1 Introduction

In this chapter, micronutrient deficiencies in schoolchildren, other health risks such as soil-transmitted helminth infection and an intervention with multiple micronutrient fortified rice are introduced and the thesis objectives are presented.

Micronutrient deficiencies are still a critical public health issue in most developing countries, affecting about one third of children and women in reproductive age (3, 4). Micronutrient deficiencies have various clinical and sub-clinical manifestations, contributing to suboptimal growth, impaired cognitive development and increase the risk of morbidity and mortality from infectious diseases (5). The most documented micronutrient deficiencies of public health concern are deficiencies of vitamin A, folate, iron, iodine and zinc; however several other micronutrients are likely to be a health problem too in populations at risk of food insecurity and malnutrition (5). Deficiency of micronutrients along with general malnutrition and poor living conditions can result in delayed cognitive development, preventing millions of children from reaching their full potential (1, 2). As a result, it adversely impacts socio-economic development at individual, community and national levels (6). It has been estimated, for example, that in Cambodia, stunting and deficiencies of iron, iodine, vitamin A and zinc annually cost 266 million (7).

Combating micronutrient deficiencies among vulnerable groups has been a public health priority for both developing and developed countries. The Copenhagen Consensus 2012 has prioritized combating nutritional deficiencies among the most effective strategies in improving health (8), especially in developing countries where micronutrient malnutrition is an immense burden.

In Cambodia, despite a considerable reduction in poverty and improvements in health and nutrition since the mid-1990s, Cambodian children are still at high risk of stunting and anemia affecting 32.4% and 43.6% of children under 5 years, respectively (9). In addition, the 2014 Cambodian Micronutrient Survey classified 67.5% and 20.2% of preschool children as deficient in zinc and folate respectively (10). While the prevalence of frank iron deficiency was low (<10%), 24.7% of preschool children had marginal iron stores (10).

Micronutrient deficiencies and malnutrition are widespread among schoolchildren. A review from 2010 estimated that 20-30% of school-age children in Southeast Asia were affected by

zinc, iron and vitamin A deficiencies (11) which can impair physical and mental development during their school ages and affect school performance as a result of common illness. Some studies have reported that it is still possible to improve cognition during the primary school years by improving micronutrient status (12, 13), and reduce morbidity incidence and growth deficits; however the overall effects on these outcomes in school children are context specific and more evidence is required from studies in different populations in order to provide recommendations for nutrition programs for school-age children.

Food fortification has been suggested to be the most cost-effective intervention to address micronutrient deficiencies (14). A systematic review showed that fortification with multi-micronutrient has the potential of improving micronutrient status, growth and cognition, as well as reducing morbidity (15). Only few studies have investigated the impact of multi-micronutrient food fortification on the micronutrient status, growth, health, and cognitive development in school-age children (15).

Fortification of staple foods such as rice could be a promising strategy for Cambodia, where approximately 70% of the daily energy intake comes from rice (16). The fortification of staple foods is advantageous because it does not require the target population to change their dietary habits and allows fortification with multiple micronutrients since deficiencies often co-occur (17). However, the Cambodian government needs evidence on the impact of fortified rice on nutrition, health and development in school-age children to support inclusion of fortified rice in country-wide programs, as well as to support future national food fortification guidelines.

Assessing the bioavailability and stability of the micronutrients added to staple foods is essential to estimate the potential impact of a fortification program on public health. Losses during storage and cooking can have a direct impact on the sustainability of a program due to either reduced impact or additional cost to compensate the lost micronutrients. A study showed that cooking rice in excess water destroyed up to 80% of the fortified vitamin A (retinyl palmitate) which is one of the most expensive vitamins in the fortified rice kernel and overage of 50% of vitamin A in fortified kernel at production might not be sufficient and could increase the potential risk for toxicity (18).

Another factor affecting nutritional status, health and cognitive function of schoolchildren is soil-transmitted helminths (STH) infection. It is estimated that a third of the world population is infected with one or more species of intestinal helminthes, which may impair children’s nutritional status, growth, health and cognitive development (19, 20). School-age children are

considered particularly at risk to STH infection (21), often having the highest intensity and prevalence of infection (22). Both the World bank and World health organization (WHO) promote helminth control programs in developing countries as a cost effective intervention (23). Despite lack of national data, Cambodia is considered to be one of the highest STH prevalence rates in Southeast Asia. Although several studies have reported associations between helminth infection and children's academic performance or cognitive performance, the results are inconsistent.

The intervention study "Fortified Rice for School Children in Cambodia (FORISCA)" was conducted between 2012-2013 as a partnership between Institut de recherche pour le développement (IRD), PATH and World food program (WFP), Department of fisheries post-harvest technologies and quality control (DFPTQ) and University of Copenhagen. The project aimed to quantify the impact of multi-micronutrient fortified rice (MMFR), which was distributed through the WFP school meal program as a single meal per day, on micronutrient status, health and cognition of Cambodian schoolchildren.

1.1 Objective of PhD research

This PhD study was conducted under the FORISCA study with the aim of contributing to the evaluation of the impact of fortified rice on nutrition, health and development of Cambodian schoolchildren.

Specific objectives of this PhD Thesis are:

1. To determine the stability of micronutrients in fortified rice from different processing technologies over storage conditions and time (paper I)
2. To assess the prevalence of soil-transmitted helminths (STH) infection and investigate associations between STH, micronutrient status and cognitive performance in Cambodian schoolchildren (Paper II)
3. To evaluate the impact of three different types of multi-micronutrient fortified rice on zinc and folate status of Cambodian schoolchildren (paper III)

Other outcomes of the FORISCA study are evaluated by other research fellows.