

WORKING PAPER

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# Food security, nutrition and health: Implications for maize and wheat research and development

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Olaf Erenstein, Itria Ibba, and Natalia Palacios

International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico





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# Preamble: How to read this document

This document summarizes a vast literature and multiple insights concerning agricultural research and development (R&D) for food security, nutrition and health, with a specific focus on maize and wheat. Such agrinutrition research encompasses agrifood systems from farm production through the food system to food consumption. To help the reader navigate this vast agrifood landscape, the report is divided into relatively independent sections, each headed by key points that serve as stepping-stones for readers who want to know the overall direction of thinking. Other readers will be able to focus on individual sections and the literature to which reference is made.

We hope this contribution and its conclusions stimulate debate and further agrinutrition research that include staple cereals. Our primary focus on maize and wheat reflects the mandate of the International Maize and Wheat Improvement Center (CIMMYT), but many of these considerations may also apply to rice and other cereal grains. In the end we see this working paper and its conclusions as a work in progress that will benefit from the further input of specialists in CIMMYT, the CGIAR and the broader agrinutrition community, whose evaluation of and reflections on content within their disciplinary areas should help to elaborate a refined research agenda for maize and wheat up to and beyond 2030.

Some of this material has been recently published in the journal *Food Policy* (Poole *et al.* 2021). The present working paper goes beyond the confines of a journal paper and allows for more comprehensive coverage. Other short companion pieces aim to enhance reach, e.g. Poole (2021). We thereby aim to help rebalance the agrinutrition research agenda for maize and wheat. However, we reiterate that “cereals and ‘nutrient-rich foods’ are complementary in agrinutrition and require additional research and resources, and increased attention for one should not replace the other” (Poole *et al.* 2021).

# Acknowledgements

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This report is presented without a thorough peer review with the main purpose of making it available to research teams and partners, and for use in further developing the agrinutrition R&D agenda for maize and wheat.

The contents and opinions expressed herein are those of the author and do not necessarily reflect the views of the associated and/or supporting institutions. The usual disclaimer applies.

# Executive summary

## A. Key messages

1. In addition to energy, maize and wheat provide other significant contributions to human nutrition that are scaled up by the volume of cereal products consumed;
2. Opportunities exist to better understand the bioactive components of maize and wheat, to quantify their nutrition and health benefits and to accelerate their improvement through plant breeding;
3. Investment in maize and wheat to address the Sustainable Development Goals (SDGs) should be targeted to ensure tangible nutrition benefits and reductions in noncommunicable diseases (NCDs);
4. Improving cereal food system performance in line with public health objectives requires consensus among multiple stakeholders from the public and private sectors, including plant breeders and food scientists; specialists in socioeconomics; political economy and behavioral sciences; advocacy and education groups; policy makers; and food industry strategists.

## B. The urgency of food security, nutrition and health

Agriculture is a key factor driving progress towards the Sustainable Development Goals (SDGs) for the year 2030. Here we focus on the links between agriculture, food security, and human nutrition and health. The social and economic costs of diet-related morbidity and mortality due to malnutrition are huge from an individual level to a global scale. These issues are comprehended within the targets for SDG2 “Zero Hunger” — to end undernutrition (manifested as hunger), micronutrient deficiencies (hidden hunger), and overnutrition (overweight and obesity), which constitute the “triple burden” of malnutrition. We draw attention also to the direct relationships between agriculture, food production and consumption, and also to the diet-related noncommunicable diseases (NCDs) comprehended within SDG3 “Health and Well-being.” NCDs include diabetes and some cancers, circulatory and respiratory diseases. Obesity is a critical risk factor for NCDs.

The global community has invested significantly and successfully since the mid-20<sup>th</sup> century in boosting agricultural productivity, particularly that of staple crops, and the quantity of energy-rich foods to combat hunger. In the last two or three decades, concern has been growing that food production and distribution systems have not delivered diets of adequate nutritional quality in terms of essential micronutrients to many millions of people. Recent estimates of the unaffordability of nutritious foods for many populations highlight the importance of much-improved availability of, access to, and utilization of diverse diets for nutritionally vulnerable populations. However, monitoring and assessment are problematic due, in part, to poor data, metrics and indicators<sup>1</sup>. The COVID-19 pandemic is exacerbating these food system challenges, viz, ensuring that agriculture produces sufficient nutrient-rich foods sustainably within planetary boundaries, and that diverse and nutritionally adequate diets are physically available and economically accessible to vulnerable people in all regions of the world, including poorer populations in rich countries.

Some agrinutrition researchers have suggested rebalancing the research agenda and budgets in order to provide more resources for work on fruits and vegetables and other micronutrient-rich foods such as pulses and nuts. Such research is overdue. The dominant role of the food industry is also coming under scrutiny regarding nutritionally detrimental

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<sup>1</sup> Viz the recent revision downwards of the global figures for undernourishment in the recent report *The State of Food Security and Nutrition in the World 2020* (FAO, IFAD, UNICEF, WFP and WHO (2020)). *The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets*. Rome, United Nations Food and Agriculture Organization (FAO). Retrieved 07 December 2020, from <https://doi.org/10.4060/ca9692en>. resulting inter alia from new estimates for China from 2000.

grain-processing technologies and practices, its shaping of consumer behavior and food consumption choices, and the diet-related causes of ill-health. Governments in some countries have implemented efforts to combat the consumption of ultraprocessed foods with food taxes and labeling requirements. More must be done.

In this background paper, we focus on the links between agriculture, food security, and human nutrition and health, and on the contribution of maize and wheat towards achieving the nutrition objectives of the SDGs.

### C. Cereals provide more than energy for global nutrition and health

Maize and wheat are two of the major staple foods in global diets. In most contexts, thanks to the carbohydrate content, cereals provide 50–70% of essential dietary energy and are often categorized as “starchy staples.” Wheat alone contributes 18% of total dietary calories and 19% of proteins globally. Recent research into the agronomy and breeding of biofortified hybrids and varieties has successfully enhanced the micronutrient content of maize and wheat respectively. The efficacy of industrial micronutrient fortification of flour and cereal-based foods is generally accepted, and mandatory fortification is increasingly widespread.

Wheat and maize provide more than simple energy. The nutrient contribution of wholegrain cereals is commonly emphasized in dietary guidelines. Unfortunately, the milling and subsequent processing of cereal products tend to reduce or remove much of the important protein, fat, vitamin and mineral content. Moreover, cereals are implicated in the proper concerns about the excessive consumption of dietary energy, and more specifically of some carbohydrates that can have adverse effects on the health of susceptible individuals. Some consumers, such as those who suffer from clinically diagnosed Irritable Bowel Syndrome (IBS), may need to reduce their consumption of cereal foods containing certain non-digestible, rapidly fermenting carbohydrates, also referred to as FODMAPs (Fermentable Oligo-, Di-, Mono-saccharides And Polyols). And in recent years, there has been increasing concern about the ultraprocessing of cereal-based food products containing noxious dietary components that exacerbate the incidence of NCDs.

For these reasons, and because of the focus on energy content, maize and wheat are often considered not to be among the categories of “nutrient-rich” foods that can contribute to reducing micronutrient malnutrition. Consequently, it is unsurprising that a popular but ambivalent perception of the limited contribution of cereals to nutritious diets has been purveyed. The persistence of this view has not been successfully challenged by a necessarily nuanced understanding of the complex role of cereals, and particularly the carbohydrate fractions, in human nutrition. In addition to the hidden micronutrients, there is sound scientific and popular awareness of the importance of some dietary components such as dietary fiber (DF).

### D. Cereals are rich in bioactives which can be enhanced through breeding

Nevertheless, there is as yet imperfect scientific understanding and public awareness of the carbohydrates which make up DF. Biomedical research continues to elucidate the importance of carbohydrates in health and well-being. Moreover, there is a need for further knowledge on the nature and roles of many other bioactive food components that are not usually considered to be nutrients. These bioactives are substances such as carotenoids, flavonoids, and polyphenols. Most of the beneficial effects of the consumption of wholegrain cereals on NCDs are currently attributed to the bioactive components of DF and the wide variety of phytochemicals. A growing body of evidence from cereal chemistry, food science and metabolic studies is showing that the bioactives in cereals are important for nutrition, health and well-being. There is considerable potential for plant breeding strategies to improve these elements of grain composition through exploiting natural variation, genetic and genomic selection methods, and mutagenesis and transgenesis in order to modify cell wall polysaccharides, and specifically to improve the starch composition and structure in breeding material through natural and induced mutations.

### E. Implications

Rebalancing the agrinutrition research agenda is necessary in order to explore, explain and exploit the contribution to diets of hitherto less-researched nutrient-dense crops and other foods. Nevertheless, because of the quantities in which cereals are consumed, the nutritional contribution of cereals in addition to energy complements the consumption

of micronutrient-rich fruits, vegetables, nuts and pulses in diverse diets. To leverage the bioactive content of cereals, including DF, as well as the macro- and micronutrient content, a comprehensive approach to food and nutrition systems from farm to metabolism is needed. This spans research disciplines and food systems' stakeholders throughout the agrifood industries, and embraces policy makers, nutrition advocacy, and consumer education and behavior change.

## F. Conclusions

- Micronutrient malnutrition is critical, but food contributes more to nutrition and health than the macro- and micronutrients as commonly understood. The diverse non-nutrient bioactive food components including DF are also essential for health and well-being. Cereals are rich sources of critical food components.
- Open multidisciplinary dialogues are needed on the relatively unexplored and underexploited bioactives in cereals, and on how to sustain and enhance the nutrient contribution of cereals through the food system from farms, processing, manufacturing, distribution and consumption of cereal-based foods. Reform and renewal of the CGIAR mandates provide the opportunity for cereals research to coalesce further among existing or reformed national and international centers, the U.N. system, bilateral and multilateral agencies and philanthropic organizations, in order to achieve greater efficacy and efficiency.
- Nutrient-rich, or nutrient-enriched, foods are only beneficial if they are available to, affordable by, and acceptable to vulnerable consumers. Agriculturalists, cereal food scientists and nutritionists must look beyond their fields and take a multidisciplinary approach to delivering healthy products to vulnerable consumers through sustainable food systems.
- Context matters in constructing optimal diets. Researchers in the natural sciences and socioeconomics must understand local food environments and production and consumption patterns in order to refine dietary guidelines and reconcile household food knowledge and consumption practices. Identifying, understanding and addressing end-users' quality preferences is essential if novel nutritious foods are going to be accepted by consumers. Social support policies are becoming integrated into food systems for vulnerable populations and specifically disadvantaged groups in humanitarian situations such as international migrants and internally displaced peoples, and need to address dietary needs which recognize the nutritional and cultural contribution of cereals.
- Equally, nutrition-sensitive business strategies for food processing, manufacturing and promotion are necessary to add substance to the concept of a revitalized global partnership for sustainable and improved agriculture, food, nutrition and health (SDG17). Fiscal and regulatory tools have been found to be necessary and successful in some contexts in promoting responsibility among food firms for addressing the challenges of diet-related malnutrition and ill-health. Research scientists need to engage with the political economy of industry strategies to leverage the potential benefits of global stakeholder partnerships.

## Postscript

This paper is primarily about maize and wheat. Rice is another global staple cereal, consumed by billions of people in most regions of the world, and many of the concerns and issues around maize and wheat apply to rice. In particular, the ubiquity of the "polishing" process after rice production is implicated in the loss of important nutritional components, being some proteins and fats, minerals and vitamins. Equally, the presence of other bioactive food components could be enhanced and exploited. Barley is another major cereal of global importance.

There is also potential to expand the nutritional exploitation of minor staple cereals, research into which is gathering pace: spelt, rye and oats in temperate regions, and millet and sorghum in warmer climes, all of which, it is often claimed, are relatively nutrient-rich. Pseudo-cereals could be added to the list. These food crops are not only important for biodiversity conservation, but are often well-adapted to local ecological conditions with sustainability attributes that could be exploited under conditions of climate change.

Organizational re-alignment of research into grain crops will achieve greater efficacy and efficiency, with an enhanced agenda for food security, nutrition and health of the vulnerable global populations.

# 1

## Introduction

### 1.1 The Sustainable Development Goals (SDGs): Faltering progress

#### Key points

- Agriculture is a key driver in efforts to promote sustainable development as well as tackle food insecurity
- The latest data suggest that the world is unlikely to achieve SDG2 “Zero Hunger” by 2030
- Globally, foods that are essential for a healthy diet are not always physically available either through own-production or through markets
- Healthy diets are not economically accessible to many poor households in vulnerable population groups in both poor and less-poor countries and regions

The agenda for development agreed by world leaders in September 2015 is defined by the Sustainable Development Goals (SDGs), which shape thinking until the target date of 2030: “... a plan of action for people, planet and prosperity,” (United Nations General Assembly 2015). Addressing the 17 SDGs is a complex and multidisciplinary process, requiring specialists to escape the substantive disciplinary and sectoral silos in research, knowledge management and development intervention (Waage *et al.* 2015). Agriculture, food and nutrition security are intimately linked in the SDGs. It is argued now that because of multiple entry points to the agenda, agriculture should recover its place as the central driver for achieving inclusive and sustainable economic growth, reversing environmental damage, and boosting the resilience and welfare of the most disadvantaged populations (Omilola and Robele 2017). “The importance of agriculture to human welfare cannot be overstated,” (Fan *et al.* 2019a:1).

A stocktaking by the U.N. noted:

“... that the world is not on track to eradicate hunger and malnutrition by 2030 and that, at the current pace, the targets of Sustainable Development Goal 2 will not be achieved in many parts of the world ... women are more likely to be food insecure than men in every region of the world, that almost one third of women of reproductive age worldwide suffer from anaemia, a persistent problem that also puts the nutrition and health of many children at risk, that, despite considerable reduction in the global prevalence of stunting between 2005 and 2017, 150.8 million children under 5 years of age still suffer from stunted growth, and that wasting, undernutrition, overweight and obesity are recurrent problems for children in several countries ...”

(United Nations General Assembly 2018).

The recent report “*The State of Food Security and Nutrition in the World 2020*” (FAO *et al.* 2020) has revised downwards the global figures for undernourishment resulting from new estimates for China from the year 2000. In 2019 almost 690 million people were still hungry, and preliminary assessments suggest that the current health pandemic may add a further 82–133 million in the current year 2020. The data confirm that the number of people affected by hunger globally has been rising since 2014, and that SDG2 “Zero Hunger” targets 2.1 and 2.2 are not going to be met by 2030. Current trends indicate that the number of hungry people will exceed 840 million by 2030, almost 10 percent of the global population. The prevalence of child stunting has been declining but will still fail to meet the SDG target (Heidkamp *et al.* 2021; Shekar *et al.* 2021; Victora *et al.* 2021). Obesity is increasing, and “If the prevalence continues to increase by 2.6 percent per year, adult obesity will increase by 40 percent by 2025, compared to the 2012 level,” (FAO *et al.* 2020:27).

The United Nations Secretary-General has argued for a gearing up of action for sustainable development for the decade to 2030 because ...

“ ... the shift in development pathways to generate the transformation required to meet the Sustainable Development Goals by 2030 is not yet advancing at the speed or scale required. It is cause for great concern that the extreme poverty rate is projected to be 6 per cent in 2030, missing the global target to eradicate extreme poverty; hunger is on the rise for the third consecutive year and little progress is being made in countering overweight and obesity among children under the age of 5 .... ” (United Nations 2019b: i)

There is a consensus that “Progress on malnutrition is not just too slow, it is also deeply unfair,” (Development Initiatives 2020:13), with inequities in all countries due to location, age, gender, and contrasting levels of education and wealth. The cost of a healthy diet is highlighted by extensive recent analysis: “Healthy diets are unaffordable for many people in every region of the world, especially for the poor and those facing economic challenges,” (FAO *et al.* 2020:64), a total of 3 billion people globally in 2017.

The generational consequences of failure on nutrition are likely to be severe: the latest estimates of child malnutrition in 2019 show that globally, 144 million children under the age of 5 years suffered from stunting, 47 million children under 5 were wasted, of which 14.3 million were severely wasted, and there are now 38.3 million overweight children, up from 8 million since 2000 (UNICEF *et al.* 2020).

## 1.2 Drivers of the nutrition security crisis

### Key points

- Multiple factors including climate change and conflict drive food and nutrition insecurity
- COVID-19 has many direct and indirect negative impacts on health and well-being by reducing the effectiveness of food systems and the economic capacities of poor people
- Global public resources for tackling Food and Nutrition Security and Health (FNS&H) are likely to be limited in the near future
- Immediate public focus on the pandemic is likely to distract attention from the fundamental challenges for FNS&H of climate change and global unsustainability
- There are challenging but disputed projections of global food demand

Climate change and conflict are among the principal drivers of food insecurity (FSIN 2020). Latterly there is a widespread fear that the COVID-19 pandemic will increase poverty, hunger and malnutrition among the world's poorest populations through impacts on food systems, reductions in dietary quality and healthcare provision, economic contraction and the multiple effects of global recession (Headey and Ruel 2020; Linn *et al.* 2020; World Bank 2020a). Lack of capacity in terms of financial and human resources is likely to exacerbate the consequences in the most disadvantaged countries (Salazar Mather *et al.* 2020; Shah *et al.* 2020). Increasing food insecurity is an impending natural disaster, with potentially devastating short-term and long-term consequences for human health (The Lancet Planetary Health Editorial 2020). Due to COVID-19, the number of people living with acute food insecurity in low-income and middle-income countries is likely to increase dramatically, unless mitigatory action is taken (WFP 2020). Among those affected by increasing malnutrition, children are likely to bear the most severe consequences (Fore *et al.* 2020).

The commitment expressed in the G20 ministerial statement on COVID-19 on food security highlights the importance of cooperation, appropriate support mechanisms and functioning markets “ ... to help ensure that sufficient, safe, affordable, and nutritious food continues to be available and accessible to all people, including the poorest, the most vulnerable, and displaced people in a timely, safe, and organized manner, consistent with national requirements,” (G20 Extraordinary Agriculture Ministers Meeting 2020: no page numbers).

Both shocks and the secular trends of modernization are driving the nutrition crisis. With inequality masked by income growth in some regions and increasing poverty elsewhere, these factors affect food demand and create challenges in the development of safe and efficient food systems, both in the private sector and also through public distribution

policies and programs. Over the long term, food demand is expected to increase in line with estimated population growth during the rest of this century. The U.N. estimated that the global population could grow to around 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100 (United Nations 2019a). Sub-Saharan Africa is likely to see the highest rates of growth, whereas other countries and regions may register population declines due to reduced fertility. By the year 2100, Asia and Africa are expected to have a combined population of 9 billion of the projected total of 11 billion people. The FAO considers that the demand for food and other agricultural products will increase by 50 percent between 2012 and 2050 (FAO 2017). At the same time, climate change is likely to imperil food production.

Hunter *et al.* (2017) challenged the discourse of increasing production without specifying commensurate environmental goals. Rebalancing the production of different foods may be necessary to match sustainable resources with evolving demand (Krishna Bahadur *et al.* 2018). However, there are also uncertainties about population growth and food demand. According to Vollset *et al.* (2020a; 2020)(2020a; 2020)(2020a; 2020)(2020a; 2020)(2020a; 2020), global population is likely to peak well before the end of the century. Their reference forecast for the global population was far below other estimates due to lower assumed fertility rates, with a projected peak in 2064 at 9.7 billion people, declining to 8.8 billion in 2100. Africa's population would grow significantly, with Nigeria's population reaching almost 800 million by 2100. In contrast, significant declines in most other populations are likely. At the same time, there would be a major shift in the age structure towards much older populations. These authors envisage less stress on the climate and on global food systems, but major consequences resulting from reduced economic participation and challenging social provision and fiscal arrangements. Global food supplies may be met through market mechanisms, but poorer countries such as Niger, Chad, and South Sudan may remain low-income countries with large, potentially unsustainable population growth. Such uncertainties and differentiation in the nature of demand and supply characterize projections for the 21<sup>st</sup> century.

### 1.3 The evolving One CGIAR

#### Key points

- CGIAR successes
- Nutrition initiatives
- Disarticulation of SDG2 from SDG3

Food, nutrition and health are now recognized as constituting a nexus of global significance as undernutrition and hidden hunger persist, and overnutrition and overweight/obesity spread. The CGIAR “... is a global research partnership for a food-secure future dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources.” Formed in 1971, “By any measure, the [CGIAR] System succeeded in terms of its objectives half a century ago. But times have changed, and so have the needs for international agricultural research for development.” (Barrett 2020:1)

In the 2010s the CGIAR structured itself around a portfolio of CGIAR Research Programs (CRPs). The impetus given through the Agriculture for Nutrition and Health (A4NH) research program, led by the International Food Policy Research Institute (IFPRI) has involved a wide range of international partner and donor organizations and has catalyzed significant interactions between agriculture and nutrition globally (A4NH 2020a). The CGIAR are now looking beyond current research projects through a reformed ‘One CGIAR’ structure, in order to implement a renewed 2030 research and innovation strategy to transform food, land, and water systems in the climate crisis. The strategy revolves around five impact areas: nutrition, poverty, gender, climate and environment, with the first comprising “Nutrition, Health, and Food Security” (CGIAR System Organization 2021).

The renewed approach captures the multidisciplinary nature of the complex and interlinking tasks, of which agriculture is the foundation for impact. One needs to think beyond the narrow focus of SDG2, and linkages must be established with other dimensions of sustainable development. As this paper shows, the contribution of agriculture extends beyond “zero hunger”, playing a part in other SDGs. Agriculture can contribute significantly to alleviating other human health conditions such as noncommunicable diseases (NCDs), the target for which is nested within SDG3, not

SDG2. Hence, the original disarticulation of targets for (dietary-related) NCDs from SDG2 in the CGIAR system and CRP portfolio was unhelpful. At the same time, this exacerbated the operational challenges for many national and international policy and research organizations that have struggled hitherto to integrate thinking about nutrition and health, rather than just food security, into agricultural research.

## 1.4 Purpose of this paper

### Key points

- To review changes in nutrition paradigms and the implications for 2030
- To highlight the contribution of cereals, particularly maize and wheat, to healthy diets and to overall FSN&H
- To advocate a food systems approach for CIMMYT engagement with re-shaping agrifood research and policies, the processing and manufacturing of cereals-based products by the food industries, and consumption behavior in relation to cereals-based foods
- To note that multidisciplinary and interorganizational collaboration from seed to plate — and beyond — will be necessary to leverage the contribution of cereals to addressing both SDG2 “Zero Hunger” and SDG3 “Health and Well-being”, and in particular to combating the rising global tide of noncommunicable diseases

This working paper is a background document to help CIMMYT conceptualize a potential food security and nutrition strategy, ultimately aimed at the multidisciplinary global network of CIMMYT researchers and partners. It is not intended to explore in depth the natural sciences base which underpins much of CIMMYT’s work, nor issues of cereal production systems and environmental sustainability that are well-known to the staff themselves. The key points in each section are summaries to serve as “stepping-stones” through the document. This document was the basis for a shorter *Food Policy* article<sup>2</sup>. Some text (e.g., some recommendations) may thereby overlap and may not always have been fully and properly cited here.

It sets out historic trends driving research in agriculture and nutrition and summarizes the state of the world and the sciences of agriculture, food, nutrition and health. It presents a critique of an important feature of agrinutrition efforts — the focus on SDG2 “Zero Hunger”, micronutrient deficiency diseases and the indicator of child stunting, and the lesser attention given to other aspects of malnutrition. It argues that agrinutrition researchers should take into account targets for reducing important diet-related noncommunicable diseases (NCDs such as cardiovascular diseases, some cancers, and diabetes) nested within SDG3.

The paper reiterates the positive contribution of cereals to global diets, highlighting the significance for human health not only of carbohydrates for energy, and fats, proteins and micronutrients, but also of the essential and so-called “bioactive non-nutrient food components” of cereals that contribute to good nutrition and human health. Among these is dietary fiber of which cereals are a particularly rich source. The paper acknowledges the controversies concerning the adverse health effects of cereals in diets, and advocates engagement with the food industry and policy makers to create more understanding of the role of cereals in Food and Nutrition Security and Health (FNS&H), and to promote healthier public policies on carbohydrates in the food system and in global diets. Engagement with consumers to gain a better understanding of dietary choices, particularly in respect of cereals-based foods, is also important. It will identify unexplored research avenues that CIMMYT could open up in order to make a greater contribution towards meeting the SDGs up to 2030 and enhancing global food and nutrition security towards the middle of the 21<sup>st</sup> century.

According to Lobell (2020:2), “In ten years, we will look back and ask whether the number of people suffering from malnourishment has declined, and whether the menace of climate change has been slowed ... only time will tell.” Hence the need for a food security, nutrition and health strategy for the period up to 2030.

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<sup>2</sup> Poole, N., Donovan, J. and Erenstein, O. (2020). Agrinutrition research: “Revisiting the contribution of maize and wheat to human nutrition and health.” *Food Policy*: 101976. <https://doi.org/10.1016/j.foodpol.2020.101976>.

# 2

## Approaches to agricultural development, food security and nutrition

### 2.1 Agrinutrition policies in transition

#### Key points

- Emphases in research on agriculture and nutrition have fluctuated over time
- Change should be ongoing in order to respond to evolving knowledge, contexts and needs

Thinking about research and development goes through periods of transition as contexts evolve, shocks occur, and new thinking and findings emerge about failures and successes in development mechanisms and processes. Research and development organizations must keep at least abreast of changing contexts, and, preferably through forecasting, formulate strategies and policies that anticipate and manage their contribution to the periods of transition. Latterly, the wide-ranging impacts of climate change on agriculture have received much-needed attention. And latest of all, the recurrence of zoonotic conditions that, in the case of coronavirus, have become a pandemic that has been predicted but for which most countries were ill-prepared; it was noted in 2017 that: “As the line dividing human and wild habitats becomes thinner, we might be brewing the world’s next big pandemic.” (Gruber 2017)

While there is always more to learn, it is not the dearth of science but the chronic lack of political will and the acute shocks to regional and global natural and social systems that limit human development and well-being around the globe. As the editors of *Global Food Security* have noted, food security and nutrition have been prominent features of the international development agenda for decades, but development priorities and challenges have fluctuated, appropriate investments have not been sustained, nor the challenges and constraints become more interconnected (Fanzo *et al.* 2020). New knowledge is being generated, but to a significant degree, the international policy-making community have not “got it”, and still do not “get it”.

The scale of the current challenges is daunting. “Nutritional security has now emerged as the central issue in world food production as well as the key link between food security and human health. Nutrition security occurs when availability, access and stability not only refer to calories, but also to proteins, fats, fibers and micronutrients,” (Sanchez 2020:1). This understanding of nutrition security sums up succinctly the state of current thinking on food, nutrition and health.

But things have not always been thus. We have arrived at where we are now along a pathway of policies, and progress will depend on the revision of agrinutrition research. Evolving approaches to agriculture have been central to the international development research agenda for decades. A very brief review of development thinking since the middle of the last century will illustrate significant trends in thinking.

### 2.2 Agriculture and food security

#### Key points

- In the past the links between agriculture and nutrition have been mediated through a limited concept of nutrition, focusing on macronutrients, and especially dietary energy, and also on the economic role of agriculture
- Since the Green Revolution, agricultural research has been focused on the productivity of staple crops and food energy to overcome hunger
- A broader approach to agriculture and nutrition is necessary to re-shape the research agenda for 2030

An account of policies and approaches to agricultural development and to food security reveals shifting phases since the middle of the last century (Poole 2010; Levinson and McLachlan 2013; The World Bank 2014; Nomura *et al.* 2015; Gillespie and Harris 2016; Harris 2019). As Headey and Masters comment, “For most of human history, agricultural development has focused on addressing food insecurity by providing sufficient dietary energy for survival and work each day. Population growth called for increased yields of staple foods to meet daily energy requirements, particularly the cereal grains and root crops that were selected over centuries to ensure human survival and then scaled up for use in modern food systems.” (Headey and Masters 2019:17)

A diminishing interest in technical agricultural sciences followed the early post-Soviet era. This was substituted by a timely focus on the political economy and institutions affecting development processes (North 1994). However, the loss of focus on agriculture resulted in a diminished political concern about investment in technologies for food supply, commonly measured in the quantity of energy per capita.

Arguably, there has been a remarkable and damaging persistence in the policy perception of agriculture primarily as a source of export revenues, employment and a generator of economic growth. For example, in an agriculture sector paper on Afghanistan, the World Bank (2014) advocated a strategy to increase agricultural gross domestic product and employment. The paper admitted that this strategy “... downplays efforts to raise the productivity of the rain-fed farming and nomadic livestock systems. These are important for the food security and livelihoods of some of the poorest people in Afghanistan” (p.17). Within this paradigm, agriculture is an input-output process (Ridgway *et al.* 2019), delinked from the consumer and pro-poor nutrition policies.

Overall, knowledge of hunger, food security and malnutrition has developed enormously since the 1960s and 1970s when hunger and protein-energy malnutrition were the focuses of policy intervention. Agricultural interventions were thereby targeted at increasing staple food production in order to increase food energy without addressing dietary quality, to combat all forms of malnutrition (FAO *et al.* 2020).

## 2.3 Food security and nutrition

### Key points

- Agrifood security is now considered in terms of nutrition, and particularly micronutrient deficiencies
- The concept of sustainable food systems illustrates the broader perspective on FSN&H: meeting nutritional needs within “planetary boundaries”

The Committee on World Food Security, which had been founded in 1974, underwent a process of reform in 2008-09, giving greater emphasis to nutrition (Committee on World Food Security 2009). As deficiencies in the Millennium Development Goals (MDGs) were identified, food security was, in the eyes of the global community, becoming associated more with the quality of nutrition than the quantity of energy in the global diet. New insights and renewed enthusiasm emerged for investment in agriculture and food, with new attention being given to lagging regions, not least the continent of Africa.

At the turn of the century, the Millennium Declaration was the main output of the United Nations Summit in September 2000 and contained “... a statement of values, principles and objectives for the international agenda for the twenty-first century” (United Nations 2000). It was the first concerted and global attempt to enhance the livelihoods and prospects of the disadvantaged sectors of the global population. Reducing poverty and hunger were re-established as global goals. The shock of the world food crisis of 2007-08, followed by the financial crisis of 2009, reignited more serious interest in food production to meet growing global demands: lives and livelihoods were at risk, and millions were still inadequately fed.

An unintended consequence of the Green Revolution in the production of rice and wheat was that “... cereals displaced other more micronutrient-dense crops such as legumes and vegetables,” (Miller and Welch 2013:117). Fan *et al.* (2019a) suggest that in the development of agriculture-nutrition thinking, “The early 2010s seemed to signal a turning point,” (p.5). Micronutrient deficiencies are now widely recognized to be as important, if not more important, than undernutrition. However, even in better-resourced countries such as China, there is persistent incoherence between agriculture and nutrition policies and interventions (Chen and Wang 2019). (Ecker 2019) attributes the

obesity epidemic to public policies in the agricultural and food sectors, and especially to distortions in agricultural incentives. The private industrial farming sector and the commercial food sector have been heavily implicated over the years (Altenburg and von Drachenfels 2006; Monteiro *et al.* 2018; Frison and Clément 2020).

Gómez *et al.* (2013) noted the post-Green Revolution research and policy shift away from productivity increases in agricultural staple crops to reduce undernourishment. Agrifood policies are again in transition, and adoption of the “food systems” concept has changed minds about the nature and intensity of agriculture and nutrition links and sustainable diets (FAO *et al.* 2020). Yet, like Kuhn’s paradigm shifts (Kuhn 1962), implementation of a global foods-based approach to malnutrition takes time. Tackling SDG2 (“Zero Hunger”) has demanded revised and multidisciplinary approaches to agricultural development and nutrition.<sup>3</sup>

Reviewing experience from the 1960s, the World Bank (2014:1) commented that “... both the fields of agriculture and nutrition have lacked unified zeal for addressing nutrition problems explicitly through food over the past several decades,” (p.1). The changes in policy approaches and types of intervention have evolved from a concern about protein-energy malnutrition in the 1950s–1960s towards the UNICEF framework and adequate intakes of vitamins and minerals (Gillespie and Harris 2016). Latterly the paradigm has shifted towards the so-called “triple burden.” On the disciplinary disjuncture between agriculture and nutrition, hitherto, “... ownership of nutrition issues has been limited in agriculture, and emphasis on food has been low among nutritionists.” (The World Bank 2014:29)

At the same time, agrifood concerns are now broader, linked to sustainability through biodiversity, climate change, ecology, water resource management, economics, employment and cultures. The challenge now is that unhealthy diets are delivered by food systems that are environmentally unsustainable: “much of the world’s population is inadequately nourished and many environmental systems and processes are pushed beyond safe boundaries by food production,” (Willett *et al.* 2019: 447). These factors and others are implicated in the search for sustainable and healthy diets (FAO and WHO 2019). The “food systems” paradigm (A4NH 2020a) recognizes that food and health are fundamental in all ecosystems.

## 2.4 Trends in nutrition thinking

### Key points

- Nutrition is said to have undergone paradigm shifts and now focuses on the triple burden of undernutrition (hunger), micronutrient deficiencies (hidden hunger) and overnutrition (overweight/obesity)
- The current approach inadequately addresses the diet-related noncommunicable disease (NCD) dimensions of health
- There is a need to reframe our understanding of malnutrition and health

Recent nutrition literature has explored these changes: Jonsson (2010) traced the “paradigm shifts” in public health nutrition (PHN) from 1950, noting that the “micronutrient paradigm” – prevailing at the time of writing – began in 2005. Ridgway *et al.* (2019) refer to the changes in nutrition science, guidance and policy since the early 20th century as “paradigm shifts” in public health nutrition, with a current focus on foods, diets and diet-related chronic diseases within a food systems framework. Similarly, Rifkin (2020) has published a critique of the shifts in thinking about primary health care and criticized the attention given to “microcosms” (meaning “a narrow and siloed focus” on

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<sup>3</sup> SDG2 (“Zero hunger”) is “... ending hunger, achieving food security and nutrition, and promoting sustainable agriculture” United Nations (2020a). “Sustainable Development Goals. Goal 2: Zero hunger.” New York, United Nations. Retrieved 07 December, 2020, from <https://www.un.org/sustainabledevelopment/hunger/>. The targets for nutrition are:

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.

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.

The two nutrition targets above each have two indicators:

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).

health) “that block the critical importance of viewing improvements in health in the much wider environment of social, political and economic contexts” (p.1). Kawabata *et al.* (2020) take a broader perspective, suggesting that the 2030 agenda has introduced a new development paradigm. Both Ridgway *et al.* and Rifkin frame their critiques within Kuhn’s “The Nature of Scientific Revolutions” (1962).

A review of the World Bank’s approaches to nutrition has depicted the historic disciplinary siloes underlying food and nutrition security (The World Bank 2014). Latterly, significant trends indicate a convergence between agriculture and nutrition. Table 1 adopts and updates this review of trends in the light of evolving challenges and research emphases:

**Table 1. Approaches to, and convergence over time between agriculture and nutrition.**

Era	Agriculture	Nutrition	Priorities of the agri-nutrition community
<b>1900-1960s</b>	The emergence of agricultural economics as a discipline	The emergence of nutrition as a science and its initial approach	Vitamins
<b>1960s-70s</b>	The food shortage era	The food shortage era	Calories and proteins
1970s-80s	The era of integrated rural development programs	The era of multisectoral nutrition planning	Calories
<b>1980s-2000s</b>	The era of low global food prices	The era of nutrition isolationism and therapeutic/health interventions	Micronutrients
<b>2008-</b>	The current food price crisis-spurred era of increased investment	Nutrition-specific interventions and multisectoral nutrition-sensitive interventions	Dietary diversity with attention to both undernutrition and obesity
<b>SDG era with increasing climate sensitivity</b>	Sustainable intensification of terrestrial natural resources and water resources management; food value chains for nutrition and health	Integration of gender, health and education objectives; recognition of multiple agriculture-nutrition improvement pathways	The triple burden; multidisciplinary approaches with multisectoral policy interventions; upscaling, of local interventions in conflict- and climate-specific contexts
<b>Some current challenges</b>	Management of soils, water, carbon and nitrogen under conditions of climate stress  Consumer-acceptable bio- and industrial, mandatory and voluntary fortification  Zoonoses	Metrics beyond calories, stunting and BMI  Integrating nutrition interventions in ‘vulnerable’ (disaster-relief, humanitarian and development) contexts  Linking with biomedics and food scientists on food and diet-related NCDs  Reclassifying ‘nutrients’	Research and policy engagement with the food processing, manufacturing and distribution industries and with epidemiologic and population transitions; food loss and waste  Foods systems thinking  Global partnerships (SDG17)

Adapted from the World Bank (2014). [Time periods used here represent main trends related to agriculture, food and nutrition, and current challenges].

(Fanzo *et al.* 2020) have recently reviewed the scale of the interconnected challenges for sustainable food systems, improved nutrition and health. Global nutrition is characterized by a shift towards unhealthy diets (Willett *et al.* 2019) delivered by food systems that are environmentally unsustainable. Frison and Clément (2020) summarize the shift towards unhealthy diets as characterized by increased intakes in particular of sugar-sweetened beverages, processed foods containing trans fatty acids, ultraprocessed foods, foods high in sodium, and animal products. Recent research into shifting patterns of non-optimal levels of blood cholesterol show that poorer countries have been experiencing worsening indicators. Richer countries such as those in western Europe have demonstrated reductions in levels of harmful (non-HDL) cholesterol. These reductions may be attributable to medical interventions such as lipid-lowering medications, rather than, or as well as, behavioral changes reducing exposure to risk factors such as poor diets (Taddei *et al.* 2020).

Evidence for the “nutrition transition” has been accumulating since the last decades of the last century (Popkin 1993; Drewnowski and Popkin 1997), although the concept of deleterious dietary change was noted as early as the 1970s (Burkitt 1979). What is now widely recognized is that malnutrition has arisen not just through changing dietary behaviors and food consumption patterns. Key drivers of economic development, rising incomes and globalization of the food industry have made manufactured food products available and appealing, if not accessible, to all consumers. The significance of the transition, hitherto somewhat hidden within the MDGs, came to the foreground in the SDGs, accompanied by a concern for the political economy of nutrition (Gillespie *et al.* 2015). It is evident that even in poorer regions such as sub-Saharan Africa, changing diets are impacting nutrition, health and well-being (Reardon *et al.* 2021).

It is timely to update the schema presented in Table 1. Data on both agriculture and nutrition need to be developed, but the point of this document revolves around the “**Priorities of the nutrition community**” and the potential contribution of CIMMYT to resolving the challenges. Cereal products as a component of varied and healthy diets contribute more than a sufficiency of energy, essential proteins and fats, and micronutrients. Digestion and metabolism of the macro- and microconstituents of cereal-based food products are strongly implicated in reducing or preventing diverse digestive disorders and noncommunicable Diseases (NCDs).

There is an absence of a wider concept of “health” (SDG3) in the nutrition literature. Health is not an outcome solely of nutritional status, and nutritional status is not an outcome solely of dietary adequacy. Conversely, dietary adequacy results in household harmony and satisfaction about self-provisioning, because hunger is not only a physiological state but has also significant psychological effects (Kalm and Semba 2005). The interactions between specific foodstuffs including ultraprocessed foods and eating disorders are important not only for undernutrition but also for overnutrition, obesity, and NCDs, among other conditions and phenomena. The agrinutrition community still needs to recognize the fundamental health attributes of multiple food components in addition to the role of micronutrients. This is hinted at in Table 1 and will be explored in section 6, and demands, if not a paradigm change, at least a shift in thinking.

Latterly, Scrinis (2020) has published a critique of the “tripartite paradigm of malnutrition” — under-nutrition, micronutrient deficiencies and over-nutrition/obesity/over-weight. He argues that these are not separate, specific, distinct and uniform conditions, but are a fragmented framing of the problems resulting in fragmented research and policy proposals that are abstracted from the non-dietary social and environmental contexts. The limitations imply a new “framing” or paradigm. He suggests that diets should be “... characterised and measured across three dietary levels — nutrients, foods and dietary patterns and across the dimensions of food quantity, quality, type and diversity, with key indicators including the nutrient profile, the proportion of ultra-processed foods, and the diversity of food groups.” He argues that “Dietary patterns also need to be socially and culturally contextualised,” (p.9), cognizant particularly of the commercial food production and distribution environment.

Scrinis advocates defining malnutrition only in terms of the dietary status of the body, which he admits is “not directly measurable,” (p.9) but can be linked backwards to dietary patterns. Thinking in terms of the immediate and proximate causes of the dietary status of the body, he is rightly keen to avoid the “... simplifications, reductions and siloed approaches of the current nutritional or biologically specific classification” (p.9), and to undermine the assumption that “... malnutrition can be adequately and safely addressed and alleviated through isolated, narrowly-focused and reductive technical interventions.” (2020:9)

It is arguable that the current agrinutrition research focuses attention on indicators or proximal objectives (underweight, stunting, wasting, and overweight), whereas the distal outcome of good nutrition should be healthy lives. However, Scrinis seems to retreat to “freedom from hunger and malnutrition” as a desirable condition, when he could emphasize the link forwards in the pathway of causation to a more comprehensive notion of health and well-being (for example SDG3) as the ultimate objective. In this respect it is the contribution of diets to freedom from disease (of which there are multiple and complex causes), and specifically from diet-related NCDs (which also have non-diet-related causes) that are the ultimate objective.

## 2.5 Addressing malnutrition

### Key points

- Malnutrition comprises a complex or “wicked” problem with multiple causes including factors outside agriculture and nutrition (UNICEF conceptual framework).
- Research and funding fail to embrace the comprehensive range of food, nutrition and health issues. Stronger links between agriculture, nutrition and health research are needed.

While agriculture is now fully embracing the environmental sustainability dialogue and production within planetary boundaries, probably the agricultural research community has been slow to embrace the nutrition agenda. The availability of food energy still appears in the literature as a proxy for food security: see for example, studies which who all used a simple energy-based index of food availability as an indicator of dietary adequacy, in Sub-Saharan Africa (Frelat et al. 2016), East and West Africa (Ritzema et al. 2017); in Bihar, India (López-Ridaura et al. 2018). Recent research and multidisciplinary initiatives have succeeded in integrating perspectives (Waage et al. 2018; Gillespie et al. 2019; Fanzo et al. 2020). However, the gap is still reflected in state programmes and policies and interventions of many international and national organizations (Poole et al. 2019).

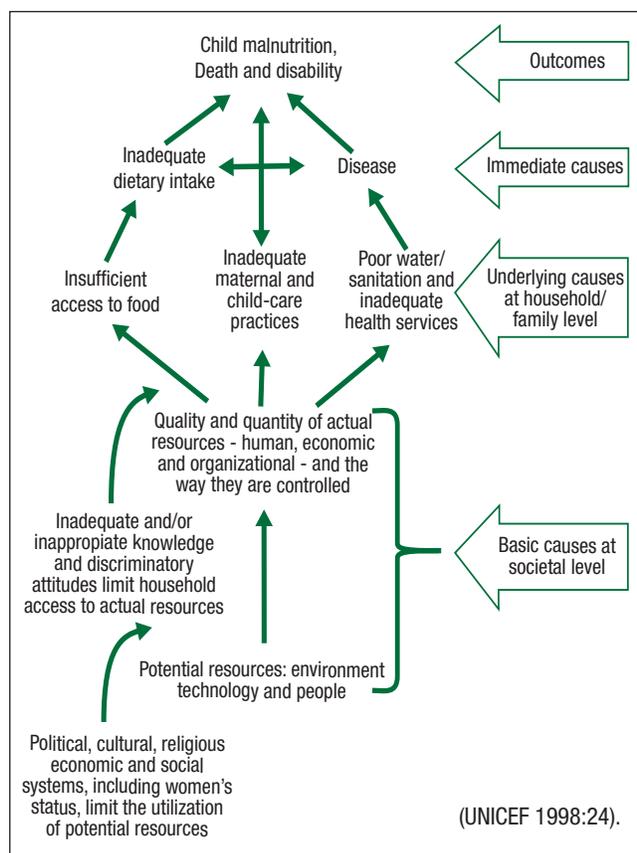
Research and funding still do not embrace the range of food, nutrition and health issues that are indicated in the UNICEF conceptual framework (Figure 1) which was formulated in 1990 to explain the causes of child malnutrition:

“The framework shows that causes of malnutrition are multisectoral, embracing food, health and caring practices. They are also classified as immediate (individual level), underlying (household or family level) and basic (societal level), whereby factors at one level influence other levels. The framework is used, at national, district and local levels, to help plan effective actions to improve nutrition. It serves as a guide in assessing and analysing the causes of the nutrition problem and helps in identifying the most appropriate mixture of actions.”

(UNICEF 1998:24)

The framework is explicitly designed to show the causes of child malnutrition, and implicitly the double burden of undernutrition (hunger from lack of calories) and micronutrient malnutrition (hidden hunger from micronutrient deficiencies). Since its formulation, the phenomenon of overweight/obesity has increased globally and affects both genders and all ages in most regions of the world. Regarding food intake, there is a problem both of access to excess and qualitative insufficiency. Adequate dietary intake is achieved through diversity in respect of consumption of foods from a wide range of categories that provide not only macronutrients in the form of carbohydrates, fat including essential fatty acids, and proteins containing essential amino acids, but also adequate intakes of essential vitamins and minerals for healthy growth and development.

The framework envisages many other causes of disability, morbidity and mortality that may or may not be associated with poor nutrition. It suggests a hierarchy of causes from the basic nature of society in terms of culture, capitals and capacities, to diet and disease. Better nutrition is one element of a complex of “wicked problems.”



**Figure 1. The UNICEF framework of factors affecting child malnutrition, death and disability.**

# 3

## The 'triple burden': Where to on nutrition and health?

### 3.1 Healthy diets

#### Key points

- The triple burden defined: undernutrition (hunger), micronutrient deficiencies (hidden hunger) and overnutrition (overweight/obesity)
- The micronutrient paradigm

Current thinking about human nutritional challenges focuses on the so-called “triple burden” of concurrent and often co-located problems. Three forms of malnutrition constitute the triple burden (Ritchie and Roser 2020):

- *Undernutrition, or hunger*, which results from dietary energy intakes below the minimum level necessary to maintain health, usually indicated by an individual’s Body Mass Index (BMI); more than 800 million people eat a calorie-deficient diet every day.
- *Micronutrient deficiencies* or micronutrient-deficiency diseases (MNDs), often called “hidden hunger”, which arise from a lack of consumption or absorption of essential vitamins and minerals; about 2 billion people suffer from inadequate consumption of micronutrients.
- *Overnutrition or overweight/obesity*, which is a level of dietary energy intake which leads to an excessive BMI.

This formulation of the global nutrition agenda is widely accepted. Undernutrition and overnutrition are usually linked to inadequate or excess intake of macronutrients (energy, protein and fat). Inadequate intake of micronutrients is one of the key factors causing “hidden hunger” (Arimond and Ruel 2004; Moursi *et al.* 2008; Nithya and Bhavani 2017; Ogutu *et al.* 2019; Zanello *et al.* 2019):

“Micronutrient deficiencies form an important global health issue, with malnutrition affecting key development outcomes including poor physical and mental development in children, vulnerability to or exacerbation of disease, mental retardation, blindness and general losses in productivity and potential. Unlike energy-protein undernourishment, the health impacts of micronutrient deficiency are not always acutely visible; it is therefore sometimes termed “hidden hunger” (the two terms can be used interchangeably). The World Health Organization (WHO) estimate that more than two billion people suffer from micronutrient deficiency globally.”

Ritchie and Roser (2020: no page number)

Iron deficiency is the most common nutritional disorder causing anemia, particularly affecting women and children in developing countries. Anemia is also prevalent in advanced economies and affects 800 million women and children globally. Deficiencies of vitamin A and zinc are also widely prevalent. Other minerals of interest include calcium, magnesium, copper, potassium, phosphorus, iodine, selenium, vitamins C, D, E, K, and the B vitamins (thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acid, folic acid, B6 and B12). Low dietary diversity implies lack of consumption of micronutrient-rich foods such as fruits and nuts, vegetables, and animal and fish products.

## 3.2 Dietary diversity

### Key points

- Dietary diversity helps to overcome micronutrient malnutrition
- Healthy dietary patterns can be difficult to sustain under varying seasonal conditions and in the “lean season”

There are multiple potential sources of food and dietary diversity for nutritionally vulnerable populations. A study by Remans *et al.* (2014) signaled the importance of agricultural diversity for food supply diversity at the national level in poorer (more heavily agricultural) economies. For middle- and higher-income economies, trade was more strongly implicated in diversity of the food supply. Since then, a number of studies have highlighted the importance of marketed food supplies even among rural peoples in developing countries (Sibhatu *et al.* 2015; Zanello *et al.* 2019; Muthini *et al.* 2020). Overall, there is an abundant literature that links diverse diets incorporating a range of foods to provision of the vitamins and minerals that prevent “hidden hunger” and micro-nutrient deficiency diseases (MNDs).

Dietary diversity matters because it provides richer diets that reduce maternal and infant micronutrient malnutrition and thus is a proxy for nutrient adequacy (FAO 2010). Dietary diversity can be inferred from estimates of the nutrient content and frequency of consumption of foods from different food groups, elicited through individual and household surveys (Ruel 2003; WFP 2008a; Zezza *et al.* 2017). Using such data, the World Food Programme approach to estimating food consumption scores (FCS) is commonly used (WFP 2008b), but there is no single best approach and there are many shortcomings in practice (Berney and Blane 1997; Naeem Ahmed *et al.* 2006; Brzozowski *et al.* 2017; Sununtnasuk and Fiedler 2017). The adequacy of diets can be inferred from estimating the nutrient content and consumption frequency of foods. However, it is not possible to point to individual nutrition requirements and deficiencies. These will depend on an individual’s age and stage of development, level of activity, gender, health status, and interactions between these factors, and the specific micronutrients of concern (Poole *et al.* 2019:417).

The impact of this research has been significant, and many agriculture-nutrition interventions now regularly incorporate dietary diversity in their work (Fan *et al.* 2019b). Much recent research argues that dietary diversity for vulnerable populations that achieve increased consumption of “nutrient-rich foods” can be addressed through multiple strategies, including own-food production among the rural poor, better incomes, enhanced market availability and access for all consumers (Masset *et al.* 2012; Jones *et al.* 2014; Pellegrini and Tasciotti 2014; Jodlowski *et al.* 2016; Jones 2017; Komatsu *et al.* 2018; Rosenberg *et al.* 2018; Zanello *et al.* 2019). There has also been abundant research clarifying the complexity of linkages between agroecological, economic and social systems and interventions, and dietary diversity and nutrition. This complexity is partly due to agricultural and socioeconomic context-specificities, and, perhaps, to diverse research designs.

In relation to context, Poole *et al.* (2019) explored the effect of seasonality in intakes of different food groups by rural households in Bamyán Province, Afghanistan, where diets are characterized by a major dependency on wheat. They found that a range of factors impinged on dietary diversity throughout the year where the effects of seasonality were extreme. The seasonal household economy was driven by differential patterns in household composition, in own-production of different food categories, food storage capacity for the “lean season,” external labor and income-earning opportunities, and physical access to markets in extreme weather conditions. A result of the mix of factors meant that the timing and extent of the so-called “lean season” of nutrition insecurity varied between households.

(Bevis *et al.* 2019) analyzed the relationship between diets and seasonality in body mass index (BMI) in multiple types of household members in rural farming households in Tanzania. Summarizing the nature of seasonality, they noted that fluctuations in anthropometric indicators of nutritional status were usually attributed to variations in food production and availability, and fluctuations in access through incomes and prices. They found significant variations in BMI during the seasons and different patterns of variation amongst different household members. Pre-school-age children and working adults were the most vulnerable to reductions in nutritional status.

One critical feature of seasonality in both Afghanistan and Tanzania was adults’ access to energy-rich foods at times of major labor requirements. While not ignoring the physical and psychological impacts of hunger, evidently the availability of energy-rich staples, both cereals and root crops, can facilitate or hinder the capacities of household members to fulfil time-critical agricultural and other labor tasks.

### 3.3 Assessing diet quality

#### Key points

- The limitations of assessing nutritional and dietary quality through crude food categories
- Aggregating staple foods as “nutrient-poor” is simplistic

Referencing intake from different food groups is the principal way of defining a healthy diet and is the basis of most guidelines including the diverse and healthy diet of the EAT Lancet recommendations (Willett *et al.* 2019). The outcome of much research on dietary diversity is often the Food Consumption Score (FCS) (Wiesmann *et al.* 2009; Arimond *et al.* 2010; Kennedy *et al.* 2010). The FCS is constructed by using weightings based on estimated nutrient content at the food category level (Table 2). Twelve categories are commonly used, with a quality ranking according to nutrient density, with, for example, animal-sourced foods (meat, fish and milk) weighted more than less nutritionally dense foods, such as tubers.

**Table 2. Food groups and weights.**

	Food items	Food groups	Weight
1	Maize, maize porridge, rice, sorghum, millet pasta, bread and other cereals	Cereals and tubers	2
2	Cassava, potatoes and sweet potatoes		
3	Beans, peas, groundnuts and cashew nuts	Pulses	3
4	Vegetables and leaves	Vegetables	1
5	Fruits	Fruit	1
6	Beef, goat, poultry, pork, eggs and fish	Meat and fish	4
7	Milk, yoghurt and other dairy products	Milk	4
8	Sugar and sugar products	Sugar	0.5
9	Oils, fats and butter	Oil	0.5
10	Condiments	Condiments	0

Source: WFP (2008), (INDDEx Project 2018).

Based on this score, a household’s food consumption can be further classified into one of three categories: poor, borderline, or acceptable. The weightings are crude estimates of the nutritional value of different food groups and do not discriminate between the varying values of different items within groups, nor take into account the precise nutrient values of foods: for example, cereals and tubers vary considerably in their nutritional content, and the fat soluble-vitamin content (vitamins A, D, E and K) of oils is arguably not reflected accurately.

Revision of the Food Consumption Score Nutritional Quality Analysis Guidelines (FCS-N) (WFP 2015) has introduced a more disaggregated food list which discriminates nutrient-rich foods from other less nutrient-rich items belonging to the same general food group: that is to say, not all vegetables and fruits are equally rich in important micronutrients. Nevertheless, FCS-N focuses on protein as a macronutrient “crucial for the prevention of wasting as well as stunting which takes place largely within the first 1000 days” and on two of the main micronutrients, vitamin A and iron, “which because of widespread deficiencies, cause death and disease in developing countries” (WFP 2015). “Why these nutrients?” is a good question.

#### Why these nutrients?

All macronutrients (carbohydrates, proteins and lipids) and micronutrients (vitamins and minerals) are important to ensure a healthy life, and all nutrients should be represented in a sufficient quantity for a balanced diet.

Macronutrients are good sources of energy. A lack of energy quickly leads to acute undernutrition. An insufficient intake of protein (essential for growth) is a risk for wasting and stunting. It also has an impact on micronutrient intake as protein foods are rich sources of vitamins and minerals.

Deficiencies over a long period of time in micronutrients such as vitamin A and iron lead to chronic undernutrition. Iron deficiency leads to anemia and Vitamin A deficiency leads to blindness and interferes with the normal functioning of the immune system, growth and development as well as reproduction.

This tool [FCS-N] chooses to focus on three key nutrients; Protein, Vitamin A and Iron (hem iron) primarily for their nutritional importance but also that foods rich in these nutrients can be easily grouped from food consumption data.

Source: WFP (2015:8).

The revised food group list with sub-groups and estimated nutrient contributions has added important nuance to the classification of foods by WFP (2015:10). The FCS-N is a tool that is operationally tractable and can contribute to valuable nutritional-epidemiological work for identifying dietary adequacy. While the food consumption score is a plausible indicator of dietary adequacy, it is not without limitations (Lovon and Mathiassen 2014). Review and analysis of dietary indicators has clarified methodological and conceptual limitations to food nutrition and security measures: FCS, for example, is considered a valid household-level proxy for energy intake but not for individual (micro)nutrient adequacy (Leroy *et al.* 2015). There is a lack of refinement due to wider contextual shortcomings: for example, the need to integrate evaluation of the sustainability, economics and nutritional performance of agrifood systems; the formulation of model diets; and the implications for the agrinutrition research agenda (Hirvonen *et al.* 2019; Mason-D'Croz *et al.* 2019; Willett *et al.* 2019; Drewnowski 2020; Sanchez 2020).

The use of indicators and proxies involves inevitable imprecisions concerning individual nutrition requirements and deficiencies, and seasonal effects.

Two areas are raised here that should give rise to wider discussion:

#### **“Missing nutrients”?**

A content issue for the food consumption score concerns both the macronutrients (fats, carbohydrates and proteins) and the micronutrients. The score does not differentiate among or include all essential vitamins and minerals which are epidemiologically significant, nor essential fats — or more precisely, polyunsaturated fatty acids (Machate *et al.* 2020), nor essential amino acid content and hence protein types. This narrow focus ignores other nutritional deficiencies including those that are serious but are context-specific to the national, regional (within country) and even local level (WHO 2020a). Zinc, iodine, folic acid and vitamin D deficiencies would be notable examples.

Taking into account the current emphasis on dietary diversity approaches to micronutrient deficiency diseases, there is a wider omission of the so-called “non-nutrient” components of food that are bioactive and contribute to health. The significance of foods containing such bioactive components is well-understood in biomedical research but is largely unrecognized in the agrinutrition literature. It is noteworthy that dietary fiber (DF) only appears parenthetically as a constituent of certain food groups (nuts and grains) in the EAT Lancet Commission report on healthy and sustainable diets (Willett *et al.* 2019). The omission of fiber as a specific dietary component” has important significance for healthy diets, even though the contribution of whole grains and fiber from whole grains is cited in association with some NCDs, overall mortality and some adverse metabolic conditions (pp.457-8). Discussion on the cereal contribution to dietary fiber as a “missing nutrient” will be expanded in section 6.

#### **Miscategorization?**

Following the point about “missing nutrients” is an operational issue — foods with different attributes are included within a single category. For example, different flesh meats and other foods based on animal-sourced products have varying nutritional qualities; vegetables and fruits differ considerably in their micronutrient content; biofortified (orange) sweet potatoes are categorized with orange vegetables rich in vitamin A, whereas fortified (yellow) rice is not so distinguished, and nor are other bio- or industrially fortified products<sup>4</sup>. On the other hand, it has been noted elsewhere that most national dietary guidelines do not distinguish between proteins derived from animal and plant

<sup>4</sup> Footnotes to the table explain some of these issues (WFP (2015). *Food Consumption Score Nutritional Quality Analysis Guidelines (FCS-N). Technical Guidance Note*. Rome, United Nations World Food Programme (WFP). Retrieved 07 December 2020, from <https://www.wfp.org/publications/food-consumption-score-nutritional-quality-analysis-fcs-n-technical-guidance-note>.

sources, and that explicit targets for plant-based protein sources would help to align dietary guidelines with both healthy and environmentally sustainable dietary patterns (Springmann *et al.* 2020). Dependence on food groups rather than nutrients as the dietary variable oversimplifies what is complex and nuanced.

Plant species vary hugely in the content and bioavailability of micronutrients, and a disaggregated approach to estimating nutritional content needs to replace over-broad categorization. Moreover, there are many plants that are not commonly considered as food sources, sometimes because they are of only local significance. For example, perennial vegetables (PVs) are a diverse category of plant species with the potential to make a sustainable and ameliorating contribution to ecological, agronomic, and climatic crises as well as to human health; the essential micronutrients, iron, vitamin A, zinc and folate are found at high levels in some PVs (Toensmeier *et al.* 2020), and these need to be represented in more detailed dietary analyses and guidelines. The study by Toensmeier *et al.* identified various “standout” PVs that are “superabundant” in individual key nutrients, as well as some “multi-nutrient” crops with high levels of two or more nutrients essential to addressing deficiencies. The same qualifications probably apply to the minor cereals which are poorly represented in the general agrinutrition literature (e.g. see Palanisamy *et al.* (2014)).

Because many “non-nutrient” dietary components are found in staple foods, it is easy to misclassify staples automatically and universally as “nutrient-poor”. In particular, the single “staples” category of cereals and tubers includes innumerable diverse foods. They are derived from a wide range of crops which exhibit considerable inherent between-species differences. They also often exhibit appreciable within-varietal nutritional qualities due to diverse production systems and conditions. From these staples many foods are derived through processing and manufacturing that alter nutritional quality for better — by improving digestibility — and often for worse — by stripping out valuable nutrients. The basic agricultural products can be subject to, or contribute to, ultra-processing into other forms, for example products high in saturated fats, sugar and salt that can be nutritionally noxious, obesogenic and can contribute to NCDs (WHO 2020b).

The nutritional value of so-called “superfoods” such as quinoa and amaranth, which admittedly are not of global significance, are not accounted for. Similarly, the energy content of oils and fats is important, particularly in situations of severe acute malnutrition where disaster and humanitarian relief programs aim to provide emergency ready-to-use therapeutic foods such as “plumpy nut.” Starchy staples such as cassava are highly valued by vulnerable communities for food security (Barratt *et al.* 2006) and are a major component of the agro-economic systems of many poor rural households (Poole *et al.* 2013; Harris 2019).

The shortcomings of the tools cast a shadow over their use in the dominant dimension of dietary diversity and quality in combating micronutrient malnutrition. Popkin has recently urged caution in using crude data and categorizations of food to evaluate the nutrition transition (Popkin 2021). There is also a particular dilemma when overt hunger due to insufficient food calories is an immediate population and policy concern, and in humanitarian situations where energy needs are paramount. Similarly, in many countries there is high dietary dependence on “starchy staples” such as maize and cassava (Poole *et al.* 2013; Harris 2019), and wheat (Poole *et al.* 2018). Likewise, rice is fundamental to food energy security for half the world’s population (Fukagawa and Ziska 2019; Zhao *et al.* 2020). Harris characterizes the policy dilemma in Zambia in nutrition emphasis on “overt” versus “hidden” hunger as “opposing policies” (p.208).

### 3.4 The significance of stunting, dietary diversity and beyond

#### Key points

- Stunting has major and intergenerational social and economic costs
- Childhood stunting is a principal indicator in many research and development interventions
- There are nutrition and health issues beyond stunting that matter
- A more comprehensive expression of food and nutrition security and health is needed

Since Black *et al.* (2008), it has been clear that maternal and child malnutrition evidenced in childhood stunting contributes significantly to the global disease burden. The condition of childhood stunting is attributed to micronutrient-deficient maternal and infant diets and affects the poor disproportionately (Arimond and Ruel

2004; UNICEF 2013; Smith and Haddad 2015). Stunting incurs major and intergenerational health, economic and development costs. Investment in research into childhood malnutrition and stunting is a key strategy for work in nutrition (Prendergast and Humphrey 2014).

Many international organizations currently address stunting as a major challenge for nutrition and development:

- ◆ The World Bank highlights stunting (2018);
- ◆ The USAID's child nutrition program includes prominent indicators for stunting and wasting of under-fives (USAID 2020);
- ◆ The Gates Foundation strategy on nutrition acknowledges the importance of "hidden hunger", or micronutrient malnutrition (BMGF 2020);
- ◆ The European Union Action Plan on Nutrition directly targets stunting (European Commission 2019);
- ◆ The U.K. Global Challenges Research Fund (GCRF) addresses global issues faced by developing countries, among which stunting is a significant theme (UKRI 2020);
- ◆ The U.N. agencies State of Food Security and Nutrition in the World 2020 includes a spotlight on stunting (FAO *et al.* 2020)

The CGIAR A4NH program adopts a broad approach to address malnutrition that includes undernutrition, micronutrient deficiencies, overweight, obesity, and associated noncommunicable diseases (A4NH 2020b) and recognizes that stunting has become a global development objective. The consequences for children of stunting and wasting are likely to be poor physical, cognitive and reproductive development, metabolic disorders and future morbidity. Learning difficulties reduce economic potential and opportunities to participate in society, and hence a failure to reach potential. Outcomes are probably irreversible and can be perpetuated intergenerationally. Childhood obesity is linked to adult obesity and the increased prevalence of noncommunicable diseases and morbidity, accompanied by reduced participation in society and increased social and healthcare costs. "The joint estimates [of UNICEF, WHO and World Bank Group], published in March 2020, cover indicators of stunting, wasting, severe wasting and overweight among children under 5, and reveal insufficient progress to reach the World Health Assembly targets set for 2025 and the Sustainable Development Goals set for 2030." The global rate of child stunting was reported as 21.3%, or 144 million, with rates above 30% in much of sub-Saharan Africa and South and West Asia, and parts of Oceania. Overweight is a concern in almost all regions of the world, with more than 5% of children under the age of five, or almost 40 million, overweight (UNICEF *et al.*).

Very often the focus of nutritional studies is on infants and young children, and adolescent girls and women. Recent research on the height and BMI trajectories over age and time of school-age children and adolescents has implicated nutrition patterns as a cause of diverging trends and performance at the national level. The analysis was based on pooled data from 2,181 population-based measurement surveys and studies, with anthropometric measurements of 50 million people aged 5–19 years and 15 million people aged 20–30 years. Findings highlighted differential performance across countries, and implied that the quality of nutrition, among other factors, affected school-age children and adolescents throughout the period of human growth and development, with potentially lifelong impacts on health and well-being (Rodriguez-Martinez *et al.* 2020).

Older age is another dimension of nutrition studies that has been neglected. While the lifelong impact in terms of Disability Adjusted Life Years (DALYs) of poor nutrition in older age is undoubtedly less than at younger ages, and the social elements of poor growth and development are not compromised, the social costs to families and the economic costs of morbidity among older age groups at household and national levels is of increasingly political significance.

The importance of child micronutrient malnutrition that causes stunting is beyond debate (UNICEF *et al.* 2020): see for example the summary of six years' work on agriculture and nutrition in South Asia (Gillespie *et al.* 2019) and work on dietary diversity and nutrient-rich foods in Afghanistan (Poole 2018; Poole *et al.* 2019).

Work by Babu *et al.* (2017) attempts to provide terminological clarity on definitions of nutritional challenges and indicators. (Prendergast and Humphrey 2014) refer to "linear growth failure" as a "stunting syndrome" that is the most common form of undernutrition globally, causing multiple adverse pathological changes particularly in children

under the age of five years. For children suffering severe acute malnutrition (SAM), other childhood conditions, often attributable to maternal malnutrition such as low birthweight, can have long-term consequences for the chronic disease burden which may be intergenerational or occur preconception, *in utero* (in the womb) or in early life (Briend and Berkley 2016; Lelijveld *et al.* 2016).

In a recent review, Leroy and Frongillo (2019) analyzed the use of stunting as a nutritional indicator. They acknowledged that with the growing acceptance of the global nutrition challenges, child stunting — or linear growth retardation — has become a widely-used and useful tool. But, they argued, stunting is associated with, but does not cause, the health correlates of linear growth retardation, except for a causal relationship with difficult births for mothers who have suffered from stunting, and poor birth outcomes for children of stunted mothers. Arguably, stunting is an indicator of malnourishment, and not the condition itself, and a wide range of malnutrition and health conditions are attributable to a deficient environment. The authors advise donors, program planners and researchers to be specific in selecting nutrition outcomes and to target those outcomes directly.

The dependence in nutrition metrics on stunting as an indicator is indisputably important, but it is but one measure of food and nutrition security. A danger of indicators and targets such as stunting is the tendency to reduce the multiple dimensions of complex or “wicked” problems, like good nutrition and health, to simple solutions. Just as the conditions for food security and good health cannot be reduced to good nutrition, good nutrition in turn cannot be reduced to an adequate micronutrient intake, even if it is a simple truth that diverse diets enhance micronutrient intake and reduce stunting.

The focus on stunting and wasting as indicators of micronutrient deficiencies also misses the point that nutritional indicators are not the outcome to be desired. It is important to look beyond malnutrition indicators and recognize that other nutrition- or dietary-related diseases are important for the ultimate goals of health and well-being. Other food and nutrition challenges affecting adults are also a global problem. Hunger — energy insufficiency — is a persistent challenge in poor communities and humanitarian situations, and overnutrition due to excess energy intake is increasing the levels of many noncommunicable diseases (NCDs).

For many humanitarian and other contexts, the dimensions of food insecurity used in the Integrated Food Security Phase Classification (IPC) are more comprehensive than the use of stunting as an indicator by the agrinutrition research community. The Global Report on Food Crises (FSIN 2020) uses a broader food concept. The annual reporting process is facilitated by the Food Security Information Network (FSIN), which was founded by FAO, IFPRI and WFP and is the platform of the Global Network Against Food Crises, itself co-founded by the European Union, FAO and WFP. It is this international humanitarian IPC background to the report that highlights the incidence of macro drivers of food insecurity such as conflict and insecurity, macroeconomic crises, climate change and pests. The IPC indicators of first level outcomes of food insecurity are twofold:

- i. food consumption in terms of quantity (energy intake), quality (dietary diversity and food consumption score), the level of hunger, and evidence of coping strategies and livelihood protection.
- ii. change in household livelihood assets and strategies.

IPC second level outcomes are indicators of nutritional status: wasting and mortality.

This mix of indicators is more comprehensive than that used by most agrinutrition researchers and captures a wider range of health drivers and outcomes than does the focus on dietary diversity and stunting. It also links to SDG3 Good Health and Well-being and to targets for reductions in infant and child mortality in NCDs<sup>5</sup>. The total global costs of NCDs, nested within SDG3, are less cited than those of micronutrient diseases and stunting (SDG2), but pose a significant threat to healthcare budgets and to human welfare, and are likely to increase over time (Muka *et al.* 2015). Such morbidities are partly attributable to overnutrition and are conditions that are a proper concern of the agrinutrition community.

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<sup>5</sup> SDG3 is Good Health and Well-being: “Ensure healthy lives and promote well-being for all at all ages” United Nations (2020b). “Sustainable Development Goals. Goal 3: Good health and well-being.” New York, United Nations. Retrieved 07 December, 2020, from <https://www.un.org/sustainabledevelopment/health/>. The following targets are directly nutrition-relevant:

- 3.2 By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and mortality in under-5s to at least as low as 25 per 1,000 live births.
- 3.4 By 2030, reduce by one third premature mortality from noncommunicable diseases through prevention and treatment and promote mental health and well-being.

Attaining other SDGs such as those for education (SDG4), gender equality (SDG5), employment (SDG7), among other things, are also more or less directly linked to the nexus of food, nutrition and health.

These complexities are also illustrated in recent work in Tanzania; using data from National Panel Surveys conducted in 2008/09, 2010/11 and 2012/13, Chegere and Stage (2020) found that agricultural production diversity increased household dietary diversity (HDD) but the effects were small. Market sales did not increase HDD, and household nutritional status was most impacted by improving education and overall income levels. Increasing HDD did not improve child nutrition outcomes, but increasing the consumption of specific nutrient-rich foods (fish and dairy products) did. Given the complexities, “focusing on dietary diversity per se may not be as important for [nutrition] outcomes,” (p.10) which should focus on education and income pathways as well. Hence there is a need to go beyond food intakes by adopting a multisectoral approach to dietary diversity studies.

Agrinutrition research must open up to a broader perspective on the nature of agriculture, food, nutrition and health (and indeed other SDGs), recognizing the complexity of this nexus. At the heart of this new complexity is a need to acknowledge that foods contain more than the conventional macro- and micronutrients, and that agrinutrition research should address the nutrition and health requirements for the essential “non-nutrient bioactive food components”.

# 4

## Current food security and nutrition

### 4.1 The economic cost of malnutrition

#### Key point

- Despite questions of accuracy due to methodological challenges, estimates of the scale of the economic costs of global malnutrition and food insecurity are huge

There have been few, but frequently quoted, estimates of the global cost of malnutrition. Drawing on earlier work (Horton and Steckel 2013; Horton and Hodinott 2014), the Global Panel endorsed the high economic estimates and added other costs to society: mortality, physical health, mental well-being, and degradation of the environment. The GDP losses per year could be 11% across Africa and Asia (Global Panel on Agriculture and Food Systems for Nutrition 2016:16):

Malnutrition, in all its forms, carries huge direct and indirect costs to individuals, families and to entire nations. The estimated impact on the global economy could be as high as US\$3.5 trillion per year, or US\$500 per individual. Such enormous costs result from economic growth foregone and lost investments in human capital associated with preventable child deaths, 45% of which can be ascribed to poor nutrition, as well as premature adult mortality linked to diet-related non-communicable diseases (NCDs). Further costs are incurred through impaired learning potential, poor school performance, compromised adult labour productivity, and increased health care costs.

(Global Panel 2016:3)

Methodological difficulties and data gaps surround these estimates, but the signs are clear: actual costs of treatment and foregone benefits of health are in US\$ billions each year, and the benefit-cost ratio of nutrition interventions can exceed 15%. In addition to historic concerns about undernutrition, and the more recent concerns about MNDs, overnutrition is posing increasing hazards. An analysis of the economics of obesity by the McKinsey Global Institute (MGI) in 2014 suggested that the global cost was about US\$2 trillion, or 2.8 percent of global GDP, “roughly equivalent to the global impact from smoking or armed violence, war, and terrorism,” (MGI 2014:1). In the UK alone, a portfolio of initiatives and interventions could save about \$1.2 billion a year — an estimate that is likely to be steadily increasing.

As the prevalence of obesity increases throughout low- and middle-income countries to match rates in high-income countries, the impact on economies of reduced productivity and life expectancy, and increased disability and health care costs will increase significantly:

“The estimated economic costs of obesity vary considerably, since studies use different methodologies to estimate direct and indirect costs. For example, estimates for the United States vary from US\$89 billion to US\$212 billion in costs; those from China are estimated at 3.58 and 8.73 per cent of gross national product (GNP) in 2020 and 2025 respectively; and Brazil projects a doubling of obesity-related health care costs from US\$5.8 billion in 2010 to US\$10.1 billion in 2050. The effects of obesity on productivity, early retirement, and disabilities have rarely been studied in low and middle-income countries. In addition, the same poor diets dominated increasingly by ultra-processed foods and the reduced activity patterns that affect obesity, increase the risk of a wide array of NCDs directly as well as indirectly” (Shekar et al. 2021:5-6)

In order to consider the challenges of estimating the effects of malnutrition, Nugent *et al.* (2020) examined methods for undertaking economic evaluations. Their focus was on the double-burden, i.e., undernutrition and overnutrition,

for which lack of data availability is a constraint. They did not address micronutrient malnutrition that is likely to contribute a large proportion of the total costs of malnutrition. Any improvements in methods have to take into account the triple burden.

## 4.2 The need for multi-disciplinarity

### Key point

- Arguing the need for an integrated, multidisciplinary perspective rather than maintaining disciplinary silos

Integrated and multidisciplinary, multisectoral approaches to overcoming problems of nutrition present significant challenges. For policy makers to embrace the diverse factors depicted in the UNICEF framework, and others which are absent, the task is daunting in its diversity, with investments needed not only in nutrition-specific and nutrition-sensitive projects and policies, but across a range of sectors (Smith and Haddad 2015; Gillespie *et al.* 2019). Food security and nutrition still remain marginal topics in research on agrifood sustainability transitions and transformations (El Bilali 2019). At a time when natural and social phenomena are circumscribing food security into the future, the conceptions of sustainability are inadequate (Béné *et al.* 2019). Agriculture and nutrition must be much more closely linked than hitherto. More than five years of research in South Asia has exposed disciplinary gaps between agriculture and nutrition (Gillespie *et al.* 2019). For example, in Afghanistan, the World Bank conceived agriculture as “productivist”, prioritizing economic growth, exports and employment (World Bank 2014). Agriculture as the basis for food security and nutrition has often been a secondary consideration with incoherent intersectoral policy linkages (Poole *et al.* 2018). Re-orienting food systems to be “pro-nutrition” requires substantial changes across a range of issues:

- “a) the strengthening of institutional and policy environments (including accountability systems) to enable agriculture and food systems to support nutrition goals,
  - b) modifying the design, location and/or implementation of agri-food system interventions to enhance their effects on nutrition outcomes,
  - c) developing capacity and leadership to use and demand appropriate evidence to improve decision-making to this end.”
- (Gillespie *et al.* 2019:7)

Frison and Clément (2020) report on the WFP approach to work in Tajikistan and argue in favor of a food systems approach to the current challenges of nutrition, and that embracing the three elements of food supply chains, food environments, and consumer behavior will be instrumental in achieving SDG2. From the perspective of the SDGs, many other disciplinary bridges can be added to this agenda.

## 4.3 Agriculture-nutrition research, interactions and pathways

### Key points

- Agriculture-nutrition interactions are complex and there are multiple impact pathways
- Pro-nutrition agricultural interventions need to consider this complexity

### Complex agrinutrition relationships and pathways

There are various pathways through which agriculture influences nutrition (Gómez *et al.* 2013). Building on Kadiyala *et al.* (2014), the multiple and complex ways in which agriculture relates to nutrition have been reformulated to take into account food industry and economy-wide dimensions (Poole *et al.* 2018:1583):

1. Agricultural production as a source of food for own consumption;
2. Agricultural sales and employment as a source of income for household expenditure on food and non-food goods;
3. Agricultural and food policies, which influence food access and availability through the relative prices and affordability of specific foods, and foods in general;

4. Women's roles in agriculture, household decision making and resource allocation affecting intrahousehold allocations of and expenditure on food, health and care;
5. Women's employment in agriculture balanced with childcare and feeding responsibilities;
6. Women's own nutrition and health status, affecting childcare and nutrition, which may be compromised by own agricultural labor;
7. Competition and entrepreneurship in the scale and diversity of agricultural production, transport, processing, manufacturing and distribution; and changes in productivity, which affect food access and availability at market, cf. household level;
8. Changes in the agricultural sector and related industries as a whole that have a macrolevel and medium-to-long term impact on gross domestic product and productivity.

Within the agriculture-nutrition community, there is a growing recognition that food and nutrition security is mediated through markets even among rural people (Sibhatu *et al.* 2015; Zanello *et al.* 2019). This was made explicit by Kadiyala *et al.* (2014) in pathway 2, but the impacts of wider food systems are present in pathways 7 and 8, the first of which captures the role of the food system from farmgate to consumption, and the second of which attempts to capture indirect economy-wide effects on food systems (Poole *et al.* 2018:1583). A close relationship is implied between agriculture and nutrition on the one hand, and on the other, between the agriculture-nutrition-food-industry-health nexus and related other-sectoral concerns such as education, employment, natural resources, gender equality and other SDGs.

The convergence of interests between i) agriculture as food and ii) nutrition as health has been accompanied by the growing recognition that climate change, largely through global warming, and other environmental stresses, now imperil agriculture, food and nutrition (Dangour *et al.* 2017). Food systems and value chains including manufacturing, processing and distribution are now considered to be failing to deliver food and nutrition security (Global Panel on Agriculture and Food Systems for Nutrition 2016). There are different levels of expectations of how researchers and policy makers can engage with food businesses (Altenburg and von Drachenfels 2006; Haddad 2019). For cereal systems the implications are significant.

### **Agrinutrition interventions**

As noted, agricultural development and the nutrition and health agendas have developed in a largely disarticulated manner, ignoring the complex linkages mediated through incomes, markets and the environment (Dangour *et al.* 2012; Kadiyala *et al.* 2014; Bird *et al.* 2019). While many studies have thrown light upon the importance of market linkages, recent work by Bevis *et al.* (2019) found that proximity to markets was a significant factor in maintaining the BMI of some household members in times of seasonal hardship in Tanzania, however, market access did not mitigate reductions in nutritional status among children below school age, and therefore they admit that “we do not understand the data-generating process behind seasonality in the nutritional status of young children, despite the critical implications of this seasonality for long-term growth, cognitive development, and later life productivity.” (p.12)

### **Agrinutrition research communities**

However, the agrihealth community, of which agrinutrition is a subset, has been growing significantly (Waage *et al.* 2018). As noted, Agriculture for Nutrition and Health (A4NH) is the flagship program of the CGIAR. Led by IFPRI with the participation of other centers including CIMMYT, it takes a food-systems approach to agriculture, nutrition and health.<sup>6</sup> Transform Nutrition, a consortium of five international research and development partners, also led by IFPRI, worked from 2012 to 2017 in agrinutrition policy, political economy and innovative intervention spaces to boost the contributions of agriculture, social protection and health systems to improving nutrition.<sup>7</sup>

HarvestPlus<sup>8</sup> (H+) is another international consortium of large donors and research organizations. Through the biofortification of staple foods, H+ targets improvements in the micronutrient content of the daily diets of vulnerable

<sup>6</sup> <https://www.ifpri.org/program/agriculture-nutrition-and-health-a4nh>

<sup>7</sup> <http://www.transformnutrition.org/>

<sup>8</sup> <https://www.harvestplus.org/>

populations in the world who do not get enough essential vitamins and minerals, specifically vitamin A, iron or zinc. The ambition to improve the nutrition of 1 billion people by 2030 requires a range of supply, demand and policy strategies implemented by multiple stakeholders (Bouis and Saltzman 2017; Bouis 2018).

Latterly, there has been a growing awareness that it is not just the science of production but the socioeconomics of household production and consumption decisions and the operation of food markets that affect food security. People's individual and household decisions influence access to nutritious foods through home production and market interactions. Intrahousehold utilization patterns and preferences in food preparation and distribution determine the consumption of nutritious foods by vulnerable groups such as children, women, and older people. Numerous interventions by national and international public sector organizations, academia and (I)NGOs have built a substantial body of evidence about how to increase the production, distribution and consumption of nutrient-dense foods in order to combat the hidden hunger of micronutrient malnutrition. There is a need to learn more through more targeted research:

“Viable options for policy and programme interventions across the food system must be identified and costed: Researchers and other development partners must collaborate in identifying locally appropriate scalable evidence-based actions, supportive of nutrition. The evolving portfolio of potential actions should guide policymakers on priority investments and legislated actions.” (Global Panel 2016:17)

The distribution of foods through public sector education systems and social safety net programs, and through large-scale industrial fortification programs for staple foods, is an important part of the food environment in countries where governments have the necessary human and economic capacities (Ruel and Alderman 2013; Maestre and Poole 2018).

Home gardens for fruits and vegetables, dairy and other livestock production initiatives have links with women's roles and empowerment due to gendered roles in production, processing and marketing. Besides addressing the zero poverty and hunger goals (SDGs 1 and 2), such approaches make essential links to other SDGs, such as achieving gender equality and empowerment for all women and girls (SDG5), inclusive and sustainable economic development (SDG8), and reducing inequality within and between countries (SDG10). Other nonagricultural food production systems such as the production and harvesting of fisheries and forest products may also be subject to similar gendered socioeconomic dimensions.

## 4.4 Interactions with the private sector

### Key points

- Highlighting the importance of engaging with the private sector responsible for food processing, manufacturing and distribution
- Cautions about the extent to which the private sector (if left alone) is likely to contribute to better nutrition and health

The concept of the “food environment”, (maybe) originally attributable to Hawkes (2009), has been elaborated to identify and explain the forces which affect the way the food industries, governments and civil society operate, and in which consumer behavior is shaped. The concern is that food systems have failed and continue to fail to ensure the primacy of health and nutrition in food consumption and dietary choices over the business interests of the food industries. Among the implications for food policies is the need to identify points in the supply chain that could be leveraged to create healthier food environments. Researchers' task is to undertake multidisciplinary value chain analysis of the incentive structures faced by food firms and of how they might be amenable to leveraging the supply chain towards healthier eating (Hawkes *et al.* 2012). Diverse regional experiences and chain approaches have been shared in the literature which, taken together, highlight the need for analysis of systems as a whole, from supply industries and producers to consumers, inclusive of all stakeholders — public, private, civil society — and from a multidisciplinary perspective (Devaux *et al.* 2016; Maestre *et al.* 2017; Turner *et al.* 2017; Thow *et al.* 2018; Pérez-Ferrer *et al.* 2019; Fanzo *et al.* 2020).

The role of agrifood industries is critical for the delivery of safe and nutritious foods to consumers. The global public sector contemplates working with the private sector to achieve the SDGs. The Global Alliance for Improved Nutrition

(GAIN) is an alliance of 20 agrinutrition stakeholder members. GAIN aims to increase the availability, affordability and consumption of nutritious and safe foods, and to change market incentives, rules and regulations to promote nutritious diets.<sup>9</sup> The “Scaling Up Nutrition” (SUN) Business Network addresses key challenges and opportunities to accelerate the private sector’s contribution to healthy diets.<sup>10</sup> Another important player with respect to business is the Access to Nutrition Foundation, supported by philanthropic and public funds, which aims to boost the performance of the private agrifood sector, particularly manufacturers of packaged foods, in respect of healthy diets for all consumers.<sup>11</sup>

## 4.5 Expectations of the private sector

### Key point

- Leveraging the power of the private sector requires public intervention

Poole *et al.* (2020a) discuss the link between food supplies, nutrition and the food industry, highlighting the challenges for linking public food policy objectives to private business initiatives (Box 1). Based on experience in South Asia and the growing literature on public sector-private sector food, nutrition and health linkages, they identify potential ways for researchers to engage in the delivery of nutrient-rich foods and limit the consumption of harmful foods. Products derived from cereals are implicated in the manufactured and processed food sectors, and there are lessons to be learnt for the mode of engagement of cereals researchers with agrifood business and policy.

#### Box 1 What can we expect of the private sector?<sup>12</sup>

It is logical and urgent — and consistent with the SDGs — to look to agri-food businesses to support the pro-nutrition agenda. SDG17, enjoining global partnerships, implies so. Moreover, the strategy of the UN Global Compact is to drive business awareness and action towards fulfilling the SDGs (UN Global Compact 2018).

Global advocacy and accountability initiatives have also been promoted, such as the Access to Nutrition Index (ATNI) which scores the 22 biggest food and beverage companies — headed by Nestlé, Unilever, Danone — on their efforts to improve nutrition through actions on marketing and product formulation (ATNF 2018).

Compared with the ‘corporate responsibilities’ oriented towards social and environmental objectives enshrined in the accepted international conventions, the agri-food and nutrition agenda lacks a specific international policy framework and interventions. Governments struggle to shape regulations and incentives for better nutrition: note, for example, the difficulties in reducing sugar and salt content in processed foods, despite the huge social cost of overconsumption such as the increasing levels of non-communicable diseases. Resolving the trade-offs between conflicting goals and sectors involves acute scientific and political judgements. Without clear goals and a framework, it is problematic to align these multiple interests. Nevertheless, the increasing strength of the critique of ultra-processed foods highlights the scale of the international challenge (Monteiro *et al.* 2018; Lawrence and Baker 2019; Vandevijvere *et al.* 2019).

Global corporates such as large-scale food manufacturers, *inter alia*, are responsible for promoting ultra-processed products that contribute to unhealthy diets. However, they are aware of the challenges and can be engaged and monitored. Much agri-food production and distribution are conducted in small and medium-sized firms. SUN and GAIN have programs working with such SMEs<sup>13</sup>. Through public-private sector partnerships governments can promote nutrition-related goals.

<sup>9</sup> <https://www.gainhealth.org/about>

<sup>10</sup> <https://sunbusinessnetwork.org/>

<sup>11</sup> <https://accesstonutrition.org/>

<sup>12</sup> This extract is reproduced with permission of the publisher

<sup>13</sup> SMEs: small and medium-sized enterprises

As evidence supporting these approaches, we report on initiatives and interventions from South Asia researched under the DFID-funded program 'Leveraging Agriculture for Nutrition in South Asia' (LANSA: <http://59.160.153.187/>) that test these propositions.

Summarizing lessons from the case studies, we conclude:

- Firm profitability sits uncomfortably beside promoting consumer health. There should be no assumption that public and private sector objectives are aligned. Policy makers must accept limitations constraining public-private partnerships (Henson and Agnew 2020), and acknowledge that market failure to deliver nutritious foods may have to be addressed through public sector interventions
- Business policies are dynamic: senior staff and production and marketing strategies change due to internal management reasons, shareholder pressure, and because of evolution in the external business and advocacy environment. Clear, stable and supportive pro-nutrition public policy and food regulatory frameworks will help firms to maintain more stable strategies. As Haddad (2019) notes, it is governments who, together with civil society, shape the incentive and regulatory environment
- Important elements of the external business environment which condition industry behaviour are beyond the control of firms and may be more, or less, conducive to stability and efficiency. Investments in essential supporting sectors such as infrastructure, communications and logistics constitute a complex mix of public and private responsibilities; and security from man-made and natural disasters that threaten food systems can pose extreme risks, the management of which is more complex still
- While the marketing 'reach' of some major food and beverage multinationals is ubiquitous, for most firms, and in many markets, there are genuine challenges in reaching the 'Bottom of the Pyramid' with safe and nutritious food, challenges which are difficult to target directly through global initiatives. For business to reach remote markets, external supports are necessary
- Public-private-NGO partnerships can be effective, but because of the potential misalignment of objectives over time, long-term formal agreements with monitoring and enforcement are necessary to ensure that such initiatives are efficient and sustainable
- There are context-specific factors which determine the nature and success of agri-food policies for nutrition:
  1. The policy environment is conditioned by the design and delivery capacity of public sector organisations and the characteristics of local socioeconomic structures
  2. Benign influence of the stakeholder environment depends on multi-sectoral engagement and the strength of advocacy and resilience of mechanisms for accountability
  3. Advertising and education should be jointly regulated, balancing public and private interests

Among international agreements, SDG17 appears vacuous and the UN Global Compact lacks teeth on global health and nutrition. GAIN and SUN are struggling to have impact, but global movements are necessary and need governmental support. A genuine commitment to 'corporate responsibility for health and nutrition' is needed from the agri-food sector — and more quickly — in order to achieve change in the global food industry culture. Some interventions should be mandatory: pro-nutrition interventions such as industrial fortification should be taken up universally and made effective. Other potential food policies require cautious but no less determined approaches.

We need further knowledge of how to leverage the ongoing transformation of food environments by shifting incentives, managing and distributing risks and profits in the agri-food cycle, and targeting consumer behaviours. Research with the private sector is essential (Haddad 2020). The ethics of marketing of unhealthy foods has been questioned for quite some years (Hawkes 2007) but legislative controls have lagged. There is an increasing body of research in diverse food contexts suggesting that taxation potentially can change consumption patterns away from unhealthy sugar-sweetened

beverages and energy-dense ultra-processed foods (Bíró 2015; Batis et al. 2016; Smed et al. 2016; Caro et al. 2017). However, empirical evidence is still lacking. Individual firms may have different or unpredictable responses to policy interventions, and impacts are therefore indeterminate (Veerman 2017). Hence, political economy analyses of food policies are necessary to identify and resolve the private constraints to pro-nutrition public interventions.

Overall, public policy must include stronger direct intervention in the large firm sector through taxation, subsidies, regulatory incentives, and controls on advertising and distribution, with appropriate monitoring and sanctions. There is a potential role here for civil society. Indirect intervention also can facilitate firm efficiency and reduce the costs to poor consumers of nutritious foods by mitigating food chain costs of contracting, of regulatory compliance, and of financial services (capital and insurance) particularly to the 'hidden middle' of small and medium-size food firms (Reardon 2015). In particular, more knowledge is needed among researchers and policy makers to understand the operations of SMEs in South Asia and more widely.

Source: edited and adapted from Poole et al. (2020:92-100). Included with the permission of the editor of the journal Food Chain.

This understanding of the need for engagement of researchers with food businesses is consistent with the recent call by Haddad (2020) for the CGIAR system to take a more active approach to research in the decade leading up to 2030. The Intergovernmental Panel on Agriculture and Food proposed by Haddad would bring together multiple stakeholders in a concerted effort to shape improved health and the sustainability of food systems, and to combat poverty and hunger. It is important that the CGIAR engages coherently with policy makers and agrifood businesses, as is the *modus operandi* (way of operating) for A4NH, and that the initiatives on food policy are not left to IFPRI.

# 5

## Framing the research: Food systems

### 5.1 “Food systems thinking”

#### Key points

- Food systems approaches are gaining currency
- Highlights the need for multistakeholder participation
- Implies a multidisciplinary approach to addressing agrinutrition challenges

For agricultural scientists, increasing knowledge and management systems for improving the technologies of production systems are fundamental activities. Ultimately, knowledge management concerns the issues affecting food consumers, and in the language of food security, how availability, access, utilization and stability in the food environment at the household level influence the livelihoods and prospects of individuals. The food systems concept is becoming a common lens for a comprehensive analysis of agriculture, food, nutrition, health and sustainable development (Global Panel on Agriculture and Food Systems for Nutrition 2016; FAO *et al.* 2020; Frison and Clément 2020). The theme of IFPRI’s 2020 Global Food Policy Report is the inclusion of marginalized and vulnerable people in food systems to support sustainable development, create better economic opportunities and mitigate the impacts of climate change for the most vulnerable, and to promote the production and consumption of healthy foods (IFPRI 2020). Interventions and initiatives at the value-chain level with a focus on integrating smallholders and vitalizing small enterprises can be effective approaches for redesigning food systems to meet the economic and nutritional needs of the most vulnerable. The report is policy-oriented and does not directly address specific nutritional needs but explains IFPRI’s understanding of the meaning of food systems:

Food systems are the sum of actors and interactions along the food value chain — from input supply and production of crops, livestock, fish, and other agricultural commodities to transportation, processing, retailing, wholesaling, and preparation of foods to consumption and disposal. Food systems also include the enabling policy environments and cultural norms around food.

Food systems provide basic sustenance in terms of meeting populations’ minimum caloric needs and affect nutrition, positively or negatively, through crop health, dietary diversity, and impacts on human health and the environment. Food systems also provide livelihoods for a sizable share of the global population, through agricultural labor and nonfarm jobs in other segments of the food value chain. The income garnered from these jobs can be used to purchase a wide array of healthy foods, send children to school, purchase health services and medications, and more. At the macro level, food systems power local and national economies, shaped in part by governance, trade, and investment at the global level.

Ideal food systems would be nutrition-, health-, and safety-driven, productive and efficient (and thus able to deliver affordable food), environmentally sustainable and climate-smart, and inclusive. But to realize this vision, continued investments must be made in agricultural research and development and technological innovations, paving the way for programs and policies that are based on sound evidence.

(IFPRI 2020:8)

Understanding how food systems operate from input supplies to consumers, and how the food environment is shaped by natural resources, agribusiness, public policies, civil society, and the multidimensional phenomena of risks and

uncertainty, is necessary in order to identify the leverage points where research and new knowledge can bring about positive change. A food systems approach to knowledge management looks beyond production and the immediate post-harvest environment to downstream functions and players. The roles of gender, inclusiveness and entrepreneurial engagement have been flagged by IFPRI (Malapit et al. 2020).

The importance of food-based approaches to addressing nutrition challenges is surprisingly novel in some situations. Within public sector health and nutrition ministries and departments, it occurs that “therapeutic approaches”, even “therapeutic feeding units” are employed to treat malnutrition and are divorced from efforts to boost agricultural production and exports (Poole *et al.* 2018). Similarly, a recent systematic literature review of the relationships between ecology and agricultural sciences, nutrition and public health, and political economy and policy science and SDG2 “Zero Hunger” found that “the most common approaches to addressing undernutrition have not primarily focused on changing dietary patterns, but have instead emphasized providing supplements and pharmaceutical treatments to vulnerable populations (e.g., supplementation of women of reproductive age and preschool-aged children with micronutrients; deworming, medication; and malaria prophylaxis)’ (Blesh *et al.* 2019:5). Disarticulation of agriculture from nutrition and health, and even health from nutrition, imposes profound disciplinary constraints on what is a multifaceted phenomenon.

Frison and Clément (2020) attribute the poor performance in terms of environmental, social and health impacts of global food systems to the core (mal-)practices of agricultural production, food processing and manufacturing, marketing and regulation of industrial food and farming systems. New food systems approaches are required to cope with the evolving challenges of feeding the growing global population, particularly in the light of changing environmental conditions (Davis *et al.* 2019).

The importance of a systems approach to improving food supply and consumption has been explained by the FAO:

“Agricultural production and trade policies and public investments in research and development (R&D) and in infrastructure are some of the factors that influence the supply of different types of foods. Income, culture and education, among other factors, influence consumers’ tastes and preferences, which, together with relative prices, determine the demand for different foods. Demand, in turn, influences production as well as processing and marketing decisions throughout the food system, in a continuous cycle of feedback loops. The food system thus determines whether the food people need for good nutrition is available, affordable, acceptable and of adequate quantity and quality.”

(FAO 2013:6)

## 5.2 Environmental sustainability

### Key point

- The need for environmental sustainability in agrifood systems

Frison and Clément (2020) advocate in favor of diversified agroecological systems, the principles of which are “based on an integrated understanding of food systems, encompassing their ecological, economic, and social dimensions,” (p.4). For Tajikistan, Kawabata *et al.* (2020) highlight the three food system elements of food supply chains, food environments, and consumer behavior that will be instrumental for achieving SDG2.

Latterly, there has been a call for agricultural systems and development initiatives to shift from traditional plant breeding and the intensification of staple food crops towards more diverse production systems, and particularly nutrient-rich foods such as fruits and vegetables, which can meet the micronutrient malnutrition challenges that are uppermost in the minds of nutrition researchers, development specialists *and* policy makers.

The importance for sustainable development of new “food systems thinking” has been recognized in training packages and found to be attractive and impactful in a variety of geographical contexts, and the multidisciplinary nature of the task is reiterated: “Solutions and improvements in the functioning of food systems are often expected to derive from technological — and especially agricultural — innovations. Yet, we cannot look to these alone to address

all the challenges. New approaches based on ‘food-systems thinking’ are required, drawing on innovative types of learning, analysis and institutional arrangements, coupled with greater horizontal collaboration between economists, agriculturalists, policy makers, ecologists, engineers, food and crop scientists, and business, among many others,” (Ingram *et al.* 2020: 9), and in a vertical sense from international to local levels (Coffman *et al.* 2020).

The EAT Lancet Commission has called for a “Great Food Transformation”: “a substantial change in the structure and function of the global food system so that it operates with different core processes and feedback. This transformation will not happen unless there is widespread, multi-sector, multilevel action to change what food is eaten, how it is produced, and its effects on the environment and health, while providing healthy diets for the global population,” (Willett *et al.* 2019:476). Haddad (2020) emphasizes that international researchers must gain a better understanding of the terrain from post-production to fork: “processing, distribution and storage and retail and marketing spheres” (p.3), and he is insistent on also understanding food consumer behavior. We make the case here for extending post-fork knowledge — from farm to the metabolism of the whole contribution of cereals to nutrition, health and well-being.

A range of analytical frameworks and tools have been developed to research food systems. An early stage of analysis from the perspective of agricultural markets was captured by Kaynak (1986). Another formative approach was derived originally from industrial organization theory (Bain 1968) and subsequently from Porter’s analyses of competitive advantage (Porter 1985; Porter 1990) that introduced the value chain concept. Value chain analysis was launched by Kaplinsky (2000) and developed by Gereffi and Korzeniewicz (1994). Various analytical tools and approaches have been employed and adapted to conduct research into particular aspects of food systems (Bernet *et al.* 2006; Devaux *et al.* 2009; Donovan and Stoian 2012; Devaux *et al.* 2016). Latterly the link between markets or value chains and nutrition has received significant attention (Maestre *et al.* 2017; Maestre and Poole 2018; Donovan and Gelli 2019).

### 5.3 Economic and business sustainability

#### Key point

- The need for economic and business sustainability in agrifood systems

Sustainability approaches have demonstrated a shift in analytical focus from a generalized view of markets and food systems to the more particular and precise analysis of specific value chains and issues of environmental management and sustainability, firm competitiveness, smallholder participation, poverty reduction, gender equity, inclusiveness and profitability, inter alia (Belt and Hellin 2017). The growing advocacy of a “systems approach” to agriculture, food and nutrition (Global Panel on Agriculture and Food Systems for Nutrition 2016; Gillespie and van den Bold 2017) means adopting a broader sectoral and multidisciplinary approach as well as focusing on specific value chains. Analyses will commonly link the micro-issues with meso- and macro issues: “A value chain framework is key to designing inclusive food systems — from improving farmers’ access to resources and information to creating off-farm jobs and enterprises in the midstream of the chain” (IFPRI 2020:6).

Researchers use and abuse what is in reality a fluid terminology. Blesh *et al.* (2019) recently conducted a comprehensive and integrated review of literature concerning ecology and agricultural sciences, nutrition and public health, and political economy and policy science to consider whether the framing of SDG2 “Zero Hunger” is appropriate given current understandings of transitions to sustainable food systems. They identified several limitations to current research that are related to a lack of multidisciplinary among the natural and social sciences, including insufficient analysis linking nutrition with agroecology and policy. They proposed changes in the research agenda and development practices in ways that would require participatory processes of “localization” of concepts, knowledge, initiatives and interventions. They acknowledged the need “to look beyond production to include processing, distribution, and retail steps in food systems [and] that food policy must attend not only to agriculture but also to food supply chains” (p.10). However, recent research has questioned the extent to which the “localization” of food production and consumption along the lines of “food sovereignty” is feasible (Kinnunen *et al.* 2020).

The “quality of local diets” was mentioned by the authors, but despite emphasis on a “food systems perspective,” food processing, manufacturing and consumption patterns did not figure in their analysis, and the discussion of nutrition itself was abstract.

Evidently some analytical compromises have to be made. In the case of cereals, the “systems” range from global trade and the multinational food processing and manufacturing industries, to small-scale systems and local production-consumption chains. Both require detailed engagement with multisectoral partners from production through transformation to consumption and should include disciplines such as regulatory law, education and the psychology of behavior change. It has become of particular importance to understand the determining power of powerful businesses and how they inform and influence the decisions of consumers and thereby determine global nutrition and health (Landwehr and Hartmann 2020; Wright *et al.* 2020).

Tanumihardjo *et al.* (2019) refer to “agro-food systems” to assert the need for sustainability within the world’s major staple crops (maize, wheat and rice). Their systems approach considers interventions from plant breeding, soil fertility, and pest and disease control for improving the nutritional efficiency of maize systems. They also mention alkaline methods of processing the grain (nixtamalization) in order to improve its nutritional and organoleptic characteristics. Ideally, analysis would also contemplate downstream issues in manufacturing, distribution and consumption, and the alternative end-uses for maize as a component of livestock feeds for different species, although they do consider nonfood uses of maize such as energy through the manufacture of bioethanol.

Identifying the potential policy impact pathways on food security and nutrition must be accompanied by an appreciation of the complexities and uncertainties of real markets, practical initiatives and limitations to interventions in the search for sustainable nutritional and health improvements among vulnerable populations:

“agri-food value chain interventions must address the needs of businesses (of all types and sizes) to develop sustainable models, while also contributing to improved diets. This process often involves trade-offs. For example, strategies such as developing new distribution systems, good quality packaging, or brand development will raise costs, undermining the fundamental requirement that poor and nutritionally vulnerable populations can buy the products. Public distribution systems may overcome some of these challenges while facing sustainability and dependency issues ....

“Perhaps the key to sustainable food systems is a ‘food sovereignty’ approach, and sub-national decentralised planning, management, and procurement. This calls for awareness at all levels of decision-making within the different actors – public, private and civil society – for the promotion of nutrition-sensitive agri-food value chains. There is not one solution, but there is space for policymakers and practitioners to set nutrition as a priority and use this framework and these recommendations as a starting point.”

(Maestre and Poole 2018: 15-16).

The decentralized “food sovereignty approach” is consistent with the argument of Frison and Clément (2020) in favor of “diversified agroecological systems” as a means of transitioning away from the unhealthy impacts of industrial food and farming systems. It also respects cultural contexts and local specificities in food supply and demand, and in policy and program decision-making (Poole 2017).

## 5.4 Food safety

### Key point

- Safety and health throughout the food system

Food systems thinking is driven by concerns about multiple players and objectives in food production and distribution, and trade-offs between economic, social and environmental issues. Recollecting that food chains end in human consumption is a reminder that food safety is one dimension that spans the whole food system and demands diverse but coherent technical, commercial and policy responses. One recent framework for considering the sustainable delivery to vulnerable consumers of food products that characterize a healthy diet identifies three required outcomes: (i) Food must be safe to eat; (ii) Food must be nutrient-dense at the point of consumption; and (iii) Food must be consumed in adequate amounts on a sustained basis. This approach highlights the downstream aspects of food security and the relationship between agrifood businesses and their customers (Maestre *et al.* 2017; Maestre and Poole 2018). The “health” envisaged in the SDGs is, of course, not just a consequence of adequate nutrition, and is much more than the absence of disease. Food safety, intrinsically linked to the concept and definition of food security, has to be linked to nutrition in the same way as the provision of clean water, adequate sanitation and hygiene.

As an example of the food-safety challenges to nutrition and health, and the importance of taking a food systems approach to assuring nutrition and health, mycotoxins are an important agent. The health and economic threats are considerable: “Mycotoxins not only pose a risk to both human and animal health, but also impact food security and nutrition by reducing people’s access to healthy food,” (WHO 2018b). For cereal food systems, aflatoxicosis is a common health hazard in Africa, first identified in the 1960s. It is caused by ingestion of mycotoxins derived from the soil-inhabiting fungi *Aspergillus flavus* and *Aspergillus parasiticus* that can invade the plant and growing seeds by wind dispersion and insect damage. Aflatoxins in maize can develop in the field, causing ear-rot, and in the absence of field contamination, during post-harvest grain processing and storage. They can also be found in groundnuts, cotton and certain tree nut species (Council for Agricultural Science and Technology 2003).

*Aspergillus spp* are found worldwide but principally in subtropical and warm temperate regions. Crop susceptibility to the fungi is likely to become more widespread due to climate change and global warming (EFSA no date). Aflatoxin is a contaminant of human food and livestock feed due to its common occurrence in cereals, especially maize, and derived food products. Aflatoxins are a potent hepatotoxin causing acute impaired liver function but are also associated with a range of other chronic diseases, including cancer, whose epidemiology is less well researched. The European Food Safety Agency consider aflatoxins to be genotoxic and carcinogenic (EFSA no date). In livestock aflatoxins can reduce milk and egg production, and cause suppression of immunity and increased susceptibility to infectious diseases such as salmonellosis. It is a particular threat to poultry industries.

In the maize sector, the potential for aflatoxin contamination throughout multiple food and feed chains of both human and livestock diets imposes significant systemic control challenges. The implementation of international food safety standards is problematic in developing economies where knowledge and regulatory controls are weak. Research in Africa is led by the Partnership for Aflatoxin Control in Africa (PACA). A systems approach to food safety in the maize sector was recently designed and implemented in Kenya, funded by the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH) (PACA no date). Results suggested that testing procedures throughout the maize value chain could enhance food safety from aflatoxin poisoning for 10 million Kenyans (Hoffmann 2020). The significance of sectoral interventions was also highlighted. Recommendations included “the adoption of coregulation that is a governance option that uses government-backed standards adopted by industry, leading to shared responsibility to manage aflatoxin risk in Kenya and elsewhere in the region” (Herrman *et al.* 2019: 146). This and other research illustrate the importance of collaboration with farmers and with private sector firms such as maize millers (Fisher *et al.* 2019; Pretari *et al.* 2019). More understanding of the political economy of food businesses and the regulatory environment, and of how food choices are influenced by state and commercial policies is one area for research. Another is more understanding of the importance of the behavioral questions underlying consumers’ food preferences and consumption patterns (Haddad 2020). Research objectives have to include the identification of viable context-specific approaches to multistakeholder behavioral change, with a focus on knowledge and experience downstream of production, notably of the food industries and final consumers in developing country contexts.

## 5.5 Food waste

### Key point

- Food waste is a major global source of nutritional losses and food insecurity

As well as increasing productivity, another strategy for improving food security is to reduce the losses in food systems. Post-harvest losses are known to account for a major part of global food production. Food waste is a serious threat to narrowing the gap between supply and demand (Mason-D’Croz *et al.* 2019), and the causes of losses persist throughout the food system. In 2011, the FAO estimated that roughly one-third of food produced for human consumption, amounting to somewhat more than 1 billion tonnes, was lost (throughout the supply chain) or wasted (at the retail and consumption level) globally, although there are major gaps in data availability and in understanding the phenomenon:

“The causes of food losses and waste in low-income countries are mainly connected to financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities in difficult climatic conditions, infrastructure, packaging and marketing systems. Given that many smallholder farmers in developing countries live

on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods. The food supply chains in developing countries need to be strengthened by, inter alia, encouraging small farmers to organize and to diversify and upscale their production and marketing. Investments in infrastructure, transportation, food industries and packaging industries are also required. Both the public and private sectors have a role to play in achieving this” (FAO 2011:v).

Improvements in food systems may not be costly or technologically advanced. Recent research on combating losses in Tanzania, mainly for maize, found that the use of inexpensive 100kg (maize) hermetic storage bags could reduce infestation by and losses through insects and other pests and mitigate food insecurity by 38% in the lean season for smallholder farmers (Brander *et al.* 2020). In this case, disentangling the effects of the technology itself from the effects of training on the adoption of new storage technology needs further work, and illustrates the multisectorality of many of the food security and systems challenges which constrain good nutrition and health.

# 6

## The food value of staples

### 6.1 Not just micronutrients

#### Key points

- Good health is more than good nutrition, and good nutrition is more than micronutrient sufficiency
- Cereals provide macro-, micro- and other nutrient components of a healthy diet

While child micronutrient malnutrition is center-stage, the health consequences of undernutrition (energy insufficiency) and overnutrition (energy excess) for adults and children are also quantitatively significant. Energy matters universally, but has particular importance for poor people and victims in the many humanitarian situations which persist due to natural disasters such as famines and floods, and anthropogenic disasters such as conflict (Global Panel 2020). Stocks and storage of relatively non-perishable staples are necessary not only for acute humanitarian situations but also for the chronic challenges that are likely to arise from anticipated climate change. Under seasonal conditions of hardship and hunger, staples provide necessary bulk and energy. It is evident also that poor people appreciate the addition of carbohydrates in the form of sweeteners to otherwise impoverished diets (Poole *et al.* 2019).

Starchy staples are the predominant source of carbohydrates and energy in the “global diet.” Wheat, maize and rice are the principal staple cereals, and they also contribute significantly to protein intake (Lafiandra *et al.* 2014). The nutritional content of different species varies, but cereals are an important source of some micronutrients and a range of phytochemicals such as phenolics, flavonoids, anthocyanins, phytosterols, carotenoids, policosanols, and phospholipids (Saldivar 2016).

Accordingly, wheat makes a huge global contribution in terms of food supply, nutrition and health (Saldivar 2016; Peña-Bautista *et al.* 2017) and provides about one-quarter of the global annual demand for plant proteins, carbohydrates, and dietary fiber (Shewry and Hey 2015b). Similarly, maize is of incalculable food and cultural significance in the Americas, has become a pervasive staple in sub-Saharan Africa and is produced and consumed in many other regions (Bañuelos-Pineda *et al.* 2018; Palacios-Rojas *et al.* 2020). The milling of cereal grains tends to reduce nutritional content (Heshe *et al.* 2015; Oghbaei and Prakash 2016), while some forms of processing such as the nixtamalization of maize — an important benefit of which is to release niacin (vitamin B3) — and sprouting and fermentation can improve the nutritional content of foods derived from cereals (Rosales *et al.* 2016). Like wheat, maize is food, livestock feed, and an important food industry input for producing so-called “nutrient-rich” livestock foods.

Cereal proteins are low in the essential amino acids lysine and to a lesser extent threonine. The lipid fraction contains essential fatty acids such as palmitic and linoleic acids, fat-soluble vitamins and phytosterols. Polar lipids present in cereals may contribute to reducing cholesterol absorption and improving the microbiome of the gastrointestinal (GI) tract. There are also significant dietary amounts of the B vitamins thiamine, riboflavin, niacin and pyridoxine, some biotin and folic acid, and tocol derivatives which are vitamin E precursors and inhibit cholesterol biosynthesis. There are appreciable amounts of phosphorous and potassium, calcium, zinc, magnesium and copper. Antioxidants and phytochemicals present in grains provide some protection against oxidative processes against cancers, cardiovascular diseases, cataracts, impaired immune systems and brain damage. Cereal grains also include phytates which may reduce the bioavailability of minerals, amino acids and starch. Levels of bioactive compounds can be increased or decreased by processing such as milling and breadmaking (Dewettinck *et al.* 2008).

Besides containing some protein, wheat is relatively rich in vitamins (notably B vitamins), dietary fiber, and phytochemicals. Maize protein is deficient in tryptophan as well as lysine but contains important sulfur-containing amino acids (methionine and cystine) and some minerals. The whole grain is rich in anthocyanins with many nutritive properties which can be conserved by the process of the traditional process of nixtamalization (Bañuelos-Pineda *et al.* 2018).

Cereals provide many essential food components besides macronutrients and some vitamins and minerals. Bañuelos-Pineda *et al.* (2018) outlined the nutraceutical properties of many constituents of maize: important bioactive peptides, resistant starches that are components of dietary fiber, phenolic compounds including non-anthocyanin flavonoids, phenolic acids, and anthocyanin flavonoids, carotenoids and other antioxidants, some of which are implicated in the regulation of fat in the diet and in insulin responses in diabetics. There is probably a prebiotic effect of the high-amylose type 2 resistant starch of maize that can contribute to the modification of the gastrointestinal microbial flora, potentially contributing to the management of obesity through controlling energy expenditure. Also, in combating cancers, the pigmented varieties of maize rich in anthocyanins have been shown to have antimutagenic properties. Positive effects on the nervous system, on Alzheimer's disease have also been suggested.

Thus, only relative to other so-called “nutrient-rich” foodstuffs are starchy staples apparently “nutrient-poor.” This terminology reflects the focus on micronutrient malnutrition and tools like the food consumption score and is not helpful. Most staples provide varying amounts of proteins, fats, minerals and vitamins (Jones *et al.* 2020), and such content, particularly in major cereals, is amenable to improvement (Mattei *et al.* 2015; Shewry and Hey 2015b; Yu and Tian 2018; Fukagawa and Ziska 2019; Palacios-Rojas *et al.* 2020; Zhao *et al.* 2020). Above all, there are the “non-nutrient” food components of staples to consider.

Since the Joint FAO/WHO Expert Consultation on Carbohydrates in Human Nutrition in 1997, carbohydrates have been known not only as an energy source, but also as having important impacts on the maintenance of health (Nishida and Martinez Nocito 2007). Carbohydrates are a complex and contested “nutrient.” Based on their chemistry, carbohydrates are usually divided by molecular size into sugars (monosaccharides and disaccharides), polyols, oligosaccharides (malto-oligosaccharides and non-digestible oligosaccharides) and polysaccharides (starch and non-starch polysaccharides) (Cummings and Stephen 2007; SACN 2015). Additional terms can be used to define groupings based on their physiological properties (Cummings and Stephen 2007; Nishida and Martinez Nocito 2007). Thus, carbohydrates can also be classified according to their digestion and absorption properties: digestible carbohydrates are absorbed and digested in the small intestine; nondigestible carbohydrates are resistant and reach the large intestine where they are at least partially fermented by the commensal bacteria present in the colon (SACN 2015). It is principally the overconsumption of the disaccharide sucrose — common sugar — and not carbohydrates as a whole, which is implicated in obesity, diabetes, dental caries and possibly other adverse health conditions (Prinz 2019). However, adverse reactions to specific carbohydrates are also well documented: for example, specific components of wheat affect people with celiac disease and wheat allergy, and possibly nonceliac gluten sensitivity (Brouns *et al.* 2019).

## 6.2 “Non-nutrient” food components of staples

### Key point

- Cereals are rich in non-nutrient components of foods, in particular dietary fiber

Given the pre-eminent preoccupation with micronutrient malnutrition, the World Bank review (2014) also points to other essential components of foods that, puzzlingly, are not considered to be nutrients: “Other components of food that are not technically ‘nutrients’ also contribute to nutrition and health, such as fiber, probiotic bacteria, and phytonutrients,” (p.3). Ecker's assessment of the contribution of foods to diets is helpful in going beyond “nutrients” to include both fiber and also the unhealthy components, primarily derived from processed and manufactured foods (Ecker 2019). The beneficial bioactive but “non-nutrient” food components (BIOFOCS) are known to prevent and combat diet-related NCDs and other health conditions. NCDs are highly significant for global health and are recognized in SDG3 “Good Health and Well-being” and specifically, target 3.4 “to reduce premature mortality from non-communicable diseases” (United Nations 2020b). In addition to energy and the modest micronutrient content, many “non-nutrient” dietary components such as fiber and phytochemicals are found also in staple foods. For this reason also, it is a mistake to classify staples automatically and universally as “nutrient-poor”.

The 2020 State of Food Security and Nutrition departs from conventional terminology on non-nutrient food components, notably specifying dietary fiber as a carbohydrate nutrient and a constituent of a healthy diet: the report counts as nutritious those foods that “tend to be high in essential nutrients such as vitamins and minerals (micronutrients), as well as proteins, unrefined fibre-rich carbohydrates, and/or unsaturated fats and are low in sodium, free sugars, saturated fats and trans fats” (FAO *et al.* 2020:256). The report also notes that a healthy diet protects against NCDs such as diabetes, heart disease, stroke and cancer. However, the report still focuses on SDG2, and economic “health costs” are only addressed directly in the SDG3 target, demonstrating the lack of wider consideration of the dietary contribution of carbohydrates, in addition to energy, i.e., DF and other bioactive food components.

It is difficult to tread the lines between the different food, nutrition and health objectives because of the nuances about the contribution of staple foods, and cereals in particular, to nutrition and health. This is partially acknowledged in the recent Global Panel report on food systems in fragile contexts that acknowledges the need for calories and micronutrients to meet SDG2 but ignores the contribution of staple cereals to health and well-being (SDG3): “diets based primarily on staple cereals or tubers lack diversity, which contributes to micronutrient deficiencies .... A much greater effort on enabling access to healthy diets is required, rather than focusing on consumption of staples or relying on humanitarian interventions to ‘fix’ serious and widespread nutrient deficiencies,” (Global Panel 2020). Nevertheless, the need for balance is indicated in priority 3: “Focus on nourishing as well as hunger. Ensuring the supply of staples is vital. Other high-nutrient foods are also vital for health development, particularly for pregnant women, infants and adolescent girls. This means paying extra attention to interventions that increase dietary diversity” (p.24).

Hence, BIOFOCS are not well-covered in agriculture and nutrition literature and in research focusing on SDG2, and seem to be largely siloed in the biomedical disciplines, food sciences and discussions of functional foods, in the same way, it is argued, that nutrition is siloed from agrifood sustainability (El Bilali 2019). BIOFOCS discussions are, however, present in popular health media (Brouns *et al.* 2017; Duyff 2017). It is often difficult there to disentangle food science and policy from food populism and marketing, whose concerns “have generally not been substantiated by detailed scientific review,” (Shewry 2018:470). Research and advocacy alike in this area need a boost, considering the dangers of what has been called an “infodemic” (The Lancet 2020): an over-abundance of information that may or may not be accurate — i.e., “fake” evidence.

### 6.3 Dietary fiber (DF) for human health

#### Key point

- DF is essential for metabolic processes

Knowledge of the role of dietary fiber (DF) in reducing the incidence of diabetes, circulatory diseases and some cancers is evidenced in many studies (Lockyer *et al.* 2016). DF is at the heart of many pro-health metabolic processes, yet there is scant detail in the WHO Fact Sheet (WHO 2018a)vegetables and other dietary fibre such as whole grains... Eating at least 400g, or five portions, of fruit and vegetables per day reduces the risk of NCDs (2 on the role of fiber in the diet: “Eating at least 400 g, or five portions, of fruit and vegetables per day reduces the risk of NCDs and helps to ensure an adequate daily intake of dietary fibre.” Indeed, recognition of the complex contribution of carbohydrates is absent when entering into recommendations to policy makers on healthy and unhealthy foods, and when engaging with the industrial food sector. Dietary fiber is one of the principal “non-nutrient” components of food at the heart of key metabolic processes. Understanding of DF and its implications for health, and policies associated with it, have lagged behind those of the commonly accepted macro- and micronutrients. Recalling the earlier work that predates much of the knowledge of vitamins and minerals will serve to highlight the knowledge gap.

#### *Evolution of work on DF*

In 1979 a medical doctor named Denis Burkett<sup>14</sup> summed up years of research in a short, popular book entitled, “*Don’t Forget the Fibre in your Diet: To Help Avoid Many of our Commonest Diseases.*” Burkitt had identified the role of diet as one cause of the differences in the epidemiology of NCDs between western countries and sub-Saharan Africa, where

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<sup>14</sup> Burkitt identified the eponymous lymphoma.

he had worked for 20 years post-World War II, and subsequently for 13 years in the U.K. Burkitt commented that an insufficiency of fiber in the diet had been noted by Dr T.R. Allison in the last two decades of the 19<sup>th</sup> century, and a warning of the dangers of overprocessing food was raised by Sir Robert Macarrison in the early 1900s. This observation was largely ignored until Surgeon Captain T.L. Cleave of the British Royal Navy linked a number of diseases of unknown cause to the consumption of overrefined carbohydrate foods. Burkitt attributed his own recognition of the importance of unrefined carbohydrates in diet and health to Cleave.

Burkitt knew that the dietary importance of proteins, fats, carbohydrates, minerals and vitamins was well understood, even though nutrition and food science continued advancing, of course. From the first edition of *"The Composition of Foods"* (McCance and Widdowson 1940), DF appeared in the nutritional discourse mostly as an inert substance, and Burkitt also noted that dietary fiber did none of the things that macro- and micronutrients do. But "its significance has been ignored," (Burkitt 1979:9). He wrote that the importance of what is now referred to as the nutrition transition "is only beginning to be grasped by scientists throughout the world. A significantly increased intake in fibre-rich cereal foods... might significantly reduce the prevalence of some of the diseases [NCDs] mentioned earlier." (p.11)

### **Current thinking about DF**

An issue of the *European Journal of Clinical Nutrition* (Mann *et al.* 2007) summarized the FAO/WHO Scientific Update on carbohydrates in human nutrition. It is now somewhat old, but not yet superseded, and highlights the complexity of carbohydrate sciences, the importance of DF, and some knowledge gaps.

In their recent review of the early work on DF, Cummings and Engineer (2018) noted that not all the conditions envisaged four decades ago can now be linked to dietary fiber. There is now a much better understanding of what DF is, of its physiology, biochemistry, metabolism and its importance in disease prevention. Its significance is still poorly acknowledged compared with the early nutrition era preoccupation with protein-energy malnutrition and latterly the massive concern about micronutrient malnutrition. Dietary guidance still focuses on topics other than fiber (Stephen *et al.* 2017).

Nevertheless, the importance of DF is common currency among food scientists, nutritionists, food manufacturers and in food packaging and promotion; DF is also a major segment of the functional foods market (Mudgil and Barak 2019). Broad guidelines for DF intake exist in national and international nutrition policies but awareness lags behind that of vitamins and minerals. In fact there is scant detail in the WHO Fact Sheet on the role of DF: "... many people do not eat enough fruit, vegetables and other dietary fibre such as whole grains .... Eating at least 400g, or five portions, of fruit and vegetables per day reduces the risk of NCDs and helps to ensure an adequate daily intake of dietary fiber" (WHO 2018a)vegetables and other dietary fibre such as whole grains... Eating at least 400g, or five portions, of fruit and vegetables per day reduces the risk of NCDs (2).

DF is largely made up from carbohydrates but unlike specific "nutrients" DF includes diverse substances. A universal definition has yet to be agreed, but the Codex Alimentarius Commission established a definition in 2008 as substances composed of carbohydrate polymers with ten or more monomeric units, which are not hydrolyzed by the endogenous enzymes in the small intestine of humans. Whether or not non-digestible polysaccharides are included was left to national authorities (Tobaruela *et al.* 2018). As noted by the EU Science Hub:

"AOAC fibre includes NSP fibre but in addition it also includes non-digestible carbohydrates (naturally present and isolated from foods and/or synthesized) that can be added as ingredients to foods. In general, figures for AOAC fibre are higher than NSP fibre. As such, the reported fibre content in foods can vary depending on the definition and/or the method used to quantify it."

(EU Science Hub 2020: no page numbers).

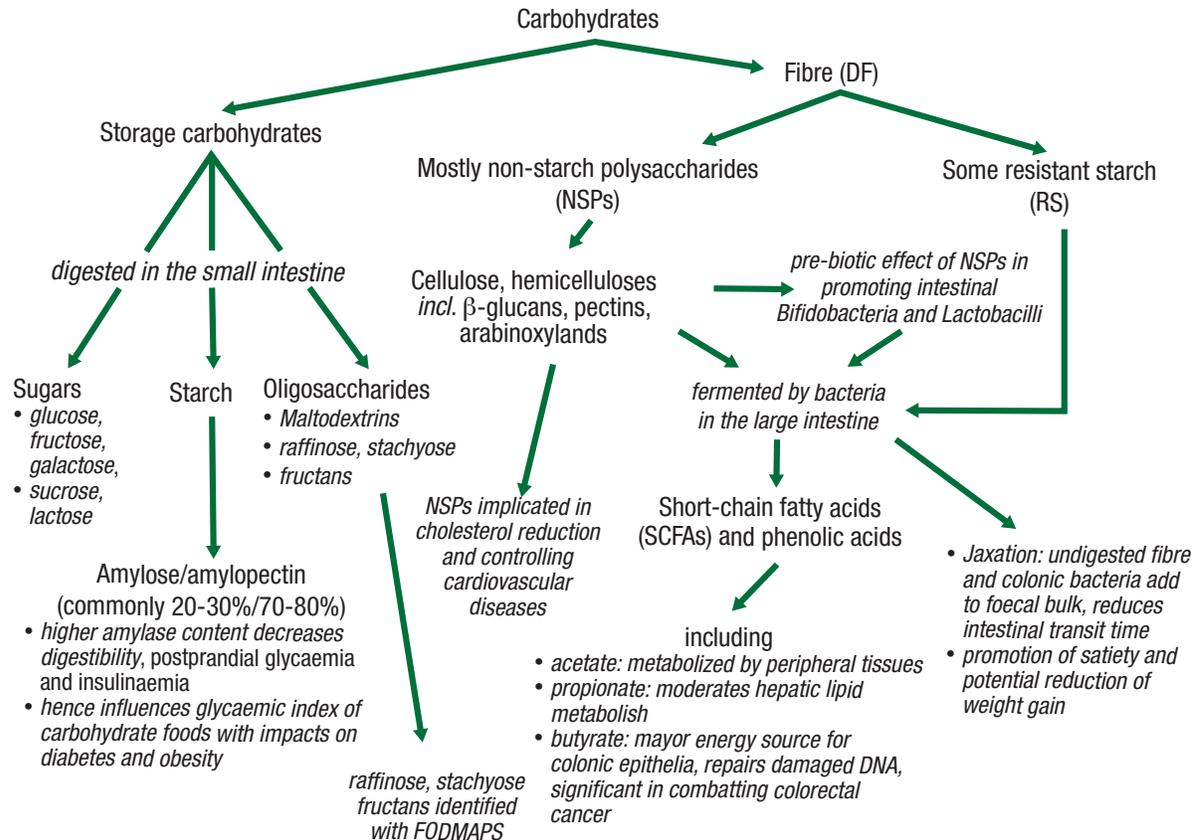
Greater precision has been proposed since, although both the definition and the analytical methods are still not universally agreed:

"Dietary fibre is made up of carbohydrate polymers with three or more monomeric units (MU), which are neither digested nor absorbed in the human intestine and includes: (1) NSP [non-starch polysaccharides] from fruits, vegetables, cereals and tubers whether intrinsic or extracted, chemically, physically and/or enzymically

modified or synthetic (MU $\geq$ 10); (2) resistant (non-digestible) oligosaccharides (RO) (MU 3–9); and (3) resistant starch (RS) (MU $\geq$ 10). When extracted, chemically, physically and/or enzymically modified or synthetic, generally accepted scientific evidence of benefits for health must be demonstrated to consider the polymer as dietary fibre. Most definitions also include ‘associated substances’, which are non-carbohydrate such as lignin and substances which are present in cell walls linked to polysaccharides and quantified as dietary fibre by the accepted analytical methods.”

Stephen et al. (2017:150).

Figure 2 provides a simplified summary of the types of dietary carbohydrates, digestion and the metabolic contribution.



**Figure 2. Carbohydrate digestion and metabolism.**

Source: Poole et al. (2020)

### DF intakes and human health

The current pandemic of NCDs suggests that there is more to be learnt about dietary fiber and consumption patterns. Even what is now well-known has had limited influence on public policy and still less on public health. The food industry continues to mill away much of the nutritional content of cereals including micronutrients, DF and other essential components (Jones et al. 2015c) and create UPFs containing substances such as added polyols which are identified with FODMAPs (Fermentable Oligo-, Di-, Mono-saccharides And Polyols, Figure 2). Consumers continue to eat UPFs out of individual preference in the absence of a strict pro-health public policy, resulting in the huge and increasing global economic and social costs of NCDs (Muka et al. 2015).

Table 3 shows results from the U.K. National Diet and Nutrition Survey (NDNS) illustrating the high proportion of the population whose fiber intake falls below the national guidelines. The age and gender group with the highest percentage meeting the fiber recommendations of the Association of Official Analytical Chemists (AOAC) fiber was men, 19-64 years, at 13%, and the lowest was girls, 11-18 years, at 2%.

**Table 3. Dietary fiber intake gaps.**

Average daily intake of AOAC fibre for NDNS RP UK Years 7 and 8 (combined) (2014/15-2015/16)									
	NDNS age groups (years)								
	1.5-3	4-10		11-18		19-64		65+	
	combined	boys	girls	boys	girls	men	women	men	women
AOAC fibre intake (g/day)	10.3	14/5	13.5	16.5	14.1	20.7	17.4	19.0	16.4
% meeting the AOAC fibre recommendations	10	11	9	6	2	13	4	9	4

Source: PHE (2018:12)

In the European Union, “Despite the different methodologies used for the assessment of food consumption in the surveys and lack of comparable data between countries, it appears reasonable to conclude that many EU citizens do not meet recommended intakes of dietary fibre” (EU Science Hub 2020: no page numbers). According to the Scientific Advisory Committee on Nutrition (SACN), the dietary reference value for total carbohydrate should approximate to 50% of total dietary energy, with lower intakes of free sugars, being an intake for adults of 30g/day, representing a significant increase in intakes (2015). The study of U.K. diets by Nocella and Srinivasan (2019) commented that “Compliance with guidelines for dietary fibre intake is generally poor in all the segments” (p.9). Lockyer *et al.* (2016) attributed deficient intakes of DF to a range of factors:

- Limited public interest from the media compared with other nutrients such as sugars;
- The economic cost of fruit and vegetables;
- A public perception of starchy carbohydrates as unhealthy;
- Consumer preferences for refined grain products rather than whole grains;
- Lack of a clear and comprehensible recommendation and awareness campaign for DF or wholegrain intake — unlike in other countries such as the United States and Denmark;
- Regulatory constraints on health claims for fiber and wholegrain;
- No mandatory labeling of fiber values on food packaging.

Summarizing other research, they noted that high prices, limited availability and convenience, rapid spoilage of fresh food sources of DF, attractiveness of competing foods and unwillingness to change consumption behavior as other factors.

DF science is complex, with interactions and some trade-offs between nutrients and dietary objectives, and contrasts with the (over-)simplicity of dietary guidelines:

“Assessing the specific or unique role of dietary fibre in reducing the risk of NCDs and on other health outcomes is complicated by the existence of other nutrients in fibre-rich diets that may also exert a protective role as well as other confounding factors. For example, fibre is found in many foods that also have lower energy density (e.g., most fruits and vegetables), low glycaemic index (e.g., pulses, vegetables, whole grain cereals, some fruits), and that are sources of a wide variety of micronutrients and bioactive compounds (pulses, fruit, vegetables, whole grain cereals, seeds, nuts).”

(EU Science Hub 2020: no page numbers).

For example, “guidance to reduce energy intake for obesity concerns is likely to result in reduced fibre intake, and emphasizes the need for increased energy expenditure to enable not only higher energy intakes but higher intakes of other necessary nutrients, such as fibre” Stephen *et al.* (2017:150). And not all fiber is equal. On the most beneficial types of fiber and foods, Stephen *et al.* note that “... although there are benefits from consumption of all sources of

fibre, associations and degree of protection conferred are generally greater for grains. Grain sources of fibre are not all equivalent, however, and there are marked differences in composition between wheat, rye, oat and rice ....” (2017:150)

Stephen *et al.* (2017:150) highlight the latest knowledge on DF intake, types and dietary sources, and the relationships with NCD risks. The last are numerous: all-cause mortality, cardiometabolic health and risk factors including hypertension and/blood pressure, hyperlipidemias, type 2 diabetes, obesity in terms of both energy intake and appetite effects, gastrointestinal health including fecal weight and constipation, diverticular disease, esophageal disease and a range of cancers. DF increases fecal weight, bulk and softness, frequency of defecation and reduces intestinal transit times — contributing to the reduction in colon cancer and other bowel disorders. Soluble fibers slow down glucose absorption, reduce plasma cholesterol concentrations and assist the management of diabetes and heart diseases (Dewettinck *et al.* 2008).

A series of systematic reviews and meta-analyses of prospective studies conducted on carbohydrate quality and human health by Reynolds *et al.* (2019) went beyond studies using a single marker (e.g. dietary fiber, whole grains or pulses, dietary glycemic index, or glycemic load) and a limited number of clinical outcomes. They examined several markers in NCD incidence, mortality, and risk factors in order to establish more precise recommendations for intakes of DF. They concluded that higher intakes of DF or whole grains were likely causally associated with reductions in the risk of mortality and in the incidence of a wide range of NCDs and risk factors. Interestingly, in the light of popular concerns about starchy foods intakes, they found less evidence for the potential benefit of low glycemic index or glycemic load diets. Whole foods that required chewing were also reported to affect satiety, glucose and insulin responses and lipid absorption, and to influence fermentation in the large intestine by the gut microbiome. They found convincing evidence for dietary recommendations to replace refined grains with whole grains and to increase DF consumption to at least 25–29 g per day, with greater benefits likely from greater intakes. The significance of satiety effects is likely to increase in this era of obesity (Hasbay 2019).

The most recent research on the implications post-prandial glucose levels and glycaemia in appetite and energy intake modulation has cast further doubt on the value of the glycemic index and glycemic load diets as accurate markers: reductions in postprandial glucose levels 2-3 hours after a meal were found to be better predictors of self-reported hunger and subsequent energy intake than levels 0-2 hours after eating (Wyatt *et al.* 2021). A result of these ongoing bio- and metabolic studies are beginning to demonstrate more persuasively that the precise composition of diets, including consideration of DF content, and variation in individual’s responses to food intakes, have a major part of play in energy metabolism and health and well-being more generally.

It is evident that there is still more complexity to research on DF science, and carbohydrates in particular, with implications for plant breeding. Another fertile area is the ways in which DF is the prebiotic substrate for the gut microbiota which act on undigested polysaccharides (resistant starches, hemicellulose, pectins and gums) and oligosaccharides as well as proteins, peptides, and glycoproteins (Machate *et al.* 2020). Short-chain fatty acids (SCFAs), for example, butyrate, together with propionate and acetate, are essential products of microbial fermentation and are major components in the maintenance of healthy gut integrity and physiology, promoting immune and metabolic homeostasis and having important anti-inflammatory and antitumorigenic effects (Francino 2016). Butyrate has for a while been known to be associated with gut health and possibly improved immune response beyond the gut (Slavin 2003), and seems to have a role in both alleviating and promoting obesity (Liu *et al.* 2018). More generally, SCFA production contributes to health promotion and disease prevention and is implicated in managing obesity and associated disorders (Jefferson and Adolphus 2019; Machate *et al.* 2020), even improving cognition and mood. Work by De la Cuesta-Zuluaga *et al.* (2019) suggests that gut microbiota dysbiosis affecting gut permeability and hence reducing absorption of fecal SCFAs derived from DF is associated with obesity, hypertension and subclinical measures of cardiometabolic disease. They highlight the interrelationships between gut microbiota richness, the role of SCFAs and the intake of DF. They note the potential for SCFA modification through diet, pre- and probiotic interventions, and also the need for greater knowledge.

#### **DF intakes and cereal grains**

As Stephen *et al.* note in their review of DF in Europe, “Grain products provide the largest proportion of fiber in the diet for all countries studied, with bread by far the largest grain source, with smaller contributions from breakfast cereals, pasta and biscuits and pastries. Vegetables, potatoes and fruits also contribute substantially, but these vary

more widely from country to country, depending on climate and cultural norms. Recommendations about types of fiber to consume are therefore difficult as ‘not one size fits all’, with some foods more likely to be consumed in some countries compared with others” (Stephen *et al.* 2017:182). Nevertheless, a recent systematic review of the effects of intact cereal grain fiber (both the soluble and insoluble non-digestible carbohydrates) on the composition of gut microbiota and hence the products of carbohydrate fermentation noted positive effects even from modest dietary intakes (Jefferson and Adolphus 2019), such that people with the lowest intakes have the most to gain: “The strongest evidence lies in the role of wheat bran and wholegrain wheat fiber promoting gut microbiota diversity,” (p.18). The effects of processing also matter: considerable caution should be exercised about the quality of processed grains and of fiber added to manufactured foods compared to naturally occurring DF within whole grain foods (Slavin 2003; Reynolds *et al.* 2019). All research points towards dietary guidelines with more fiber, less processing and manufacturing, and more whole foods, including staples.

A U.K. report on “Carbohydrates and Health” (SACN 2015) makes a series of important observations about the health effects of DF and whole cereal grain foods and intakes. Overall, the balance of carbohydrate qualities rather than quantity is likely to determine the major health outcomes: “total carbohydrate intake appears to be neither detrimental nor beneficial to cardio-metabolic health, colo-rectal health and oral health ... there are specific components or sources of carbohydrates which are associated with other beneficial or detrimental health effects,” (SACN 2015). Moreover, “A standardized definition of ‘wholegrain’ and wholegrain foods should be developed, both to facilitate recommended portion sizes for wholegrain foods and to complement public health messages about the importance of dietary fibre... SACN would welcome research to improve the functional categorization of specific dietary fibres and relevant extracts: building structure-function understanding to link and predict from defined, measurable physical and chemical properties to specific physiological effects. This should include defining physiologically meaningful effect ranges for colonic and faecal pH, short chain fatty acids, and bacterial populations,” (p.199).

## 6.4 Broader health effects of cereal foods

### Key points

- Other nutritional dimensions of cereal food products
- Cereals cause adverse effects in the diets of some people

It is well-established that whole-grain cereal intake is protective against cancer, cardiovascular disease (CVD), diabetes and obesity through complex and diverse mechanisms, which are not yet well understood because nutritional studies usually look at individual nutrients rather than foods (Slavin 2003; Fardet 2010; Brouns *et al.* 2013; Lafiandra *et al.* 2014). The meta-analysis by Zong *et al.* (2016) showed inverse associations between whole grain intake with mortality from all causes, CVD, and cancer, and findings were particularly strong and robust for CVD mortality.

A recent series of publications has shown the major contribution of grains and carbohydrates to disease prevention (Jones *et al.* 2015c; Jones *et al.* 2015b; Jones *et al.* 2016; Korczak *et al.* 2016; Jones *et al.* 2017b; Jones *et al.* 2017a; Jones *et al.* 2017c), and Bach Knudsen *et al.* (2016) report that the dietary fiber components of wholegrains together with the BIOFOCS are likely to exert at least two positive effects: a direct impact on glycemia and insulinemia, and an indirect influence on the gut microbiome and the products of colonic fermentation.

Using data from 11 countries participating in the Global Nutrition and Epidemiologic Transition Initiative, Mattei *et al.* (2015) concluded that research to identify and promote the intake of culturally-acceptable, high-quality staple foods could be crucial in preventing diabetes: “The evidence from both observational and intervention studies is sufficiently strong to support the notion that improvements in the quality of main staple foods could lower the risk of diabetes. Strategies for such may include substituting whole wheat staple foods for refined ones (i.e. brown for white rice, whole grain bread for white bread, or high-fiber corn or whole wheat tortillas for refined flour tortillas)” (2015:15). The anthocyanins of maize have antioxidant properties and functions that modulate intracellular signals in different tissues of the organism. Arguably, maize is a “functional food” which combats diseases such as cancer, diabetes, obesity, and neurodegenerative disorders. Likewise, a diet that includes corn can be implemented during the treatment of these diseases (Bañuelos-Pineda *et al.* 2018).

Biofortification and industrial fortification are proven and feasible means to increase the already respectable levels of micronutrients (Prasanna *et al.* 2020). Staples are by definition the principal dietary constituent through which to undertake effective fortification (Altenburg and von Drachenfels 2006; Ansari *et al.* 2018; Maestre and Poole 2018). Traditional plant breeding must also play a part in meeting increased nutrient demands. For example, cereal research technologies can be used to enhance DF content: Shewry *et al.* argue that there is potential to identify or develop lines with increased amylose content (2015b:7). Regarding the heritability of DF, there is a need to identify molecular markers to reduce the need for expensive chemical analyses during screening.

Relatively new research on the role of microbiomes — the complex of organisms in the microbial community of a host — is casting light on the interactions between gut microbial flora in humans and on the significance of these for auto-immunity and health (Antwis *et al.* 2020). Cereals, and specifically the DF components, are implicated significantly in these processes. New understanding is being generated on the symbiotic associations between individual organisms, ecosystems, and microbial flora. Interactions between gut microbes and nutrition in humans are particularly important in respect of foods, digestion and nutrient assimilation (Donkersley *et al.* 2020). In particular, increasing levels of gut microbiome dysbiosis and novel medical interventions such as fecal transfers are being tested to improve guidance and technologies for improved human nutrition and health. Further work with biomedical researchers is necessary to clarify the metabolic contribution of cereals due to their resistant fiber, carotenoids and polyphenol content. “Non-nutrients” such as bioactive peptides with significant biological activity also contribute nutraceutical qualities to cereals. The challenge for plant breeders is to preserve and increase these biomedical properties, and for industry to conserve them during food processing.

#### ***Adverse health reactions to wheat and other cereal products***

There are foods and food components that make a negative contribution to diets. This is highlighted by the growing concerns about ultraprocessed foods (UPFs) and super-intakes of salt, hydrogenated fats and free sugars, *inter alia* (Monteiro *et al.* 2018; Vandevijvere *et al.* 2019). At worst, these foods and food components are “anti-nutrients”, noxious rather than nutritive, and exacerbate the consequences of the third dimension of the triple burden — overnutrition. In effect, they undermine SDG3 (Collins *et al.* 2019; United Nations 2020b).

Wheat and wheat-derived products are associated with a range of adverse effects on human health and well-being, notably irritable bowel syndrome (IBS), a generalized dietary condition of the digestive system, and celiac disease, a more specific adverse immunological response to gluten (Brouns *et al.* 2019; Rustgi *et al.* 2019). The Well on Wheat (WoW) project integrates scientific and industrial researchers in a public-private consortium to elucidate the health aspects of wheat consumption and wheat gluten avoidance, and in particular to understand the chemical composition of different wheat species and the compositional changes that may occur as a result of processing wheat through milling, yeast/sourdough fermentation and baking.<sup>15</sup> One of the principal challenges is to separate the science from communication through social and celebrity media and popular health publications (Brouns *et al.* 2017; Duyff 2017; Jones *et al.* 2020). As noted earlier, disentangling food science and policy from unsubstantiated food populism and marketing is a challenge for science and health education.

Glutens and amylase trypsin inhibitors (ATIs), are considered to be responsible for adverse reactions among humans suffering from digestive disorders such as celiac disease, include different protein groups. They are principally gliadins and glutenins, but total somewhere between 50–100 different proteins, the levels of which are affected by crop nutrition (Koning 2012; Rustgi *et al.* 2019). Proportions may also vary between wheat species, and further work in a number of disciplines can be conducted to understand the physiology, biochemistry and metabolic processes in order to focus plant breeding and genetic manipulation on health-promoting varietal development.

ATIs may have a role in inducing inflammation and eliciting an innate immune response, with implications for celiac disease, and for bakers’ asthma and food allergy to wheat (Juhász *et al.* 2018). A growing body of evidence links ATIs to food allergies and celiac disease. Different proteins including ATIs are also implicated in non-celiac wheat (gluten) sensitivity, (NCW(G)S), as well as perhaps in other gastrointestinal disorders.

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<sup>15</sup> <https://www.wellonwheat.org/index.php>

Various attempts have been made to overcome NCWS, including analyzing the benefits of genetic diversity. Contrary to some expectations, it has been noted that ancient wheat varieties do not have superior nutritional quality compared to modern high-yielding varieties (Shewry and Hey 2015a; Shewry 2018). At the breeding stage, genetic engineering techniques have been used to try to develop celiac-safe wheat genotypes through the detoxification or elimination of gluten proteins, and through silencing the genes which regulate the accumulation of most gluten proteins in grains (Rustgi *et al.* 2019). Springer and Schmitz (2017) expect that epigenome engineering can be used for crop improvement. At processing, according to Rustgi *et al.* (2019) and Juhász *et al.* (Juhász *et al.* 2018) it is possible to produce flour with reduced immunogenicity from regular wheat genotypes by applying specific processing procedures such as milling and twin-screw extrusion techniques. Due to the differences in the distributions of proteins in the grain, with the gliadins and glutenins being expressed only in starchy endosperm cells, and other members of the prolamins superfamily, including ATI proteins, being enriched in the aleurone and transfer cell layers, it may be possible to reduce the levels of specific proteins by milling. Microwave treatments have also been used to remove antigenic properties (Landriscina *et al.* 2017).

Rustgi *et al.* (2019:1763-1764) conclude:

Wheat sensitivity is an umbrella term used to represent a heterogeneous group of disorders, which are alleviated by transfer to a gluten-free diet or a wheat exclusion diet. Current research using animal models (as proxies for coeliac disease or NCWS in humans) and double-blind placebo-controlled human trials with pure wheat grain components are providing a detailed understanding of the factors contributing to NCWS and identifying the wheat component(s) that trigger specific responses. This knowledge will facilitate the development of therapies for NCWS and also of new types of wheat, which can be tolerated by those with sensitivity to wheat.

Overall, there is strong evidence indicating a genetic predisposition among certain individuals to develop celiac disease, or sensitivity in other ways to wheat proteins. It is necessary that such individuals limit or avoid eating wheat and other cereals and derived products containing proteins (Brouns *et al.* 2013). As noted above, there is work to be done to find alternative product formulations using non-sensitive varieties.

#### ***FODMAPs (Fermentable Oligo-, Di-, Mono-saccharides And Polyols)***

Recently, the popular media have promoted an issue related to wheat (gluten) sensitivity. Brouns *et al.* (2017) have commented on the global trend advising consumers to cut back on nondigestible, rapidly fermentable carbohydrates, also referred to as FODMAPs. The FODMAP diet aims to help IBS sufferers to adapt their diet by reducing the intake of foods containing certain short-chain carbohydrates including fermentable oligosaccharides, disaccharides, monosaccharides and polyols. These are said to be imperfectly digested in the small intestine and are then fermented in the large intestine causing discomforting effects such as bloating associated with IBS and nonceliac gluten sensitivity (NCGS, cf. NCWS). Some oligosaccharides, raffinose, stachyose and fructans in particular, have been closely identified with the FODMAP case, and further research is needed to refine the knowledge of their adverse effects on digestion, and the potential for modifying the FODMAP content of cereal-based products through plant breeding and food processing.

#### ***Ultraprocessed foods (UPFs)***

It is well understood that dietary patterns trending towards greater consumption of processed food rich in carbohydrates is linked to the increasing incidence and individual and social costs of obesity, diabetes and most other NCDs. The science on ultraprocessed foods (UPFs) is more solid, although there are definitional problems as yet unresolved. The attention of policy makers has been drawn to this phenomenon, and the abuse of sugar in particular, in order to promote adequate dietary controls (Caro *et al.* 2017; Lawrence and Baker 2019). Monteiro and the Brazilian advocates have been foremost in classifying foods according to their apparent “healthiness” using a four-group “NOVA” schema: Group 1: unprocessed or minimally processed foods; Group 2: processed culinary ingredients; Group 3: processed foods; and Group 4: ultraprocessed foods (UPFs) (Monteiro *et al.* 2018). Public policy lags behind the science, partly due to the political economy of food systems. There has not been a formal uptake of the concept yet in specific national government policies, but individual countries are taking regulatory measures against certain categories of UPFs (Vandevijvere *et al.* 2019).

There continues to be debate about the value, accuracy and utility of this classification. This concerns lack of definitional clarity — for example, how to classify foods with whole grain cereals versus milled or refined flour. Critics also note that the association of certain food types with certain diseases does not prove causation and ignores

other demonstrable factors — such as sedentary lifestyles (Fraanje and Garnett 2019). Nevertheless, there is an understanding among researchers and civil society that Group 4 UPFs are industrial formulations of cheap sources of dietary energy and nutrients plus diverse additives, which are energy-dense, high in fat, sugars and salt, and make little contribution to intakes of valuable protein, dietary fiber and micronutrients: “the rapidly increasing production and consumption of ultra-processed food and drink products, which is contributing to climate disruption and also to pollution, degradation and depletion of air, land, water and sources of energy, is in itself now a world crisis to be confronted, checked and reversed as part of the UN Sustainable Development Goals and its Decade of Nutrition” (Monteiro *et al.* 2018: 7).

Staple food grains are implicated in the growing literature on ultraprocessed foods (UPFs): while whole grains are viewed positively for their contribution to healthy diets, grain-based foods are often highly processed and are perceived to contribute to obesity and morbidity. Vandevijvere *et al.* (2019) found in their industry analysis that in five out of eight global regions, baked goods such as cakes, pastries and bread were an important contributor to UPF volume sales (13.1%–44.5%). “Although not all ultra-processed foods are unhealthy, a high intake of these food and beverage products is linked to poor diet quality, obesity, and diet-related NCD risks. These products (e.g., cheap instant noodles and biscuits) might also contribute to undernutrition and micronutrient deficiencies by displacing more nutritious whole foods,” (Swinburn *et al.* 2019: Panel 6, p.807).

“Big Food,” — i.e., large agrifood — manufacturers, are highlighted as the industrial sector largely responsible for the manufacturing and promotion of UPFs. Swinburn *et al.* (2019) for the Lancet Commission consider the political economy to be distorted in favor of such firms: “subsidies for their commodity ingredients, deregulated business operating environments, weak or ineffective accountability systems for the human health and environmental externalities that result from their production and marketing, and industry’s privileged access to policy makers and decision makers to maintain these business operating conditions,” (p.807). Understanding how the agro-industrial complex creates and responds to policy and consumer incentives for different foods is an important topic for future research.

### **Obesogenicity**

Obesity is one condition in which the specific consumption of wheat has been implicated. Analysis of the literature has not found evidence of adverse effects on health by mechanisms related to addiction and overeating, rather than overeating and lifestyle factors. Brouns *et al.* (2013) concluded that wholewheat consumption cannot be linked to the increased prevalence of obesity in the general population. Nevertheless, with increasing rates of diabetes globally, there is major popular and scientific interest in understanding the nature of individuals’ glycemic response, which is a known factor in the incidence and management of NCDs such as obesity and diabetes (Lafiandra *et al.* 2014).

Concluding their review of UPFs in the U.S., Laster and Frame argue with confidence that consumption of UPFs is obesogenic and may contribute to adverse metabolic syndromes and chronic disease (Laster and Frame 2019). The global analysis conducted by Vandevijvere *et al.* (2019:15) suggested that “A diet based on UPFD [ultraprocessed food and drink] may promote obesity also through high energy density, high glycemic load, large portion sizes, and low content of phytochemicals. UPFD high-intensity flavoring, often further enhanced with artificial ingredients, may override endogenous satiety mechanisms and produce behavior akin to addiction .... UPFDs are also typically packaged in plastics, and several plasticizers (eg, bisphenol A) have been shown to be associated with obesity,” (p.15).

## **6.5 Potential for improving the nutritional contribution of cereal foods**

### **Key points**

- Biofortification, industrial fortification and conventional breeding opportunities can improve nutritional attributes

We have noted above some of the strategies whereby the wheat industry can improve the nutritional contribution of wheat. Bio- and industrial fortification are two important approaches. Lafiandra, Riccardi and Shewry (2014) reviewed the literature on the health benefits of wheat and identified strategies for improving the content and composition of grain polysaccharides. These include plant breeding approaches to take advantage of the natural variation in wheat

varieties and use mutagenic and transgenic techniques to generate further genetic variation. Thereby new food products can be developed by the cereals industry to combat the major nutritional challenges of the 21st century (Lafiandra *et al.* 2014).

Opportunities exist to further explore the genetic variation of cereals, such as the varietal differences in maize with respect to micronutrients and other bioactive anti-oxidant food components such as tocochromanols and phenolic compounds in maize (Muzhingi *et al.* 2017).

Biofortification of cereals has been practiced for millennia through natural and purposive methods of varietal selection. Modern agronomic practices, conventional selection techniques and latterly biotechnology have proved to enhance the mineral (zinc) and vitamin (vitamin A) content of wheat and maize, as well as of other cereals and other staple root and legume crops. Matching cultivars of maize to soil types offers ways to enhance plant productivity and kernel micronutrient content in specific locations and production systems (Hindu *et al.* 2018). Biofortification can also enhance the nutritional content of livestock feed and hence livestock products such as eggs (Heying *et al.* 2014; Sowa *et al.* 2017).

Biofortification is particularly attractive because staples form a large part of the diets of the poorest people, and the interventions are thus likely to be pro-poor. Efficacy and effectiveness studies are increasing in number (Bouis *et al.* 2013; Garcia-Casal *et al.* 2016; Bouis and Saltzman 2017). Working with iron, zinc, and provitamin A, Bouis (2018) commented in 2018 that over 150 varieties of 12 biofortified crops had been approved in 30 developing countries, and that within 5 years, biofortified crop varieties would be available in 25 more countries. HarvestPlus (2020) estimated that 20 million farmers and consumers at the time grew and consumed biofortified crops in eight target countries. Bouis and Saltzman noted that the principal challenge remaining was to upscale biofortification among relevant institutions and organizations. The need to increase micronutrient fortification of cereals has been reiterated in a new nutritional analysis of a global panel data set from 1990–2017 (Lenaerts and Demont 2021). Farmer and consumer acceptance also need to be assured. CIMMYT's experience with quality protein maize has been instructive: derived from conventional plant breeding, the new varieties contain almost double the levels of lysine and tryptophan — amino acids that are essential for humans and monogastric animals.

Ekpa *et al.* (2018) have identified a range of strategies across the whole value chain — a “crop-health systems approach” — to increase the contribution of maize to improved diets in Africa through plant breeding techniques. They argue that “Strategies that enhance nutrition-focused food uses of maize can contribute to providing daily dietary requirements of micronutrients as well as macronutrients,” (Ekpa *et al.* 2018:55). Understanding the needs of different maize system stakeholders from growers through intermediaries to consumers is necessary to be able to implement the appropriate technologies for:

- Addressing end-users' quality preferences and for enhanced nutrient density;
- Improving processing and manufacturing characteristics;
- Improving usage as green maize;
- Reducing anti-nutrient grain components.

Uptake and distribution are common challenges for introducing new varieties. The SPRING project in Uganda (SPRING 2018) has shown how the barriers to the procurement and use of fortified maize flour in boarding schools in Uganda as a way to increase micronutrient intake and overcome widespread iron deficiency in vulnerable populations can be overcome. Using a mixed methods research approach, they found that boarding school children derived over 50 percent of their energy needs from the maize flour component of their diet. However, the existing diet was poor in micronutrients, and would not meet dietary requirements for vitamin A, folate, iron, and zinc. Use of fortified maize would increase zinc, folate, and vitamin A intakes. Boys, but not girls, would find all their iron needs met. Foods made from fortified maize flour were found to be acceptable but different from foods made from unfortified flour (SPRING 2018). This again highlights the importance of linking technological developments with a sound understanding of consumer preferences, which ultimately determine the uptake of innovations.

# 7

## Dietary guidelines

### 7.1 Global review

#### Key points

- Food-Based Dietary Guidelines (FBDGs) are essential tools to improve nutrition
- What constitutes a healthy diet?
- Important quantitative detail in FBDGs is often lacking

The EAT Lancet Commission report on the potential for healthy diets from sustainable food systems (Willett *et al.* 2019) reviewed the compelling evidence available for what constituted a healthy diet and sustainable food production and suggested a universal and diverse healthy reference diet that “largely consists of vegetables, fruits, whole grains, legumes, nuts, and unsaturated oils, includes a low to moderate amount of seafood and poultry, and includes no or a low quantity of red meat, processed meat, added sugar, refined grains, and starchy vegetables.” (p.447)

From the Lancet reference diet, the authors proposed a redesign of global food production systems in order to meet the objectives for the sustainability of natural resources. Apart from passing references to reducing food loss and waste in supply chains, and brief comments about an “indicative role for industry,” (Table 6, p.478), the primary focus on diet and food production begs questions about how to bring about the required shift towards healthy dietary patterns and also the necessary transformations of food distribution. There are limited recommendations about supply chains and distribution systems in Strategy One, which seeks international and national commitments to shift towards healthy diets, but this requires further work (p.479). Industry and consumer-oriented work on food access — i.e., distribution — and food utilization — i.e., consumption — is necessary in order to better understand the food purchasing and preparation choices of different people, and how nutrition and health education might effect positive dietary changes.

A global review of Food-Based Dietary Guidelines (FBDGs) identified 90 countries where information was currently available: 7 in Africa, 17 in Asia and the Pacific, 33 in Europe, 27 in Latin America and the Caribbean, 4 in the Near East, and 2 in North America, with the year of publication of current versions dating from 1986 to 2017 (Herforth *et al.* 2019). There were significant commonalities but also significant variations. The authors suggest moves towards regional and global recommendations for refining national FBDGs and argue for clearer definition and communication.

Towards a similar end, but taking a quantitative approach, Springmann *et al.* (2020) modeled the health and economic benefits of the adoption of 85 national dietary guidelines and the dietary recommendations from WHO and the EAT-Lancet Commission. Adoption of national FBDGs resulted in an average 15% reduction in health costs as well as significant environmental benefits. However, about one-third of national FBDGs were not compatible with NCD targets, which was comparable to the adoption of WHO guidelines, but markedly lower than the health and environmental benefits of the EAT-Lancet diet. They commented that “dietary changes towards those recommended by national FBDGs could be associated with reductions in premature mortality, in particular from non-communicable diseases, in all of the 85 countries with FBDGs that were included in the analysis,” (p.10) and that “the value of just the health benefits from adopting progressive FBDGs could amount to 10–25% of national gross domestic product.” (p.13)

Like Herforth *et al.* (2019), Springmann *et al.* (2020) concluded that dietary recommendations were vague and that revision of national FBDGs and WHO guidelines would be beneficial from a health perspective. “For improving global dietary recommendations, a more comprehensive and specific set of recommendations would be necessary, including suggested minimum values for whole grains ....” (p.13) among other food items.

Consensus may not be easy to achieve, but there would be considerable value in coherent guidelines on the accepted science and better public information on issues such as the non-energy dietary contribution of carbohydrates, and of BIOFOCS in general, which may be more controversial. As regards cereals, Jones *et al.* (2019) pointed out the uncertainties, even apparent contradictions, concerning both epidemiological and intervention studies, and dietary advice concerning cereals. They also criticized the methodological weaknesses of a number of studies. Reviewing the evidence on morbidity concerning intakes of foods derived from cereal grains, they recommended a balance of foods obtained through the right mix, type, and quantity of wholegrain and refined grain foods, especially those fortified by mandate through industrial processes with micronutrients such as folate and other B vitamins, and minerals such as iron and zinc. Evidently guidance has to be nuanced.

## 7.2 Variability and uncertainty in Food-Based Dietary Guidelines (FBDGs)

### Key points

- Agreement on FBDGs is absent, but increasing intakes of “whole grain foods” is well-established
- New knowledge and knowledge transfer are needed to inform FBDGs about appropriate cereal intakes

It has been argued that national food-based dietary guidelines are political documents (Muka *et al.* 2015), tools for public health education and advice for promoting healthy food consumption patterns. They “can also serve as the basis for developing food and agriculture policies” (FAO and FCRN 2016:v). New research reported by Herforth and Masters (2020) reviews methodologies, approaches and metrics for estimating the affordability of nutritious diets around the world. A proposal to harmonize nutrient reference values could introduce new rigor to dietary guidelines (Allen *et al.* 2020), and new analytical tools for estimating human nutrient requirements are becoming available (e.g. Schneider and Herforth (2020)). However, guidelines are as yet unavailable for many countries, and details are often vague and incomplete (Herforth *et al.* 2019; Springmann *et al.* 2020). In particular, substantial gaps persist on the quantity and quality of DF essential to meet dietary recommendations (Stephen *et al.* 2017). The relative inattention given to DF and other BIOFOCS in dietary guidelines is significant for agricultural sciences research, a result of which is an ineffective demand for foods that contain these dietary components. A balanced approach to the contribution of carbohydrate-rich staples to the diets in respect of undernutrition, overnutrition and NCDs will alter the dietary research and guideline agendas.

The formulation of model sustainable diets that are affordable by the global poor in different food cultures is still pending and must take into account food environment and context specificities. This has been highlighted in responses to the EAT-Lancet Commission (Hirvonen *et al.* 2019; Willett *et al.* 2019; Drewnowski 2020). This model was developed primarily with a view to satisfying micronutrient requirements, without so far addressing DF and other BIOFOCS intakes. Economic modeling suggests that increasing the supply of fruit and vegetables to meet the WHO’s dietary recommendation of 400g/person per day is for many countries unlikely by the year 2050 (Mason-D’Croz *et al.* 2019). Recent research on the EAT-Lancet diet in India has highlighted the challenge in achieving nutritious diets, particularly in rural India (Gupta *et al.* 2021). Therefore, assuring diverse diets incorporating nutrient-rich foods is not a trivial matter. This suggests the need for more research into how, in diverse food cultures and seasons, intakes of staples such as cereals and other fiber-rich foods such as pulses can also complement “nutrient-rich” foods to meet revised dietary recommendations. FAO and WHO (2019) and the High Level Panel of Experts (HLPE 2020) recommend moving towards context-specific “territorial diets” based on locally available, economically accessible and culturally acceptable foods, delivered through sustainable systems. Staples, for energy and more, will be the foundation of such diets.

Food systems thinking extends the scope of guidelines beyond health and into the realm of environmental sustainability: “Aligning FBDGs with the latest evidence not just on healthy eating but also on the wider social and environmental implications of dietary choices is therefore an important starting point for enabling policy coherence and building a food environment that contributes to good public and personal health, as well as to local and global environmental sustainability” (Muka *et al.* 2015:2).

All the evidence hitherto points towards consumption of more fiber and more whole foods, including staple grains. The study by Springmann *et al.* (2020) found that in all FAO-defined geographical regions, with the exception of North

America, current intakes of wholegrain foods should at least double compared with national dietary guidelines, and in the cases of WHO and EAT Lancet guidelines, they should increase by 241 percent and 362 percent respectively. Adoption of dietary guidelines would lead to major reductions in the burden from diet-related, noncommunicable diseases.

New knowledge is also needed: “[The U.K.] SACN would welcome research to improve the functional categorization of specific dietary fibers and relevant extracts: building structure-function understanding to link and predict from defined, measurable physical and chemical properties to specific physiological effects. This should include defining physiologically meaningful effect ranges for colonic and faecal pH, short chain fatty acids, and bacterial populations.” (SACN 2015:199)

There are important implications for agriculture, research and food industry policies among other things: “Policy measures that could incentivise a greater uptake of FBDGs include investment in targeted health promotion programmes, adopting public procurement standards that are in line with FBDGs, and making sure policies from other governmental departments and ministries are aligned and do not contradict the recommendations of FBDGs—for example, when it comes to national agricultural strategies, public-private partnerships, and regulation of the food sector.” (Springmann *et al.* 2020:13)

It is for cereal scientists, food scientists and nutritionists together to combine existing knowledge and fill the gaps in order to inform the design of dietary guidelines and locally-adapted reference diets to guide public policy, private industry strategies, and consumer behavior. Mann *et al.* (2007:S133) acknowledge that there are gaps for research to fill: “Further research is needed to determine the exact properties of different non-starch polysaccharides and their food sources, to explain their metabolic and physiological effects. The whole-grain concept, along with fruit and vegetables is central to the healthy diet message, but the term whole-grain requires much clearer definition. In particular, the extent to which health properties are influenced by milling as compared with consumption of the intact grain should be established.” Even the energy content of different foods is uncertain due to the considerable difference which may be found between metabolizable energy (ME) and net metabolizable energy (NME), and a shift towards a single global food energy system for food energy tables and product labeling is desirable.



# Cereals and the agrifood industry

## 8.1 Political economy of food and nutrition

### Key points

- The food industry is a major player in determining the nutritional value of food products and how consumers behave
- Researchers must engage with agribusinesses
- Governments have a role in shaping private sector behavior

The role of industry in undermining public health has been the target of critics for many years (Stuckler *et al.* 2012). Open-minded engagement between researchers and industry is essential (Fanzo *et al.* 2020). The political economy of food has much to do with current nutritional challenges, through lobbying and advocacy of the food industry, civil society, and public regulation and policies of research and investments; sectoral taxation, prices, subsidies and incentives; and food trade and security policies. Balarajan and Reich (2016) have identified six themes in the political economy of nutrition that highlight current challenges, which concern leadership, intersectoral coordination, accountability, issue framing, hierarchy and demonstrating the effectiveness of nutrition actions. Agrifood scientists and socioeconomists have an opportunity to participate in this agenda and make multidisciplinary approaches, particularly through joint ownership of issues, shared prioritization, industry engagement, and above all by deploying food systems thinking (Gillespie and van den Bold 2017; Gillespie *et al.* 2019).

Legislation and regulatory approaches to food markets are part of the political economy of food and are not uncommon means to address malnutrition. Mandatory fortification with micronutrients (for example some minerals and B vitamins) is frequently part of public health policy, and voluntary fortification by food firms (for example with vitamins A and D) address both public health and marketing objectives. In many jurisdictions there is mandatory fortification of bread flour with micronutrients such as calcium carbonate, iron, thiamine (vitamin B1) and nicotinamide (vitamin B3).

Food supplies are partly a result of public policies and growth phenomena. Ecker's Table 8.1 shows a highly significant ( $<0.01$ ) correlation between increases in calorie supply per capita and animal protein supply per capita for the period 1981–83 to 2011–13 for the world that is significant for all of 22 regions except western Europe and Melanesia. Rising overconsumption is attributable to economic growth and urbanization, decline and relative changes in real food prices, and changes in the global food system: trade liberalization, globalization technologies, super-marketization and advertising have expanded access to nutrient-poor obesogenic foods.

Swinburn *et al.* (2019:836) make a strong recommendation about the public-private food interface:

“The influence of large commercial interests on the public policy development process needs to be reduced so that governments can implement policies in the public interest that benefit the health of current and future generations, the environment, and the planet. Governments should adopt and institutionalise clear, transparent, and robust guidelines on conflicts of interest and processes for policy development and implementation. They should also strengthen democratic institutions, such as freedom of information laws, declarations of political donations, independent ombudsman and commissioner positions, and platforms for civil society engagement in public policy decision making.” (p.836)

Recent research has provided further evidence of the importance of public intervention in food retail marketing, in this case in Mexico (Marrón-Ponce *et al.* 2020).

A coherent multidisciplinary advocacy approach to key stakeholders and “champions”, based on sound and consistent evidence, is more likely to shift public policy and ensure industry compliance than is lobbying by special interests. Agrinutrition researchers need to engage in this world of political economy to understand the incentive frameworks facing industry, policy makers and food consumers.

## 8.2 Processing and manufacturing

### Key point

- The potential of industry engagement

Another dimension is for researchers to engage more with industry in order to exploit the nutritional potential of cereals. Whereas the objective of milling is to separate the nutrient-rich bran and germ from the starchy endosperm, there is potential for processing to preserve and enhance the nutrient content of cereal-based foods, possibly by reducing the extraction rates, thereby retaining more of the bran (Pedersen *et al.* 1989). Protein and starch qualities are affected by both milling temperature and type of mill (Jones *et al.* 2015a). The loss of nutritional quality of cereals through processing is significant, as is the development of ultraprocessed foods (UPFs) (Poole *et al.* 2021). UPFs often contain noxious components, contributing directly to NCDs (Monteiro *et al.* 2018; Vandevijvere *et al.* 2019).

There is a need for interdisciplinary collaboration to influence product formulation and marketing by food industries. Collaboration between cereal scientists and industry food scientists is also needed to overcome the spoilage of fats in whole grain foods, and the substitution of “free” or added sugars that have adverse health effects, *inter alia*. Overall, food manufacturing should be nudged towards processes and products that enhance the nutritional contribution of cereal foods (Poole *et al.* 2021).

Adeloye *et al.* (2020) undertook research using innovative technological processes and food formulation to show how defatted coconut flour and nixtamalized maize can be combined to give a nutritious and acceptable product that happens to be rich in dietary fiber. This illustrates the potential for cereal and food scientists to overcome some of the barriers to dietary improvement.

A specific task for plant breeders is to exploit the genetic variation and nutritional values of different cereal varieties. Because of its high heritability, plant breeders can select for dietary fiber (Shewry and Hey 2015a; Shewry and Hey 2015b; Shewry and Hey undated) — high amylose wheat, for example. “More research is needed to be able to produce healthy, fiber-rich bakery products with an appealing texture and taste,” (Dewettinck *et al.* 2008: 252), not least to better understand the therapeutic potential of low GI diets for individuals with diabetes. Further research is also needed to elucidate the relationship between dietary components of cereals and cereal foods and glycemia/insulinemia that underlies some of the critical increase in NCDs (Mann *et al.* 2007).

New metrics have been proposed to assess the dietary quality of carbohydrate-rich foods in respect of calories and other macro- and micronutrients, which should generate enhanced dietary guidelines, promote novel and healthy foods, increase the accuracy of product labeling, and reduce consumer confusion about nutritional qualities (Liu *et al.* 2020).

## 8.3 Dietary improvement: Understanding consumption

### Key points

- local food environments in respect of the relationships between the public sector and nutrition and health education
- the private sector and product formulation and promotion strategies
- consumer awareness and decision making on food utilization

Understanding consumption and the factors that affect consumer behavior is essential for understanding how food systems work and how dietary patterns are framed. Besides price, consumers respond to the promotion, packaging and distribution strategies of food firms, and integral to marketing strategies is the nature and communication of product information.

According to the 2020 Global Nutrition Report, adult obesity has supplanted underweight, both globally and in all regions except parts of sub-Saharan Africa and Asia (Development Initiatives 2020). Two recent research examples among many illustrate the importance of understanding consumer behavior in the varying contexts of economic and nutrition transition. Law *et al.* (2019) affirm the growing problem of obesity in India, and highlight the contribution of such diet-related risks to NCDs. The nutrition transition in India, like in many other countries, is marked by increased sales of processed and packaged foods. They analyzed data from a representative sample of take-home purchases of packaged food and beverages by urban Indian households between 2013 and 2017. They found that purchased quantities per capita lagged behind those in western economies that have advanced further along the transition, except for high levels of staples such as packaged milk, processed wheat or edible oils. Income was not a simple determinant of purchasing patterns.

Similar health and research challenges have been reported by Smart *et al.* (2020) in sub-Saharan Africa, where undernutrition and increasing overnutrition are prevalent. Investigating the changes in food demand in Mozambique, they found that urbanization is impelling the consumption of more nutritious foods and more processed foods at the same time, with both positive and negative impacts on diet quality and implications for health. Notably, in light of the global challenges of obesity and NCDs, increased incomes, urbanization and increased consumption of processed foods were significantly and strongly associated with deterioration in diet quality. They conclude that “As urbanization continues and incomes rise, African cities need to consider what mix of policies and programs might counteract the negative effects we see from both these factors on diet quality” (p.16).

A range of factors is implicated as drivers of the nutrition transition, including liberalization of trade, investment in processing and manufacturing, liberalization of food markets and marketing, expansion of the global mass media, changing patterns of employment and time use, particularly for women, and changes in activity patterns: “Considering the complexity of these drivers, as well as heterogeneity in trends observed, it is clear that detailed empirical analyses are needed to disentangle their roles in driving the trends in urban India”, (p.199). The authors noted that Kerala was the only state registering a reduction in sweet and salty snack purchases and suggested that this was attributable to higher levels of education, health awareness and possession of the top-performing health sector. Also, policies targeting reductions in sugar-sweetened beverages may have contributed to slight reductions in consumption in some parts of urban India.

An analysis of nutrient labeling by (Wright *et al.* 2020) showed how even within a strongly regulated food environment, firms in the U.S. used labeling ingeniously — or disingenuously? — to enhance consumer perceptions of products: the regulation of the nutrition facts panel (NFP) labeling had three primary goals that have been partially frustrated by firms’ strategies: “help consumers make healthy food choices, reduce consumer confusion about food labels, and provide an incentive for firms to improve the nutritional quality of food. Due to the rounding guidelines, the NFP does not fully realize these goals” (p.12). Wright *et al.* call for increased consumer education and dietary awareness as well as revision of the labeling regulations. Similarly, Landwehr and Hartmann’s study of E.U. self-regulation throws doubt on the sincerity of firms supposedly limiting the advertising to children of foods and beverages high in fat, sugar or salt, suggesting that more robust controls are necessary (Landwehr and Hartmann 2020). There is increasing evidence that regulatory approaches can be effective: findings from the imposition of a tax on sugar-sweetened beverages showed that fiscal policies can alter consumption patterns (Colchero *et al.* 2017), while evidence from Chile suggests that comprehensive food regulation including labeling and advertising does have a positive health impact on purchasing and consumption patterns (Taillie *et al.* 2020).

At least three key issues emerge from these investigations and other similar studies:

- There is a need for more detailed and disaggregated studies of patterns of consumption of all foodstuffs, and processed and manufactured foods in particular;
- Recognition that despite the global trends, local social, cultural and economic contexts and food environments seem to shape heterogeneous behaviors;
- Public policies such as taxation can influence industrial strategies and consumer behavior.

## 8.4 Behavioral change: Engagement with industry, policy and civil society

### Key points

- Specific knowledge on consumer awareness, education and behavioral change is necessary to influence demand towards more nutritious products
- Natural and social scientists together should engage with policy makers to enhance knowledge and public policies and tackle disinformation

Aspects of these fundamental issues are associated with the food industry, from processing to consumption. Hence the demand for a “systems” approach to food, nutrition, diet and health. There are public health and industry regulation issues, hence researchers must engage in the political economy of the cereals sector, just as in that of other sectors (e.g., livestock production and consumption, and the sugar industry). Consumer behavior is the ultimate determinant of demand and is potentially influenced by regulation and education. Hence the demand for a greater understanding of consumer awareness and choices, and for working alongside civil society regarding research into behavioral change. Haddad (2020) has recently identified this wider perspective as a task for the CGIAR.

Understanding eating patterns and behavioral change among consumers resulting from policy-induced incentive structures is critical (Babu *et al.* (2017). Collective action is necessary, including policy engagement, linking with local ownership and leadership, together with civil society collaboration, to take control of nutrition policy and interventions, addressing both under- and overnutrition. Above all, “nutrition is a challenge that requires intersectoral coordination of actors and players from multiple sets of stakeholder groups ... [failure] is partly due to a lack of multidisciplinary skills among the professionals working in nutrition.” (p.22)

Similarly, lack of skills among health professionals is a factor identified by Lockyer *et al.* (2016) in the U.K. They also note that:

“Promotion of good dietary patterns, as depicted by the recently launched ‘Eatwell Guide,’ which includes plenty of fruit and vegetables, wholegrain and high-fibre starchy foods, beans, peas, lentils, nuts and seeds will increase fibre in the diet, as well as dietary quality via the displacement of calorie-dense, nutrient-poor foods. Educating the consumer is therefore important. However, knowledge is rarely enough to elicit behaviour change.” (p.227)

Nocella and Srinivasan agree that collaboration among food system participants is necessary to induce lasting changes in consumption behavior. Their analysis of U.K. diets identified the heterogeneity of U.K. consumer dietary patterns and the varying levels of disconformity to WHO guidelines, and noted that all diets required modification to be considered “healthy.” They also noted that voluntary commitment by industry to product reformulation had apparently been unsuccessful, suggesting the need for more robust intervention through taxation. Like Scrinis (2020), Nocella and Srinivasan consider that for lasting behavioral change, public interventions to promote healthier diets should address overall patterns of consumption rather than specifying intakes of individual nutrients or foods.

In short, understanding how to influence choices of food system stakeholders, from growers, through agribusiness firm owners/managers, and distributors, to consumers and public policymakers raises a vital set of research questions (Haddad 2020).

## 8.5 Trade in cereals

### Key points

- Cereals are a major component of international trade
- The economics and commodification of cereal-based foods have potential nutritional impacts
- Crises such as the COVID-19 pandemic affect countries’ production and distribution systems
- Economic and health crises and conflict also affect the ability to import and distribute food, not least cereals

Agri-food trade policy appears to be somewhat remote from nutrition. However, changing regimes and philosophies of trade have converted food into an economic item, subordinating issues of nutrition and health and limiting the potential for incentives and interventions to promote sound diets and health. Thow and Nisbett (2019) have signaled how some sovereign states have attempted to use trade rules in order to regain political autonomy over issues of social policy driven by trade. “The time is ripe for action on trade policy in favor of sustainable food and nutrition systems.” p.717

The work by Remans *et al.* (2014) has signaled the importance of the association between diversity in national food supplies and nutrition outcomes. They note that national supplies do not equate to equitable access to a diverse diet and food distribution at the household level but argue that national food diversity can be achieved in some contexts through national production, and in others by international trade, subject to “the country’s national income and access to regional and global markets.” (p.181)

Remans *et al.* (2014) have already made clear that appropriate metrics are available for including nutritional security in national agricultural and food security strategies. Thow and Nisbett (2019) argue that trade policy is both a barrier to and a potential catalyst for health, implying a functional conjuncture between food production, trade and agribusiness, in which cereals play a major part. In this context, there should be more effective stakeholder engagement by disciplinary specialists in formulating trade and investment agreements within a development discourse “that makes explicit the nutrition imperative.” (p.717)

The importance of trade for food security is made clear in the latest Global Food Security Index (GFSI) that “now in its eighth year, tracks the performance of 113 countries in providing for the dietary needs of their populations.” (EIU 2019:5) “Singapore and Ireland remain the two most food-secure countries, with Kuwait, Qatar and Malawi making the most improvements since 2018,” (p.6). The four dimensions used are affordability; availability; quality and safety; and resilience of natural resources, a fourth category intended to capture the impact of climate-related and natural resource risks.

The fragility of food systems in terms of production, logistics and distribution, and consumption has been made evident during the current pandemic. Impacts have been largely negative but differ by degree across countries (Laborde 2020). Some countries have experienced a severe reduction in the terms of trade that affect the opportunity to import foodstuffs and make food available and accessible, and this tendency will be exacerbated by any imposition of restrictions by major cereal exporters, as in the 2007 food crisis. Maybe more than global trade effects on cereals and food supplies, efficient trade and distribution within countries and regions is an essential element of effective food systems from input supplies to the distribution of final products. Domestic logistics constraints and price rises limit availability and access to foods and feed inputs for livestock.

Engaging with policymakers such as those involved in the African Continental Free Trade Area which, as of 2018, includes 28 countries, is an opportunity to inform elements of trade agreements such as phytosanitary standards and technical barriers to trade (World Bank 2020b). This is particularly true for Africa, where the costs of trade and nontariff measures are the biggest impediments to trade performance, both formal and informal, with significant implications for poverty reduction and food security (Bouët *et al.* 2020). Such engagement has the potential to benefit not only producers and consumers but also small-scale intermediaries who are often among the rural and urban poor and are vulnerable to nutritional insufficiencies.

## 8.6 Going local and contextual

### Key points

- Many researchable issues have a strong contextual dimension: one size will not fit all
- The nature and performance of agricultural production, agribusiness strategy and food consumption practices are likely to be strongly context-dependent
- Local knowledge and understanding are necessary to inform food, nutrition and health policies

The impact of the 2007 food crisis was a warning that global markets do not always function smoothly, and the disruption of local and regional supply chains under COVID-19 conditions reinforces the vulnerability of “food import dependency” and the political and nutritional risks of relying on market solutions. While one recent study has shown

that trade openness and economic growth are found to exert positive and significant impacts on dietary energy consumption and also to improve dietary diversity and diet quality-related aspects of food security (Dithmer and Abdulai 2017), this question of subjecting food and nutrition security to the vulnerability of international political hiatus needs further examination.

There may be greater food and nutrition security through territorialization, or even “going local” in thinking of food systems from production to distribution (Poole 2017). As noted earlier, moving towards context-specific “territorial diets” based on locally available, economically accessible and culturally acceptable foods, delivered through sustainable systems, may be preferable to the search for global dietary solutions (HLPE 2020). This will demand some further decentralization of agronomic and agro-industrial research and development. Poole (2017) envisages three areas of downscaling to local contexts which might support more tractable stakeholder relationships and effective food policies: decentralization of policy making to provincial levels; improved knowledge management, say of both agrinutrition science and industry/consumer behavior; and investment in capacity building to increase local competence.

# 9

## Conclusions and recommendations

### 9.1 The fundamental contribution of staple cereals

Some have argued against “staple grain fundamentalism,” (Pingali 2015:583). However, this misrepresents the case for nutrition and health. A recent publication by Hazard *et al.* ((Hazard *et al.* 2020) presents a balanced review of the contribution of wheat to global diets, and of adverse health impacts of wheat. They link the health challenges to overrefinement of the raw materials in wheat-based foods and set out the potential for enhancing positive dietary impacts through novel wheat genomics technologies. Staple foods, of which cereals are only one sub-group, are immensely important in global diets, being foods “consumed frequently and in sufficient quantities as to constitute the dominant part of the diet and supply a substantial proportion of energy and nutrient needs,” (Mattei *et al.* 2015). Rather than shifting away from grains, a broad research agenda is needed to develop healthy food products that are commercially viable and acceptable to the billions of consumers.

Staple cereals by themselves are not a panacea for diverse diets, but it should be recognized that staple grains are genuinely “fundamental” for at least three important nutritional reasons, inter alia. The first two points are well-established, but need appropriately balanced emphasis:

- Staples are essential for overcoming hunger and staple grains particularly so because they contain more nutritive value than just energy. Whole grains contain essential amino acids, vitamins and minerals, some of which are lost through milling and downstream processing. Hunger still afflicts hundreds of millions of people, and the micronutrients in cereals are nutritional assets. Overcoming hunger and adding micronutrient value through cereals should remain on the research agenda.
- Continuing research into biofortification of seeds and industrial fortification of processed products can deliver additional levels of essential micronutrients.
- It is increasingly evident that other constituents of grains, particularly dietary fiber, and a range of bioactive food components found in maize and wheat are essential to health for their major contribution in combating a range of NCDs.

It is this last point that is poorly acknowledged in international research on nutrition and food policy. Among staples, the overall dietary contribution of cereals receives less prominence in public health recommendations than the focus on an individually appropriate energy balance. We know that reducing the consumption of non-nutritious foodstuffs such as those rich in saturated fats and sugar — including those derived from cereals — is necessary, and we know also that healthy diets include an adequate consumption of so-called “nutritious”, i.e., micronutrient-rich, foods.

However, insufficient distinction is made between increasing dietary intakes of wholegrain foods and reducing the resource-intensive production of staple foods, including cereals. The nutritional content of maize and wheat is often understated due to ignorance of the content of bioactive components essential to health and well-being. Still, there is a need to think through the agricultural investments needed for nutrient-rich diets while ensuring affordability for the masses and staying within planetary boundaries.

The argument to sustain research on maize and wheat has been made in Poole *et al.* (2021), with recommendations concerning the need to:

- Bridge and bond various natural and social sciences disciplines;
- Adopt a comprehensive approach to nutrition by expanding the micronutrient paradigm or “microcosm;”
- Redefine the meaning of nutrient to include the cereal components that are important or essential to health.

On cereal food systems research there are a number of specific points to consider (Poole *et al.* 2021):

- Accelerate plant breeding for nutritional quality and biofortified crop varieties, and scale up industrial fortification, both being proven strategies for enhancing the nutrient-intensity of major cereals among other crops, with considerable prospects for further advances (HarvestPlus 2020; Prasanna *et al.* 2020);
- Persist in crop productivity and sustainability research in diverse soil and production conditions and in the context of climate change, especially under the resource-constrained conditions of smallholder farmers (Ritzema *et al.* 2017; Kihara *et al.* 2020);
- Enhance practices for the processing, manufacturing, storage and distribution of natural, bio- and industrially enriched cereal foods to reduce losses and nutritional harm in terms of both quality and quantity (Ekpa *et al.* 2019; Sharma *et al.* 2020);
- Understand consumer behavior at a disaggregated level: livelihood patterns and access to different foods among vulnerable groups, in different cultures, and in different production and marketing systems (Haddad 2020);
- Identify the inherent contradictions and resolve the trade-offs within cereal food systems concerning environmental sustainability, poverty reduction, profitability for actors and firms throughout the value chain, and improved nutrition and health of vulnerable populations.

Below we reiterate and expand some of these points.

## 9.2 Not just micronutrients ...

Since micronutrients have taken center stage in the last decade or so, we have heard calls that the emphasis on staple foods be reduced. We suggest that historic patterns of investment in agricultural research should be revised and re-balanced, not overturned. The reasons for maintaining research in staple cereals are that:

- The positive contribution of cereals to improving micronutrient malnutrition has been understated;
- The negative contribution to obesity, diabetes and other noncommunicable diseases has been exaggerated and misreported by populist commercial initiatives;
- The positive contribution of bioactive food components of maize and wheat to wider health issues has not been fully appreciated.

We endorse Haddad's argument for research on both staples **and** "foods like vegetables, fruits, fish, pulses, nuts, eggs, dairy, and meat," (Haddad 2020:4), that is, a balance that recognizes that cereals are more than "not-nutrient-rich" foods and contribute to nutrition and health in ways that are complex and hitherto understated by the agrinutrition research community.

The direction of travel in food systems studies to address the SDGs is towards multidisciplinary knowledge: "Perhaps the most welcome and vital trend in research related to food security and nutrition is the breaking down of disciplinary silos and the shift to more multi-disciplinary, multi-sectoral research," (Fanzo *et al.* 2020:6). The farm-to-fork concept captures input supplies and production systems; the transformation of raw materials through processing, transport and storage; consumer-facing marketing and distribution systems; nutrition and health education; commercial strategies, advocacy and public regulatory actions. Nested within the food system is also the need for strong linkages with food- and biomedical sciences, whose advances in knowledge impart a greater understanding of the role of cereals in diets and the potential to enhance the contributions to better nutrition and health.

## 9.3 Recommendations

- A number of factors impel the need for further collaborative agrinutrition research:
- CIMMYT is not the only player in cereals research worldwide and should exploit opportunities to collaborate with other CGIAR centers, national and international research organizations, and industrial partners;

- Improving nutrition is a multi-stakeholder, multi-disciplinary activity for crop and animal scientists, food scientists, biomedical scientists and social scientists, as well as policy makers, industry and advocacy organizations;
- Work with major donors and other programs sponsored by international organizations and philanthropic-capitalist funders is necessary to leverage limited resources, expand knowledge of the dietary contribution of cereals towards adequate intakes of bioactive food components, and reduce NCDs as well as the triple burden of malnutrition;
- Given the need to address multiple research contexts, centralized global research systems and programs must reach out to and collaborate with national and regional institutions to localize applied research, extension and education.

The previous points imply upscaling impact through enhanced capacity building among national agrinutrition research systems, and the effective and efficient generation and deployment of new context-specific knowledge.

In sum, agrinutrition challenges call for a multi-pronged and multi-stakeholder R&D effort across the vast agrifood systems from farm production through the food system to food consumption. This inter alia calls for:

1. Continuing the good plant breeding work: Lobell (2020) comments on the need for continued investment in plant breeding that is the longstanding strength of the CGIAR system and centers such as CIMMYT. Beyond nutrition, progress on major crops is needed, especially in the face of climate change and the demand for sustainability to stay within planetary boundaries. To this he adds a second priority: “precision agronomy, often also referred to as site-specific or digital agronomy,” (p.1). Barrett (2020: 1) emphasizes the ongoing need for research on global staples: “Climate change, in particular, compels continued advances in staple crops such as maize, rice and wheat lest the world risk declining supplies per capita and more frequent staple crop failures,” but he acknowledges that embracing “nutrition” requires a rebalancing of research to include nutrient-rich crops:
  - Hence, to sustain the plant selection and breeding agenda, increasing yields and productivity levels under conditions of climate change within the increasing constraints of environmental sustainability objectives is essential;
  - Identification and improvement of traits that are associated with enhanced micronutrient content can bring important improvements to global diets;
  - Working with seed companies to accelerate the distribution of new varieties ... Accelerating Genetic Gains in Maize and Wheat for Improved Livelihoods (AGG) seeks to achieve these results by speeding up genetic gains in maize and wheat breeding to deliver improved, stress resilient, nutritious seed to smallholders in sub-Saharan Africa and South Asia;
  - Another key element is to incorporate gender-intentionality — special attention should be paid to the needs of women farmers and consumers — from the traits bred into new varieties, through communication and technology deployment strategies.
2. Working with the processing industry and food scientists to develop crops to improve both the nutritional and the industrial qualities of whole grain products. Working similarly with industry to reduce quality losses during food processing and manufacturing.
3. Working with the processing sector, consumers, breeders and agronomists to identify best production practices that guarantee better nutritional quality.
4. Engaging with WHO and national governments about more refined categorization of foods and food components, in order to establish clearer dietary guidelines for foods and bioactive food components derived from cereals, and cereal foods as a component of balanced and nutritionally rich diets.
5. Collaborating with food scientists and biomedical researchers to consolidate and verify the evidence on the adverse effects of cereals, and engaging in communication with policy makers, popular media and wider nutrition education initiatives to present clear guidance.
6. In collaboration with local researchers, understanding the socioeconomics of local and specific value chains for cereal foods will help to identify opportunities for increased efficiency in food transformations (storage and transport, as well as processing).

7. Similarly, multidisciplinary natural and social science approaches to cereal food systems are necessary to address food safety challenges such as aflatoxicosis and to minimize food waste.
8. There is a communication and advocacy role to perform in respect of the dietary contribution of cereals: food energy from cereals is essential for most of the world's population, and DF and other bioactive food components in cereals are essential nutrient contributors to healthy diets.
9. There is a need for consumer-focused research that will inform policy makers on the appropriate regulation of food systems, behavioral change programs and education on food choices and food utilization at the (intra)household level.

Tackling the evolving and complex agrinutrition research agenda calls for rebalancing and rethinking priorities, but also more investment. In the end “cereals and ‘nutrient-rich foods’ are complementary in agrinutrition and require additional research and resources, and increased attention for one should not replace the other” (Poole *et al.* 2021).

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