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List of papers included in the thesis

1. **Paper I**: Mulia Nurhasan, Daream Sok, Shakuntala H Thilsted, Samnang Nguon, David James, Seyha Sok, Chamnan Chhoun and Nanna Roos. Impact of Mekong River biodiversity on the food culture of women and children in Prey Veng, Cambodia. Under review in *Aquatic Ecosystem Health & Management.*

2. **Paper II**: Mulia Nurhasan, Rizal Adi Prima, Søren Bøye Olsen, Frank T. Wieringa, Marjoleine A. Dijkhuizen, Chamnan Chhoun and Nanna Roos. Caretakers' perceptions and willingness-to-pay for complementary food in urban and rural Cambodia. *Maternal & Child Nutrition* 2021;17(3):e13130. https://doi.org/10.1111/mcn.13130

3. **Paper III**: Mulia Nurhasan, Nanna Roos, Jutta KH Skau, Frank T Wieringa, Henrik Friis, Kim F Michaelsen, Marjoleine A Dijkhuizen, Ken D Stark, Christian Ritz, Chamnan Chhoun, and Lotte Lauritzen. Effect of complementary food with small amounts of freshwater fish on whole blood n-3 fatty acids in Cambodian infants age 6–15 months. *Prostaglandins, Leukotrienes and Essential Fatty Acids* 2018;135:92-101. https://doi.org/10.1016/j.plefa.2018.07.002

Oral and poster presentations (academic and non-academic audience) related to the dissemination of the results of this PhD research:

1. **Mulia Nurhasan**, Daream Sok, Shakuntala H Thilsted, Samnang Nguon, David James, Seyha Sok, Chamnan Chhoun and Nanna Roos (21st June – 1st July 2021). *Impact of Mekong river biodiversity on food culture of women and children in Prey Veng, Cambodia*. Poster presentation at Agriculture, Nutrition & Health (ANH) Academy Conference 2021 – Online.

2. **Mulia Nurhasan**, Rizal Adi Prima, Søren Bøye Olsen, Frank T. Wieringa, Marjoleine A. Dijkhuizen, Chamnan Chhoun and Nanna Roos (7th-9th December 2020). *Understanding the Cambodian market for processed complementary food in packages*. Oral presentation at the 4th International Conference on Global Food Security - Online Edition.

3. Nanna Roos, **Mulia Nurhasan**, Bun Thang, Jutta Skau, Frank Wieringa, Kuong Khov, Henrik Friis, Kim F. Michaelsen and Chamnan Chhoun (3rd – 5th of November 2010). *WinFood Cambodia: improving child nutrition through improved utilization of local food.* Poster presentation at International Scientific Symposium Biodiversity and Sustainable Diets: United Against Hunger – FAO Headquarters, Rome.

The following publications related to the topic are not included in the PhD thesis:

1. **Mulia Nurhasan**, Yusuf Bahtimi Samsudin, John F McCarthy, Lucentezza Napitupulu, Rosita Dewi, Dian N Hadihardjono, Aser Rouw, Kuntum Melati, William Bellotti, Rodri Tanoto, Stuart J Campbell, Desy Leo Ariesta, M Hariyadi Setiawan, Ali Khomsan, dan Amy Ickowitz. 2021. Linking food, nutrition and the environment in Indonesia: A

perspective on sustainable food systems. Bogor: *Center for International Forestry Research (CIFOR).* https://doi.org/10.17528/cifor/008070

2. **Mulia Nurhasan**, Nanna Roos, JJ Aristizabal Henao, Chamnan C, KD Stark and Lotte Lauritzen. Effect of storage temperature in a Cambodian field setting on the fatty acid composition in whole blood. *Prostaglandins, Leukotrienes and Essential Fatty Acids* 2015;96:57-61. https://doi.org/10.1016/j.plefa.2015.02.001

3. Kim F. Michaelsen, Kathryn G. Dewey, Ana B. Perez-Exposito, **Mulia Nurhasan**, Lotte Lauritzen and Nanna Roos. Food sources and intake of n-6 and n-3 fatty acids in low-income countries with emphasis on infants, young children (6–24 months), and pregnant and lactating women. *Journal of Maternal & Child Nutrition* 2011;7(s2):124–140. https://doi.org/10.1111/j.1740-8709.2011.00302.x

Selected articles in food and nutrition topics published in mass-media:

1. **Mulia Nurhasan**, Stepha McMullin and Amy Ickowitz (7th of July 2020). Contribution of forest, trees and agroforestry to sustainable food security and nutrition in a time of crisis. *CGIAR Research Program on Agriculture for Nutrition and Health*. https://a4nh.cgiar.org/2020/07/07/contribution-of-forests-trees-and-agroforestry-to-sustainable-food-security-and-nutrition-in-a-time-of-crisis/

2. **Mulia Nurhasan**, M Hariyadi Setiawan and Miranda (5th of May 2020). Global pandemic needs local solutions for sustainable food systems. *The Jakarta Post; Academia*. https://www.thejakartapost.com/academia/2020/05/05/global-pandemic-needs-local-solutions-for-sustainable-food-systems.html

3. **Mulia Nurhasan** (13rd of May 2019). Poor fishery management costs Indonesia $7 billion per year. Here's how to stop it. *The Conversation*. https://theconversation.com/poor-fishery-management-costs-indonesia-7-billion-per-year-heres-how-to-stop-it-109671

4. **Mulia Nurhasan** and Amy Ickowitz (2nd of November 2018). The pressing discussion of sustainable food system. *The Jakarta Post; Opinion.* http://www.thejakartapost.com/academia/2018/11/02/the-pressing-discussion-of-sustainable-food-systems.html

5. **Mulia Nurhasan** (13 September 2017). In search of 'Indonesian salmon'. *The Jakarta Post; Academia*. http://www.thejakartapost.com/academia/2017/09/13/in-search-of-indonesian-salmon.html

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Summary in English

Introduction

Cambodia has rich freshwater resources, which have been described as the most productive in the world. Together with rice, fish and other aquatic animals (OAA) are part of Cambodia's traditional diet. The fish consumed in Cambodia are a variety of several hundred freshwater species from the Mekong River system, sometimes consumed with the bones and the head. Fish is an excellent source of high-quality animal protein, micronutrients, and essential fatty acids, such as n-3 long-chain (LC) polyunsaturated fatty acids (PUFA). Fish and their associated LC PUFA have many health benefits, including stimulating cognitive development in children.

Despite the rich and productive aquatic food resources, Cambodia ranks among the most food-insecure countries in the world, with a high prevalence of undernutrition. The diets of infants and young children in Cambodia are of low diversity with nutritionally insufficient amounts of fish and OAA. The WinFood project in Cambodia aimed to develop nutritious foods for infants and young children, based on the utilization of traditional foods (rice and fish) as processed complementary foods (PCF). Fish-based PCF can potentially be a nutritious and practical complementary food for infants and young children in Cambodia.

The main objective of this thesis is to explore the potential of freshwater fish-based PCF to improve the nutritional status of infants and young children in Cambodia, with particular focus on the diversity of species consumed, the impact on fatty acid status, the caretakers' preferences, and the willingness to pay (WTP).

Method

Paper I used data from the WinFood cross-sectional survey. As part of the survey, mothers of children aged 6-15 months in Prey Veng Province were interviewed to retrospectively assess the consumption of fish and OAA among mothers and their young children. In this study, the mothers recalled fish and OAA consumption from the previous rainy season with the details on species, types of processing, and parts consumed. The study used 157 cards with pictures of fish and OAA species native to the surroundings and 11 cards with names of processed fish to support recall of fish and OAA consumption.

Paper II investigates the impact of freshwater fish consumption on blood n-3 LC PUFA of children aged six to 15 months over a nine months intervention period. Data for the study was from the individually randomized, single-blinded, community-based intervention trial for WinFood, which involved 419 children. The blood fatty acid composition was analyzed before and after a complementary feeding intervention with fish-based (WinFood (WF) and WinFood Lite or (WF-L)) and non-fish-based (CSB+ and CSB++) PCF. The WinFood study was designed primarily to assess the effect of locally developed complementary foods on child growth, body composition, iron status, and gross motor development. The impact on blood fatty acid composition is a secondary outcome.

Paper III explores the market potential of fish-based PCF in packages (PCFP) in urban and rural Cambodia. The data were collected in a cross-sectional field experiment in Phnom Penh and Prey Veng Province. The sites were selected to represent urban and rural settings in Cambodia. All caretakers in the selected sites with a child aged 7-24 months and who reported that the child ate porridge on a daily basis were invited to participate. The study assessed the preferences and the WTP for PCFP. Preference for organoleptic characteristics of the PCFP were measured through a hedonic ranking test. The WTP measurement followed the Becker–Degroot–Marschak (BDM) method and the Contingent Valuation Method (CVM). Respondents' knowledge and perspectives on, and familiarity with PCFP, were also assessed. The findings from the **Paper I, II, and III** are discussed from the perspective of sustainable food systems.

Results

Paper I included data from 100 mothers. The findings in **Paper I** showed that, on average, mothers recognized 113 fish species and 14 OAA species available in their surrounding aquatic environments. The numbers of species reported to be consumed by mothers and children were 69 and 14 species of fish, respectively, and eight and one species of OAA, respectively, in the preceding rainy season. Consumption of fish with the head and bones was common among mothers but not children. The diversity of children's fish and OAA consumption was positively correlated with age. The study showed that the rich biodiversity of fish and OAA in the Mekong River basin is reflected in the mothers' knowledge of fish species and their food culture but is not translated into their children's diets.

Paper II included data from 308 children. The study found no differences in whole blood n-3 LC PUFA among the intervention groups or between the fish-based and the non-fish-based groups. Exploratory analysis on a stratified sample of children who were no longer breastfed at 15 months of age (endline) showed a significantly lower ratio of blood n-6/n-3 in the fish-based group. The lower ratio of n-6/n-3 in the fish-based group among non-breastfed children indicates that the effect of the intervention foods was modified by breastfeeding.

Paper III included data from 520 caretakers. Among the four PCFP included, the fish-based PCFP (WF-L) was preferred over food aid CSB++ by rural participants. The organoleptic qualities of fish-based PCFP have room for improvement in consistency and taste. WTP analysis showed that participants were on average willing to pay 1,667 Khmer Riel (KHR or ± 0.40 USD in the urban setting and 1,192 KHR (±0.30 USD) in the rural setting for a portion of 35 grams of fish-based PCFP. The study also found that the Cambodian market was penetrated by various brands of global and local PCFP. The caretakers said they are familiar with at least one of those brands (75% urban and 46% rural). Still, only 31% of the urban and 21% of rural caretakers had ever consumed them. Most participants considered homemade porridge healthier, more practical, and preferred by children.

Conclusion

Findings in this thesis suggest that to improve fish consumption in Cambodian children, fish processing, such as fish powder and fish-based PCF, are likely to be feasible in nutrition interventions. In improving the children's blood fatty acid composition; the fish-based PCF is

likely to be superior to the non-fish-based PCF, especially in non-breastfed children. Potential consumers and recipients of the fish-based PCF were willing to pay for the fish-based PCFP. Similar products were known and consumed by some of the target consumers/ recipients. This finding indicates the potential accessibility of fish-based PCF by the target consumers.

The high diversity and local availability of fish in Cambodia are important in supporting the availability and stability dimensions of fish-based PCF in food and nutrition interventions. From an environmental sustainability perspective, fish-based PCF is potentially sustainable because it utilizes small and locally available fish species, which are lower in the trophic level, hence facing less environmental pressure. Fish are associated with 'good or healthy for children' by caretakers in this study. The target consumers and caretakers in rural Cambodia also preferred fish-based PCF compared to the global food aid CSB++.

In conclusion, fish-based PCF is a feasible nutrition intervention because it can improve fish consumption in children, and potentially improve fatty acid composition, especially in non-breastfed children. Furthermore, fish-based PCF is also potentially accessible, as target consumers were willing to pay for it. From the sustainable food system perspective, fish-based PCF can be a sustainable intervention to improve the nutrition status of infants and young children in Cambodia.

Dansk Resume

Introduktion

Cambodjas rige ferskvandsressourcer er beskrevet som blandt de mest produktive i verden. Sammen med ris udgør fisk og andre akvatiske dyr (OAA) en vigtig del af Cambodjas traditionelle kost. Fiskene i den Cambodjanske kost dækker flere hundrede ferskvandsarter fra Mekong-flodsystemet. Nogle arter spises hele, med ben og hoved. Fisk er en fremragende kilde til animalsk protein af høj kvalitet, mikronæringsstoffer og essentielle fedtsyrer, såsom n-3 langkædede flerumættede fedtsyrer (LC PUFA). Fisk og deres bidrag til LC PUFA har mange sundhedsmæssige fordele, herunder stimulering af børn kognitive udvikling.

På trods af de rige og produktive akvatiske føderessourcer rangerer Cambodja blandt de mest fødevareusikre lande i verden med en høj forekomst af underernæring. Spædbørns overgangskost i Cambodja mangler variation og indtaget af fisk er ernæringsmæssigt utilstrækkeligt. WinFood-projektet i Cambodja havde til formål at udvikle ernæringsrigtige produkter til spædbørn baseret på traditionelle fødevarer (primært ris og fisk), egnet til distribuering som forarbejdede pakkede produkter (PCFP). Fiskebaseret PCFP har potentiale til at bidrage til at forbedre overgangskosten i Cambodia ved at give adgang til et nærende, praktisk og stadig kulturelt traditionelt produkt.

Hovedformålet med denne afhandling er at undersøge potentialet for at produkter baseret på lokale ferskvandsfisk kan bidrage til bedre ernæring blandt børn i Cambodja, ud fra perspektiver på behov, indvirkningen på n-3 LC PUFA status, og omsorgspersoners præferencer og prioritering til at betale for sådanne produkter.

Metoder og deltagere

Artikel I anvender data fra et tværsnitsundersøgelse under WinFood projektet. Som en del af undersøgelsen blev 100 mødre til børn i alderen 6-15 måneder i Prey Veng-provinsen interviewet for retrospektivt at rapportere indtaget af fisk og OAA. I dette studie rapporteres det retrospektive fiskeindtag for den forudgående regntid, med detaljer om arter, typer af forarbejdning og hvilke dele af fiskene der blev spist. Undersøgelsen brugte 157 kort med billeder af fisk og OAA-arter som er almindeligt forekommende i området, og 11 kort med traditionelt forarbejdede fiskeprodukter til at støtte den retrospektive rapportering af indtaget.

Artikel II undersøger virkningen af dagligt indtag af produkter med ferskvandsfisk på n-3 LC PUFA i blodet over en interventionsperiode på 9 måneder, fra alderen 6 til 15 måneder. Studiet bygger på sekundære data fra det individuelt randomiserede interventionsforsøg udført i et landdsitrikt under WinFood projektet. Blodets fedtsyresammensætning og koncentration blev analyseret før og efter en intervention med et dagligt supplement af fiskebaserede grødprodukter (WinFood (WF) og WinFood Lite eller (WF-L)) eller ikke-fiskebaserede grødprodukter (CSB+ og CSB++). WinFood-studiet var primært designet til at vurdere effekten af de lokalt udviklede fiskebaserede produkter sammenlignet med de eksisterende nødhjælpsprodukter på børns vækst og kropssammensætning, jern-status og motorisk udvikling.

Artikel III undersøger markedspotentialet for fiskebaseret PCF i byer og landdistrikter i Cambodja. Data for studiet er fra et tværsnits-eksperiment i Phnom Penh og Prey Veng-provinseerne. Studiets lokationer repræsenterede by og land i Cambodja. Alle omsorgspersoner med et barn i alderen 7-24 måneder i områderne blev identificeret, og dem der rapporterede at barnet spiste grød dagligt, blev inviteret til at deltage. Undersøgelsen var designet til at måle præferencer, kendskab til produkter og villighed til at betale ('willingness-to-pay', WTP) for PCFP. Præference for de organoleptiske karakteristika af PCF blev målt gennem en hedonisk rangeringstest. WTP undersøgelsen anvendte Becker-Degroot-Marschak (BDM)-metoden og Contingent Valuation methoden (CVM). Respondenternes viden og perspektiv på og kendskab til PCFP'er blev ligeledes undersøgt.

Resultaterne fra de tre studier inkluderet i afhandlingen diskuteres i perspektivet af bæredygtigt fødevaresystem.

Resultater

Studie I fandt at mødre i gennemsnit havde kendskab 113 fiskearter og 14 OAA-arter fra deres omkringliggende vandmiljøer. Antallet af arter der blev rapporteret at være spist af mødre og børn var henholdsvis 69 og 14 fiskearter, og henholdsvis otte og én art af OAA, i den forudgående regntid. Indtagelse af fisk med hoved og ben var almindelig blandt mødre, men ikke børn. Mangfoldigheden af børns fisk og OAA-forbrug var positivt korreleret med alderen. Undersøgelsen viste, at den rige biodiversitet af fisk og OAA i Mekong-flodbassinet afspejles i mødres viden om fiskearter og deres madkultur, men er ikke omsat til deres børns kost.

Studie II inkluderede data fra 308 børn. Der var ingen forskelle i blod-koncentrationer af n-3 LC PUFA mellem de fire interventionsgrupperne eller mellem grupper der fiskebaserede (WF og WF-L) og de ikke-fiskebaserede (CSB+ of CSB++) produkter. En eksplorativ stratificeret analyse på børn der ikke længere blev ammet ved 15 måneders alderen viste en signifikant lavere blod n-6/n-3 ratio i gruppen der indtog de fiskebaserede produkter. Den lavere n-6/n-3 ration i den fiskebaserede gruppe blandt ikke-ammede børn indikerer at effekten af interventionsfødevarer blev modificeret af amning.

Undersøgelse III inkluderede data fra 520 omsorgspersoner, primært mødre. Blandt de fire undersøgte produkter blev WF-L foretrukket fremfor nødhjælpsproduktet CSB++ blandt forsøgsdeltagerne på landet. WF-L's organoleptiske kvaliteter kan forbedres med fokus på konsistens og smag. WTP-analyse viser at deltagerne i gennemsnit var villige til at betale 1.667 KHR (± 0,40 USD) blandt deltagerne i byen og 1.192 KHR (±0,30 USD) blandt deltagerne på landet, for en pakke med 35 gram WF-L. Undersøgelsen fandt også, at der på det Cambodjanske marked fandtes forskellige mærker af globale og lokale PCFP. Nogle af deltagerne rapporterede at de var bekendte med mindst et af disse mærker (75 % by og 46 % på landet). Alligevel havde kun 31 % af byerne og 21 % af omsorgspersonerne på landet smagt disse produkter. De fleste deltagere betragtede hjemmelavet grød som sundere, mere praktisk og foretrukket af børn.

Konklusion

Resultaterne i denne afhandling tyder på, at for at øge fiskeindtaget hos cambodjanske børn, er forarbejdning af fisk til for eksempel fiskepulver og fiskebaseret PCF en mulig fremgangsmåde i ernæringsinterventioner. En lokalt fremstillet fiskebaserede PCF vil sandsynligvis kunne bidrage til at forbedre n-3 LC PUFA status, i sammenligning med en ikke-fiskebaserede PCF, især hos ikke-ammede børn. Potentielle forbrugere af den eksperimentelle fiskebaserede PCF var villige til at betale for den fiskebaserede PCF i pakker. Andre grød-produkter der allerede var tilgængelige på markedet var kendte og brugt af en andel af målgruppen af omsorgspersoner, hvilket indikerer at der er et potentielle for at et tilgængeligt fiskebaseret PCF ville kunne nå målgruppen.

Den store naturlige diversitet og lokal tilgængelighed af fisk i Cambodja er vigtig for at understøtte tilgængeligheds- og stabilitetsdimensionerne af at udbrede fiske-baseret PCF som led i en ernæringsintervention. Fra et miljømæssigt bæredygtighedsperspektiv er fiskebaseret PCF potentielt bæredygtig ved at være baseret på arter af små fisk, som er lavere i de tropiske niveauer, og derfor udgør mindre miljømæssigt pres. Mødre og andre omsorgspersoner betragter fisk som godt eller sundt for børn. Målgruppen af omsorgspersoner på landet i Cambodja foretrak fiskebaseret PCF sammenlignet med den globale fødevarehjælp CSB ++.

Det konkluderes at et fiskebaseret PCF i Cambodia er relevant i ernæringsinterventioner med formål at øge fiskeindtaget hos børn, og dermed potentielt forbedre n-3 LC PUFA status, især hos ikke-ammede børn. Et fiskebaseret PCF har potentiale for at gøres tilgængelig gennem forskellige distributionskanaler da målgruppen var villige til at betale for produktet. Fra et bæredygtigt fødevaresystems perspektiv kan fiskebaseret PCF være en bæredygtig intervention for at forbedre ernæringsstatus hos børn i Cambodja.