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Nutrition and Food Safety as Strategic Assets

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***Abstract*—**The world is facing a growing food crisis. The concerns of food nutritional value, food safety and food security are becoming increasingly real. There is also a direct relationship to the risk of diseases, particularly chronic diseases, to the food we consume. So, there are increasing concerns about the modern day food ecosystem creating foods that can provide the nutritional components for organ function sustenance, as well as, taking a serious view on diet-related diseases. This paper addresses some of the above concerns and gives an overview of the current global situation relating to food nutrition and safety. The paper reviews nutritional aspects of food today compared to those of the last century, compares whole foods found in supermarkets versus those organically grown, as well as population behaviour towards food choices. It provides scientific insights into the effects of some of the global trends such as climate change and other changes environmental changes, and presents what individuals and corporations are doing to use the latest nutritional technologies as strategic assets. Finally, it briefly highlights some of the innovative solutions that are being applied to address several of the above concerns.

***Keywords*—**Food crisis, food safety, nutritional aspects of food today compared to those of the last century, global trends.

I. Introduction

THE world is facing an increasing health burden. The World Health Organization (WHO) relates this rising trend to demographic and dietary concerns. Scientific evidence shows that unhealthy diet and physical inactivity, as well as tobacco use are major global determinants of non-communicable diseases [1]. More adults, at younger ages, are now faced with chronic diseases such as osteoporosis, diabetes and cancer, diseases once associated with geriatric care [2]. The work force is facing an all-time high loss in productivity due to staff sicknesses and medical leave. In a recent Forbes report [3], the costs of absenteeism from work due to health problems amounts in the billions of dollars (US) annually.

This paper reviews some of the issues that the world is facing that has resulted in an essential nutrition deficiency in our food supply chain. Many of the factors are within our individual control, but collectively as a population appear to be heading for the worse. If diet-related diseases can be curtailed, countries, societies, national organizations and even corporations may start to deem good nutrition and food safety also as a strategic asset to reduce this escalating health burden to society [2].

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II. Global Food & Nutrition Problems in Perspective

A. The Scale of the Problem

The most common nutritional problems in the developing world range from protein-energy malnutrition (PEM), vitamin A deficiency, iodine deficiency disorders (IDD) and nutritional anemias. Estimates by world bodies such as the United Nations Food and Agriculture Organization, as well as the WHO suggests that more than a quarter of the developing world is chronically undernourished with PEM affecting 192 million children and over 2 billion exhibiting signs of micronutrient deficiencies towards the end of the last century [4]. Prevention becomes a more feasible solution rather than facing the causative health burden.

B. Food Production and Food Security

Achieving food security in households should be made a priority in all nutrition planning with the inclusion of interior food policy. Accomplishing this achievement means 1) a safe food supply which is adequate in good nutrition both socially and at the individual level; 2) a relative stable food supply, accessible to every household for the requirements of its members. There is also a greater emphasis by nutrition experts on the need of a well-balanced diet to provide all the necessary macronutrients such as protein and energy-giving carbohydrates and fats and micronutrients such as vitamins and minerals. Beyond household food security is the need to encourage food distribution that ensures good nutritional status for all the members of the household. However, there exists a paradox in the nutrition aspect of the equation; on the one hand, malnutrition results in serious health ailments, while on the other, excessive intake of food and certain nutrients has negative health consequences [5].

C. Food Security

The ability to have regular access to sufficient food and good nutrition for healthy living is what defines food security. There is general recognition of the fact that most malnutrition cases in Third World nations are the result of inadequate energy and protein consumption and the link between malnutrition and infectious diseases. Severe protein deficincy seldom occurs in populations with staple foods being ceral crops unless there is a food shortage. This is due to protein being found in most cereals and that these crops are often consumed with moderate amounts of legumes and vegetables. Lack of protein in these populations is seen mainly in adolescents with frequent infections affecting their protein intake [4].

III. Depleting Nutrition in the Food Ecosystem

As food production around the world becomes more

commercial, repeated planting cycles of the same crops year after year depletes the soils of their vitamins and minerals. Furthermore, farms use fertilizers that do not replenish the soil of their depleted micronutrients, making the poor soil status even more pronounced. Genetic reproduction and several other modern agricultural practices to aid competitiveness has driven foods with better aesthetic features but are severely lacking the essential nutrients as in the past. Thus, the above circumstances are negatively affecting the much-needed micronutrient supplements in the human diet to help achieve optimal organ function and better health. Agricultural quality has therefore directly affected food quality; especially, over the past 75 years [5], [6].

With the increasingly busy lifestyles of the younger generation, especially in the metropolitan areas, convenient and pre-prepared foods have become the preferred grazing habits. These foods typically contain saturated fats, highly processed meats and refined carbohydrates, which lack vital micronutrients but are dense with various chemical additives. This phenomenon of 'instant' and 'highly processed' foods are increasingly linked to the rising levels of nutrition-related health problems. This has in turn become an increasing societal burden globally [5].

A. Mineral Depletion in Foods Past and Present

Thomas [6], presented a ground-breaking revelation when he published the findings of how various nutrient levels have changed for produce such as vegetables, fruits and different cuts of meats. A summary of his findings is tabulated in Table I. The statistics were calculated by comparing and contrasting data first published in 1940 by McCance and Widdowson [7]. Since the majority of vegetables are harvested whole, they therefore serve as the good indicators for soil mineral status.

TABLE I
SUMMARY OF CHANGES IN THE MINERAL CONTENT OF VEGETABLES, FRUIT AND MEAT BETWEEN 1940 AND 1991 [6]

Type of Mineral	Vegetables (27 varieties)	Fruits (17 varieties)	Meats (10 cuts)
Sodium (Na)	49% less	29% less	30% less
Potassium (K)	16% less	19% less	16% less
Phosphorous (P)	9% more	2% more	28% less
Magnesium (Mg)	24% less	16% less	10% less
Calcium (Ca)	46% less	16% less	41% less
Iron (Fe)	27% less	24% less	54% less
Copper (Cu)	76% less	20% less	24% less

Just early last century, scientists realized that nitrogen, phosphorous and potassium were the main minerals required for plant growth. The plant growing conditions were then updated to require these minerals together with sufficient water, sunlight and carbon dioxide. Because of this, the so-called NPK fertilizers gained favor and were adopted by farmers. Calcium and iron were also sometimes added to fertilizers [8]. Over time, with increasing cost of minerals and cost pressures on farming, the presence of these minerals in the fertilizers used declined. Coupled with food processing techniques that expose the food to often higher temperatures for longer times, the aggregate effect results in food items with a significantly lower mineral content.

It was also noted that mineral ratios had occurred between 1940 and 1991. Several key ratios, such as Ca:P, Na:K, Mg:Ca, Fe:Cu, are presented in Table II. The figures were calculated using each vegetable studied [6]. The change in ratios represent a major alteration in the ratios between the minerals in our human body. This is due largely to more recent discovery of biochemical interactions and biosignal pathways within the human body.

TABLE II
SUMMARY OF CHANGES IN THE MINERAL RATIOS OF VEGETABLES BETWEEN 1940 AND 1991 [6]

Mineral ratio \ Year of test	1940	1991
Calcium (Ca): Phosphorous (P)	1:2	1:1
Sodium (Na): Potassium (K)	1:10	1:17
Magnesium (Mg): Calcium (Ca)	1:4.8	1:3.4
Iron (Fe): Copper (Cu)	0:10	1:30

Chemicals such as herbicides, fungicides, pesticides, antibiotics and hormones are often found in the materials used to produce the foods that we eat. These generally tend to cause significant deterioration to the mineral content in our foods. As such, the general populace, especially in developed regions, are not facing a shortage of food, the critical issue is that the new foods give a lot less essential micronutrients. The combined effect of sustained micronutrient malnourishment typically results in wellness and health problems [5].

B. Nutrient Depletion of Agricultural Soil

An increase in nutritionally related diseases in both animal and human populations is reflected by the nutrient depletion in the soil composition. Loss of important nutrients especially vitamins and minerals in our crops is caused by the depletion of the soil nutrient content through unsustainable agricultural practices [9]. The accelerated depletion and reduced bioavailability of vital micronutrients and trace elements in the soil has been attributed to over-use of nitrate, phosphate and potassium (NPK) fertilizers. Research found significant declines in the mineral and vitamin content of 43 garden crops grown in the US [10]. United Kingdom vegetables grown between 1940 and 2002 displayed loss of important minerals ranging from 15% to 62% [11].

Soil fertility is also reduced by extremely toxic pesticides with the destruction of important soil microorganisms that aid in plant nutrient uptake and natural replenishment of the soil.

IV. FOOD PROCESSING & MANUFACTURING

The complete range of essential nutrients are important to the human body for ensuring optimal organ function. Food nutrients are classified into macronutrients such as proteins, fats, carbohydrates and micronutrients such as vitamins and minerals. When foods are processed, nutrient loss may occur due to sensitivity to heat, light, oxygen, pH of the solvent or combinations of these [12]. Nutrient loss may also occur during food transport, food handling and storage [13], [14].

A. Nutrition Comparison in Fresh, Frozen and Canned Fruits and Vegetables

Food storage and processing have long been around because of the need for converting perishable fruits and vegetables into safe and more stable products that can be consumed year-round. Increasing shelf life also meant that these perishables could be transported, and therefore, exported to consumers around the world. In general, this is done by slowing the respiration of fruits and vegetables by refrigeration. The main objective here is to ensure a safe product of the highest possible quality. Changes in color, texture, flavor and nutrition of the food ultimately depends on how food processing is carried out [15].

Some loss of water-soluble nutrients is attributed to washing, peeling and blanching steps prior to processing. Thermal processing such as canning and pre-freezing blanching treatments cause the loss of heat-sensitive nutrients such as ascorbic acid (vitamin C) and thiamin. Degradation of some nutrients prior to consumption is expected due to the need for both unprocessed and processed fruits and vegetables to undergo transport and storage processes. Additional cooking of the processed food can also destroy nutrients. Vitamin C, the B vitamin complex and phenolic compounds are water-soluble and sensitive to heat and oxidation. All these properties make these nutrients more vulnerable to degradation during food processing, storage and cooking. Recent studies examined the effects of food processing using heat on ascorbic acid for various commodities (see Table III). A decrease in ascorbic acid was observed across all products studied under commercial thermal processing conditions [15].

The results showed that freshly picked vegetables consistently contained the greatest amounts of vitamin C in all vegetables studied [16]. Immediately after harvest, the process of vitamin C degradation is initiated. Green peas, for example, were found to lose 51.5% w/w of ascorbic acid during the first 24–48 hr after picking [17]. Vitamin C content in fresh peas and spinach stored at 4°C were lower than that in the same produce frozen after 10 days. Fresh storage at ambient temperatures resulted in greater loss with 50% loss of vitamin C in peas within a week, and all vitamin C in spinach within 4 days [18].

TABLE III
VITAMIN C (G/KG WET WEIGHT) IN FRESH AND CANNED VEGETABLES [19]-[23]

Commodity	Fresh	Canned	Loss (%)
Broccoli	1.12	0.18	84
Corn	0.042	0.032	0.25
Carrots	0.041	0.005	88
Green Peas[a]	0.40[b]	0.096[b]	73
Spinach	0.281[b]	0.143[b]	62
Green beans	0.163[b]	0.048[b]	63
	0.053	0.05	NS
Beets	0.148	0.132	10

[a] Average of two consecutive years.
[b] Based on USDA nutrient database.

B. Impact of Cooking on Food Nutritional Content

Food is an essential factor for our growth and sustenance. The food procured directly from nature is typically rich with macro- and micro-nutrients. Proteins are seldom destroyed during cooking. Cooking, and especially overcooking, may alter the macro-nutrients into harmful products by altering the structure of nutrients and cause nutrient loss in food [24].

Proteins are not lost during cooking as easily as vitamins, but are lost through degradation when food is overcooked or cooked at high temperatures. Three factors are important: 1) duration of cooking, 2) temperature, and 3) method of cooking. Cooking also influences the structure, amount and activity of the vitamins and minerals [25], [26]. By changing the cooking method, the nutrient composition of the food also changes. For example, most of the vitamins are lost during the processes in manufacturing wheat flour. Prolonged cooking of vegetables cause the depletion of most of their vitamin C [23]. Based on vitamin C, Fig. 1 depicts the effect of various cooking methods on vitamin C losses.

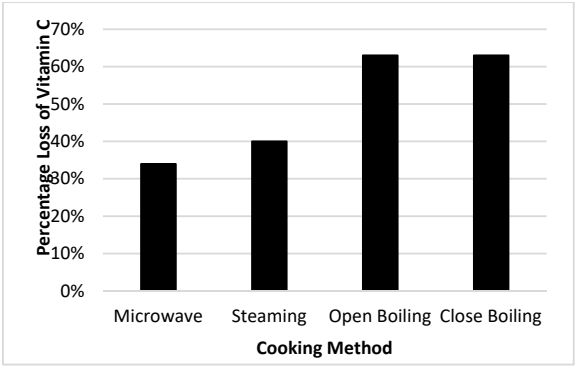

Fig. 1 Percentage vitamin C loss using different cooking methods

In the case of vitamin C, Fig. 1 shows that the percentage loss for boiling vegetables is higher than that for steaming and microwaving, respectively [24].

C. Nutrient Depletion through Other Factors

Nutrient depletion of foods also occurs through the harvesting, storing and transport to markets. The natural ripening of agricultural produce is disrupted with premature harvesting. For some of the produce, artificial ripening was applied when they arrived at their destination. All these processes cause further reduction in their nutritional quality. Despite the dwindling nutrient content of foodstuffs by the time they reach the palate, it is in the final preparation for the dinner table where considerably greater nutrient damage occurs. The amount of loss depends upon the food preparation and cooking methods, as mentioned previously. In food preparation, the greater the surface area to volume ratio exposure, the greater will be the nutrient depletion [5].

Thiamine and vitamin C, which are the most susceptible to thermal degradation, indicate overall loss in nutrients which is due to exposure to light, heat, oxygen, and pH changes.

V. Food Safety

Food safety refers to the conditions and practices that preserve the quality of food and reduce risks associated with foodborne illnesses. Third-party verification and certification to food safety standards exists. For businesses to remain competitive, they adopt certified standards and are subjected to food safety audits on a regular basis. These give a common ground for food businesses and generally lower business costs by reducing the burden of multiple customer audits and variations in requirements [27]. Key differences between the certification schemes relate to where the business is along the food supply chain line (primary producer, manufacturer, logistics/transport etc.), the produce sector (e.g. aquaculture, produce, meat, poultry etc.), as well as the scope of the business (i.e. local versus international trade). Some examples of ingredients that have received more significant debate are presented.

A. Nitrites and Nitrosamines

Nitrosamines are formed from secondary or tertiary amines reacting with a nitrosating agent usually nitrous anhydride, formed from nitrite in acidic, aqueous solution, in foods. The volatile nitrosamine which occurs most commonly in food is nitrosodimethylamine (NDMA). Foods containing nitrosamines such as NDMA include cured meats, beer, cheeses, non-fat dry milk, and salted or dried fish [28], [29].

N-nitroso compounds in foodstuffs are potent cancer-causing substances. In a 1999 study, a significant positive association was observed between intake of NDMA and subsequent occurrence of colorectal cancer, demonstrating that N-nitroso compounds can induce colorectal cancer in humans [30]. N-nitroso compounds can induce tumors in various animal species at various sites [29]. Exposure to nitrosamine compounds is derived both from the diet and other environmental sources and from endogenous synthesis within the body [31], [32].

B. Monosodium Glutamate (MSG)

MSG in foods has been associated with obesity, sleep disordered breathing (SDB), cardiovascular and pulmonary diseases, amongst other health problems [33].

MSG and SDB, a sleep disorder, is becoming another public health concern, since they could increase the mortality and morbidity such as by causing cardiovascular or pulmonary disease. SDB also includes obstructive sleep apnea (OSA). Recently, an association between the consumption of MSG and SDB was found in a study conducted by the Jiangsu Nutrition (JIN) among Chinese adults in normal weight [34], [35]. Snoring was also associated with MSG in people with normal weight. Recent research had theories that OSA was associated with gastro-esophageal reflux due to MSG increasing gastrointestinal motility [33].

C. Aspartame

Consumption of food or beverages containing the artificial sweetener, aspartame, leads to three natural substances being released into the body: the amino acids phenylalanine and aspartic acid, and alcohol methanol [36]. Many Americans consume aspartame (L-aspartyl-L-phenylalanyl-methyl ester), mainly in beverages, causing plasma phenylalanine to rise significantly, with a three-fold elevation in plasma levels of phenylalanine is some studies [37]. The phenylalanine in aspartame could cause neurologic effects given that phenylalanine can be toxic to nerves and can affect inhibitory monoamine neurotransmitters synthesis. Phenylalanine consumed in the form of aspartame, with the other large neutral amino acids (LNAA), caused a rise in plasma phenylalanine levels relative to those of the other LNAA, and hence, a rise in the plasma phenylalanine ratio (the ratio of the plasma phenylalanine concentration to the summed concentrations of the other LNAA) [38].

The rise in the plasma phenylalanine ratio causes a rise in brain phenylalanine levels with a drop in brain levels of the other LNAA, due to phenylalanine competing with the other LNAA for the single transport macromolecule within the endothelial cells lining the brain's capillaries mediating the uptake of LNAA [38], [39]. The imbalance of LNAA in the brain might have attributed to an increase in the likelihood of seizure in people who regularly consume aspartame [40]. Based on the results of a study conducted by the Cesare Maltoni Cancer Research Center of the European Ramazzini Foundation, aspartame is potentially a carcinogen [41], [42]. This was possibly attributed to the methanol being released from aspartame during metabolism in the digestive system and converted into formaldehyde and then to formic acid [36], [43]. This is supported with other studies on methanol's and formaldehyde's potential carcinogenicity [41], [42].

VI. Discussion

A. Global Problems

Several problems worldwide, both natural and man-made, put a severe strain on the Earth's limited natural resources, one of which is nutrients in the soil which relates to the nutrients in our food. Climate change brought about by new highs in carbon emissions cause unusual weather such as heavy rains and drought, which in turn causes nutrient-rich top soil to be eroded by heavy rains or hardened and rendered useless from prolonged periods of drought. The world's population continues to increase and hence there is an increased demand for food. Farmers resort to the use of chemical fertilizers and pesticides to boost food production to meet the increase in demand. These chemicals, while improving food production, cause a decrease in food nutrition levels by distorting the mineral ratios in food, as in fertilizers that boost phosphorous levels in the soil and destroy nutrient producing soil bacteria. The chemicals also cause leaching of soil nutrients. Nowadays, people do not practice sustainable farming such that soil nutrients taken up by crops are returned to the soil via means such as compost or organic fertilizers. This unsustainable practice is seen worldwide, particularly in countries with huge growing populations such as China and India.

Because of the above unsustainable farming practices, the nutrition in food today is affected and significantly less compared to those produced last century. As a result, the diminishing nutrient-level and range in food has inadvertently caused an increase of chronic diseases, such as cancer, rheumatoid arthritis and osteoporosis, once seen in the elderly, now diagnosed amongst young adults in their 20s and 30s. This is observed not just in developing countries, but in developed countries [5]. Thus, there is a growing need to supplement these nutrients to complement our usual food intake. We are growingly less able to depend solely on eating whole foods to obtain the full spectrum and recommended levels of essential nutrients that our bodies need to function well.

B. Food Processing

As mentioned, food processing is very common in the 21st Century, especially in the developed countries. Food processing such as canning and frying is required for hygiene reasons to kill bacteria, viruses and other food-borne pathogens before they are consumed. However, many of the food processing methods such as canning, boiling and deep frying involve very high temperatures. Food processing was also carried out for the convenience of consumers such as the cut fruit sold in supermarkets. Many people, especially youths, consume a lot of such processed convenience food. These fast and often 'cheap' instant foods are usually void of many of the essential micronutrients that fuel our organs for optimal function. Eaten on a sustained basis without the proper nutrient supplementation, our organs start to gradually prematurely degrade and start to underperform, giving rise to a host of health issues.

Food processing causes the degradation of important vitamins and minerals from food and cause the food to be dense in energy-rich, disease-associated carbohydrates and lipids. Even if no heat is involved, for example food preparation that only involves slicing and cutting vegetables and fruits sold in wet markets and supermarkets, a decline in important nutrients is still observed. Some vitamins, such vitamin C, are oxidized in the presence of oxygen.

C. Food Safety

In order to transport food and agricultural produce over long distances, food producers and manufacturers tend to add substances to prolong the shelf-life of their food products. In the past, people preserve food in salt and salt water. But with scientific advancement in food additives, food producers resort to chemical preservatives such as sodium nitrite. Artificial chemical food additives such as aspartame and monosodium glutamate (MSG) were preferred over natural food additives such as sugar and salt to give flavor to food. Cost was partly the reason. Innovative products such as caffeinated energy drinks have been known to cause caffeine intoxication and dependence, with negative withdrawal symptoms for some.

Many of these food additives when metabolized in the body produce carcinogenic products that induce cancer from prolonged consumption, as seen in food preserved with nitrates such as bacon and ham. Such compromises in food safety has led to induced health problems including cancer and atherosclerosis due to prolonged consumption of these foods

D. Solutions

Scientists working with industrial players have been creating technologies to compensate for the global malnutrition plight caused by global warming and unsustainable farming practices. Organic fertilizers are now used to replenish soil nutrient levels to reduce the likelihood of nutrient leaching from the soil or improper mineral ratios in the soils. Scientists also found that the use of fertilizers of organic origin improve soil nutrition levels with increase in soil organic matter and other soil properties [44]-[47]. Another method is the incorporation of greenhouse technologies and vertical farming in an urban setting where the soil nutrient levels are closely monitored and regulated. In the second method, less land space is used and the risk of malnutrition to poor soil quality and human transmitted diseases is reduced [48].

More technologies that could retain or built into foods with the essential nutrients are required. This is important since consumers are more inclined to eat meals rather than to purposefully consume nutritional supplements separately. These new nutrients need to withstand the current food processes or new food preparation techniques have to be created – such as blast freezing and blast chilling.

In Singapore, a survey conducted in 2014 studied healthy lifestyle trends amongst individual workers in large multi-national corporations, small-medium enterprises, government bodies, statutory boards, voluntary welfare organizations [49]. The study included age, gender, as well as race and seniority level within the hierarchy of that organization. The result of that survey revealed that many, if not most of the top leadership within an organization today regularly exercised and ate healthy. For this group, nutritional supplementation was almost always present as part of their healthy diet, along with a good amount of exercise and sports weekly. The findings here suggest that to perform well in today's competitive and complex world, nutritional supplements was required to serve as a strategic plus point to an individual's performance – mental and physical. The study also suggested that the cost of ongoing poor health and medical leave for the employees can add a significant cost to the organization, particularly business corporations.

By creating awareness of the essentials of nutritional elements for human organ function, the problems faced with today's foods and food processes, and augmented with new nutritional technological solutions, it is hoped that the growing health burden on our society can be curtailed and better managed.

VII. Conclusions

Nutrition is important for a healthy population to be active and productive. However, with climate change, unsustainable farming and the heavy use of chemicals to preserve and add

flavor to food, people are not only getting less of important nutrients, but also more toxic chemicals which will make them susceptible to diseases such as cancer, and a rise in mortality within the population.

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