	0.08
Fe	0.32	0.19
K	95.10	195.00
Mg	53.50	49.40
Na	27.40	29.80
P	9.70	5.11
S	30.70	87.10
Zn	0.10	0.09

There was no significant difference between the technologies in the dry matter content (*Table 3*). Regarding the varieties, we can state that the ‘Lollo Rossa’ (leaf lettuce) showed the highest dry matter content (87.48 ± 0.08% and 8.51 ± 0.36%) in both systems. The variety and the cultivation method can influence the dry matter content. The chemical composition of the plants influences the quality of the products, and so the quality is determined by both organic and mineral components.

The higher nitrate and nitrite content in leaf vegetables can result lower quality. The nitrate content was several times higher in the hydroponic cultivation method than in aquaponics, which difference was also measured by water samples. For both gardening methods, the ‘Edina’ (head lettuce) showed the highest value of nitrate (170 ± 48.08 mg kg^{-1} and 406.50 ± 4.95 mg kg^{-1}).

Table 3. Nitrate and nitrite (mg kg^{-1}) and dry matter content (%) in the raw material

Growing method	Variety	Dry matter content %	Nitrate mg kg^{-1}	Nitrite mg kg^{-1}
Aquaponic system	**'Edina'**	5.76 ± 0.74	170 ± 48.08	1.39 ± 0.04
	'Lollo Rossa'	7.48 ± 0.08	23.25 ± 4.31	0.53 ± 0.02
	'Lollo Bionda'	6.52 ± 0.06	73.40 ± 5.52	0.81 ± 0.01
	'Május királya'	6.99 ± 1.49	53.55 ± 0.49	0.68 ± 0.03
Hydroponic system	**'Edina'**	5.62 ± 0.11	406.50 ± 4.95	4.91 ± 0.11
	'Lollo Rossa'	8.51 ± 0.36	325.50 ± 16.26	2.95 ± 0.28
	'Lollo Bionda'	6.55 ± 0.66	299.00 ± 16.97	3.10 ± 0.08
	'Május királya'	5.42 ± 0.39	269.50 ± 28.99	2.43 ± 0.03

A similar tendency was also measured among the genotypes and the systems by nitrite. The 'Edina' variety produced the highest value in the aquaponic (1.39 ± 0.04 mg kg^{-1}) and in the hydroponic system (4.91 ± 0.11 mg kg^{-1}) as well.

Boron can help the nutrition uptake of plants. There was no significant difference between the various technologies for this microelement supply. However, differences were found in the boron content between the varieties (*Table 4*), considering that the highest boron content was detected in leaf-forming varieties ('Lollo Rossa' and 'Lollo Bionda') in both systems.

Magnesium is one of the most important mineral elements as it is necessary for many biochemical processes. It also has to be mentioned that the magnesium is the central atom of the chlorophyll, which plays a key role in photosynthesis.

Concerning the magnesium content, we measured higher values in the hydroponic system – with the exception of 'Május királya', where this value was lower. The varieties with an open head ('Lollo Rossa' and 'Lollo Bionda') have higher magnesium content (293.50 ± 10.61 mg kg^{-1} and 264.00 ± 28.28 mg kg^{-1}) than head-forming varieties ('Edina' and 'Május királya') in the hydroponic system (215.00 ± 1.41 and 178.50 ± 13.44 mg kg^{-1}).

Table 4. Boron and magnesium (mg kg^{-1}) content in the raw material

Growing method	Variety	B mg kg^{-1}	Mg mg kg^{-1}
Aquaponic system	**'Edina'**	1.63 ± 0.11	200.00 ± 32.53
	'Lollo Rossa'	2.25 ± 0.05	231.50 ± 0.71
	'Lollo Bionda'	2.17 ± 0.21	204.00 ± 4.24
	'Május királya'	1.65 ± 0.44	203.00 ± 38.18
Hydroponic system	**'Edina'**	1.67 ± 0.01	215.00 ± 1.41
	'Lollo Rossa'	2.97 ± 0.09	293.50 ± 10.61
	'Lollo Bionda'	2.28 ± 0.25	264.00 ± 28.28
	'Május királya'	1.51 ± 0.08	178.50 ± 13.44

Copper as a constituent of enzymes participates in the respiratory metabolism and electron transport. It is also involved in photosynthesis and carbohydrate as well as protein synthesis. The copper content of the water in the hydroponic system was ten times higher than in aquaponics, which clearly appeared in the copper supply of plant samples. It can be stated that leaf lettuce varieties have a higher mineral content (*Table 5*).

In addition, the iron content also confirms this as the genotypes showed higher value in the hydroponic system, which partly appeared in the iron content of the hydroponic water. Moreover, the iron is essential for the processes of assimilation, photosynthesis, and protein synthesis.

Regarding the zinc supply, the 'Lollo Rossa' (1.63 ± 0.09 and 1.68 ± 0.01 mg kg^{-1}) had the highest zinc content among the varieties by the growing methods.

Table 5. Copper, iron, and zinc element content (mg kg^{-1})

Variety	Growing method	Cu mg kg^{-1}	Fe mg kg^{-1}	Zn mg kg^{-1}
'Edina'	**A**	0.73 ± 0.05	47.95 ± 5.15	1.43 ± 0.17
	H	7.34 ± 0.17	51.20 ± 1.00	1.02 ± 0.05
'Lollo Rossa'	**A**	0.62 ± 0.02	64.00 ± 0.90	1.63 ± 0.09
	H	10.80 ± 0.30	77.70 ± 1.40	1.68 ± 0.01
'Lollo Bionda'	**A**	0.43 ± 0.01	59.20 ± 0.90	1.18 ± 0.04
	H	12.50 ± 1.00	78.90 ± 4.50	1.03 ± 0.05
'Május királya'	**A**	0.46 ± 0.03	61.30 ± 8.80	1.10 ± 0.16
	H	9.99 ± 0.21	52.30 ± 1.70	0.80 ± 0.04

A – Aquaponic system
H – Hydroponic system

Sulphur and phosphorus are important components of organic compounds. According to the data, it can be concluded that the sulphur content of leaves was almost two times higher in the aquaponic than in the hydroponic system (*Table 6*).

There was no noticeable tendency for the phosphorus content.

Table 6. Sulphur and phosphorus (mg kg^{-1}) content in the raw material

Variety	Growing method	S mg kg^{-1}	P mg kg^{-1}
'Edina'	**A**	106.75 ± 10.25	317.50 ± 33.50
	H	58.60 ± 2.70	278.00 ± 2.00
'Lollo Rossa'	**A**	18.30 ± 1.60	330.00 ± 1.10
	H	8.69 ± 0.19	388.50 ± 11.50
'Lollo Bionda'	**A**	55.50 ± 2.80	289.50 ± 10.50
	H	27,15 ± 1,25	233.50 ± 20.50
'Május királya'	**A**	77.80 ± 11.30	289.50 ± 35.50
	H	43.25 ± 1.15	329.50 ± 16.50

A – Aquaponic system
H – Hydroponic system

4. Conclusions

In the experiment, two head-forming (‘Edina’ and ‘Május királya’) and two leaf-forming (‘Lollo Rossa’ and ‘Lollo Bionda’) lettuce were examined in two different soilless cultures (hydroponic and aquaponic).

It can be stated that the head weights of the varieties were higher in the case of the hydroponic growing method than in the aquaponic system. The ‘Edina’ (head lettuce) showed the highest value (190.13 ± 10.09 g), while the two leaf lettuce (‘Lollo Rossa’ and ‘Lollo Bionda’) showed nearly equal values (170.77 ± 10.22 g and 185.59 ± 19.36 g) in the hydroponic system.

Furthermore, in this system (hydroponic), a higher nitrate content (31.20 mg l^{-1}) was measured compared to the aquaponic one. The nitrate content was several times higher in the plants in the hydroponic system, which difference was also measured in water samples. Regarding dry matter content, the ‘Lollo Rossa’ (leaf lettuce) produced the highest content in both aquaponic and hydroponic systems (7.48 ± 0.08% and 8.51 ± 0.36%). Moreover, varieties with an open head (‘Lollo Rossa’ and ‘Lollo Bionda’) contain higher amounts of iron compared to those head-forming (‘Edina’ and ‘Május királya’) by hydroponic cultivation. Regarding the other mineral elements (Zn, B, Mg), the ‘Lollo Rossa’ stood out with higher element content in both cultivation methods.

Finally, we can conclude that the production in the hydroponic system is more profitable (higher head weight) than the aquaponic system. The use of wastewater with the aquaponic system is more favourable for lettuce growing due to the non-chemical production. The productivity can be a bit lower, but the raw material is healthier and without any harmful compound.

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