

SUPPLEMENTARY MATERIAL

Nitrogen transformations across compartments of an aquaponic system

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Supplementary tables

Table S1. Lettuce cycles with seeding, transplantation and sampling times.

	Seeding of the lettuce	Lettuce transplantation	Start sampling	End sampling
1st lettuce cycle (22 days)	Week 23, 2017	Week 26, 2017	Week 27, 2017	Week 29, 2017
2nd lettuce cycle (28 days)	Week 27, 2017	Week 30, 2017	Week 31, 2017	Week 34, 2017
3rd lettuce cycle (26 days)	Week 33, 2017	Week 36, 2017	Week 37, 2017	Week 39, 2017

Table S2. Fish and lettuce biomass gained during three lettuce cycles.

	Fish gained biomass [kg per lettuce cycle]	Lettuce biomass ^a [kg per lettuce cycle]
1st lettuce cycle (22 days)	3.10 ± 0.17	14.06 ± 1.73
2nd lettuce cycle (28 days)	5.57 ± 0.10	12.56 ± 0.86
3rd lettuce cycle (26 days)	4.53 ± 0.17	8.20 ± 0.63

^a calculated from the average of 12 measured lettuces in each aquaponic system

Table S3. Mean \pm SEM of measured parameters in different compartments (FTW, fish tank water; DFW, drum filter outflow water; BFO, biofilter outflow water; HPI, inflow into hydroponic part of the system; HPS, sump water; HTI, hydroponic table inflow; HTO, hydroponic table outflow; HPO, outflow from hydroponic part of the system; RFI, radial flow settler inflow; RFO, radial flow settler outflow; FS, settled fresh sludge; DS, digested sludge; SS, supernatant of digested sludge returned back to the system) of an aquaponic system, measured six times during the experiment. Letters represent the significant differences between the compartments of the system based on a Kruskal-Wallis test followed by a Wilcoxon rank-sum test ($\alpha = 5\%$).

	System water (aerobic loop)								Radial flow settler (loop connection)		Sludge (anaerobic loop)		
	FTW	DFW	BFO	HPI	HPS	HTI	HTO	HPO	RFI	RFO	FS	DS	SS
Temperature [°C] (n = 18)	25.63 \pm 0.22 b	25.85 \pm 0.35 ab	26.04 \pm 0.42 ab	25.93 \pm 0.38 ab	25.55 \pm 0.46 abc	25.91 \pm 0.46 abc	25.72 \pm 0.58 abc	25.87 \pm 0.57 abc	26.52 \pm 0.88 abc	25.29 \pm 0.70 abc	23.57 \pm 0.42 c	27.89 \pm 0.45 a	26.87 \pm 0.36 ab
Dis. oxygen [mg L ⁻¹] (n = 18)	9.00 \pm 0.12 ab	8.92 \pm 0.14 ab	9.82 \pm 0.16 c	9.52 \pm 0.15 ac	8.78 \pm 0.14 bd	8.60 \pm 0.12 bd	8.20 \pm 0.14 d	8.57 \pm 0.15 bd	3.05 \pm 0.30 e	2.55 \pm 0.29 e	0.22 \pm 0.02 f	0.24 \pm 0.03 f	0.29 \pm 0.07 f
pH [-] (n > 17)	7.25 \pm 0.05 ac	7.31 \pm 0.03 a	7.33 \pm 0.03 a	7.30 \pm 0.05 a	7.37 \pm 0.05 a	7.40 \pm 0.05 a	7.39 \pm 0.05 a	7.38 \pm 0.04 a	7.03 \pm 0.03 bc	6.99 \pm 0.02 b	6.50 \pm 0.09 d	6.62 \pm 0.04 d	6.65 \pm 0.03 d
EC [μ S cm ⁻¹] (n = 18)	811.7 \pm 33.2 a	808.8 \pm 33.6 a	808.4 \pm 34.8 a	811.2 \pm 32.4 a	807.4 \pm 34.9 a	804.9 \pm 35.5 a	813.2 \pm 32.3 a	808.0 \pm 34.2 a	817.7 \pm 33.0 a	820.2 \pm 36.3 a	963.9 \pm 34.7 a	2558 \pm 123 b	2553 \pm 126 b
Redox [mV] (n = 18)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-244.6 \pm 10.5 a	-331.2 \pm 5.5 b	-328 \pm 3.7 b
Ammonium-N [mg L ⁻¹] (n > 17)	0.16 \pm 0.01 ac	0.19 \pm 0.02 a	0.13 \pm 0.01 abc	0.12 \pm 0.01 bc	0.10 \pm 0.01 b	0.11 \pm 0.01 b	0.09 \pm 0.01 b	0.11 \pm 0.01 b	2.47 \pm 0.79 d	3.70 \pm 1.18 d	12.19 \pm 2.10 e	176.1 \pm 14.6 f	169.6 \pm 15.3 f
Nitrite-N [mg L ⁻¹] (n = 18)	0.13 \pm 0.01 a	0.14 \pm 0.01 a	0.13 \pm 0.01 a	0.14 \pm 0.01 a	0.12 \pm 0.01 a	0.12 \pm 0.01 ab	0.12 \pm 0.01 ab	0.11 \pm 0.01 ab	0.94 \pm 0.15 c	0.99 \pm 0.18 c	0.14 \pm 0.04 ab	0.10 \pm 0.07 bd	0.02 \pm 0.01 d
Nitrate-N [mg L ⁻¹] (n = 18)	57.19 \pm 3.08 ab	57.23 \pm 3.31 ab	54.36 \pm 3.74 abc	52.69 \pm 2.60 ab	59.23 \pm 2.81 a	54.23 \pm 2.79 ab	56.03 \pm 3.09 ab	54.11 \pm 2.45 ab	44.20 \pm 2.43 bc	36.04 \pm 3.35 c	0.75 \pm 0.51 d	0.22 \pm 0.05 d	0.24 \pm 0.04 d

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Ninorg^a [mg L ⁻¹] (n = 17)	57.48 ± 3.08 a	57.56 ± 3.31 ab	54.60 ± 3.74 ab	52.95 ± 2.60 ab	59.46 ± 2.81 a	54.45 ± 2.79 ab	56.24 ± 3.10 ab	54.32 ± 2.45 ab	47.61 ± 2.59 ab	40.73 ± 3.51 b	13.08 ± 2.09 c	176.39 ± 14.59 d	169.87 ± 15.32 d
Norg^b [mg L ⁻¹] (n > 14)	10.32 ± 1.05 acd	8.68 ± 0.90 abcd	6.94 ± 0.76 ab	4.22 ± 0.36 b	6.48 ± 0.61 ab	8.03 ± 0.39 ac	11.44 ± 0.77 cd	8.35 ± 0.80 ac	29.70 ± 5.48 e	18.19 ± 4.50 de	515.3 ± 68.2 f	250.7 ± 24.7 fg	157.5 ± 16.7 g
Sodium [mg L ⁻¹] (n = 18)	24.03 ± 3.89 abc	22.09 ± 3.06 abc	22.46 ± 4.00 abc	16.64 ± 2.57 ab	16.13 ± 1.76 b	19.47 ± 2.98 ab	14.64 ± 1.79 b	20.72 ± 4.44 abc	24.15 ± 5.06 abc	28.68 ± 6.21 abc	26.79 ± 2.95 abc	37.55 ± 3.71 c	34.63 ± 3.33 ac
Potassium [mg L ⁻¹] (n = 18)	40.20 ± 6.80 a	38.93 ± 6.20 a	41.19 ± 7.88 a	32.02 ± 6.22 a	31.01 ± 4.32 a	35.83 ± 6.52 a	29.07 ± 4.61 a	39.01 ± 9.00 a	43.02 ± 11.44 a	51.22 ± 12.06 a	37.27 ± 4.92 a	41.27 ± 6.60 a	39.30 ± 5.71 a
Magnesium [mg L ⁻¹] (n = 18)	20.98 ± 1.00 a	21.32 ± 0.77 a	20.09 ± 1.13 a	19.19 ± 1.00 a	20.30 ± 0.76 a	21.30 ± 1.18 ab	18.91 ± 1.29 a	19.65 ± 0.86 a	21.02 ± 0.78 a	21.10 ± 0.70 a	22.37 ± 1.74 abc	28.35 ± 0.97 c	27.02 ± 1.17 bc
Calcium [mg L ⁻¹] (n = 18)	73.50 ± 2.92 a	74.55 ± 1.38 a	70.36 ± 3.32 a	66.25 ± 2.85 a	71.65 ± 1.47 a	74.38 ± 4.14 a	64.17 ± 4.37 a	68.69 ± 2.32 a	74.82 ± 1.46 a	74.52 ± 1.48 a	121.1 ± 10.5 b	129.9 ± 6.2 b	127.1 ± 6.2 b
Chloride [mg L ⁻¹] (n = 18)	26.58 ± 1.49 a	26.66 ± 1.65 a	25.54 ± 1.95 a	23.65 ± 1.07 a	25.66 ± 1.33 a	24.13 ± 1.37 a	24.45 ± 1.39 a	23.49 ± 1.19 a	26.54 ± 1.47 a	24.71 ± 1.67 a	28.12 ± 1.98 a	24.89 ± 1.73 a	26.61 ± 2.18 a
Phosphate-P [mg L ⁻¹] (n = 18)	7.37 ± 0.89 a	8.11 ± 0.91 a	8.21 ± 1.16 a	7.47 ± 0.70 a	7.39 ± 0.71 a	7.51 ± 0.75 a	7.48 ± 0.77 a	7.24 ± 0.68 a	9.23 ± 0.92 a	10.64 ± 1.18 a	47.75 ± 6.51 b	121.6 ± 12.7 c	114.1 ± 9.9 c
Sulfate-S [mg L ⁻¹] (n > 12)	43.72 ± 1.16 a	43.74 ± 1.71 ab	42.11 ± 2.07 ab	38.57 ± 0.79 ab	43.24 ± 2.1 a	40.48 ± 1.02 ab	42.3 ± 0.75 ab	39.11 ± 0.81 ab	42.85 ± 0.89 a	38.96 ± 0.94 ab	28.59 ± 2.97 b	3.07 ± 0.50 c	4.14 ± 0.94 c

	System water (aerobic loop)								Radial flow settler (loop connection)		Sludge (anaerobic loop)		
	FTW	DFW	BFO	HPI	HPS	HTI	HTO	HPO	RFI	RFO	FS	DS	SS
Boron [mg L ⁻¹] (n = 18)	0.088 ± 0.012 a	0.086 ± 0.011 a	0.084 ± 0.011 a	0.087 ± 0.010 a	0.082 ± 0.010 a	0.081 ± 0.010 a	0.077 ± 0.010 a	0.082 ± 0.01 a	0.117 ± 0.014 ab	0.094 ± 0.011 a	0.200 ± 0.018 b	0.317 ± 0.021 c	0.305 ± 0.020 c
Iron [mg L ⁻¹] (n = 18)	0.028 ± 0.001 ab	0.026 ± 0.000 a	0.026 ± 0.000 a	0.026 ± 0.000 a	0.025 ± 0.000 a	0.025 ± 0.000 a	0.026 ± 0.001 a	0.025 ± 0.000 a	0.029 ± 0.000 b	0.029 ± 0.001 b	0.114 ± 0.021 c	0.055 ± 0.008 c	0.047 ± 0.003 c
Manganese ^c [mg L ⁻¹] (n = 18)	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	0.099 ± 0.016 b	0.104 ± 0.016 b	0.491 ± 0.073 a	0.463 ± 0.083 a	0.442 ± 0.081 a
Copper ^c [mg L ⁻¹] (n = 18)	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020
Molybdenum ^c [mg L ⁻¹] (n = 18)	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015
Zinc ^c [mg L ⁻¹] (n = 18)	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015

^a Calculated as a sum of NH₄⁺-N, NO₂⁻-N and NO₃⁻-N

^b Calculated by subtracting NH₄⁺-N from the measured Total Kjeldahl nitrogen.

^c if more than 50% of the values were below the detection limit, only a detection limit is written

Supplementary figure

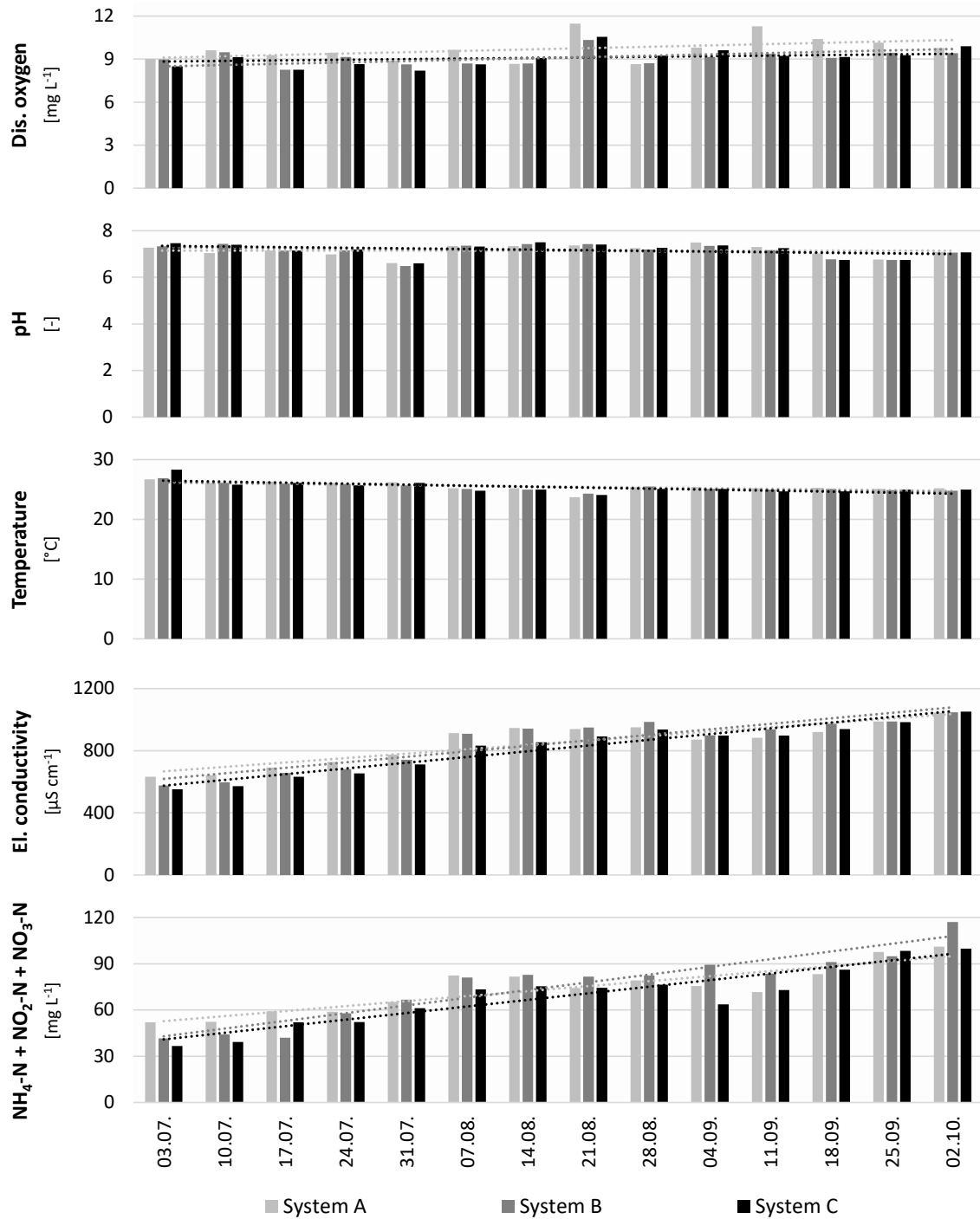


Figure S1. Weekly measurements with Cuvette quick tests (LCK304, LCK341, LCK339) and multimeter HQ40d with PHC10103, CDC40103 and LDO10101 probes (Hach Lange, Loveland, CO, USA) of parameters relevant for the fish welfare measured in the fish tank water of all three replicates of the aquaponic system ($n = 1$).