**INTRODUCTION**

By the year 2050, the world will face the task of feeding 9 billion people, the majority of which will live in developing countries. Meeting this goal must be achieved in spite of the rapidly-dwindling resources, using less energy, land, and water, minimizing environmental impact and maximizing biological and social sustainability. In the future, food must not only be produced in sufficient quantity, but it must be of high quality to support the health of 9 billion people.

For overarching all of these issues is the burden of malnutrition. Defined as the inadequate or imbalanced intake of nutrients and energy with respect to the body's needs, malnutrition affects more and more of the global population [1]. Overnutrition is reflected in both developing and developed countries in the rising incidence of obesity, metabolic syndrome and cardiovascular diseases. Yet at the same time large swathes of the globe are home to the very poorest, for whom undernutrition is the status quo. Their diets do not provide adequate calories and/or protein to support growth and maintenance of bodily functions. Finally, micronutrient deficiencies (sometimes referred to as “hidden hunger”) affect populations in both developed and developing countries worldwide, with women and children being the most vulnerable [2]. Altogether we must increase not only food quantity, but also quality, throughout every aspect of the food production and distribution chain. And to bring the final miracle to fruition, high quality foods must be available at affordable prices.

These increasingly stringent demands place the food industry in a challenging position. How the food industry rises to face the nutritional challenges of the 21st century plays a key role in meeting the Sustainable Development Goals. This article aims to provide a systematic framework that can be applied by the food industry to address the challenges of public health nutrition.

This conceptual paper first presents a short review of the changing landscape of global nutritional challenges. This provides the context why systematically adopting a public health nutrition framework by food manufacturers - as proposed in this article - is helpful to address these challenges. The following sections describe the four steps of the framework. At each step a case example taken from the Philippines demonstrates the feasibility of adopting this framework.

**NUTRITION: THE CORNERSTONE OF PUBLIC HEALTH**

The evolution in public policy over the past few decades has echoed the changes in the global nutritional landscape. In the 1970s underweight and hunger were the dominant concerns in lower income countries, and to this day remains on the agenda as an important public health nutrition issue [3-7]. But the economic development of these regions in the 1980s brought about a "nutrition transition", during which over-nutrition reared its head [8]. The increasing prosperity in what were previously lower-income areas resulted in a shift in the available diet, triggering a dramatic increase in overweight, obesity and cardiovascular diseases. From then onwards, overweight and obesity were no longer restricted to higher income countries [9]. By the early 1990s, a new alarm was raised as nutritionists faced a third, hidden aspect of malnutrition. Referred to as "hidden hunger" [10,11], micronutrient deficiency is the chronic deficiency of essential vitamins and minerals for health including, and can result in conditions that seriously undermine health and productivity. By the beginning of the 21st century undernutrition, overnutrition and micronutrient deficiencies were referred to as the “triple burden” of malnutrition, which often exists in parallel [12].

The socioeconomic, health and quality of life consequences of malnutrition are well documented [13]. Approximately two billion people suffer from various forms of malnutrition worldwide. Malnutrition is an underlying cause of approximately...
2.6 million deaths among children each year, accounting for a third of child mortality [14–16]. Adults who were malnourished as children earn at least 20% less than those who were not [17]. Undernutrition is still widely prevalent; FAO estimated that nearly 800 million people were chronically undernourished globally in 2012–2014 [18]. Undernutrition in women and children below 5 years of age accounts for 11%, and micronutrient deficiencies for about 7.3% of the global burden of disease [19]. The deficiency of iron, iodine and zinc contribute towards 2–3% percent loss of Gross Domestic Product across the globe. Evidence also shows that diets that provide unbalanced nutrition contribute to obesity and associated conditions, such as diabetes, heart disease and cancer. Worldwide, 2.5 million deaths or nearly 70% of cardiovascular disease cases can be associated with overweight/obesity [20]. Poor maternal and infant nutrition adversely impacts the mental and physical development of individuals. The Copenhagen Consensus estimated that an annual cost of 347 million USD would enable the provision of basic nutrition to 80% of malnourished people globally, and could lead to an economic benefit of 5 billion USD through improved earnings and less healthcare spending [21]. Every dollar spent on nutrition can yield benefits from 8 to 138 USD, depending on the country [22].

In light of the triple burden of malnutrition, sustaining the 9 billion people of the future calls for a fundamental transformation across multiple sectors, including healthcare, education, as well as food production and supply [12]. The food industry can make a significant contribution to these efforts. The Global Alliance for Improved Nutrition in 2014 reviewed a portfolio of commercial, social business and public service projects, and verified the valuable contribution of market based approaches to addressing public health nutrition challenges [23]. International workshops addressing micronutrient deficiencies in Southeast Asia underscored the key role of the private food industry as a major contributor towards successful food fortification programmes [24,25]. Historically, the commercial activities of food manufacturers were driven mainly by market forces (Figure 1a). The standard model was to shape their business strategies on the tastes and cultural preferences of consumers. Various authors raise attention that changes in the food system, which entails this commercial approach to food manufacturing, impaired with the spread of modern food distribution, sales and marketing had unfavourable impact on public health [26,27]. Popkin et al. points out though that this food environment shift has been happening within the broader context of globalisation, urbanisation, trade liberalisation and vast global investments in agriculture including the animal foods and feed crops sector [27]. These global trends have equally brought along social changes. Regulations, such as specific food taxes or the limitation of marketing to children, are certainly steps to change the commercial activity of the food industry, but it remains a reactive approach. Forward looking public health must be incorporated into the heart of the strategies that drive the food industry. This article aims to provide a practical framework consisting of four key steps that can help the food industry1 to successfully merge public health nutrition with business strategy in food manufacturing. We demonstrate that these steps are doable through a case example that has been implemented in a business setting to address iron deficiency anaemia among infants in the Philippines.

**Step 1: Dietary intake and behaviour research to better understand the nutrition and health needs of a population**

A key element of the business success of food manufacturers is to what extent they can offer products which respond to the tastes and dietary culture of the targeted population groups. The food industry can make a significant contribution to these efforts. The Global Alliance for Improved Nutrition in 2014 reviewed a portfolio of commercial, social business and public service projects, and verified the valuable contribution of market based approaches to addressing public health nutrition challenges [23]. International workshops addressing micronutrient deficiencies in Southeast Asia underscored the key role of the private food industry as a major contributor towards successful food fortification programmes [24,25]. Historically, the commercial activities of food manufacturers were driven mainly by market forces (Figure 1a). The standard model was to shape their business strategies on the tastes and cultural preferences of consumers. Various authors raise attention that changes in the food system, which entails this commercial approach to food manufacturing, impaired with the spread of modern food distribution, sales and marketing had unfavourable impact on public health [26,27]. Popkin et al. points out though that this food environment shift has been happening within the broader context of globalisation, urbanisation, trade liberalisation and vast global investments in agriculture including the animal foods and feed crops sector [27]. These global trends have equally brought along social changes. Regulations, such as specific food taxes or the limitation of marketing to children, are certainly steps to change the commercial activity of the food industry, but it remains a reactive approach. Forward looking public health must be incorporated into the heart of the strategies that drive the food industry. This article aims to provide a practical framework consisting of four key steps that can help the food industry1 to successfully merge public health nutrition with business strategy in food manufacturing. We demonstrate that these steps are doable through a case example that has been implemented in a business setting to address iron deficiency anaemia among infants in the Philippines.

1 Food industry in this article refers to manufacturers of packaged food products with well identifiable product portfolios.

**Figure 1** a) The historical circle of food manufacturing driven by market forces. b) The public health nutrition circle of food manufacturing.
towards the rational design of specific food products.

A case in point is iron deficiency, a condition which affects an estimated 1.6 billion people worldwide [28]. In the Philippines, iron deficiency anaemia (IDA) prevalence was between 20% and 50% among children under the age of 5 [29,30]. This high prevalence level was explored further by age-group and socioeconomic strata in an extensive analysis by the Institute of Health Economics, Zurich University of Applied Sciences. The Department of Science and Technology of the Food and Nutrition Research Institute of the Philippines facilitated the research by providing access to the Philippine Nutrition Facts and Figures 2010 data. Results of the analysis highlighted that the subgroup most severely affected by moderate and severe IDA was 6-23 month old infants in the poorest population strata [31].

In parallel with the data analysis, independent systematic reviews of the literature confirmed the effectiveness of micronutrient fortified milk and cereal in reducing iron deficiency in children [32,33].

In a third step, the analysis of the Philippine national data was supplemented with a survey which showed that less than 5% of mothers in the poorest households were aware that anaemia results from iron deficiency. Indeed, even among the wealthiest households, only 20% of mothers were aware of this key fact. This survey also explored the level and pattern of consumption of fortified milk products [34].

Taken together, the findings from the above studies suggested that fortification of the food items most widely consumed by infants who exhibit the greatest risk of iron deficiency could be a feasible strategy for addressing iron deficiency. These research findings provided a roadmap for Nestlé towards the tailoring of its products for addressing iron deficiency in the Philippines. The adoption of a public health approach to nutrition within the food industry entails an intrinsic need to actively contribute to this type of science. Many food industry representatives have already been contributing to such research over the past decade, particularly those who are concerned with the public health implications of their products. The application of dietary intake and behaviour data towards shaping product portfolios globally and locally is the first important step for the food industry in responding to public health nutrition needs (Figure 1b) in the evolution from market-based food production towards a public health-oriented nutrition business.

Step 2: Formulating policies with clear commitments to drive public health nutrition

The next important step for the industry towards adopting public health nutrition into the core business strategy is to formulate clearly articulated commitments to meet the dietary and health needs of the consumer aligned with international guidelines (Table 1).

An important cornerstone of global nutrition policies was the declaration of the UN in 2011 on non-communicable diseases (NCD), which flagged unhealthy diets as one of the four most prominent risk factors [45]. In this declaration, heads of states and governments agreed to five action areas, one being the promotion of “cost-effective interventions to reduce salt, sugar and saturated fats, and eliminate industrially produced trans-fats in foods”. The private sector was called upon to reformulate products to provide healthier options. In Europe a series of policies were developed to tackle dietary risk factors of non-communicable diseases [46-49]. Likewise, the WHO announced a global strategy to prevent NCDs in 2000, which was later refined in 2004 to encompass diet, physical activity and health [50,51].

The above guidelines together with available scientific evidence provide important building blocks for formulating public health-related policies and commitments for the food industry. Some companies have had such measures put in place for years, even prior to the publication of certain dietary recommendations, while others announced them more recently. In 2008, Nestlé issued its first creating shared value report, indicating that it had renovated 6645 of its products for nutrition or health purposes. As of 2015 Nestlé has articulated 15 nutrition commitments. Amongst the key commitments are: further reducing the risk of under-nutrition through micronutrient fortification, reducing sodium (salt), sugars, and saturated fats by 10% in its products which do not yet meet the criteria set forth by its nutritional profiling system, removing trans-fats from all products, and promoting healthy diets and lifestyles [53]. Similarly, Unilever announced its commitment to make improvements in nutritional quality across its portfolio and to focus innovation efforts on products that deliver positive health benefits. In 2008 the company reported that all its 22,000 food and beverage products went through a regular review as part of the “Nutrition Enhancement Program” and that 43% of their products were “in line with internationally accepted guidelines for saturated and trans fat, sugar and salt” [54]. By 2014 “33% of the food and beverage portfolio by volume met the highest nutritional standards” [55]. Other large multinational companies adopted public health nutrition into their policies much later. For example, it was only in 2014 that Mondeléz International set global nutrition targets for 2020 including reductions in sodium and saturated fat by 10% and increases in whole grain by 25% [56].

These company commitments are important for several reasons. First, they provide general directions, and if successfully

<table>
<thead>
<tr>
<th>Organization</th>
<th>Nutrient</th>
<th>Year of guideline publication</th>
</tr>
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<tbody>
<tr>
<td>FAO/WHO</td>
<td>Fats, fatty acids, salt</td>
<td>1994, 2010 [35,36]</td>
</tr>
<tr>
<td>FAO/WHO/UNICEF/ICCIDDD</td>
<td>Iodine in salt</td>
<td>1996</td>
</tr>
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<td>FAO/WHO/UNU</td>
<td>Protein and amino acids</td>
<td>2003, 2007 [40,41]</td>
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<tr>
<td>FAO/WHO</td>
<td>Fruit and vegetables</td>
<td>2004 [42]</td>
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<tr>
<td>WHO</td>
<td>Sodium, potassium</td>
<td>2012 [43,44]</td>
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<tr>
<td>WHO</td>
<td>Sugar</td>
<td>2015 [9]</td>
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Table 1: International guidelines on the intake of various nutrients and dietary elements.

Hutton et al. (2016)

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implemented, they become intrinsic to the entire operation of a company. Second, such commitments aid in transparency and accountability towards third parties. Third, it is now well acknowledged that food manufacturers are key stakeholders in combatting malnutrition. Company nutrition commitments that are clearly articulated and aligned with public health nutrition needs, global recommendations, and the latest scientific knowledge will aid the food industry in fulfilling their role as responsible players in addressing global nutritional challenges.

With reference to the case of the Philippines, Nestlé has made an explicit commitment to “help reduce the risk of undernutrition through micronutrient fortification” [57]. Among the overarching company objectives is to reach 200 billion micronutrient-fortified servings of foods and beverages per year worldwide by 2016, and to address micronutrient deficiencies with a special focus on children and women of childbearing age. These commitments provided the basis for setting internal performance indicators and shaping the business direction of the company in each country. These goals and commitments encouraged Nestlé associates in the Philippines and their affiliated research centres to analyse the situation of micronutrient deficiencies among children and encouraged them to seek local solutions to alleviate micronutrient deficiencies.

**Step 3: Applying food science, technology and nutritional profiling to design foods**

How can we translate national and international dietary recommendations into actual products with recipes which are acceptable for the consumer? This question leads to the third key step in the public health nutrition circle of developing nutritious products: improving foods through applying food science and technology, and nutritional profiling (Step 3; Figure 1b). Nutritional profiling refers to the classification of food items according to their nutritional composition. A good nutritional profiling system is an objective and science-based tool that can be used to characterize foods on the basis of their nutrient content. Furthermore, nutritional profiling can also be used to improve on the nutritional composition of individual products. At present, several nutritional profiling systems are available, which have different primary purposes. However, a globally-accepted system with the specific purpose to drive product innovation and reformulation is missing. Some companies have therefore developed their own nutritional profiling systems for these purposes, with the goal of evaluating and improving the nutritional profile of their products. In 2004, Nestlé began developing its Nutritional Profiling System (NNPS), with the principles of the system made public in 2010 [58]. For each category of food product, this system sets target values for energy, nutrients to encourage and nutrients to limit (i.e. public health-sensitive nutrients, such as trans-fatty acids, saturated fatty acids [SFA], sodium and sugar). It also takes into consideration the consumers’ eating habits (for example, defining nutrient targets by serving size) and the needs of specific age groups (for example, children versus adults) [59]. Unilever has also developed a system to evaluate its product portfolio for saturated fatty acids, trans-fatty acids, sodium and sugar against generic benchmarks per 100 grams of product. For some product categories where generic benchmarks could not be applied, category specific benchmarks for sodium and sugar were calculated [60].

Product reformulation is a pragmatic approach within the toolset of the food industry, which has been implemented by various food manufacturers for the purpose of differentiation and improving their foods. This work is also guided by extrinsic factors, such as the changing food and nutrition policy environment.

Nutritional profiling raises the possibility of nutritional improvement without a change in diet [61]. Applying nutritional profiling systematically across product portfolios enables manufacturers to identify products that can be improved through reformulation. Rigorous product evaluation over a period of 4-5 years using the NNPS system resulted, for example, in an improved nutritional content in 99 products across 8 product categories in the US and France [59]. Application of the nutritional profiling system assisted in lowering the levels of nutrients to limit, such as sodium, total sugars, SFA’s and total fat.

One of the biggest hurdles faced by the food industry is consumer taste preference: although most people are aware that they should make healthy food choices, they are often reluctant to divert from their taste preferences. For example, although 50% of US consumers would like to decrease their sodium intake, they are not willing to compromise on food flavour [62]. Despite the clear link between sodium and hypertension, salt is still considered a necessary attribute of taste [63].

Striking the balance between health and taste preferences requires private food companies to make considerable investments in advancing food technology. For example, removing saturated fat from products is a direction which is likely to confer public health nutrition benefits; however, it requires complex technological solutions which can preserve the taste and texture of products in order to meet consumer expectations. In the case of the Philippines, food science and technology helped to change the recipe of fortified milk offering higher iron content.

In summary, food science plus the technological know-how of food manufacturers coupled with systematic nutritional profiling are important tools that allow the renovation of existing product portfolios and the creation of novel products. Altogether, these can help food manufacturers to design products in-line with public health nutrition goals that suit the consumer’s taste, harmonizing public health nutrition with business principles.

**Step 4: Applying health economics to evaluate the impact of nutrition**

In order to achieve maximum societal and economic impact, effective public health nutrition implies going one step further and allocating available resources in a way that distributes the health and socioeconomic benefits to the largest number of people, particularly for those most in need (Step 4; Figure 1b). But perhaps the greatest challenge of all is how to measure and evaluate the impact of nutritional interventions. Nutrition is a continuum throughout life, and its contribution to health and well-being can be accessed from different angles and at different stages in life. However, there is a dearth of methodologies to assess the role of diet and nutrition not only in human health but more broadly in the society and the economy. Unlike the tools
used for testing the effects of drugs in specific diseases (i.e. the randomized controlled trial, disease-specific outcome measures such as overall survival, disease-free survival), there are no suitable equivalents to test for the full effects of nutrition on health and socioeconomic wellbeing. Thus, as soon as the signs of specific pathologies begin to manifest, nutritional factors are frequently evaluated using the tools designed for drug development. In reality, such tools cannot be expected to capture the subtle, long-term effects of particular nutrients or the food itself on overall health and socioeconomic wellbeing.

The socioeconomic impact of nutritional interventions can be measured through the application of health economics. Initially, the focus of health economics was on medical nutrition, for example assessing the impact of pre- and postoperative oral nutritional supplements on the cost of care [64]. Later studies assessed the cost burden of a medical condition and then estimated the cost effectiveness of a nutrition intervention from a disease prevention perspective. The case of atopic dermatitis provides such an example. First, researchers assessed the disease burden in different countries. Next, the cost-effectiveness of a special infant formula was compared to a standard infant formula for at-risk infants who were not exclusively breastfed [65-70]. Evaluating the disease burden in terms of cost provided the researchers with an objective outcome measure with which to compare both interventions. Nutrition has been identified as a major modifiable determinant of many chronic diseases, highlighting the need to capture and quantify the preventive value of nutritional interventions. As health economics assessments have been increasingly applied towards nutritional interventions since 2010, the term “nutrition economics” was proposed, merging health economics and nutritional sciences with the goal of evaluating the impact of diet on the prevention of health and disease [71]. With this proposal, healthcare decision makers were encouraged to look beyond medical nutrition as standard “treatment”, but instead to consider health economics as part of the greater picture of nutrition for prevention [72].

The case of the Philippines provides an example of how health economic evaluation was applied towards nutrition. The first step involved assessing the burden of micronutrient deficiencies including that of iron, zinc and vitamin A. From there, a model was built to calculate the effects of fortified milk consumption on alleviating this burden, from the perspective of society and the economy [31,73]. The study revealed several key findings. First, it showed that iron deficiency anemia among 0.5-5 year-old children resulted in production losses valued at 385 million USD due to the lifelong consequences of this deficiency [31]. At the same time 56,416 healthy life years were lost due to impaired development and premature death. Furthermore, the study discovered that the greatest cost burden was borne amongst children aged 6-23 months in the lowest socioeconomic strata [31]. Also, a large proportion of the households were already using fortified powdered milk on a regular basis. However, data from local consumer surveys indicated that price was a key barrier to the consumption of fortified milk, particularly for lowest income households [34]. From these findings the researchers concluded that interventions targeting the poorest 20% of households would be the most cost-effective [73].

These studies are attempts in the direction of evaluating the socioeconomic impact of specific nutritional interventions within the complex dimensions of public health. Future research should explore how such health economic evaluations can evolve to encompass not only traditional health care stakeholders, but all other public health policy players. These discussions are crucial to enable translating the impact of a nutritionally balanced diet into measurable public health benefits which can empower policies and practice.

CONCLUSION

The strategy presented in this article is a feasible, step-by-step approach that can be adopted by food manufacturers to address the public health nutritional challenges of the 21st century. This involves going beyond traditional market-driven operations and adopting the public health nutrition circle into the business framework. Its starting point is the careful analysis of the nutrition and health needs of the target population, through dietary intake and behaviour research. This knowledge then helps to formulate company public health nutrition policies with clear commitments. These two steps are prerequisites to successfully drive the development and design of nutritious products. Finally, leveraging the health economics of nutrition will enable all stakeholders to assess not only the health but also the socioeconomic impact of these interventions.

Policy discussions often fail to consider branded product portfolios as potential “carriers” for public health nutrition interventions. The fundamental need of the private food industry to remain profitable is reflected in the selection of tasty products that people will like and buy. However, these product portfolios hold great potential in becoming positive contributors to public health. In designing products that are in-line with public health requirements, food manufacturers can provide safe, high-quality carriers of nutrients and energy that contribute towards a healthy diet and prevent disease. Needless to say that a transparent and well regulated food environment can only facilitate the realization of this potential.

Ultimately, the success of the approach presented in this article will be influenced by the extent to which it becomes the norm across the industry. While some representatives of the food industry have already moved their research and operations in this direction, others are lagging behind. Much depends on the surrounding regulatory and political environments, but also on incentives at the level of the consumer, the company, and the country.

A collaborative effort of all stakeholders working both in nutrition policy formulation and implementation, including the industry, is paramount to make the public health circle operational ultimately deeming socioeconomic benefits across the globe.

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