Review Article

Future food

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Food systems have changed markedly with human settlement and agriculture, industrialisation, trade, migration and now the digital age. Throughout these transitions, there has been a progressive population explosion and net ecosystem loss and degradation. Climate change now gathers pace, exacerbated by ecological dysfunction. Our health status has been challenged by a developing people-environment mismatch. We have regarded ecological conquest and innovative technology as solutions, but have not understood how ecologically dependent and integrated we are. We are ecological creatures interfaced by our sensoriness, microbiomes, shared regulatory (endocrine) mechanisms, immune system, biorhythms and nutritional pathways. Many of us are ‘nature-deprived’. We now suffer what might be termed ecological health disorders (EHD). If there were less of us, nature’s resilience might cope, but more than 9 billion people by 2050 is probably an intolerable demand on the planet. Future food must increasingly take into account the pressures on ecosystem-dependent food systems, with foods probably less biodiverse, although eating in this way allows optimal health; energy dysequilibrium with less physical activity and foods inappropriately energy dense; and less socially-conducive food habits. ‘Personalised Nutrition’, with extensive and resource-demanding nutrigenomic, metabolomic and microbiomic data may provide partial health solutions in clinical settings, but not be justified for ethical, risk management or sustainability reasons in public health. The globally prevalent multidimensional malnutritional problems of food insecurity, quality and equity require local, regional and global action to prevent further ecosystem degradation as well as to educate, provide sustainable livelihoods and encourage respectful social discourse and practice about the role of food.

Key Words: food systems, food security, econutrition, ecosystem health disorders (EHD), personalised nutrition, peopleless food outlets, clinical nutrition

INTRODUCTION

Our food systems and habits have changed progressively and greatly with migration out of Africa, and since, firstly, the advent of agriculture, then with mercantilism and colonialisation, followed by industrialisation, globalisation, market-driven economies, the digital age and, now, accelerating climate change. These shifts have been characterised by unrelenting population growth and punctuated with repeated conflict. We have been identified as Homo Sapiens sapiens for only about 150-200,000 years or about 8,000 generations and many of us had ancestors who left Africa about 50-60,000 years ago. We have been remarkably resilient in our homeland and on our travels, as omnivores, ultimately being more settled through agricultural practices. With that settlement came the beginnings of population explosion and an associated intrusion and transformation of ecosystems with the features of local livelihoods, namely those of habitat and shelter, water supply, food acquisition and production, textiles, healthcare and transport. Our education was community-based. Our social structures were ones of consent, but increasingly hierarchical. Our belief systems took account of the natural world and became systematised, often with religious formats. Step-by-step we have wanted more of our environment, of others and of ourselves. Each of these factors was likely to alter our food system and habits.\(^1\) The foods which supported our socio-biological needs were varied, with a range of patterns, mainly from plants, along with fish and other aquatic creatures, eggs and birds, and occasional other animals. From earliest times we cooked, arguably what defined us, so that we rarely depend exclusively on raw food.\(^2\) Our diet was related to a minimum need for physical activity, probably not less than 30-40 minutes of moderate activity most days.\(^3\)

While the effects of agriculture on population expansion\(^4\) and of industrialisation on ecosystem degradation and more, invoking the Anthropocene era,\(^5,6\) are regarded as the most threatening and continuing challenge to food systems and habits, and to health, it is the acceleration of climate change now being experienced which is likely to irreversibly and adversely affect them.\(^7,8\) We can expect that the consequent and increasing food and water insecurity will compromise the healthful properties of food and...
beverage, even as we strive through socioeconomic and technological means to mitigate it.

In the meantime, FAO (the Food and Agricultural Organisation of the UN System) has produced guidelines as to how we might reconcile food choice and climate change.9

POVERTY AND HUNGER: ETHICS AND EQUITY

‘Poverty and hunger’ remains the world’s most pressing nutritionally-related health problem, although it is increasingly accompanied by body compositional disorders which include overfatness with sarcopenia and the preventable nutritional problem of hypertension.10,11 It is also associated with immunodeficiency and infection, which together account for most of the world’s burden of disease.12,13 Access to a biodiverse diet through home, school and community gardens and small amounts of animal-derived foods like eggs and dairy would make optimal dietary patterns possible. Short of this, more nutritious staples will help.14 The UN System through the World Food Program provides for more immediate solutions with formula foods such as Fortified Blended Foods (FBFs) and Ready-To-Use Foods (RUFs).15 Longer term solutions require integrated programs to allow overall socio-economic development with environmental sustainability.

Poor governance, conflict and illiteracy (especially of women) have remained the greatest risks for hunger and poverty16 – but to which climate change must now be added.

Against this background, it is sobering to think that so many of us are focussed on finessing our considerable relative health advantage, granted in the main by where we were born, chasing particular nutrients or foods as the answer. Yet it must be acknowledged that, in an urbanised environment, the cost of a varied plant-based diet is greater than one that has less fruit and vegetable.17,18 The fruit and vegetable consumption, however, is associated with less total medical costs.19 Complex nutritional problems have emerged as the poor have been targeted with highly processed cheaper foods, still profitable to the food processors that health gains will follow.20 For the economically marginalised, the sustained availability of affordable nutritious food is a high priority. Coupled with maternal education and literacy, poverty and hunger would progressively be solved.21

For the many, we are not talking about individual foods or nutrients, but about cooperative systems involving the environment, food, education, health, communication, transport and finance to deal not only with hunger and poverty, but with all nutritionally-related health problems.22

PERSONALISED NUTRITION

The advent of nutrigenomics and nutrigenetics, with the recognition that gene expression can be modulated by diet and that there is a host of polymorphisms which alter nutrient requirements, has encouraged consumers and food processors that health gains will follow.23-29 At the individual clinical level, the promise is real, but with the caveat that risk-benefit analysis will apply as for pharmacotherapy. In the public health domain, multifactoriality is usual, benefit must be likely for the majority and risk must be negligible.

A problem with much contemporary food research is that it seeks uni-ingredient approaches to a putative health benefit, with little appreciation or assessment of risk. There is a proliferation of product with dubious risk-benefit in the market place, where much harm may accrue before it is recognised. This is even more so in Asian food cultures where the interface between food and medicine is blurred and where the regulatory framework is still evolving.

At the same time, for those and communities at high risk, the health promotional capacity of foods in disease prevention is an active and encouraging field of nutrition science.30-62 Guidance is increasingly provided at the point of purchase on food labels,63,64 but, in the future, should be available through smart phone connections to the internet.65

Nutritionally-relevant personal behaviours like physical activity, recreation, school and work-place practices,42,66,67 adequate sunlight without skin damage,1 avoidance of substance abuse,58,68 sleep, social activity, and stress management must be invoked along with food habits to enhance food-related health and wellness benefit.

FOOD PROPERTIES: SENSORY, PHYSICAL, CHEMICAL, MICROBIOLOGICAL, NUTRITIONAL, SOCIAL, ECOLOGICAL

Nutrition and health care professionals tend to think about food properties narrowly, as those to do with nutrients, macro-, micro- and sometimes phyto-nutrients. This short-changes the characteristics of food and the appreciation of its biological effects. These are mediated jointly by its sensory, physical, chemical, microbiological, nutritional, social and ecological properties. For sensory, this means its appearance, touch, smell and taste, sound (eg crunch on eating). For physical, it means its structure, mouth feel, and bioavailabilities.70 For chemical, there is a myriad of nutrient and ‘non-nutrient’ (function not presently known) sub-types, including peptides, lipids, oligosaccharides, nucleotides and polyphenols which may be monomeric or polymeric. For microbiological, we are more prokaryotic (cells without nuclei) than eukaryotic, in gut, skin, and in respiratory and reproductive systems; many food substances are transformed by gut microbes, which produce fuels and regulatory compounds for organs distant from the gut, as in the cardiovascular system71 even brain,72 and for energy metabolism in obesity and diabetes.73,74 Probiotic and prebiotic foods are gaining much research attention.75-78

Food, with its many properties, plays a role in social discourse. Whatever they are, its availability, production and authenticity depends on ecological integrity.

DIETARY DIVERSITY, NUTRITIOUS FOODS AND STAPLES

The most consistent dietary guidelines, embedded in the FAO-WHO Cyprus declaration on Food based Dietary Guidelines (FBDGs) is to have a biodiverse diet,79 duly adapted for the Asia Pacific region.80 Dietary diversity is a measure of household food security81 and a predictor of survival and health outcomes.82-85 The struggle has been to achieve this, both in socioeconomically disadvantaged
communities and within even affluent societies. Migration and cultural diversification helps, as has been noted for countries like Australia. Some cultures like the Japanese and Chinese have food philosophies and culinary practices which encourage biodiversity.

As indicated above, staples like rice, wheat, millet, beans and potatoes can be bred for more nutritious properties, but these as monocultures are susceptible to crop failure. Wheat is vulnerable to rust and to small increases in environmental temperature. For these reasons, in North-west China, attention is being given to other grains than wheat for the bread mantou. Similar developments are seen with a wider range of products made from millet.

THE ORIGIN OF FOOD AND FOOD SYSTEMS: LOCALITY, TRADE AND GLOBALISATION, PROCESSING, PACKAGING, STORAGE, TRACEABILITY

Food manufacture and preparation away from home creates uncertainty about what has happened to it from acquisition to the point of consumption. The problem is exacerbated by globalisation and extended food trade. It involves the unknowns in food processing, packaging and storage.

This need to know and to have an input into one’s food system is a major factor in the anxiety about food safety and security. It also constitutes an added mandate for education and involvement of the family and community, especially women and children about food.

Traceability of food back to its origin is an agreed strategy for food safety regulation, but it also could be available with bar codes or QQ smart phone photography to consumers. This could have rapid uptake in economic development where internet connectedness is overtaking landline communication. Such methodology could put consumers back in informed control of their food supply.

FOOD SAFETY AND SECURITY

Food safety is a dimension of food security. Peoples’ worries about food are generally mostly about its safety, even though regulatory bodies are charged with risk assessment and management. But risk communication is often inadequate and people may be unnecessarily concerned. On the other hand, ongoing research inevitably leads to re-evaluation of risk as methods change and their sensitivity improves. Also, as major public health risks are contained, more attention can be paid to less pressing and less prevalent problems.

There are food additives and contaminants whose risk profile has changed substantially in recent years as the understanding of biomedicine and the nature of health patterns have changed. These include tastants, colorants, preservatives, food texture modifiers and packaging contaminants. Among the most evident have been pre- and probiotics and endocrine disruptors. Where little has been known about biological effects and the factor presumed safe on historical or theoretical grounds, problems may also emerge. An example is that of microbial transglutamase enzymes, now known to be dissimilar to their endogenous counterparts, but used extensively and confidently in food processing to modify food properties in various ways, such as the cross-linking of proteins. They also open gut epithelial channels and allow the penetration of larger less digested molecules. It now appears that they contribute to the rising incidence of coeliac disease and of other auto-immune disease.

Yet another area of major food safety and security concern is that of multiple antibiotic resistance genes (ARGs). The inappropriate and unnecessary use of antibiotics as growth promotants in livestock has led to this problem in farm animals, especially in China. Although cooked meat may not transmit ARGs, contaminated soil, water and farm-workers do.

Potable, clean and safe water is not available to large sectors of some recently industrialised countries, as in China where this applies to some 60% of rivers and streams. Microbiological safety can usually be achieved by boiling, as in the brewing of tea, but chemical safety cannot. Most water is used for agricultural purposes where the food produced may also be contaminated.

There is the added problem that plastic bottles may not be sufficiently food-grade and endocrine disruptive residues be leached, especially at high temperatures. There is considerable scope for innovative approaches to make water safe at the point of consumption or application. And, in terms of overall consumption, digitisation of water supplies for agricultural and domestic purposes, along with recycling is optimistically seen as a conservation measure. Smart water systems which make agricultural use of water more efficient are being developed and implemented.

Future foods and food systems will need to take account of these shifts in the nature of food safety and security.

Not just because of water, but because of limiting soil nutrients, especially phosphorus, in globally short supply and the quest for greater yields (whatever the growth potential, plant nutrients are essential) soil contamination and unfitness for agriculture; dependence on pollinators (especially bees) which are disappearing through loss of habitat, pesticide misuse and disease (some induced by pollutants like diesel fuel); loss of food crop biodiversity with less resilience to climate change; and global warming itself (for example, wheat is very temperature sensitive), food insecurity is an increasing threat and reality.

THE QUEST FOR NUTRITIONAL HEALTH: FOOD AND FUNCTION

It is reasonable to look to food and food intake patterns as a way of optimising health, provided other personal behaviours, like physical activity, sleep, stress management and substance abuse (as with alcohol, tobacco and drugs, legal and illegal) are also addressed. But neither nutrients nor other food components have single functions or act alone. Failure to understand this leads to extrapolations from nutritional biochemistry to food product where the risk-benefit profile may be unacceptable. Isolated carotenoids are such an example. Turmeric, more than curcumin, has properties relevant to health, with less risk, as with cognitive function. Insofar as possible, it is food or food patterns rather than food components that should be the therapeutic strategy to maximise its broader benefits.
and minimise the risk.\textsuperscript{111-113}

**DIGITISATION, VIRTUALITY, PEOPLELESS SYSTEMS**

Proximity and contact with our food supply allows a greater understanding and control of it. Chopsticks at least 3,000 years ago in China, and, probably later in Europe, forks, spoons and knives allowed us to distance ourselves from the food we ate at the table, and lose some of the appreciation of the touch and texture of food.\textsuperscript{114} Shopping\textsuperscript{115} and cooking\textsuperscript{2} confer survival advantage. Food dispensing or vending machines are now common place in most urban settings. Yet digital technology is enabling us to distance ourselves from the food system even more effectively.\textsuperscript{65,116,117} The smart phone allows the ordering, activation of cooking and food preparation, delivery and more to be remote. In Taiwan, peopleless shops provide ordering consoles for recipe selection and meal provision (Figure 1). Serious questions must be asked about the loss of the social role of food with these trends. We know that this role is associated with greater survival.\textsuperscript{118-120}

**THE MEANING OF FOOD: NEW AND CHANGING ROLES**

Food is culturally symbolic and distinctive food habits persist in migrant groups for longer than most characteristics.\textsuperscript{86,121} While, with time, they may undergo acculturation towards the host culture, the reverse also takes place. This is especially evident in culturally pluralistic immigrant societies like Australia, New Zealand, the USA and Canada. Future foods and habits will continue to be influenced in this way and affect nutritionally-related health patterns.\textsuperscript{122,123}

Food is also part of the art and design world. Its presentation is highly developed in some cultures like China, Japan, France and Italy. In part this has to do with the importance attached to it, its aesthetic integration into life, power and hierarchy. By contrast, food may be described as ‘fast’ or ‘convenient’ meaning relatively little attention is paid to it. At worst, food is bought and eaten absent-mindedly from a moving vehicle, one hand on the steering wheel, while in a ‘fast food’ lane-way. Contrast this with a thoughtfully chosen and savoured home-cooked meal, prepared by someone we love or for someone about whom we care! Evidence from Bangladesh,\textsuperscript{54} Korea,\textsuperscript{66} and Japan\textsuperscript{55} indicates that attention to a particular meal or pattern and its features can favourably influence overall nutrition and health risk.

Beyond this, food designers are now paying attention not only to packaging, but also to the added social and aesthetic meaning which may be given to food through its representation at purchase or the table, as well as through the dining set or eating equipment. Examples are seating, table colours and plate size, each of which can alter appetite, consumption and physiological responses.\textsuperscript{124} These developments may assume wider currency as food itself is less obviously connected to its accustomed origins. The newly acquired ability to grow meat from stem cells without the animal is already challenging food designers as demonstrated by the World Design Capital Food Project in Taipei in 2016.\textsuperscript{124} It may also spare livestock and decrease the risk of ARGs. Quite profound questions arise for food processors, consumers and regulators about this quantum leap in food culture. If present environmental pressures on the food supply exacerbate, we may find ourselves in much greater need of food and nutrition literacy to manage safely, sustainably and healthfully our food supply.\textsuperscript{125}

Food design has begun to offer an outlet for protest about oil spillage in fishing zones, animal cruelty in food production and genetic modification for socially active food processors.

Yet again, encouraging the acceptability of unattractive ‘grotesque’ fruits and vegetables has been popularised in France as a way of minimising food waste, because the nutritional value is not compromised by shape, even if retailers have aimed for uniformity and symmetry.\textsuperscript{126}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{peopleless_food_outlet.png}
\caption{A peopleless food outlet in Taiwan with no staff.}
\end{figure}
These trends in food design are to be distinguished from ‘food fashions’, which may be based on ‘hints’ from food and nutrition science, but are spruiked and given marketing impetus by commodity growers, boards or investors. It could be argued that the boom in sales of ‘ancient grains’ like quinoa and vegetables like kale fall into this category. Basic to the evaluation of these trends is whether they actually contribute to overall dietary variety or, in sum, compromise it; and whether their place in the food system is sustainable and, for more than an elite, affordable.

**ECOSYSTEMS, FOOD AND HEALTH**

We are ecological creatures and not the environmentally discrete individuals we thought in describing ourselves as the human species. We are connected with the inanimate environment through place, weather, seasons, our chemistry and natural disasters. We are connected with the animate environment through the food and beverage we ingest, our several microbiomes, our senses, our environmentally-derived hormonal profiles and more. Our wellbeing and health is linked to that of our social and physical environment.

When it comes to health, first we must endeavour to prevent disorder and disease. We may not be able to cure as we would like, especially so-called chronic disease, but we can always care about who we are, our place of abode, and others. This means we will value nature’s resources, especially our food supply. That some 30-50% of it is wasted is not sustainable. Future food systems must minimise this waste.

As we search for a deeper understanding of our condition, we find that its dysfunction is often a reflection of ecosystem degradation or loss. Such degradation or loss is, perhaps unwittingly, that of ourselves and our food system. How much more of this can we tolerate and survive? How much is amenable to the way in which we develop the future food supply?

**AUTHOR DISCLOSURES**

The author has no conflict of interest in regard to this paper.

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未來糧食

糧食系統隨著人類定居和農耕、工業化、貿易、移民以及現今的數位時代而明顯改變。這些轉型的過程中，出現人口漸增至爆炸，及生態系統的淨流失與崩壞。氣候變遷由於生態系統的失衡而加速惡化。我們的健康狀況已受到一個發展中的人類-環境不搭的挑戰。我們將生態征服及創新技術當作解決方案，但是還不了解我們如何對生態的依賴及我們是一個完整的體系。人類是生態的生物，其介面為我們的感官、腸道微生物群、共享的調節(內分泌)機制、免疫系統、生物時鐘及營養路徑。我們許多人是「自然剝奪」者。我們可能正面臨名為「生態健康失調」(EHD)的困境。如果不是那麼多人，自然的應變能力可能足以因應，但是面臨 2050 年超過 90 億的人口，地球可能無法負荷這個需求。未來的糧食需逐漸增加考量糧食系統對生態系統依賴所造成壓力，導致糧食的有較少的生物多樣性，儘管這樣吃可以有較佳的健康；較少運動與食物不當的能量密度所造成的能量失衡；以及較少有利於社會的飲食習慣。「個人化營養」，包括資源需要很高的營養基因體學、代謝體學以及腸道微生物資料，可能可提供臨床上的部分健康解答，但對公共衛生的倫理、風險管理或是永續使用並不具正當性。糧食不安全、品質及平等是全球盛行的多面向營養不良問題，需要在地、區域或是全球的行動，以預防更進一步的生態系統崩壞；並教育提供永續生計以及鼓勵尊重糧食相關的社會論述及作法。

關鍵字：糧食系統、糧食安全、生態營養、生態系統健康失調、個人化營養、無人食物商場、臨床營養