

# Nitrogen footprint of protein-free products

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## Abstract

The N footprint is an indicator of N loads from individual consumption of food as well as energy. A bottom-up approach, N-calculator method, calculates the food N footprint using the N content in consumed foods, such that the N footprint of protein-free foods is treated as zero. In this study, we propose a substitution factor, the virtual nitrogen factor for protein-free foods (VNFree), defined as the potential N load per unit weight of consumed food, to explicitly calculate the production N footprint of protein-free foods. Oil palm and its products were chosen for this case study.

Keywords: N-calculator, Oil palm, palm oil, palm kernel oil, Virtual nitrogen factor

## 1. Introduction

The current agro-food system induces a vast amount of reactive nitrogen (N) loss to the environment throughout food production and consumption. Nitrogen footprint is an indicator representing individual N loads to the environment based on consumption of food and energy. The N-calculator method, a bottom-up approach to calculate N footprint, expresses the food N footprint as the sum of the N footprint of food production and that of food consumption; the former is derived by multiplying the consumed (ingested) food-N by a conversion factor. However, there is a problem with the current method. This method treats the N footprint of protein-free foods, such as oil, fat, and sugar, as zero because of their lack of N content. The production of these foods also inevitably induces environmental N loads unless the NUE is 100%. The current N-calculator method might underestimate the N footprint of protein-free foods because it omits N loads during their production. We tried to improve the current N-calculator method by including N loads incurred during the production of protein-free foods.

## 2. Materials and methods

As a case study, we focus on oil palm and its products, palm oil (PO) and palm kernel oil (PKO). In this study, we propose a substitution factor, the virtual nitrogen factor for protein-free foods (VNFree), defined as the potential N load

per unit weight of consumed food, to explicitly calculate the production N footprint for protein-free foods. Details are shown in Hayashi et al. (2020).

## 3. Results and discussion

Global mean VNFree values of PO and PKO obtained by averaging national-scale data of the three countries with the largest production (Indonesia, Malaysia, and Thailand) were 0.0241 and 0.0037 kg N kg<sup>-1</sup> oil, respectively. The 6.5-times difference in VNFree values was attributed to the difference in oil yield. The food N footprint of PO and PKO calculated here represented less than 2% of the previously reported total food N footprints of several countries. However, oil palm products are also used for industry, and the chemical fertilizer consumption for oil palm accounted for only 8–12% of that of all oil and sugar crops. The protein-free N footprint of all these products will be much larger. We expect that the current N-calculator method as a bottom-up approach will be improved by expanding the VNFree concept, which enables the calculation of the concealed N footprint in protein-free products, including all uses of oil and sugar crops.

## References

Hayashi K, Oita A, Nishina K 2020 Concealed nitrogen footprint in protein-free foods: an empirical example using oil palm products *Environ. Sci. Technol.* doi:10.1088/1748-9326/ab68ea