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Framing Cuisine with Food Loss and Waste as a Combined Nutrition Public Health Priority and Climate Change Mitigation Action

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Abstract

This paper proposes that fortifying honored traditional recipes with natural foods in tandem with preventing food loss and waste adds a new dimension to sustainable food management—nutrient recovery and bioavailability—while reducing the global prevalence of anemia and other diet-induced maladies. Using the complementarity of iron and Vitamin C as an example, this paper demonstrates that we can recover bioavailable nutrients to ensure recovery is efficient. The authors show by example that returning food loss and waste into a healthy food environment can meet the daily and monthly needs of iron-deficiency in substantial portions of the populations with significant need and in all countries. Further, maximizing the availability of key nutrients, like iron, will reduce the stress of animal husbandry on the environment, reduce greenhouse gas emissions; and thereby, reduce agriculture impacts to climate change and global warming. Considering the quality, quantity, and convenience of food recovery, from farm—and beyond fork—to gut, is key for global policy development in nutrition public health and actions that are ready to implement today.

Keywords

Food Loss, Food Waste, Bioavailability, Climate Change, Iron Anemia, Cuisine, Food Fortification, Behavior Change

1. Introduction

Our 21st century food system problems have a complicated history and provide one of the greatest challenges for the future of humanity and our impact on the ecosystem upon which we depend for our sustenance. Since the Neolithic period when we evolved new ways to domesticate plants and animals, we have created, through our cultural information system, a highly successfully means of extracting our sustenance from our environment through co-evolution of agriculture and cuisine practices. This cultural development removed the biological and ecological barriers of our Paleolithic carrying capacity and led to an unprecedented increase in human population size.

In historic terms of civilization, this human population increase in rates and absolute size was a slow process. But in terms of our species history, ecosystem and geologic history, our population growth since the advent of agriculture represents a very rapid increase in our biological presence in the world. However, more recently, this process accelerated beyond all previous times and measures. Following post-Columbian exchange of new plant cultivars in the 16th century from the "western world" to the "old world," the development and evolution of a series of new technologies further lowered the previous environmental barriers to the bio-environmental carrying capacity of our species, the balance shifted to favor much greater population size.

The numerical magnitude of the human population growth's food needs is also accompanied by rapidly growing material demands of a widely dispersed wealth that is mathematically compounding the demands on the global food system productivity. For example, the ecosystemic impact of the increased consumption of animal food products requires vast increases in agricultural land use [1] [2]. Until recently, much of this land was virgin forest and has now been converted to provide feed for increasing numbers of animals that also produce substantially increased greenhouse gases (GHG) that was not predicted when the population was growing fastest, and when the GHG impact was not as well understood as it is now. Given current rates of climate change that are already reducing both the production of food and the quality of the food being produced, these are ominous implications that the global food system requires the best of what we can do to respond to this challenge [3].

The authors' previous work has focused on farm to fork in pairing enlightened cuisine development to solve food loss issues and create new opportunities to add to the solutions of waste [4]. However, our work is now encompassing "farm to gut," where added emphasis on metabolism, digestion and the role of gut bacteria can provide a new and substantial platform for developing significant improvement in nutrient status that is already being strained by climate change. Our concept is to identify the food synergies we already know about and begin to add many more through an active research program involving the world's indigenous people's traditional recipes to determine how this knowledge that has stood the tests of time and survival under a wide range of environmental circumstances can provide new insights from the cuisine spheres of knowledge and experience about how to manage local food production and preparation for consumption.

2. Materials and Methods

For the purposes of this brief paper, the cuisine focus is on low to middle income countries (LMIC) whose populations are mostly dependent upon plant sources of non-heme diets where Iron deficiency anemia is very high and is considered by most experts as the greatest public health problem in the world today [5]. We emphasize non-heme diets due to the efficiency of plant diets over meat diets and the environmental "costs" of animal based food products. We present a synthesis of clinical and culinary data that iron deficiency anemia among those populations can be solved incrementally without pharmacologic and other related first world interventions by emphasizing nutrient potential of local cultural traditions with specific culinary practices and recipes.

Taken as a whole, these data illustrate culinary practices that emphasize combining traditional local iron-bearing foods with the presence of vitamin C-bearing foods that directly increase adsorption of ferrous iron uptake by three- to six-fold (300% - 600%) [6]. It is well known that while animal protein is the richest source of bioavailable iron, vegetarians and those with little meat in their diet often get sufficient iron through recipes that combine foods rich in Vitamin C (such as chili, greens, and citrus) with beans and other foods that also contribute iron (such as cashews, lentils, potatoes, or kale), sometimes with scraps of meat where available. Leveraging time-tested traditional recipes from diverse cultures helps ensure that nutrients are bioavailable when consumed, maximizing their nutrient-density.

When considering dietary uptake sources of non-heme iron from plants, we factored in the other dietary constituents of the meal that interfere with absorption via binding the iron in various insoluble complexes such as with phytate, polyphenolic compounds (catechins in tea are well known to prevent absorption), dietary calcium, and animal food product proteins (eggs, meat, dairy). However, the effects of all these inhibitors of iron absorption in the duodenum, such as phytate, polyphenols, and calcium and milk proteins are overcome by dose-dependent addition of ascorbic acid (Vitamin C) either sourced through foods or added supplements to the diet [6] [7] [8] [9]. In short, by adding fresh naturally occurring fruit and vegetable sources to the recipe these interferences to ferrous iron absorption can be overcome [6] [7]. Of course, much of the Vitamin C diminishes in cooking with a review article citing ranges from 8 to 90%, but maintaining half seems to be a reasonable estimate [10].

3. Results

Table 1 illustrates how simple natural foods as ingredients can provide the essential micronutrients necessary for healthy eating.

The key combinations of Vitamin C and iron in these examples do not require extensive behavior change management because people already enjoy these culturally popular dishes. The proposition made here is that adding "food to food" is a top priority for helping people overcome diet induced maladies.

Table 1. Iron and Vitamin C complementarity before cooking in examples of traditional dishes based on best available data from US Department of Agriculture nutrient databases [11].

Traditional Dish	Select Ingredients	Iron per 100 g	Vitamin C per 100 g
Frijoles Refritos (Mexico)	Pinto Beans	**5.1 mg**	6.3 mg
	Onion	0.2 mg	7.4 mg
	Epazote	1.9 mg	3.6 mg
	Chile	0.3 mg	**118.6 mg**
Dal (India)	Lentils	**3.3 mg**	1.5 mg
	Green Chile	1.3 mg	**242.5 mg**
	Garlic	1.7 mg	**31.2 mg**
	Tomatoes	0.7 mg	**22.8 mg**
Kimchi-guk (Korea)	Tofu	**3 mg**	0.2 mg
	Kimchi	0.5 mg	**28 mg**
	Green onion	1.5 mg	**18.8 mg**
Cholent (Eastern Europe)	Kidney Beans	**8.2 mg**	4.5 mg
	Paprika	1.4 mg	0.9 mg
	Carrots	0.3 mg	5.9 mg
	Potatoes	1.7 mg	**19.7 mg**
Feijoada (Brazil)	Black beans	**2.1 mg**	-
	Kale	1.5 mg	**120 mg**
	Orange	0.1 mg	**53.2 mg**
	Chile	0.3 mg	**118.6 mg**
Hummus (Middle East)	Chickpeas	**6.2 mg**	8 mg
	Lemon	0.6 mg	**53 mg**
	Tahini	**9 mg**	-
Ugali and Sukuma Wiki (Tanzania)	Cornmeal	**1.1 mg**	-
	Collard Greens	0.5 mg	**35.3 mg**
	Tomatoes	0.7 mg	**22.8 mg**

It should be noted that Vitamin C is unstable when heated. Recipes that call for cooking of Vitamin C-rich products (for example, potatoes) will have less Vitamin C available than, for example, the feijoada, which is traditionally served with raw orange slices. Capturing cooking liquid in the form of a stew or soup, as many traditional recipes require, can further capture some of the Vitamin content that may have leaked into the cooking liquid. It should also be noted that some Vitamin C-rich foods like chiles, are used sparingly.

Beyond recipes, of course, one can imagine food processing opportunities, from local startups and community cooperatives through regional, national and international food manufacturers able to combine iron- and Vitamin C-rich foods. Examples include beans in tomato sauce, beans in chili sauce, and tofu in citrus marinade in which Vitamin C activity is preserved. Using traditional recipes for inspiration and product innovation is particularly promising for the production of sustainable, healthy and affordable food products.

According to the work of Hallberg and Hulthén, over 95% of the variability of ferrous iron uptake via intestinal absorption with Vitamin C is accounted for in a series of equations they developed to account for known sources of dietary inhibition of ferrous iron absorption and enhancement by Vitamin C [6]. Their data and method allow for more formal simulated comparisons among various diets to promote optimal absorption of iron.

Additionally, the indices of the efficiency of various recipes developed to express the degree to which they theoretically and clinically address micronutrient deficiency of iron within the cuisine traditions indicated on **Table 1** and others could be evaluated between and among regions. For example, these recipe strategies that are specific to the regional food system and traditions could be statistically compared with one another for outcomes and measured for cost-effectiveness within the possible local food systems and the social acceptability of the food recipes.

4. Discussion

In this section we explore the potential for more unified action by focusing on the well-established "field to fork" approach to lowering food loss and waste. Since beans and lentils are nearly universally consumed and provide a high level of plant-based iron, we reasoned that it is important from a sustainability perspective to provide a more complete analysis of the integration of our "food systems sensitive methodology" approach to focus on both "field to fork" and now link it to the "fork to gut" issues explicated in this paper [4].

The vision of the United Nations Sustainable Development Goal 12.3 is pointed at food waste reduction explicitly and more generally at food loss reduction. Retail and consumer food waste reduction is targeted at 50% while unquantified food loss reductions along the pre-consumer portion of the food supply chain are an integral part of the goal statement. The concept of responsible food production, processing, and consumption are foundational to achieving the goal for healthy food environments. In support, the Food and Agriculture Organization (FAO) elevated a new dimension to the Food Loss & Waste (FLW) imperative when they announced and launched the United Nations Decade of Action on Nutrition 2016-2025 [12]. FLW reduction has long been a key component of food security programs given the enormous amount of farm food that is wasted everywhere. According to the United Nations, 1/3 of all food that is raised or grown for humans in never eaten [13]. Without question, FLW occupies an important segment of the nexus between sustainable food management and health.

The United Nations Food and Agriculture Organization is a primary source of international data and information regarding food loss along the entire food chain from farms to manufactures, households, and consumers [14]. The prevalence of food loss is grouped by different regions of the world represented by

North America and Oceania, Europe, Industrialized Asia, North Africa, West and Central Asia, Latin America, and Sub-Saharan Africa. Detail is added by estimating regional food losses according to the following food chain sectors: agriculture, post-harvest, processing, distribution, retail, and consumer. The FAO also provides data on the amounts of production, and both imports and exports of specific products. By selecting specific crop types, it is possible to begin to see opportunities where production, FLW reduction, and nutrition provide complementary incentives to improve global health outcomes through sustainable food management. **Table 2** shows the amount of production and trading volumes for dry beans in four countries representing different regions of the world.

These countries were selected from the nearly two hundred for which the data are available because they illustrate certain important aspects of the problem and possibilities for reducing this wastage or, in the example from India, where the loss problem has been nearly solved.

Brazil, India, Mexico and Tanzania grow a large amount of beans for their own consumption as do many LMICs (**Table 2**). They also sustain considerable losses during production, storage, and handling. The amount of beans imported by many countries closely matches the amount of beans that are lost without regard to bean variety. For example, the weight of beans lost in India is almost the same as the weight of their bean imports. In Brazil the loss weight is equivalent to 67% of import weight. Mexico imports a modest amount, but they also lose much less than the Brazil or India. Tanzania on the other hand, imports very little and has developed a substantial bean export market. Economic scenarios for trading beans could improve if the loses were reduced among trading companies and their suppliers. These countries also experience iron-deficiency anaemia, IDA (**Figure 1**).

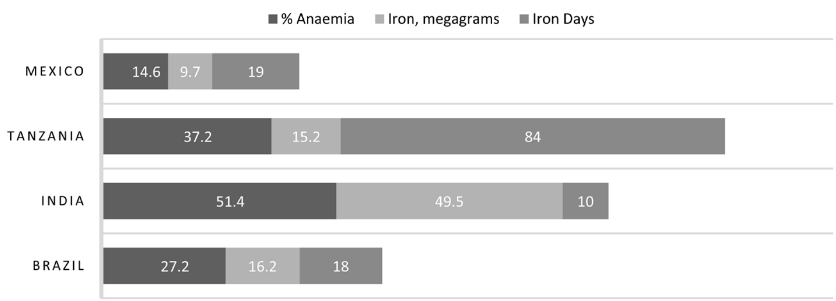

Figure 1. Prevalence of Anaemia and potential iron supplementation days from lost iron in dry beans. World health organization [16].

Table 2. 2016 dry bean trading, domestic production, and storage & transportation loss estimates (all in tons) [15].

Country	Bean Imports[1]	Bean Exports	Domestic Bean Production	Farm Production Bean Losses[2]	Post-Harvest Bean Losses	Total Domestic Bean Losses
Brazil	342,130	45,048	2,615,832	156,950	73,766	230,716
India	727,583	9719	3,897,611	272,833	434,973	707,806
Tanzania	1736	103,918	1,140,444	136,853	80,287	217,141
Mexico	163,791	32,892	1,575,989	94,559	44,443	139,002

In India, more than half the women of reproductive age, live with IDA. In Mexico, 14.6 percent of women have IDA, one of the lowest factors in Latin America. Levels in Brazil and Tanzania are high and lie between these two extremes. From a nutritional perspective, diverting lost beans back into the food system, with application in traditional recipes, represents a tangible and measurable way to reverse the trend of anemia in every country.

Figure 1 also shows bean losses in million grams and the amount of dietary iron available from the losses expressed as daily needs. It is significant in each country. In Tanzania, for example, the loss is adequate to meet 84 days of the daily requirement for iron in the meals of all women of ages 20 - 49. Robinson et al., in a broad modeling effort that evaluated different food loss and intervention scenarios, reported that iron deficiencies in some countries could be reduced by 83% with targeted efforts to recover and use lost staple crops including pulses [17]. Here we add to Robinson's finding by stressing that key enhancements to local cuisine discussed with **Table 1** will optimize the bioavailability of dietary iron. What are the causes of such widespread food loss and what can be done to reverse this persistent problem?

Based on a range of investigations over many years, the leading cause of production stage crop losses in low income countries are: pests and disease, draught worsened by poor water management, and inefficient harvest methods and timing. Kc and others found that absent or inadequate post-harvest storage controls and packaging containers were universal causes of losses for crops destined for markets and processors [18]. Distorted demand for only cosmetically appealing products in developed countries adds a perverse contribution to large quantities of food losses that impacts export opportunities and losses in low income countries. Insufficient demand for more nutritious foods is also a driver of crop losses in high income countries that can negatively impact food sales from global exporters [19].

The malfunctioning food chain has been largely repaired at least on one region of the world—Andhra Pradesh State, India—for chickpeas [20]. Here, estimated food losses are reported to be 2.5% through transport and handling with zero losses at some steps in the process. A value significantly below the 17% global average production and handling losses for pulses in other LMICs [14]. The solutions that coalesced to achieve this remarkable level of food loss reduction took time. Underlying the success was several noteworthy factors, including broad and active government support and actions, the presence of an agriculture research institution that facilitated development, testing, and quick deployment of chickpea farming advancements that worked together to get more food from farms to markets, and investment capital to launch promising technological and logistics solutions. One additional factor underlying the entire process is the ever-present desire to increase protein and improve nutrition throughout the local economy. To the degree that other countries adopt this principle as one with a great amount of transformative incentive for everyone along the food chain, the sooner pulse and other types of food losses will decrease, and populations will experience related improvements to their health outcomes.

In the initial section of the paper, we proposed a novel cuisine-specific solution to iron deficiency anemia designed to fit within existing food traditions. However, this cuisine sensitive solution needs to be integrated with issues of sustainability of the food systems providing the primary sources of plant-based iron in the diet. This example also emphasizes that need for integrated approaches that span the entire food system to work effectively toward the goals of increased sustainability in these times of great added stress by increased need for global food sources while undergoing the negative effects of global climate change on plant productivity and quality of nutrients. Our ongoing research into this topic from the perspective of Agri-Ecological zones, areas with similar agriculture potential may uncover new opportunities for countries to grow climate resilient bean varieties whose consumption would enhance targeted nutrient-based health outcomes and economic conditions for LMIC [21].

5. Conclusions

While much attention has been paid to food loss and waste in terms of tonnage of food wasted and recovered, far less has been devoted to the nutritional quality of that food loss [22] [23]. Honoring traditional recipes in tandem with preventing and recovering food loss and waste adds a new dimension to food recovery—nutrient recovery and bioavailability. More explicitly, the goal is not to just keep food in the food system to provision our growing population, but to make sure that time-tested methods are employed to maximize the bioavailability of the nutrients re-covered. The authors submit that considering both the quality and quantity of food recovery, from farm—and beyond fork—to gut, is key for global policy development in nutrition public health. We also argue that maximizing the availability of key nutrients, like iron, will reduce the stress of animal husbandry on the environment, reduce greenhouse gas emissions; and thereby, reduce agriculture impacts to climate change and global warming.

In terms of food waste, if the diet can be shifted to containing more naturally occurring Vitamin C, the net advantage would be immensely more efficient. Furthermore, if we could also improve the common Vitamin A deficiencies through this method (since it is known that Vitamin A sufficiency also relieves anemia), then the combination of two of the most limiting micro-deficiencies in the human diet can be addressed through careful emphases of dietary adaptations to nutrient problems that could make a very substantial impact upon world health [24]. This could allow for the development of new nutrient-diet-cuisine studies that could substantially improve the efficiency of diets now widely consumed. From our food loss reduction perspective, this would result in eliminating wasteful losses of nutrient absorption potential by continuing to consume contemporary diets that are composed of recipes that defeat the optimum utilization of the micronutrient constituents that produce immense public health problems that lower human ability, happiness and productivity.

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Author Contributions

Deutsch provided the culinary perspective. O'Donnell led the writing and provided the food loss and waste analysis. Katz provided the overall conceptual framework for the paper and nutrition sections.

Conflicts of Interest

The authors declare no conflict of interest.

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