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AQUAPONIC CORNER - NOTE

Importance of nickel as a micronutrient in aquaponic systems – some theoretical considerations

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Abstract – This paper calls the attention to the important role the microelement nickel plays is the decomposition of urea (produced by the fish as waste), and thus to its potential role in aquaponic systems. Since nickel is not included in the list of micronutrients essential to fish growth and development, fish feeds probably do not contain sufficient amounts of it. Therefore, trace amounts of soluble salts or complexes of nickel probably need to be added to aquaponic systems in order to achieve the systems' stable operation.

Keywords – nickel, trace element, micronutrient, aquaponics, hydroponics, urea

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Aquaponics is an emerging food production technology that integrates aquaculture and hydroponics (Pilinszky et al., 2015; Junge et al., 2017). Aquaponic systems consist of a fish tank and a hydroponic component, in which plants are grown using the wastes produced by the fish as the nutrient source. An essential module of the system is the biofilter, in which ammonia (excreted by the fish) is converted to nitrate (a plant nutrient) by nitrifying bacteria, such as *Nitrosomonas* and *Nitrobacter*. When the microbiome (microorganisms in the circulating water, and associated with the biofilter), the fish, and the plants are considered, aquaponic systems represent a rather complex ecosystem. Fish feed is the main source of nutrients and its chemical composition determines the availability of macro- and microelements all organisms within the system (an addition, limited amount of nutrients is introduced with the local water supply, but this is exhausted at an early stage of the production cycle). Since fish feeds were optimized for aquaculture uses, growth of plants in aquaponic systems may be limited because of insufficiently low levels of certain essential elements (Bittsanszky et al., 2016).

Earlier, we reported on the importance of the detoxification of ammonia in aquaponic systems (Kiraly et al., 2013). Here we discuss the significance of the efficient decomposition of another, potentially phytotoxic waste excreted by fish: urea ($OC[NH_2]_2$). Although urea is an excellent source of nitrogen for plants (Yang et al., 2015), at higher concentrations it is strongly toxic to plant tissues. Typical symptoms of urea toxicity to plants are leaf burn and chlorosis (Khemira et al., 2000).

In plants and bacteria, urease enzymes are responsible for the catabolic detoxification of urea by catalyzing its conversion to carbonic acid (that spontaneously and rapidly decomposes to carbon dioxide and water) and ammonium hydroxide according to Eq. 1.

$$OC(NH_2)_2 + 2H_2O \xrightarrow{urease} H_2CO_3 + NH_4OH \qquad [1]$$

Urease enzymes are nickel-containing metalloproteins: without the metal cofactor they are catalytically inactive (Polacco et al., 2013; Urbańczyk et al 2016; Martins et al., 2017). Ureases are present in bacteria, fungi, algae, and plants - but they are absent from fish and other animals. Measurable urease enzyme activities in fish (and other animals) are attributed to the microflora in their gastrointestinal systems, or to bacterial infections (Patra and Aschenbach, 2018). Although deficiencies of nickel in fish kept in an ultraclean environment have been demonstrated, the physiological function of this trace element in fish has not been clearly identified

(Davis, 2015; Halver and Hardy, 2002). Important micronutrients for tilapia, for example, include iron, zinc, manganese, copper, cobalt, selenium, and chromium (Jauncey 1998; Zhao et al., 2011; Lin et al. 2013): these are required in magnitudes of gram or milligram amounts per kilogram of feeds. Typically, nickel is not mentioned in papers discussing the metabolism of micro-minerals in fish (Prabhu et al., 2016).

In agriculture, high urease enzyme activity of ammonia-oxidizing bacteria in some soils could be problematic: rapid decomposition of urea-based fertilizers results in the formation of nitrous oxide (N_2O, a greenhouse gas and a scavenger of atmospheric ozone) (Martins et al., 2017). It is interesting to note that microbial nitrogen transformation reactions in aquaculture and aquaponic units also lead to the production of significant amounts of N_2O, resulting in economic loss and environmental damage (Hu et al., 2013; Zou et al., 2017).

Nickel is not an essential component of fish feed (Halver and Hardy, 2002; Davis, 2015), and may not be present in sufficient amounts in the water supply of the aquaponic system. Therefore, under circumstances of insufficient nickel supply, urease enzymes of plants and bacteria in aquaponic systems will remain inactive. As a result, urea levels may reach phytotoxic concentrations, diminishing the quantity and the quality of the plant products.

Nota bene, nickel is usually not included in commercial hydroponic nutrient formulations, although urea is routinely used as a nitrogen source in these mixtures. We hypothesize, that nickel is available in sufficient quantities as an impurity in the standard hydroponic fertilizer solutions (Khan et al., 1997).

Conclusion

Our theoretical considerations suggest that further research is necessary to investigate the effects of the availability of nickel on the concentrations of urea in aquaponic systems under different experimental conditions.

Public interest statement

This Note paper is written to call the attention of researchers and practitioners on the importance of nickel, as a micronutrient, in aquaponic systems. In addition to its role as a micronutrient in plants, nickel might also be considered as a heavy metal contaminant. Therefore, its levels have to be carefully monitored.

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References

Bittsanszky, A., Uzinger, N., Gyulai, G., Mathis, A., Junge, R., Kotzen, B., Komives, T. 2016. Nutrient supply of plants in aquaponic systems. Ecocycles 2(2): 17-20. DOI: 10.19040/ecocycles.v2i2.57

Davis, D.A., 2015. Feed and Feeding Practices in Aquaculture. Woodhead Publishing.

Halver, J.E., Hardy, R.W., 2002. Fish Nutrition. Elsevier.
Jauncey, K. Tilapia feeds and feedings. 241 pp. Pisces Press LTD, Stirling, Scotland

Hu, Z., Lee, J.W., Chandran, K., Kim, S., Sharma, K., Brotto, A.C., Khanal, S.K., 2013. Nitrogen transformations in intensive aquaculture system and its implication to climate change through nitrous oxide emission. Bioresour. Technol. 130, 314–320.
DOI: 10.1016/j.biortech.2012.12.033

Junge, R., König, B., Villarroel, M., Komives, T., Jijakli, M.H., 2017. Strategic points in aquaponics. Water 9, 182.
DOI: 10.3390/w9030182

Khan, N.K., Watanabe, M., Watanabe, Y., 1997. Effect of different concentrations of urea with or without nickel on spinach (Spinacia oleracea L.) under hydroponic culture, in: Plant Nutrition for Sustainable Food Production and Environment, Developments in Plant and Soil Sciences. Springer, Dordrecht, pp. 85–86.
DOI: 10.1007/978-94-009-0047-9_11

Khemira, H., Sanchez, E., Righetti, T.L., Azarenko, A.N., 2000. Phytotoxicity of urea and biuret sprays to apple foliage. J. Plant Nutr. 23, 35–40.
DOI: 10.1080/01904160009381995

Kiraly, K., Pilinszky, K., Bittsanszky, A., Gyulai, G., Komives, T., 2013. Importance of ammonia detoxification by plants in phytoremediation and aquaponics. Novenytermeles 62, 99–102.
DOI: 10.13140/RG.2.1.3294.4087

Lin, Y.-H., Ku, C.-Y., and Shiau, S.-Y. 2013. Estimation of dietary magnesium requirements of juvenile tilapia, *Oreochromis niloticus x Oreochromis aureus*, reared in freshwater and seawater. Aquaculture 380–383: 47-51.
DOI: 10.1016/j.aquaculture.2012.11.034

Martins, M.R., Sant’Anna, S.A.C., Zaman, M., Santos, R.C., Monteiro, R.C., Alves, B.J.R., Jantalia, C.P., Boddey, R.M., Urquiaga, S., 2017. Strategies for the use of urease and nitrification inhibitors with urea: Impact on N_2O and NH_3 emissions, fertilizer-15N recovery and maize yield in a tropical soil. Agric. Ecosyst. Environ. 247, 54–62.
DOI: 10.1016/j.agee.2017.06.021

Patra, A.K., Aschenbach, J.R., 2018. Ureases in the gastrointestinal tracts of ruminant and monogastric animals and their implication in urea-N/ammonia metabolism: A review. J. Adv. Res.
DOI: 10.1016/j.jare.2018.02.005

Pilinszky, K., Bittsanszky, A., Gyulai, G., Komives, T., 2015. Plant protection in aquaponic systems - Comment on "A novel report of phytopathogenic fungi Gilbertella persicaria infection on *Penaeus monodon*." Aquaculture 435, 275–276.
DOI: 10.1016/j.aquaculture.2014.09.045

Polacco, J.C., Mazzafera, P., Tezotto, T., 2013. Nickel and urease in plants: Still many knowledge gaps. Plant Sci. 199–200, 79–90.
DOI: 10.1016/j.plantsci.2012.10.010

Prabhu, P.A.J., Geurden, I., Fontagné-Dicharry, S., Veron, V., Larroquet, L., Mariojouls, C., Schrama, J.W., Kaushik, S.J., 2016. Responses in micro-mineral metabolism in rainbow trout to change in dietary ingredient composition and inclusion of a micro-mineral premix. PLOS ONE 11, e0149378.
DOI: 10.1371/journal.pone.0149378

Urbańczyk, E., Sowa, M., & Simka, W. 2016. Urea removal from aqueous solutions - a review. Journal of Applied Electrochemistry, 46(10), 1011-1029.
DOI: 10.1007/s10800-016-0993-6

Yang, H., Menz, J., Häussermann, I., Benz, M., Fujiwara, T., Ludewig, U., 2015. High and low affinity urea root uptake: involvement of NIP5;1. Plant Cell Physiol. 56, 1588–1597.
DOI: 10.1093/pcp/pcv067

Zhao, H. X., Cao, J. M., Liu, X. H., Zhu, X., Chen, S. C., Lan, H. B., and Wang, A. L. 2011. Effect of supplemental dietary zinc sources on the growth and carbohydrate utilization of tilapia Smith 1840, *Oreochromis niloticus* × *Oreochromis aureus*. Aquacult. Nutr. 17, 64-72.
DOI: 10.1111/j.1365-2095.2009.00707.x

Zou, Y., Hu, Z., Zhang, Jian, Fang, Y., Li, M., Zhang, Jianda, 2017. Mitigation of N2O emission from aquaponics by optimizing the nitrogen transformation process: aeration management and exogenous carbon (PLA) addition. J. Agric. Food Chem. 65, 8806–8812.
DOI: 10.1021/acs.jafc.7b03211