HIDDEN HUNGER IN THE CURRENT WORLD:

CAUSES, CONSEQUENCES AND SOLUTIONS TO A GLOBAL PUBLIC HEALTH CHALLENGE AND A PARTICULAR LOOK AT SPAIN

Alba Redón Lago

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Department of Nutrition,
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Gastronomy

Faculty of Pharmacy and
Food Sciences

University of Barcelona

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HIDDEN HUNGER IN THE CURRENT WORLD: CAUSES, CONSEQUENCES AND SOLUTIONS TO A GLOBAL PUBLIC HEALTH CHALLENGE AND A PARTICULAR LOOK AT SPAIN

HAMBRE OCULTA EN EL MUNDO ACTUAL: CAUSAS, CONSECUENCIAS Y SOLUCIONES A UN DESAFÍO MUNDIAL DE SALUD PÚBLICA Y UNA MIRADA PARTICULAR A ESPAÑA

Redón Lago, Alba[1]

[1] University of Barcelona, Department of Nutrition, Food Sciences and Gastronomy; Barcelona, Spain

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Abstract: Hidden hunger is a form of malnutrition that refers to micronutrient deficiencies. This thesis reviews the determinants of hidden hunger and its consequences in health and economic development, its prevalence globally and in Spain particularly and researches available solutions and progress done towards its eradication in the context of the 2030 Agenda for Sustainable Development and the Decade of Action on Nutrition (2016-2025). A search of different databases was performed to select relevant reviews, systematic reviews and meta-analyses on the topic and several international organizations' publications were consulted. While the prevalence of hidden hunger is alarmingly high in low and middle-income countries, deficiency in some key vitamins and minerals happens in high-income countries. Solutions to hidden hunger include supplementation, food fortification, biofortification and nutrition and food-systems approaches. Although some advances have been made in recent decades, hidden hunger continues to be a global public health challenge that requires a multi-sectoral approach in order to end malnutrition in all its forms. The present thesis might be of interest to international and national policy-makers, governments, health and nutrition workers, stakeholders and the general population in order to take further action in tackling hidden hunger.

Keywords: *hidden hunger, micronutrients, malnutrition, nutrition policy, sustainable development goals*

Resumen: El hambre oculta es una forma de malnutrición que hace referencia a las deficiencias de micronutrientes. Esta tesis revisa los determinantes del hambre oculta y sus consecuencias en la salud y el desarrollo económico, su prevalencia a nivel mundial y en España en particular e investiga las soluciones disponibles y los avances hacia su erradicación en el contexto de la Agenda 2030 para el Desarrollo Sostenible y la Década de Acción en Nutrición (2016-2025). Se realizó una búsqueda en diferentes bases de datos para seleccionar revisiones, revisiones sistemáticas y metanálisis relevantes sobre el tema y se consultaron varias publicaciones de organizaciones internacionales. Si bien la prevalencia del hambre oculta es alarmantemente alta en los países de ingresos bajos y medianos, la deficiencia de algunas vitaminas y minerales clave ocurre en los países de ingresos altos. Las soluciones para el hambre oculta incluyen la suplementación, el enriquecimiento de alimentos, la biofortificación y los enfoques de nutrición y sistemas alimentarios. Aunque se han logrado algunos avances en las últimas décadas, el hambre oculta sigue siendo un desafío de salud pública mundial que requiere un enfoque multisectorial para acabar con la malnutrición en todas sus formas. La presente tesis podría ser de interés para los elaboradores de políticas nacionales e internacionales, los gobiernos, los profesionales de la salud y la nutrición, las partes interesadas y la población general a fin de emprender nuevas acciones para combatir el hambre oculta.

Palabras clave: *hambre oculta, micronutrientes, malnutrición, política nutricional, objetivos de desarrollo sostenible*

Introduction

The World Health Organization's (WHO) definition of malnutrition is «deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients» (1). This term englobes three different forms of malnutrition also defined by WHO: *«undernutrition, which includes wasting (low weight-for-height), stunting (low height-for-age) and underweight (low weight-for-age); micronutrient-related malnutrition, which includes micronutrient deficiencies (a lack of important vitamins and minerals) or micronutrient excess; and overweight, obesity and diet-related noncommunicable diseases (such as heart disease, stroke, diabetes and some cancers)»* [(1)].

These forms of malnutrition can exist separately but can also coexist within individuals, households and populations [(2)]. In fact, in the literature we can find a considerable number of publications referring to "the double burden of malnutrition" and in some -although less prevalent- "the triple burden of malnutrition". On the one hand, the coexistence of undernutrition along with overweight, obesity and diet-related non-communicable diseases is known as double burden of malnutrition [(2)]. On the other hand, when micronutrient deficiencies are added to the previous two forms of malnutrition, one speaks of triple burden of malnutrition. As I mentioned earlier, the latter is less prevalent in the literature. I have found that the reason why this might happen is because often when framing malnutrition only two categories are established: undernutrition and overnutrition. While overnutrition clearly refers to the burden of overweight and obesity, the term undernutrition seems to include the burden of both macronutrient (carbohydrates, lipids and proteins) and micronutrient (vitamins and minerals) deficiencies.

In my opinion, it should be nuanced that macronutrient deficiencies and micronutrient deficiencies are two different forms of malnutrition and therefore contribute differently to the burden of malnutrition. In that sense, in this bachelor's thesis I will mainly focus on the second form of malnutrition, the micronutrient-related malnutrition. In particular, I will be addressing the issue of micronutrient deficiencies, also known as "hidden hunger". The term was established to differentiate it from "chronic hunger" – or simply "hunger"-, which is the result of insufficient food intake in terms of macronutrients or dietary energy (calories) over a long period of time. Hidden hunger, as the name suggests, is a different form of hunger, usually harder to see at first sight, and refers to the insufficient intake of micronutrients.

Each year, the Food and Agriculture Organization (FAO), together with IFAD (International Fund for Agricultural Development), UNICEF (United Nations International Children's Emergency Fund), WFP (World Food Programme) and WHO, publishes a report called *"The state of food security and nutrition in the world*" – named *"The state of food insecurity in the world"* prior to 2017-. The aim

of this annual report is to «inform on progress towards ending hunger, achieving food security and improving nutrition and to provide in depth analysis on key challenges for achieving this goal in the context of the 2030 Agenda for Sustainable Development» [(3)]. In its latest publication (2020), it is estimated that, prior to the COVID-19 pandemic, 690 million people (8.9% of the global population) were undernourished, showing a rising trend since 2014 [(4)]. As we can see, the numbers for chronic hunger are alarmingly high and further action needs to be taken to achieve zero hunger. However, updated estimates for hidden hunger are not provided in this report, as global data for micronutrient deficiencies seems to be harder to obtain. In FAO's 2013 *"The state of food and agriculture: food systems for better nutrition"* publication it is estimated that 2 billion people suffer from hidden hunger in the world [(5)]. At the same time, in 2016 more than 1.9 billion adults were overweight, of which over 650 million of these were obese, according to WHO [(6)].

Ending all forms of malnutrition remains a challenge, as goals established to end it haven't been met yet. Therefore, the main objective of this bachelor's thesis is to understand the importance of addressing micronutrient deficiencies just as much as addressing other types of malnutrition in order to end malnutrition in all its forms, which is still one of the biggest public health challenges, with secondary objectives being to establish the causes and determinants of hidden hunger, review its prevalence globally and in Spain particularly, research available solutions to eradicate it and analyze what policies have been made at international and national level, all in the context of the 2030 Agenda for Sustainable Development and the Decade of Action on Nutrition (2016-2025).

Methods

For the development of this thesis three databases were consulted: MEDLINE (PubMed), Scopus and Cochrane Database of Systematic Reviews. An initial search using the terms "hidden hunger", "micronutrient deficiencies", "double burden of malnutrition" and "triple burden of malnutrition" was performed in the month of February 2021. Since this thesis consists of a literature review of a long-lasting public health issue and the aim is to review the current scope of the problem but also the progress made towards its eradication, no publication date filter was applied to the search although the selection of the most recent studies was preferred. Nevertheless, an article type filter was used to restrict search results to reviews, systematic reviews and meta-analyses. From the results obtained, selection criteria consisted of title and abstract reading. Related and suggested articles were also examined. After reading selected articles and creating a first draft of the structure of this thesis, more database searches were carried out between the months of March and May 2021. Search terms were specific according to each section of this thesis. For example, the terms "micronutrient fortification", "micronutrient supplementation" and "biofortification" as well as combinations of these terms were

used to find articles that addressed solutions to hidden hunger. Some chapters of the book *"Tratado de Nutrición. Tomo 1: Bases fisiológicas y bioquímicas de la Nutrición"* were used to describe functions, dietary sources and deficiency symptoms of selected vitamins and minerals. Furthermore, many publications, infographics and other resources from the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the United Nations (UN) were consulted and used in this thesis, as these international organizations play a major role in measuring and tackling malnutrition in all its forms and providing useful information for the creation and implementation of policies at international and national level. Lastly, the reference management software Mendeley (Version 1.19.8) was used to manage all citations.

Micronutrient deficiencies

As I mentioned earlier, hidden hunger is the name given to micronutrient deficiencies, that is to say, the lack of vitamins and minerals.

Vitamins are organic compounds different from macronutrients (carbohydrates, lipids and proteins) given that they do not act as a source of energy or have a structural function in the body. Instead, they have a role in physiological functions such as growth, development and metabolism among others. They are present in food in small amounts and their requirements are lower than those of macronutrients. They are classified into fat-soluble vitamins (A, D, E, K) and water-soluble vitamins (C, B complex). Except for vitamin D, all vitamins are considered essential because they are not synthesized by the body and therefore must be obtained from food intake [(7)].

Vitamin deficiencies can be divided into two categories: primary deficiencies and secondary deficiencies. The first takes place when the deficiency is due to the poor intake of a certain vitamin which does not meet the requirements, and the second refers to a deficiency caused by difficulties in the process of absorption or metabolism of a vitamin, which may be secondary to a pathology.

Minerals differ from vitamins in that they are inorganic compounds, but alike vitamins they are also present in small amounts in food and their requirements are low compared to those of macronutrients. According to their daily requirements, minerals are classified into macrominerals (Ca, P, K, Na, S, Cl, Mg) (daily requirements of >100 mg in adults) and microminerals which are divided into trace elements (Fe, Zn, Mn, Cu, F) (daily requirements between 1 and 100 mg in adults) and ultra-trace elements (Se, Mo, I, Cr, B, Co) (daily requirements of <1 mg in adults). Other minerals can be found in the human body in very small quantities but they will not be mentioned in this thesis. Their functions in the human body are diverse, from structural functions (e.g bone formation), catalytic functions (they act as co-factors) and regulatory functions to signaling functions [(7)]. While it is clear

that vitamins are essential nutrients, there is controversy regarding mineral essentiality. However, if they have one of the cited functions, they are most likely to be considered essential.

In this thesis I will only address deficiencies in vitamin A, vitamin D, folates, vitamin B12, iron, zinc and iodine, which are of bigger concern from a public health point of view. Nevertheless, deficiencies in other vitamins and minerals should not be underestimated as their deficiency -although less prevalent- can also have serious consequences and should be addressed -if needed- when tackling hidden hunger.

Vitamin A

Vitamin A englobes retinoids and carotenoids with provitamin[1] A activity. Retinoids with vitamin A activity are found in nature in three forms: retinol, retinal and retinoic acid, but there are also other isomers with vitamin A activity. Carotenoids when metabolized transform into retinoids, and this is why they are called provitamins A, although not all carotenoids have this activity (8). Each form of vitamin A has several functions. Retinol participates mainly in reproduction; retinal, in sight; and retinoic acid, in epithelial differentiation, genetic transcription and reproduction. Vitamin A also portrays a role in cell formation and growth, bone formation and destruction, embryogenesis, immunity and hematopoiesis, among others. Some anticarcinogenic effects have been discovered recently although further studies need to be made [(8)].

Vitamin A is present in food in different forms: in the form of retinoids in animals' fat tissues and in the form of carotenoids in plants, mainly in those who are green, red, orange and yellow. In general, food with a major content of vitamin A are: liver, fish oils, butter, milk, cheese, egg yolk, some fat fish such as tuna and sardines, vegetables with dark green leaves and highly pigmented vegetables [(8)].

Vitamin A deficiency causes several diseases, being the most distinguished one's night blindness[2], xerophthalmia[3], infections and skin disorders [(8)].

Vitamin D

Vitamin D englobes two different vitamers[4]: ergocalciferol or vitamin D2 and cholecalciferol or vitamin D3. Vitamin D3 is the main source of vitamin D, and can be produced endogenously or obtained from food intake. Vitamin D2 is only obtained from food intake. It is important to highlight that vitamin D has both vitamin and hormone characteristics [(9)]. Classic vitamin D function is mineral homeostasis, acting in calcium's absorption, metabolism and excretion, as well as bone synthesis and

1An inactive form of a vitamin that needs activation before it can be used by the body
2 Night blindness or nyctalopia is a condition in which it is difficult or impossible to see in relatively low light (92)
3 Xerophthalmia is a condition in which the conjunctival epithelium and cornea become dry due to vitamin A deficiency, and can lead to corneal ulceration and blindness if it is not treated (93,94)
4 One of multiple related chemical compounds possessing a given vitamin activity

degradation. Vitamin D also regulates phosphate absorption and excretion. Besides this classic function, other functions of vitamin D have been described such as cell proliferation and differentiation and immune and nervous system response, which relate to multiple diseases –certain types of cancer, cardiovascular diseases, inflammatory bowel diseases, infections and autoimmune diseases- [(9)].

The main source of vitamin D for most humans is daily exposure to sunlight. Good food sources of vitamin D are fat fish -like salmon, sardines and herring- and fish liver oil. Eggs, liver, butter, cheese and other dairy products also contain smaller amounts of vitamin D, while vegetables, fruits and cereals are very poor sources of this vitamin [(9)].

Nowadays lack of vitamin D is considered to be widely spread in the world. Initially deficiency of this vitamin produces a reduction in calcium absorption and secondary hyperparathyroidism. Bone calcium is mobilized to restore serum calcium levels, resulting in bone demineralization, which eventually may lead to rickets[5], osteomalacia[6] and osteoporosis[7] [(9)].

Folates (Vitamin B9)

All folates have in common the structure of folic acid. In food, folates are found as derivates known as tetrahydrofolates (THF), while folic acid is the synthetic form. 5-methyl-THF is the cofactor form of folates, which is implicated in multiple transmethylation reactions in the metabolism of nitrogenous substances as well as the synthesis of purines and pyrimidines in order to synthesize DNA [(10)].

The main sources of folates are vegetables, especially those with dark green leaves like spinach, chard, turnip and beetroot leaves, and cabbage. Chickpeas also represent a good source of folates. Some fruits, such as orange, melon or banana also contain folates but in lower quantities, as well as nuts like almond and hazelnut, and avocado too. Meat and fish are poor sources of folates in general, in exception of the liver [(10)].

Folates are essential for cellular functioning, and their deficiency leads to the development of several diseases. The most frequent one is macrocytic and megaloblastic anemia[8], whose clinical symptoms are very similar to those of vitamin B12-induced anemia (explained below). General signs are asthenia and anorexia, but also sleep and memory disorders, irritability and convulsions and, in some

5 Rickets is a condition that results in weak or soft bones in children. Symptoms include bowed legs, stunted growth, bone pain, large forehead, and trouble sleeping. Complications may include bone fractures, muscle spasms, or an abnormally curved spine. (95)

6 Ostemalacia is a disease characterized by the softening of the bones caused by impaired bone metabolism primarily due to vitamin D deficiency, but also phosphate and calcium deficiencies. Signs and symptoms can include diffuse body pains, muscle weakness, and fragility of the bones. (96)

7 Osteoporosis is a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture. (97)

8 Megaloblastic anemia is a condition in which the bone marrow produces unusually large, structurally abnormal, immature red blood cells (megaloblasts). The main causes are folate (vitamin B9) and cobalamin (vitamin B12) deficiencies. (98,99)

cases, peripheral neuropathy, depression and dementia. Folate deficiency is more prone in certain populations, and is especially serious in newborns, causing neural tube disorders (spina bifida). This will be further explained in the next sections of this thesis [10].

Vitamin B12

Vitamers of vitamin B12 are known as cobalamins. This vitamin is only produced by microorganisms. Vegetables do not need it and therefore do not contain it. Sources of vitamin B12 for animals are, in general, the ingestion of microorganisms or gut microbiota production. For this matter, dietary sources of this vitamin are only animal products. Major food sources are liver, kidney and brain, although egg yolk, clams, oysters, crab, sardines and salmon are also good sources. Meat, cheese, milk, cod, hake, sole fish and tuna are low content sources [10].

Vitamin B12 participates in two metabolic reactions: conversion of homocysteine in methionine and conversion of methyl malonyl-CoA in succinyl-CoA. Through these functions, vitamin B12 is necessary in methylation processes, as well as maintenance of both central and peripheral nervous systems. Furthermore, vitamin B12 participates in the cycle of folates, and therefore plays a role in the synthesis of DNA [10].

Vitamin B12 causes two main diseases: megaloblastic anemia -very similar to the one caused by folate deficiency- and neuropathy, characterized by paresthesia (sensation of tingling, heat or cold) in hands and feet, loss of postural sense and weakness, among other symptoms [10].

Iron

Iron (Fe) is an essential mineral for humans, as it participates in numerous indispensable biological processes, like oxygen transportation and storage, oxidative phosphorylation, neurotransmitter metabolism and DNA and RNA synthesis. In the human body, most part of this mineral is found as part of hemoglobin (Hb), although it is also part of other structures such as ferritin, hemosiderin and myoglobin and as a cofactor in some enzymatic systems [11].

Dietary sources of iron are mainly meat and fish -which contain heme iron- and vegetables -containing non-heme iron, which is less bioavailable- (11). Iron deficiency is the world's most prevalent nutritional deficiency and the main cause of anemia[9] [11].

9 Anaemia is a condition in which the number and size of red blood cells or the haemoglobin concentration within them falls below an established cut-off value, consequently impairing the capacity of the blood to transport oxygen around the body, resulting in symptoms such as fatigue, weakness, dizziness and shortness of breath, among others. (100)

Zinc

Zinc (Zn) has catalytic, structural and regulatory functions that make it an essential mineral. The first are related to the participation of zinc in the conformation and functioning of numerous enzymes who participate in the metabolism of carbohydrates, lipids, proteins, nucleic acids and some vitamins and minerals. Structural functions mainly refers to the key role zinc plays in the conformation of many transcription factors that participate in genetic expression. Regulatory functions refer to the role of zinc in cell signaling and enzymatic activity [(12)].

The main dietary sources of zinc are meat, cereals and pulses, although it is widely distributed in many animal and vegetal organisms [(12)].

Zinc deficiency can lead to clinical signs of disease, mainly affecting growth, immunity and tissue repair, but also psychomotor development and behavior and regulation of body composition and appetite [(12)].

Iodine

Iodine (I) is a component of thyroid hormones. Both thyroxin (T4) and triiodothyronine (T3) play a fundamental role in growth and development, and also in macronutrient metabolism and production of heat [(13)].

Iodine is present in food mainly in the form of iodide and, to a lesser extent, covalently linked to amino acids. Food of marine origin (seafood, fish and algae) are the main dietary sources of iodine. Freshwater fish is a moderate source, while in milk and eggs, content depends on the iodides available in the animal's diet. Vegetables, fruits and cereals are scarce sources of this mineral, although their iodine levels depend on those of the soil [(13)].

Effects of iodine deficiency on growth and development are known by the generic term of 'iodine deficiency disorders' and affect population of all ages, but are especially serious in fetal, neonatal and childhood periods. Goiter[10] is the most significant symptom of iodine deficiency [(13)].

Consequences of hidden hunger: who is at risk?

Hidden hunger can affect people of all age groups and cause different consequences –in health and/or socioeconomic, as will be explained later-, but there is a period in life in which hidden hunger can have the most serious consequences: the 1000 first days of life, which is the period comprised between conception and the first two years of life. During this period is when the main development steps

10 Abnormal enlargement of the thyroid gland (101)

occur and therefore maternal and child nutritional status during this period is key for a correct development and growth [14].

In 2008, *The Lancet* published a series that focused in maternal and child undernutrition, including stunting, wasting, and deficiencies of essential vitamins and minerals [15]. 5 years later, in 2013, they published another article reassessing maternal and child undernutrition, and also examining overweight and obesity in low and middle-income countries -and therefore addressing the double burden of malnutrition- [16]. More recently, in 2021, they again published an article revisiting maternal and child undernutrition in order to analyze the progress made in alleviating it since their first publication [17].

According to *The Lancet* publications, the nutritional status of a woman before and during pregnancy is important for a healthy pregnancy outcome both for the mother and the baby. Although low maternal body mass index does not seem to increase the risk of pregnancy complications and assisted delivery -which in certain regions might not be as safe or accessible and therefore supposes a higher risk of mortality-, it is associated with intrauterine growth restriction [15]. Furthermore, micronutrient deficiencies in pregnancy can cause a number of possible short-term responses. These can include differences in fetal survival affecting risk of pregnancy loss due to miscarriage and stillbirth; organ formation affecting risks of birth defects; duration of gestation affecting risks of preterm birth, and consequent low birth weight; and rate of fetal growth, affecting birth size and consequent risks of being born small for gestational age and/or having a low birth weight [18]. In the long-term, maternal micronutrient adequacy during pregnancy might alter the health and development of offspring during infancy, childhood, and even adulthood. Some consequences that have been investigated are the risk of death in the first year after birth, and beyond the first year child mortality, growth, body composition, cardiometabolic risk, immunity, respiratory function and cognition [18].

In general, intrauterine growth restriction, low birthweight, low weight-for-height (wasting), stunting, vitamin A and zinc deficiencies are associated with higher mortality risk. This relation is not always direct, for example, there is an association between nutritional status and susceptibility to infections [19]. According to *The Lancet*, maternal and child undernutrition is the underlying cause of 3.5 million deaths, 35% of the disease burden in children younger than 5 years, and the number of global deaths in children less than 5 years old attributed to stunting, severe wasting, and intrauterine growth restriction constitutes the largest percentage of any risk factor in this age group [15].

In addition to mortality risk, micronutrient deficiencies contribute to a higher prevalence of morbidity -as explained in previous section, each vitamin or mineral deficiency can cause several diseases-. When analyzing the burden of disease, *The Lancet* series found that the largest disease burdens were

attributed to vitamin A and zinc deficiencies, while iodine and iron deficiencies had smaller disease burdens but further action to reduce them was needed. Other micronutrient deficiencies that have shown to have an effect in health outcomes during and after pregnancy are calcium, vitamin D, folates and vitamin B12 [15]. More recently, the relationship between child undernutrition on morbidity and mortality also covers effects on non-communicable diseases, as literature studying how early-life undernutrition and rapid weight gains later in childhood help shape cardiovascular and metabolic health has been published in the last years [17].

I believe it is important to mention again the relationship between micronutrient deficiencies and brain development in the 1000 first days and its effects throughout childhood, adolescence and adulthood since it is known that several micronutrients are involved in both prenatal and postnatal brain development -especially iron, iodine, zinc, folate, vitamin A and vitamin D [14]- and it has been shown that children who suffered from micronutrient deficiencies in early stages of life have poorer cognitive development and educational outcomes in later childhood and adolescence, and can also show behavioral problems [16]. As it will be explained below, this can also have an important impact on the economic development of a region.

Furthermore, similarly to what happens in pregnancy, childhood and adolescence, micronutrient deficiencies in the elderly contribute to a higher mortality and morbidity rate related to a higher risk of infections and exacerbation of age-related diseases due to poor nutritional status [20].

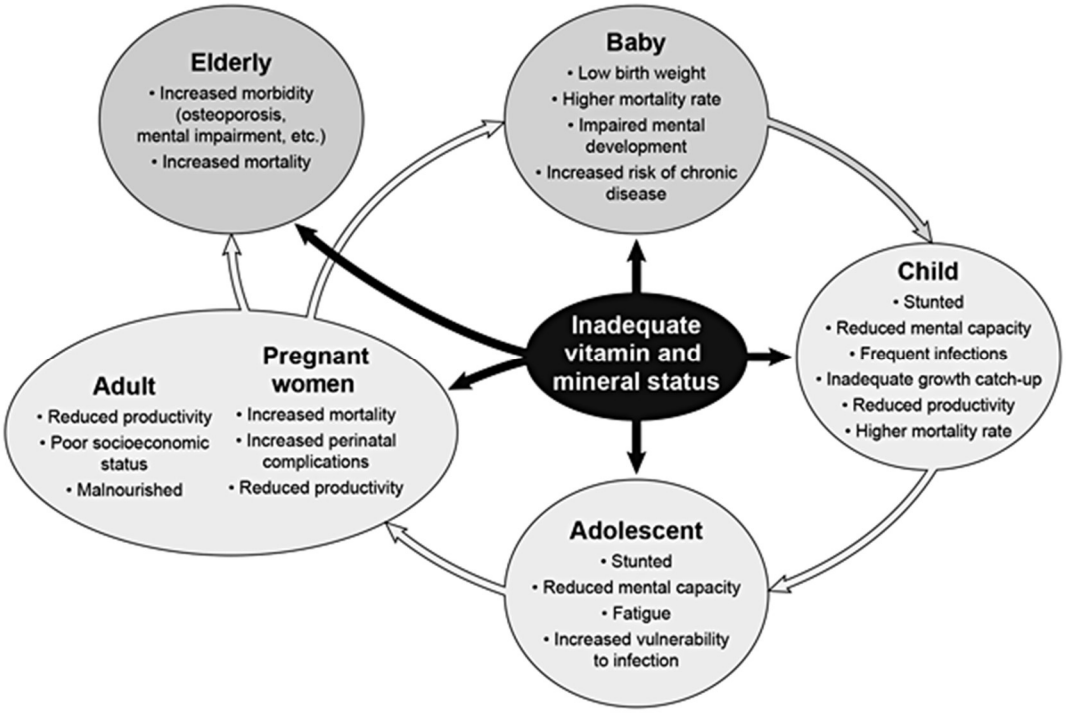

Figure 1. The conceptual framework for the cycle of micronutrient inadequacies across the life span (adapted from ACC/SCN) [23,24]

Beyond the impact of micronutrient deficiencies in health and the burden of disease, hidden hunger has also important socioeconomic consequences. In 2007, Stein and Qaim published an article addressing the human and economic cost of hidden hunger [21]. A limitation of this study is that it only focuses on India, a country where the prevalence of hidden hunger is high, as it will be shown in the upcoming sections of this thesis. Despite this limitation, the results provided in this study manage to explain accurately the economic cost of hidden hunger, as they found that micronutrient deficiencies supposed an «overall economic loss of 0.8% to 2.5% of the Indian GDP (Gross Domestic Product)[11]» (absolute losses of US$5.8–26.8 billion in monetary terms). They found that among the analyzed micronutrient deficiencies, «iron-deficiency anemia is responsible for over 40% of the total loss, while zinc deficiency causes 30% of the loss, vitamin A deficiency 25% and iodine deficiency accounts for only 2% of the overall loss of micronutrient deficiencies». They also note that the human and economic cost of micronutrient deficiencies could be higher if it was calculated for multiple deficiencies occurring at the same time instead of the sum of individual deficiencies. Furthermore, they also mention that, as historical analyses show [22], «better nutrition contributes to economic growth, both by immediately increasing work output and enlarging health endowments over time from one birth cohort to another». This supports the idea that -as Stein and Qaim mention in their conclusions- «controlling malnutrition may help to increase economic output tremendously, but this may take generations».

Figure 1 summarizes the main consequences of micronutrient deficiencies across the life span [23,24].

Causes and determinants of hidden hunger

In 2018, Gödecke, Stein and Qaim -from now on, referred to as GSQ- published an article in which they analyzed the trends and determinants of chronic and hidden hunger globally between 1990 and 2010 [25]. As previously mentioned, there is a lack of reliable country-level data in order to assess the magnitude of malnutrition in all its forms, especially hidden hunger, and consequently its determinants are not yet sufficiently understood. This gap in knowledge is what drove GSQ to write this article. In their study, GSQ compare the burden of chronic versus hidden hunger and analyze the country-level determinants of these burdens. They used Disability-Adjusted Life Years (DALYs) as a proxy to measure the burdens. As GSQ defined in their article, «DALYs are a metric to quantify the burden of health problems in terms of healthy life years lost due to disability and premature death» [25].

11 The total value of goods and services produced by a country in one year (102)

Their conclusions were that the combined burden of chronic and hidden hunger had been reduced by more than half since 1990, with chronic hunger's burden falling more rapidly. A key determinant in reducing it was economic growth -specifically, larger per capita gross domestic product (GDP). Other significant determinants were urbanization, democracy, temperate-zone climates, larger food supplies, food diversity, female schooling and access to improved sanitation and health. In *Figure 2*, determinants of hunger according to GSQ are depicted. A country's socio-economic, political and environmental characteristics are "basic determinants". Food availability and access, as well as the caregivers' resources and the resources for health are the "underlying determinants". Lastly, the individuals' dietary intakes and requirements as well as their health status are the "immediate determinants".

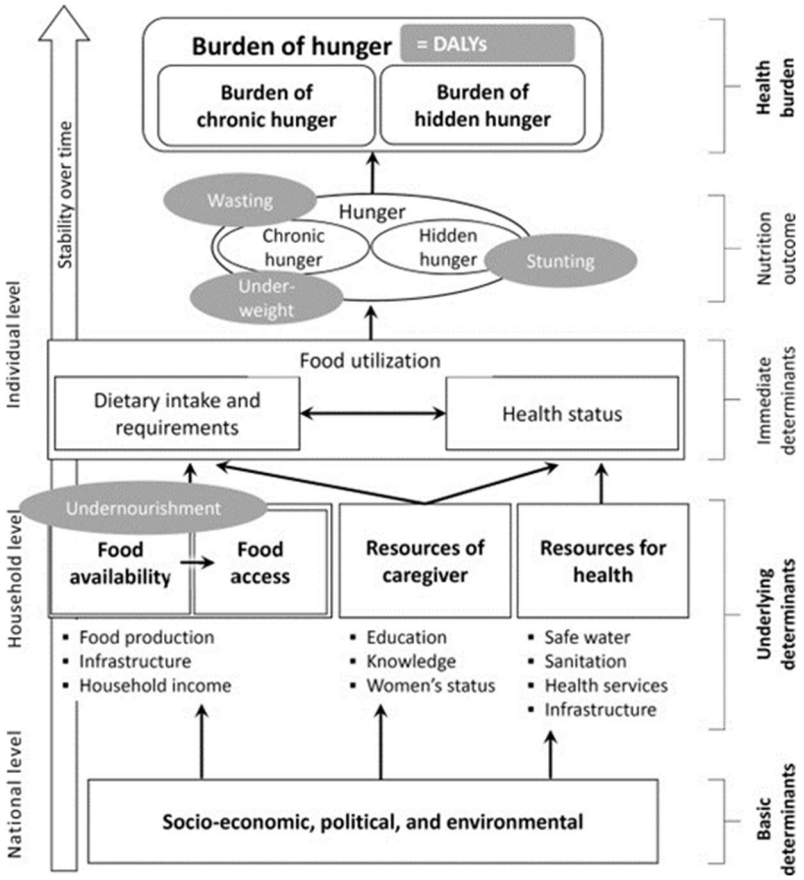

Figure 2. Determinants of hunger according to GSQ [25]

This was the first study using DALYs as a proxy of hunger. Previous studies used proxies -such as food availability as an indicator for undernourishment, or the prevalence of stunting, underweight or wasting in children [26–31]- that failed to provide a full picture of the burden of hunger in all its forms in the entire population -many studies focus on children only-. In their study, the burden of hidden hunger was calculated as the total DALYs lost due to different forms of micronutrient deficiencies in

312 a country per 1000 capita. The DALY estimates were extracted from the Institute for Health Metrics
313 and Evaluation (IHME) and comprised data from 187 countries and three years: 1990, 2005 and 2010.

314 In 2021, Lenaerts and Demont [32] reanalyzed and extended GSQ's study on the trends and
315 determinants of hidden hunger from 1990 to 2017 using the same proxy: DALYs. Since the
316 publication of GSQ's article, new DALY data had been released [33,34], calculated using a new
317 methodology, which led Lenaerts and Demont to revise and expand GSQ's work.

318 As Lenaerts and Demont well explain in their article, food security is an outcome of economic
319 development, and one of the causes of development is geography -with others being culture and
320 governance-. Geography is therefore a direct determinant of economic development and an indirect
321 determinant of food security. Furthermore, in their article Lenaerts and Demont decompose
322 geography into physical geography, biography, ecology and natural resource endowments. The first
323 refers to how centrality, topography and landlockedness determine a country's natural level of market
324 potential which at the same time can be countered by a country's level of connectivity -advances in
325 transport infrastructure and services and trade facilitation-. The second refers to how a region's pool
326 of wild plants and animal species suitable for domestication shape its development. The third,
327 ecology, refers to the living and production environment of a country, characterized by factors such
328 as temperature, rainfall, soil conditions, fragility to degradation and prevalence of pests and diseases
329 for both plants and animals. Lastly, the fourth refers to how natural resources endowments -such as
330 oil or metal reserves- can determine a country's prosperity [32].

331 As I mentioned earlier, GSQ found seven determinants for the global burden of hunger -both chronic
332 and hidden-, which according to Lenaerts and Demont can be grouped in four categories: economic
333 performance, demography, institutions and climate. They did not include countries' economic
334 geographies, so Lenaerts and Demont added it as a fifth category in their study, captured through
335 trade openness and market potential.

336 Regarding the trends of the global burden of hunger, Lenaerts and Demont's results were in line with
337 those of GSQ, as they found that the burden of chronic hunger had fallen more rapidly than the burden
338 of hidden hunger. On the other hand, regarding the determinants of the global burden of hunger,
339 Lenaerts and Demont's results differed in some aspects to those of GSQ. *Table 2* summarizes and
340 compares the results of both studies.

341 In summary, the causes of hidden hunger are diverse, with multiple determinants affecting the
342 outcome. Poverty and poor dietary diversification might be the most widespread causes of hidden
343 hunger, but other aspects such as a region's level of urbanization, governance, food availability and
344 access, gender equality and access to sanitation and health also play an important role. Furthermore,

345 **Table 1.** Summary and comparison of the determinants of hidden hunger as seen by GSQ and Lenaerts and Demont [25,32]

	DETERMINANTS OF THE BURDEN OF HUNGER AS SEEN BY GSQ	DETERMINANTS OF THE BURDEN OF HUNGER AS SEEN BY LENAERTS AND DEMONT
The role of economic growth and demographic trends	Higher per capita GDP (gross domestic product) was strongly associated with a lower burden of chronic and hidden hunger. 1% increase in GDP was associated with 0.4-0.5% decrease in the burden of chronic hunger and 0.2-0.3% decrease in the burden of hidden hunger. Demographic growth was only found to be associated with the burden of chronic hunger so will not be discussed here.	Per capita GDP was also found to be strongly associated to the burden of hunger. 1% increase in GDP was associated to a 1% decrease in the burden of chronic hunger and a 0.6% decrease in the burden of hidden hunger. Demographic trends were not studied by Lenaerts and Demont.
The role of political and environmental factors	Democracies were associated with a lower burden of both chronic and hidden hunger, as it was shown in other studies. Higher levels of rainfall and more land in temperate zones were also associated with a lower burden of both hungers.	Urbanisation and good governance had a negative but statistically insignificant effect on the burden of both hungers. According to the authors, this is probably because they act as indirect contributors. Higher levels of rainfall were found to have a statistically significant negative effect on the burden of hidden hunger. Higher temperatures had a positive effect on both burdens.
The role of food availability and food access	A higher total food supply (kcal/capita/day) was associated with a lower burden of chronic and hidden hunger. Furthermore, their results showed that calories from both plant and animal products mattered, but that effects differed across food groups. In particular, they found no significant association in the supply of cereals with neither of the burdens. This result surprised the authors, who expected at least an association with the burden of chronic hunger as cereals represent an important source of calories, especially in poor population groups.	They also found that a higher total food supply (kcal/capita/day) from both plant and animal products was associated with a lower burden of both hungers. In terms of plant products, cereals and pulses were found to be associated with the burden of chronic hunger but not hidden hunger. As Lenaerts and Demont mentioned: "these findings for plant products are in line with general views from the field of food science but contrast with the results reported by GSQ".
The role of health and gender	The level of education and women's status are considered determinants of health. In their study, GSQ found that female school enrolment and female-to-male life expectancy ratio was associated with a lower burden of both hungers. Access to improved sanitation was also associated to lower burdens, while immunization was found to be especially relevant in reducing the burden of hidden hunger.	In line with GSQ's findings, Lenaerts and Demont also found that female schooling and female-to-male life expectancy ratio were associated with a lower burden of hidden hunger, but not chronic hunger. Access to safe water and improved sanitation and immunisation were also associated with lower burdens of both hungers.
Economic geography		They studied countries' market potentials and openness to trade. The latter was found to be associated to the burden of hidden hunger but was considered to be a spurious finding. However, higher levels of market potential were associated to a lower burden of both hungers

I believe it is crucial to highlight -just like Lenaerts and Demont do in their article- that geography is a key determinant of both chronic and hidden hunger, with regions with higher temperatures and lower levels of rainfall having higher numbers of micronutrient deficiencies. This is of concern given that climate change is likely to worsen this situation and therefore contribute to a higher burden of chronic and hidden hunger in certain geographical regions of the world [35].

Prevalence of hidden hunger

Global: the Hidden Hunger Indices and Maps

Since 2009, the Global Hunger Index (GHI) has been reporting annually on hunger at global, regional and national levels [36]. While it is a powerful tool to measure hunger in the world and raise awareness on the issue, it does not take into account the burden and consequences of hidden hunger -except for its 2014 edition which specifically addressed hidden hunger [37]- because when calculating GHI, vitamin and mineral deficiencies are included within the same category as macronutrient deficiencies, under the term 'undernutrition'. It is for this reason that the development of a global Hidden Hunger Index was needed.

In 2013, the first Global Hidden Hunger Indices and Maps were created [38]. The objective was to create a tool for public health that helped to create better interventions and policies regarding micronutrient deficiencies.

The most prevalent micronutrient deficiencies worldwide are iron, zinc, vitamin A, iodine and folate, although deficiencies of vitamin B12 and other B vitamins also occur (38). However, in this study folate and vitamin B12 deficiencies were excluded because of lack of national data. National prevalence estimates of anemia were used as a proxy of iron deficiency -which is a limitation of the study because anemia can be due to non-nutritional factors-; national prevalence estimates of stunting as a proxy of zinc deficiency and low serum retinol levels as a proxy of vitamin A deficiency. National data on iodine deficiency was also used to build the indices and maps as well as country estimates of DALYs attributed to deficiencies in the previously mentioned micronutrients. The resulting Hidden Hunger Index (HHI) score ranged between 0 and 100: 0-19.9 considered mild; 20-34.9 moderate; 35-44.9 severe and 45-100 alarmingly high.

Other limitations of this HHI are that it only addresses hidden hunger in preschool-age children and it excluded from analysis those countries with a high 2007 Human Development Index[12] as they were assumed to have a low prevalence of micronutrient deficiencies.

From the 149 countries included for analysis, the one with the highest HHI score was Niger and the lowest was Hungary. *Figure 3* shows the 20 countries with highest HHI and the 20 countries with lowest HHI. It draws attention that 18 of the 20 countries with the highest HHI are in Sub-Saharan Africa, with the other two, India and Afghanistan, in Asia. The study found that there are indeed 'hot spots' of hidden hunger, with the prevalence being alarmingly high in Sub-Saharan Africa, severe in many countries in South-Central/South-East Asia and mild-to-moderate in South American countries.

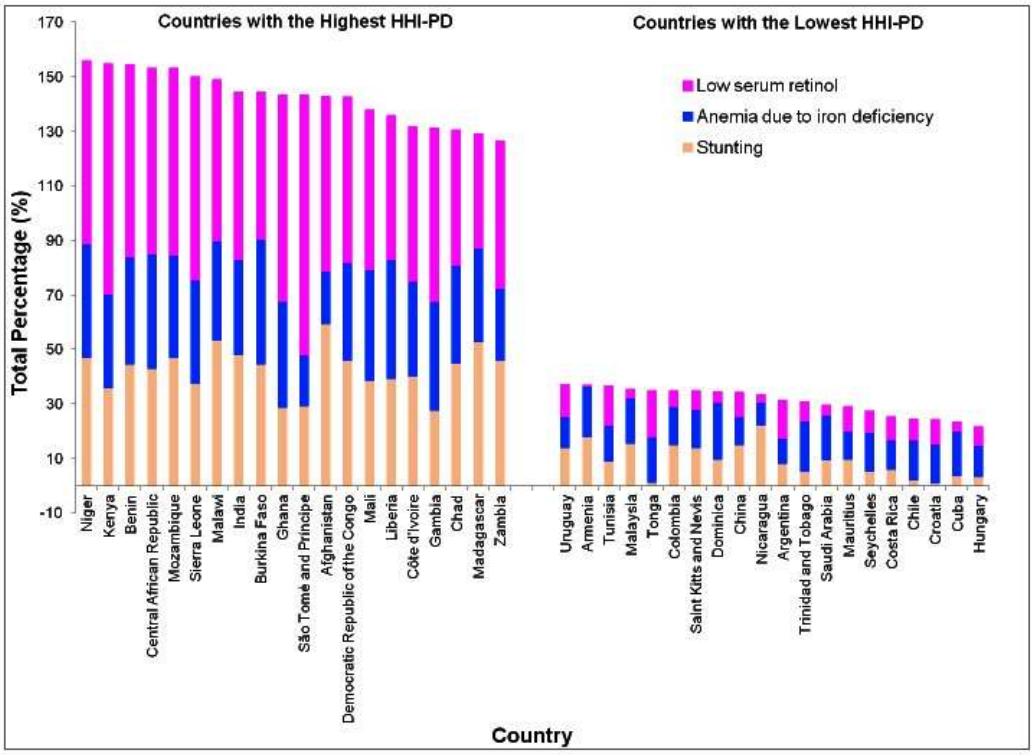

Figure 3. Prevalence of stunting, iron deficiency anemia, and low serum retinol in the countries with the 20 highest and lowest hidden hunger index based on the prevalence estimates (HHI-PD) [38]

As the authors state in their study, in developing countries it is common to find multiple micronutrient deficiencies occurring at the same time in the same population, and this was shown by finding moderate to high correlations between stunting, anemia and low serum retinol in their analysis. However, iodine deficiency was found to be an exception as its estimates did not correlate with the prevalence of other micronutrient deficiencies. Instead, the highest prevalence of iodine deficiency

12 The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living (103)

was found to be in Eastern Mediterranean, European and African regions and therefore iodine deficiency was represented separately in the Hidden Hunger Maps, as shown in *Figure 4*.

Just like it happened with the determinants of hidden hunger, a second Hidden Hunger Index was developed by other authors in 2015 in order to extend the previous one with updated data and with the difference that instead of representing a 'snapshot' in time like the 2013 HHI, they estimated a HHI score for each year during the period of 1995-2011 [39]. Apart from these differences, the methodology used to calculate the HHI was the same, as well as the limitations. It is interesting and worth mentioning that, since they calculated an HHI for each year, they were able to calculate the change in HHI score between 1995 and 2011 by making a simple subtraction.

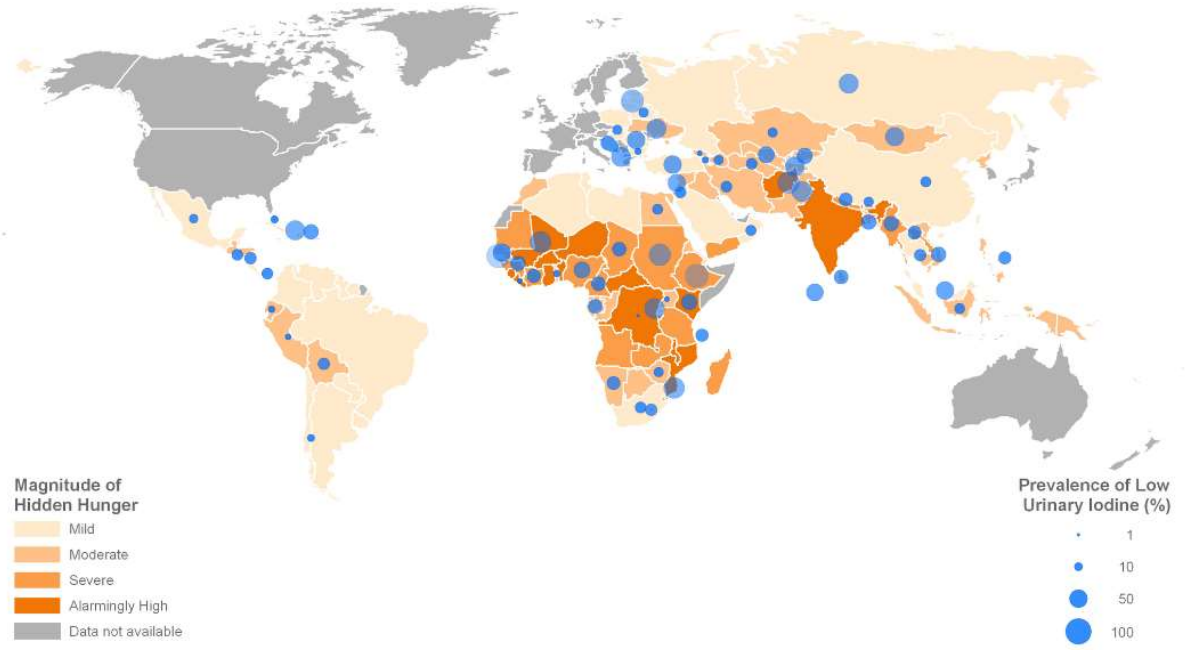

Figure 4. Global map presenting hidden hunger index based on the prevalence estimates (HHI-PD) in 149 countries and prevalence of low urinary iodine concentration in 90 countries with 2007 Human Development Index <0.9 [38]

The global average net change (± standard deviation) in HHI between 1995 and 2011 was a decrease of 6.7±5.7. As reported by the authors, «A total of 38 countries (27.5%) had an increase and 100 countries (72.5%) a reduction in HHI over this time period. Africa was the only region to experience an overall increase in hidden hunger from 1995 to 2011, with a mean increase of 1.9±3.2; this increase was higher in West and Central Africa (2.7±2.3) as compared to East and Southern Africa (1.1±3.6). All other regions made progress in reducing hidden hunger, with East Asia and the Pacific being the top performing region (-13.0±2.0) and the remaining regions achieving only modest reductions (ranging from -3.4 to -4.8)».

As per countries, the results were the following: «A ranking of countries from the lowest to highest HHI score in 1995 and 2011 respectively, shows that Chile had the lowest score of all 138 countries in both years (10.2 and 7.2 in 1995 and 2011 respectively) and that Ethiopia had the highest score in 1995 (44.0), and Niger in 2011 (45.0). All but one of the 20 countries with the highest HHI score in 2011 were in Africa (Afghanistan being the exception); the 20 countries with the lowest HHI in 2011 were from the Americas, the Middle East, and North Africa (MENA), and the East Asia and the Pacific Region (EAP)».

Figure 5 shows the evolution of HHI between 1995 and 2011 according to countries' net changes.

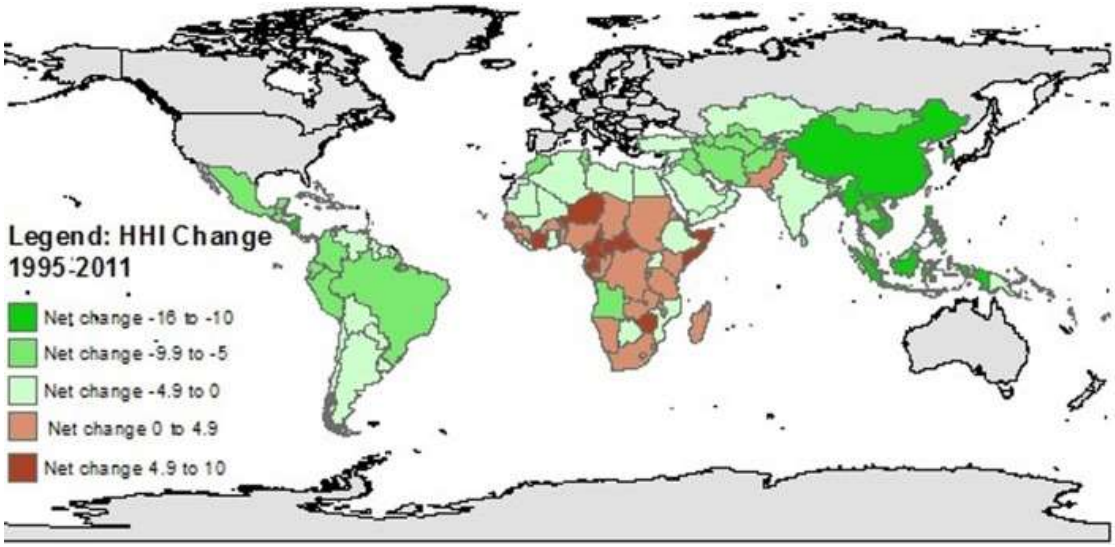

Figure 5. Global map presenting net change in hidden hunger index (HHI) scores, 1995–2011 [39][38]

Spain: the ANIBES Study

One of the limitations of the Global HHI, as I mentioned in the previous section, is that it is not calculated for those countries with a high Human Development Index (HDI). This means that most developed countries are being left out and their levels of hidden hunger -even if they are low-, despised.

In the literature, studies investigating the prevalence of hidden hunger among developed countries is scarce compared to those in developing countries. This makes sense as developing countries, especially those in Sub-Saharan Africa, are the ones most affected by hidden hunger -and hunger in general-.

However, there are some articles that address income inequalities in developed countries and food security, which is related to malnutrition in all its forms [40–42].

In Spain in particular, a study addressing hidden hunger directly has not been carried out, but one could indirectly assess its prevalence by analyzing national food intake surveys and studies, such as the ENIDE (Encuesta Nacional de Ingesta Dietética) survey and the ANIBES (Antropometría, Ingesta y Balance Energético en España) study. In this bachelor's thesis I will only discuss the findings of the ANIBES study as it is the most recent study (2013) analyzing micronutrient intakes of the Spanish population.

The ANIBES study was a cross-sectional study conducted using stratified multistage sampling, performed at 128 points across Spain and is representative of all individuals living in Spain, aged 9-75 years, and living in municipalities of at least 2,000 inhabitants. The final sample comprised 2,009 individuals (1,013 men, 50.4%; 996 women, 49.6%) [43]. Available data from the ANIBES Study was used to assess intakes using the Recommended Dietary Intakes (RDI) for each age group as reference. Results were expressed as the percentage of the population that had micronutrient intakes above 80% of the RDIs for the total, but also for plausible and non-plausible reporters [43].

For children aged 9-12 years, the ANIBES results showed that in the case of calcium, 52.5% of plausible reporters had intakes above 80% RDI when compared to total (38.5%) and non-plausible reporters (20.4%), and a similar distribution for iron and magnesium intakes was observed. Zinc, folates and vitamin D showed the lowest adequacy within this population group as less than 35% of plausible reporters had intakes above 80% RDI. Noteworthy, only 1.7% of children had intakes above 80% RDI of vitamin D. Conversely, iodine, phosphorous, selenium and vitamin B12 had the highest proportion of population with an adequate micronutrient intake [43].

In the case of adolescents (13-17 years) a low proportion of plausible reporters presented intakes above 80% RDI for calcium (36.4%), iron (27.6%), magnesium (27.6%), zinc (25%) and vitamin A (31.6%). Furthermore, folates and vitamin D showed the lowest proportion amongst adolescents, with only 9.2% and 6.9% of subjects with intakes above 80% RDI, respectively. Highest proportion of subjects reached adequate intakes for iodine, phosphorous, selenium, vitamin B12 and C [43].

In the group of adults (18-64 years), plausible reporters had higher proportions of intakes above 80% RDI for iodine (84.1%), phosphorous (99.5%), selenium (95.8%) and vitamin C (80.8%). Zinc, folates and vitamin D were the micronutrients with lowest adequacy among plausible reporters (< 20% of subjects) [43].

Finally, when studying elder individuals (65-75 years), zinc (15.6%), folates (11.1%) and vitamin D (6.7%) showed the lowest proportions of adequacy. Conversely, iron, iodine, phosphorous, selenium, vitamin B12 and vitamin C were amongst the highest [43].

In summary, the results of the ANIBES study showed inadequate intakes for several key micronutrients across all age groups in the Spanish population, and as the authors concluded: «Authorities should promote nationwide nutritional policies to address unbalanced diets focusing on reaching vulnerable populations in order to overcome this major public health problem» [43].

Solutions and policy

Background

Efforts put towards eradication of malnutrition in all its forms go back to the early 90s. In 1992, the first International Conference on Nutrition (ICN) was held jointly by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) of the United Nations in Rome, Italy. After its celebration, the *World Declaration and Plan of Action on Nutrition* was created and adopted by participant countries, which pledged to substantially reduce within the decade (1992-2002): starvation and widespread chronic hunger; undernutrition, especially among children, women and the aged; other important micronutrient deficiencies, including iron; diet-related communicable and non-communicable diseases; social and other impediments to optimal breast-feeding; and inadequate sanitation and poor hygiene, including unsafe drinking-water (44). In order to achieve such objectives, countries committed to prepare and implement National Plans of Action for Nutrition. However, when analyzing progress made towards their creation and implementation, it has been shown that it has been unsatisfactory due to inadequate commitment and leadership, lack of financial investments, weak human and institutional capacities and lack of appropriate accountability mechanisms [45].

In the late 90s, ahead of the arrival of the new millennium, it was clear that progress towards development needed to be made and new goals needed to be established in order to achieve it. For that matter, on September 2000 world leaders signed the *United Nations Millennium Declaration* to combat poverty, hunger, disease, illiteracy, environmental degradation and discrimination against women [46]. 8 goals derived from this Declaration, called the United Nations Millennium Development Goals (MDGs), targeted for 2015. In the context of this thesis, it is important to highlight MDGs 1, 4 and 5: addressing eradication of poverty and hunger, reducing child mortality and improving maternal health.

Before 2015, the year for which MDGs were targeted, a key event to understand the current state of malnutrition in all its forms, and especially hidden hunger, took place: the second International Conference of Nutrition (ICN2), celebrated in 2014, two decades after the first ICN. ICN2 was also

celebrated in Rome, Italy jointly by FAO and WHO, and its focus was malnutrition in all its forms: undernutrition, including micronutrient deficiencies, overweight and obesity. The aims of the Conference were: «(i) review progress made since the 1992 International Conference on Nutrition (ICN), respond to new challenges and opportunities, and identify policy options for improving nutrition; (ii) bring food, agriculture, health and other sectors together and align their sectoral policies to improve nutrition in a sustainable manner; (iii) propose adaptable policy options and institutional frame-works that can adequately address major nutrition challenges in the foreseeable future; (iv) encourage greater political and policy coherence, alignment, coordination and cooperation among food, agriculture, health and other sectors; (v) mobilize the political will and resources to improve nutrition, and (vi) identify priorities for international cooperation on nutrition in the near and medium terms» [47]. Two outcome documents were endorsed at the ICN2: the *Rome Declaration on Nutrition* and the *Framework for Action*. We will later discuss the implications the ICN2 and its outcome documents have for hidden hunger.

I believe it is also important to mention the creation in 2010 of the Scaling Up Nutrition (SUN) movement for its relevance in the promotion of better nutrition. The SUN movement originally consisted of several organisms and research groups who collaborated to publish two documents: *Scaling Up Nutrition: A framework for action* and *SUN Movement: Revised Road Map.* The idea was to create an informal association whose function would be providing support to countries to promote nutrition. Within months, the *Framework for Action* had been approved by over 100 entities and several countries had offered to participate. It was in 2012 that the SUN movement became more formal and a high-level Lead Group was established, operating under the UN Secretary-General. A *Scaling Up Nutrition Movement Strategy (2012-2015)* was published, together with a *Revised Road Map*, providing the guiding framework for the SUN Movement [48]. Since then, the movement has been fighting towards the eradication of malnutrition in all its forms by working with governments, the United Nations, civil society, businesses and researchers.

2015 was a key year, as it supposed the end of the MDGs-era, a revision of the progress made since their implementation and the creation of a new agenda to face the multiple challenges of the future. It was the year where the famous 2030 Agenda for Sustainable Development was established by the UN's General Assembly, together with 17 Sustainable Development Goals (SDGs) that superseded the previous MDGs. The idea of these new goals was to build on the MDGs and complete what they did not achieve, taking into consideration the three dimensions of sustainable development: the economic, social and environmental [49]. Although all SDGs are equally important to achieve sustainable development, in this thesis we will only discuss SDG2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture. In line with this SDG, the General

Assembly proclaimed on the 1st of April of 2016 the United Nations Decade of Action on Nutrition (2016-2025), a commitment of UN Member States to implement policies and programmes following the ICN2's *Framework for Action* and the 2030 Agenda for Sustainable Development [50].

ICN2: implications for hidden hunger

As stated above, the Second International Conference on Nutrition ended with two outcome documents: the *Rome Declaration on Nutrition* and the *Framework for Action*. These documents were signed by participating countries, committing world leaders to create national policies aimed at the eradication of malnutrition in all its forms, as well as transforming food systems. The *Rome Declaration on Nutrition* is a political statement of 10 commitments while the *Framework for Action* is a set of 60 recommended actions that governments could apply -by making the necessary adaptations- to their country in order to achieve the commitments of the declaration.

Leslie Amoroso -a worker at FAO's Nutrition and Food Systems Division- did a great job at analyzing the implications for hidden hunger of ICN2's outcome documents in her article "*The Second International Conference on Nutrition: Implications for Hidden Hunger"* [47]. Her findings are represented in *Table 2 and 3*. She also published another article titled *"Post-2015 Agenda and Sustainable Development Goals: Where Are We Now? Global Opportunities to Address Malnutrition in all Its Forms, Including Hidden Hunger"* where she summarizes and reviews the role of ICN2, the 2030 Agenda for Sustainable Development and the Decade of Action on Nutrition as well as provides an analysis of recent governance initiatives to address malnutrition in all its forms, including hidden hunger [51].

In summary, and following Amoroso's conclusions, ICN2 and its outcome documents led to the development of many follow-up activities such as the declaration of the Decade of Action on Nutrition, which later on when the 2030 Agenda for Sustainable Development was adopted, would play a direct role in addressing SDG2 as well as indirect roles in other goals such as health, education, gender, work, growth, inequality and climate change [47].

553

Table 2. The ICN2's outcome documents: implications for hidden hunger, as analyzed by Amoroso L [51][38]

ROME DECLARATION ON NUTRITION: IMPLICATIONS FOR HIDDEN HUNGER
We Ministers and Representatives of the Members of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO)…
Multiple challenges of malnutrition to inclusive and sustainable development and to health:
– Para 4: … acknowledge that malnutrition, in all its forms, including undernutrition, micronutrient deficiencies, overweight and obesity, not only affects people's health and wellbeing by impacting negatively on human physical and cognitive development … but also poses a high burden in the form of negative social and economic consequences to individuals, families, communities and States
– Para 12: … note with profound concern that: d. over two billion people suffer from micronutrient deficiencies, in particular vitamin A, iodine, iron and zinc, among others
A common vision for global action to end all forms of malnutrition:
– Para 13: We reaffirm that: the elimination of malnutrition in all its forms is an imperative for health, ethical, political, social and economic reasons, paying particular attention to the special needs of children, women … other vulnerable groups as well as people in humanitarian emergencies
– Para 14: We recognize that: h responsible investment in agriculture[1], including small holders and family farming and in food systems, is essential for overcoming malnutrition
Commitment to action:
– Para 15: We commit to: a. eradicate hunger and prevent all forms of malnutrition worldwide … and anaemia in women and children among other micronutrient deficiencies… b. enhance sustainable food systems by developing coherent public policies from production to consumption and across relevant sectors to provide year-round access to food that meets people's nutrition needs and promote safe and diversified healthy diets e. improve nutrition by strengthening human and institutional capacities to address all forms of malnutrition through, inter alia, relevant scientific and socio-economic research and development, innovation and transfer of appropriate technologies… g. develop policies, programmes and initiatives for ensuring healthy diets throughout the life course, starting from the early stages of life to adulthood, including of people with special nutritional needs…
[1] The term 'agriculture' includes crops, livestock, forestry and fisheries
FRAMEWORK FOR ACTION: IMPLICATIONS FOR HIDDEN HUNGER
Sustainable food systems promoting healthy diets
– Rec. 10: Promote the diversification of crops including underutilized traditional crops, more production of fruits and vegetables, and appropriate production of animal-source products as needed, applying sustainable food production and natural resource management practices
– Rec. 13: Develop, adopt and adapt, where appropriate, international guidelines on healthy diets
– Rec. 15: Explore regulatory and voluntary instruments … to promote healthy diets
Nutrition education and information
– Rec. 21: Conduct appropriate social marketing campaigns and lifestyle change communication programmes to promote physical activity, dietary diversification, consumption of micronutrient-rich foods such as fruits and vegetables…
Social protection
– Rec. 23: Use cash and food transfers, including school feeding programmes and other forms of social protection for vulnerable populations to improve diets through better access to food … and which is nutritionally adequate for healthy diets
Strong and resilient health systems
– Rec. 25: Strengthen health systems … to enable national health systems to address malnutrition in all its forms
Anaemia in women of reproductive age
– Rec. 42: Improve intake of micronutrients through consumption of nutrient-dense foods, especially foods rich in iron, where necessary, through fortification and supplementation strategies, and promote healthy and diversified diets
– Rec. 43: Provide daily iron and folic acid and other micronutrient supplementation to pregnant women as part of antenatal care; and intermittent iron and folic acid supplementation to menstruating women where the prevalence of anaemia is 20% or higher…
Health services to improve nutrition
– Rec. 47: Provide zinc supplementation to reduce the duration and severity of diarrhoea, and to prevent subsequent episodes in children
– Rec. 48: Provide iron and, among others, vitamin A supplementation for pre-school children to reduce the risk of anaemia

Achieving SDG2: how are we doing so far?

After the creation of the 2030 Agenda and the declaration of the Decade of Action on Nutrition, one would expect that countries would have implemented actions and policies to reach the objectives. In order to track progress towards the achievement of SDGs, a set of indicators was established by the UN and a progress report based on them is published annually. Although nutrition has a role in several SDGs, as discussed earlier, only progress in SDG2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" will be discussed in this section.

In addition to the UN's annual progress report on SDGs, FAO also publishes its own report regarding SDGs related to food and agriculture. In their 2020 SDG progress report [(52)], they analyzed how the indicators were before the COVID-19 pandemic, but also commented that the pandemic was likely to worsen them. This is interesting to note because the pandemic has undeniably altered the goals set for 2030, but previous reports also indicated that the world was not sufficiently on track to reach them anyways [(53)]. Regarding SDG2, there are two targets of particular interest for this thesis:

Target 2.1: "By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round"

Target 2.2 "By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons"

To track those targets, the following indicators were created [(54)]:

2.1.1 Prevalence of undernourishment

2.1.2 Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)

2.2.1 Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age

2.2.2 Prevalence of malnutrition (weight for height >+2 or <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age, by type (wasting and overweight)

According to FAO's 2020 report, and in relation to the cited indicators, «the number of people affected by hunger globally has been growing moderately since 2014. Almost 690 million people in the world (8.9 percent of the world population) are estimated to have been undernourished in 2019. (…) The world is not on track to achieve the SDG 2.1 Zero Hunger target by 2030» [(52)]. In addition,

«The prevalence of both moderate and severe levels of food insecurity (SDG Indicator 2.1.2) worldwide is estimated to be 25.9 percent in 2019 - a total of 2 billion people. (…) Although sub-Saharan Africa is where the highest levels of total food insecurity are observed, it is in Latin America and the Caribbean where food insecurity is rising the fastest: from 22.9 percent in 2014 to 31.7 percent in 2019 (…) Globally, the prevalence of food insecurity at moderate or severe level, and severe level only, is higher among women than men. The gender gap in accessing food increased from 2018 to 2019. (…) There is a large body of evidence on the links between food insecurity and forms of malnutrition (…) One factor that helps explain such links is the negative impact of food insecurity – even at moderate levels of severity – on diet quality (…) This reveals an important link between SDG target 2.1 and SDG target 2.2, which is aimed at ending all forms of malnutrition» [52].

Furthermore, as the UN's 2020 SDG report highlights: «Recent increases in food insecurity are likely to worsen as a result of COVID-19. (…) Along with conflict, climate shocks and the locust crisis, COVID-19 poses an additional threat to food systems, indirectly reducing purchasing power and the capacity to produce and distribute food, which affects the most vulnerable populations. In 2020, up to 132 million more people may suffer from undernourishment because of COVID-19» [55]. This affirmation is in line with recent publications in the literature alerting on the effects of the pandemic in relation to the different burdens of malnutrition and food security [56,57].

In conclusion, and in relation to malnutrition in all its forms, including hidden hunger, the world needs to take further action in order to achieve SDG2, which is far from being reached and is likely to worsen due to COVID-19.

Solutions for micronutrient deficiencies: what is being done and what is left to do?

There are several strategies to fight hidden hunger. The choice of one intervention or interventions should depend on the cause, severity and scope of micronutrient deficiencies as well as consider its feasibility within different countries. In general, short-term strategies to combat hidden hunger include supplementation, especially among high-risk population groups, while long-term strategies include fortification, biofortification and food-based strategies like dietary diversification. It is important to highlight that combating hidden hunger requires a multi-sectoral approach -especially agriculture and health sectors- and the implication of both international and national policy-makers, governments, international agencies, health and nutrition professionals, stakeholders as well as involving the general population.

Supplementation

Providing supplements to the population is a strategy generally used to combat or prevent severe deficiency of one or several nutrients, generally to targeted population groups such as children, adolescents, pregnant women and women of childbearing age, and the elderly. This strategy can be approached through single-micronutrient or multiple-micronutrient supplementation depending on a population or an individual's needs. The most known micronutrient supplementation program is vitamin A supplementation in children, used in many countries with a high percentage of coverage. Iron and folate supplementation in pregnant women are also well-known interventions in some countries. However, supplementation of other micronutrients is less common and there are still many gaps in knowledge regarding nutrient supplementation [58]. Although this strategy is successful in the short-term [59–62], it does not address the overall quality of the diet to ensure dietary requirements are covered for a long-lasting health. Furthermore, supplying supplements to certain population groups or regions may be challenging [63].

Fortification

Fortification is defined as the practice of adding one or multiple vitamins and minerals -called "fortificants" or "fortifiers"- whether or not they are normally contained in the food to commonly consumed foods during processing to increase their nutritional value [64,65]. There are several forms of food fortification. The most common is large-scale food fortification -also referred to as industrial, commercial or mass fortification-, which consists of the addition of one or more micronutrients to foods commonly consumed by the general population, such as salt, flour, oil, sugar and condiments. It can be mandatory -initiated and regulated by the government- or voluntary – when a food manufacturer chooses to add one or more micronutrients to processed food in compliance with government regulations and standards [57]. In general, large-scale food fortification has proved to be effective in reducing micronutrient deficiencies in high-income countries and more recently in low and middle-income countries, according to several systematic reviews and meta-analyses [59,66,67]. With the first programs being introduced in the early 20th century, nowadays over 140 countries globally have guidance or regulations in place for fortification programs -the majority of which are mandatory-, like salt iodization, fortification of at least one cereal grain (maize, rice or wheat) with iron and folic acid, and the fortification of edible oils, margarine and/or sugar with vitamin A and/or vitamin D [64,68]. Other forms of fortification include targeted fortification -aimed at a particular population group, e.g, infants with fortified infant formulas or cereals [69]-, and point-of-use or home fortification -addition of vitamins and minerals to food that has been cooked and is ready to be eaten [64].

649 It is important to note that there are several aspects to take in consideration in order to implement a
650 successful fortification program, and for that reason in 2006 the WHO published guidelines for food
651 fortification [70]. Some of those aspects are the appropriate selection of food vehicles and fortificants,
652 determining fortification concentrations and establishing an adequate design, regulation and
653 monitoring of the program [71].

654 In summary, the type of fortification that will be most appropriate and effective in a given country
655 depends on several factors including: the prevalence of certain micronutrient deficiencies, the
656 population(s) most affected, dietary compositions, available infrastructure, capacities for food
657 processing and production systems, as well as national regulation and governmental leadership [64].

658 ## *Biofortification*

659 Biofortification consists of the use of conventional plant breeding techniques, genetic engineering
660 methods and agronomic approaches such as micronutrient fertilizer applications to modify crops in
661 order to enhance micronutrient content and/or micronutrient bioavailability of food crops [72–74]. It
662 mainly targets poor families living in remote rural areas with no or limited access to industrially
663 fortified foods. Some examples of biofortification projects include iron biofortification of rice, beans,
664 maize and sweet potato; zinc biofortification of wheat, rice, beans, sweet potato and corn; and vitamin
665 A biofortification of sweet potatoes, corn and cassava [64]. This approach is more sustainable, less
666 costly and more cost-effective than large-scale food fortification as it eliminates the need to fortify
667 each batch of food; instead it is a one-time investment [73]. Although biofortification is effective in
668 fighting micronutrient deficiencies, it has some limitations such as the fact that it takes time -about a
669 decade- to grow and adopt biofortified crops [72] and it cannot deliver as high a level nor as wide a
670 range of micronutrients as supplements or industrially fortified foods can -but it can increase the daily
671 intake of micronutrients throughout a person's life-[37]. Furthermore, it has faced acceptance
672 challenges, especially when done through genetic engineering, since many people reject transgenic
673 food [75]. In conclusion, further research is needed in order to fill existing gaps and improve
674 biofortification of crops.

675 ## *Food and nutrition-based strategies*

676 During the 1970s the "Green Revolution" was launched in developing countries, with the aim of
677 increasing agricultural productivity through the implementation of technologies, fertilizers, pesticides
678 and the production of staple grains -mainly rice and wheat-. While the revolution might have had an
679 impact on alleviating chronic hunger, it had a negative impact on countries' agricultural diversity.
680 Staple grains mainly contain carbohydrates and moderate amounts of protein, but are low in other
681 essential nutrients, such as vitamins and minerals, thus contributing to hidden hunger [63]. In order to

improve the quality of food, food and nutrition-based strategies have been promoted in more recent years with the aim of promoting dietary diversification. Some of those strategies are encouraging the use of traditional crops, having home gardens and animal husbandry alongside providing education on nutrition aspects. All those strategies have demonstrated to be useful in reducing hidden hunger [65,76,77]. In this sense, empowering women plays a main role. In many regions of the world, women are often the household members who conserve, process and prepare food. Moreover, they have a direct impact on children's nutrition through their own nutritional status during pregnancy and lactation, and also through breastfeeding and childcare practices, and therefore improving the position of women has a lot of potential in reducing hidden hunger and improving child nutrition outcomes [78,79].

Policy shifts: the food systems and multi-sectoral approaches

Traditionally, nutrition policies and programs have focused on food availability and the reduction of chronic hunger -like the previously mentioned "green revolution"-, and agriculture, nutrition and health sectors have operated as separate entities. Those approaches have been criticized since food security is multi-dimensional -depends on underlying social, economic and institutional factors- and therefore it is necessary to move from vertical sectoral interventions to multi-sectoral approaches involving sectors such as agriculture, nutrition, health and environment in order to address hidden hunger [63]. In that sense, adopting a food systems approach can be a more holistic approach to the issue. Food systems should be self-reliant, controlled, accessible, safe, sustainable, resilient and food-secure, ensure that links are made between sustainable natural resource management, food production, food consumption and nutritional health, and should interact with other systems, such as the health systems, water and sanitation systems, and agriculture production systems, to be effective in reducing hidden hunger [63]. To achieve the implementation -through policy-making- of such systems, government, international agencies and public-private relationships play an important role, as well as the community itself [63,80–83].

The case of Spain

In a previous section of this thesis, it has been discussed that in Spain micronutrient intakes of some vitamins and minerals is low, as national food intake surveys and studies show. This fact seems to be widespread across several European countries, and therefore the need for creating micronutrient policies and programs such as fortification or supplementation has been discussed [84,85]. Before 2006, national regulations on food fortification varied across countries, which was considered a barrier to the European Union's (EU) free-trade philosophy, but in 2006 Regulation 1925/2006 of the European Parliament and of the Council on the addition of vitamins and minerals and certain other substances

to foods was adopted in order to harmonize legislation on fortification, although despite this regulation there are differences in fortification practices between countries [85]. Another difficulty in tackling micronutrient deficiencies in European countries is heterogeneity in micronutrient recommendations [86]. In that sense, between 2007-2011 the EURRECA (EURopean micronutrient RECommendations Aligned) network funded by the European Commission (EC) was established with the aim of creating a general framework for the development of micronutrient recommendations [87]. As part of this project, a study investigating micronutrient recommendations and policies in Spain was done [88].

In Spain nutrition belongs to the field of Public Health and therefore competencies and regulatory capacity is disseminated between centralized (national) and decentralized (regional) institutions. At the national level nutrition is responsibility of the Ministry of Health, the Ministry of Consumption and the Ministry of Agriculture, Fisheries and Food via the Spanish Agency for Food Safety and Nutrition (AESAN) and at the regional level is responsibility of each Autonomous Community Public Health agency, leading to different guidelines and strategies among regions [88]. In the past century, nutrition in Spain received little attention compared to other European countries and in more recent decades action on nutrition has focused mainly in other forms of malnutrition, in particular obesity and overweight -a good example is the NAOS strategy (Nutrition, Physical Activity and Obesity Prevention) promoted by AESAN since 2005-. Regarding micronutrient recommendations, when the previously cited study was published (2012) several documents elaborated by different scientific societies coexisted but there was a lack of government initiatives for setting micronutrient recommendations. The most current micronutrient recommendations until very recently were those set by the Spanish Federation of Nutrition, Dietetics and Food Societies (FESNAD) in 2010 [89], the methodology of which has been criticized by some [88]. However, at European level the European Food Safety Authority (EFSA) published more up-to-date nutrient recommendations in 2017 [90] and other European countries also updated their recommendations in the last decade, so in 2019 the Scientific Committee of AESAN published a report updating nutrient recommendations for the Spanish population [91], although only some vitamins and minerals present changes compared to FESNAD's recommendations.

In summary, given the context of heterogeneity in both micronutrient recommendations and legislation across Europe and across different regions of Spain, little has been done to address micronutrient deficiencies in the past. In the case of iodine, voluntary iodization of salt was regulated by the Real Decreto 1424/1983 and iodine supplementation is subsidized by the national health system under medical prescription. In the case of folic acid, like most European countries fortification of products -such as dairy products or cereals- is voluntary and folic acid supplementation is

subsidized by the national health system under medical prescription, especially in at-risk population groups (women at childbearing age, pregnant/lactating woman, and elderly people). Lastly, in the case of vitamin D, voluntary fortification of skimmed products is done by the industry and supplementation is also subsidized under medical prescription for groups at risk of deficiency [88]. Nutrition guidelines for the general population at national and regional levels -especially the most recent ones-, emphasize the importance of dietary diversification and increasing the consumption of micronutrient-rich foods, such as vegetables, fruits and pulses and reducing the intake of food with lower nutritional quality. Furthermore, nutrition guidelines for at-risk population groups such as children, pregnant women and the elderly, also encourage the consumption of critical micronutrients through food, fortified food or supplementation.

Conclusions

Deficiencies in vitamins and minerals have negative consequences in health and economic development in all stages of life, especially during the first 1000 days of life where they can have a severe impact on children's cognitive and physical development throughout childhood, adolescence and adulthood. Although the trends of hidden hunger show a decrease in its prevalence globally, hidden hunger continues to be alarmingly high in developing countries, especially in Sub-Saharan Africa and South Asia. This can be explained by the determinants of hidden hunger. Regions with poor economic growth, less urbanization and bad governance tend to have a higher prevalence of micronutrient deficiencies. Food availability, access and diversity also correlate with hidden hunger, as well as female schooling and access to sanitation and health. Furthermore, geography also plays a key role in the prevalence of hidden hunger, with regions with higher temperatures and lower levels of rainfall having higher numbers of micronutrient deficiencies, which is of concern given that climate change is likely to worsen this situation. The hidden hunger indices and maps also show that in zones with a high hidden hunger score multiple micronutrient deficiencies occur at the same time. This is not the case of iodine, which does not correlate to other micronutrient deficiencies and is more prevalent in other regions of the world including some Eastern Mediterranean and European countries.

High-income countries are not included in the hidden hunger indices and maps because their levels of micronutrient deficiencies are considered low. Nevertheless, dietary intake surveys and studies show that in developing countries deficiencies of key vitamins and minerals also occurs although in much smaller proportions. In Spain particularly, the most prevalent micronutrient deficiencies across all age groups seem to be zinc, folates and vitamin D, according to the results of the ANIBES study. It is important to highlight that existing gaps in national data on micronutrient deficiencies as well as

782 the lack of more accurate proxies to measure hidden hunger call for further research on estimating
783 the prevalence of micronutrient deficiencies globally.

784 This thesis reviewed international and national policies and actions towards the eradication of
785 malnutrition in all its forms with a particular focus in ending micronutrient deficiencies. ICN2 and its
786 outcome documents have implications for hidden hunger and led to the creation of the Decade of
787 Action on Nutrition (2016-2025). At the same time, the 2030 Agenda for Sustainable Development
788 set SDG2: "End hunger, achieve food security and improved nutrition and promote sustainable
789 agriculture", with target 2.2 being ending malnutrition in all its forms by 2030. Despite efforts done
790 since the implementation of the Agenda, the world is not on track to achieve SDG2, and the number
791 of people suffering from different forms of malnutrition is likely to worsen due to the COVID-19
792 pandemic.

793 Although the same determinants are associated with decreases in chronic and hidden hunger, the latter
794 calls for more specific interventions at community, household or individual levels. Available
795 solutions to hidden hunger include short-term strategies like micronutrient supplementation and long-
796 term strategies such as fortification, biofortification and food and nutrition-based strategies -
797 traditional crops, home gardens, animal husbandry and nutrition education-, in which women
798 empowerment plays an important role. Furthermore, ending hidden hunger requires a multi-sectoral
799 approach involving sectors such as agriculture, nutrition, health and environment. In that sense, a
800 change in food systems through policy shifts can be a more holistic solution to hidden hunger
801 involving governments, international agencies, public-private institutions and the community. In the
802 case of Europe and Spain particularly, heterogeneity in micronutrient recommendations and
803 legislation needs to be addressed and action beyond voluntary fortification and subsidized
804 supplementation of some micronutrients might be needed.

805 In summary, although some progress has been done in the last decades, micronutrient deficiencies
806 continue to be hidden from international and national policy-makers given that most nutrition
807 interventions in the past have been aimed at the eradication of other forms of malnutrition. In that
808 sense, this thesis might provide useful information for policy-makers, governments, health and
809 nutrition workers, stakeholders and the general population in order to take further action in tackling
810 hidden hunger and ending malnutrition in all its forms.

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