Review Article

Novel foods across the lifespan: From infant formula to impact on ageing

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The purpose of the present paper was to examine the scope of novel foods in improving and/or preventing the nutritional disorders in different stages of lifespan. First, attempts were made to review the current trend and magnitude of the nutritional problems in each of the stages starting from fetal development to old age. The paper then describes the possible potential role of novel foods in alleviating and/or preventing these nutritional/health problems. The conclusion made is that the novel foods have a great potential for improving the overall nutritional status throughout the lifespan, thereby reducing the risk of early death or disability due to chronic diseases. However, to achieve a noticeable impact of novel foods on public health, efforts are needed to ensure that these foods are available and affordable to the population most at risk.

Key words: lifespan, novel foods, nutritional status.

Introduction

Starting from conception, the human being depends on nutrients for growth, development and long-term survival. Poor nutrition often begins in the intrauterine environment and extends throughout the lifespan. For example, low-birthweight infants are born undernourished as a consequence of intrauterine growth retardation, and grow up to be undernourished and stunted children and adolescents and, eventually, undernourished women of child-bearing age who enter into pregnancy and deliver low-birthweight babies.[1] Thus, nutrition challenges continue but vary as we progress through the lifespan. Adequate nutrition for pregnant women, infants and young children is essential for both physical and mental growth and development. The issues are quite different in adulthood, where the challenge is to prevent premature death or disability from diet-related chronic diseases in order to progress into a healthy old age. However, it is now clear that these two issues are interrelated. Good nutrition in early life, as early as gestation, pays dividends in later life. Furthermore, the impact of early nutrition on a young woman may, in turn, have an impact on the health of her children. New scientific understanding amplifies the profound importance of linking maternal nutrition with fetal changes and effects into old age.

Novel or functional foods have been defined in many ways. It is generally accepted that the foods that have a health benefit beyond those attributable to the traditional nutrients, are known as functional foods. However, the working definition adopted by the European Union is that ‘a food can be considered functional if it is satisfactorily demonstrated to have a beneficial effect in one of more target functions of the body, beyond those attributable to the traditional nutrients, in a way which is relevant to either the state of well-being and health or the reduction of the risk of disease.’[2] However, a functional food is not necessarily a novel food. The foods or food ingredients that are not previously consumed to a large extent by a population are considered to be novel foods. The concept of novel foods has been considered to be a challenge as a new frontier in food science and public health nutrition. The present paper aims to assess the potential role of novel foods in improving the overall nutritional status across the lifespan. The paper first provides a brief review of the current trend of nutritional problems in different stages of lifespan, and then discusses the scope of novel foods in preventing or alleviating these nutritional/health problems during each of the stages.

Embryo/Fetus

Intrauterine growth retardation (IUGR) refers to impaired fetal growth (commonly defined as weight below the 10th percentile of birthweight-for-gestational-age reference curve) and is now considered to be a major clinical and public health problem in developing countries. In the year 2000 it was estimated that approximately 30 million newborns per year in developing countries or 24% of all births suffered

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from IUGR. The important determinant of IUGR is the nutritional environment *in utero*, that is, poor maternal nutrition during pregnancy.[3] Although the roles of micronutrients in IUGR still remain to be elucidated more clearly, the consequences of anaemia, folate deficiency and iodine deficiency disorders in fetal development are well recognized.[4]

Neonates

In the year 2000 it was estimated that at least 17 million infants had a low birthweight (LBW) at term, representing approximately 16% of all newborns in developing countries.[5] Further, nearly 80% of the infants with LBW at term were born in Asia, particularly South–Central Asia, with Bangladesh having the highest incidence rate in the world.[6] Low birthweight has significant health consequences. Infants with LBW are at a higher risk of dying during infancy. If they survive, they experience acute morbidity from illness, such as infections and a variety of developmental deficits, and are more likely to be underweight and stunted in early life.[7,8] Recent evidence relates LBW to an increased risk of chronic diseases including high blood pressure, non-insulin-dependent diabetes and coronary heart disease later in life.[9] During the neonatal period, iodine deficiency disorder is also very common and a major threat to brain development.

Preschool children

It is estimated that in the year 2000, 182 million preschool children, representing 32.5% of children under 5 in the developing countries, were stunted (< –2 SD height-for-age).[10] Stunting is a consequence of the failure of linear growth as a result of poor diet and disease. Stunting can be directly related to impaired physical, emotional and mental development.[7] The nutrients that are now known to affect brain development are iron, iodine, folic acid, vitamin B_{12} and n-3 fatty acids.[11–13] The current estimated prevalence of underweight (< –2 SD weight-for-age) preschool children in the developing countries is 27%, which translates into 150 million children. Protein–energy malnutrition (PEM) is known to be the major cause of child malnutrition.[4] In contrast, an estimated 17.6 million children in the developing world, particularly in the transitional societies, representing 3.3% of the total, were found to be overweight in 1995. Clearly, a large number of the developing countries are now facing a double burden of the nutritional problems. Vitamin A deficiency, iodine deficiency disorder and anaemia are still a major threat among the preschool children in the developing countries.[4]

School-age children

Based on the limited data on growth of school-age children, stunting appears to be very common in most developing countries.[1] Protein, energy, zinc and iron have been suggested as having a specific role in the cause of stunting.[14] In contrast, approximately 10% of the school children in industrialized countries are obese and high rates of obestity are also evident in countries with a rapid transition.[4] Childhood obesity is now considered to be a major risk factor in developing a number of non-communicable diseases, such as cardiovascular diseases and diabetes. The World Health Organization (WHO) global database indicates that nearly half of the world's school-age children suffer from anaemia. Among the other micronutrients, iodine deficiency disorder and vitamin A deficiency are also common among school children.[4]

Adolescents

Adolescence is an important stage of life for physical growth and sexual development, and in the developing countries, physiological preparation for motherhood occurs during this period. More than 20% of total growth in stature and up to 50% of adult bone mass are achieved during adolescence, hence nutrient requirements are significantly increased from the childhood years.[15] In addition, concurrent pregnancy and growth has been found to have a particularly detrimental effect on the micronutrient status of adolescent girls, even after controlling for energy intake and other confounders. Furthermore, it is well documented that the growth velocity during adolescence is slower in undernourished populations, giving rise to cephalopelvic disproportion, which in the adolescents who become pregnant is related to an increased risk of maternal and fetal mortality.[16] The problems associated with deficiencies of specific nutrients are a particular concern during adolescence in young women. Data on adolescent nutritional status are scarce. Based on a dataset of a multicountry study by the International Centre for Research on Women, the prevalence of stunting in adolescent girls has been found to range from 27 to 65%.[17] High rates of anaemia among adolescents were also found (16–55%) in six out of seven countries.[17] Evidence from small studies also indicates that a sizeable proportion of adolescent girls from poor societies are thin (low body mass index (BMI) for age) and are also suffering from multiple micronutrient deficiencies.[18,19]

Women of reproductive age (pre-pregnancy period)

Only recently, being an underweight adult has been recognized as an important concern because there is now evidence that it is directly associated with progressive functional impairment, increased rates of sickness and premature mortality.[20] Underweight is widespread among women in developing countries, especially in South Asia (30–50%) and in Africa (15–30%).[1] However, nearly one-third of the women in some countries in Africa (Egypt) and Latin America (Peru, Bolivia and Colombia) are overweight. Obesity is one of the major risk factors for a number of non-communicable diseases, such as diabetes, cardiovascular disease, high blood pressure and stroke. New evidence shows that the major global burden of chronic dietary diseases in adult life affects more developing countries than developed countries.[4] Clearly, in many developing countries obesity coexists with undernutrition. In these countries, micronutrient deficiencies are also common among women of reproductive age. The risk of iron deficiency in pregnancy and lactation begins with inadequate pre-pregnancy iron reserves among women of fertile age. Approximately 47% of non-pregnant women have anaemia globally, and including iron deficiency without anaemia, the figures may approach to 60%.[21] Folate and iodine deficiency are also reported to be common among this group of the population, especially those who live in Africa and Asia.[4]

Pregnant and lactating women

Besides PEM, various micronutrient deficiencies have long been documented among pregnant women in most developing countries. Iron deficiency during pregnancy is extremely common even among otherwise well-nourished populations. Nearly 60% of pregnant women have anaemia worldwide, and including iron deficiency without anaemia the figure may approach 90%. In the industrial world as a whole, anaemia prevalence during pregnancy averages 18%, and more than 30% of these populations suffer from iron deficiency.[21] Folate deficiency has also been documented during pregnancy, often leading to combine iron–folate deficiency anaemia, particularly among lower socioeconomic groups consuming mostly cereal-based diets.[21] Iodine and vitamin A deficiency are also predominant nutritional problems among pregnant women in developing countries.[4] From a global perspective, lactating women are more likely to suffer from micronutrient deficiencies than from a shortage of dietary energy or protein. Iron deficiency during lactation is mostly a residual deficiency resulting from pregnancy and delivery. Micronutrient deficiencies in lactating women are more likely to affect breast milk composition, and hence the development and nutritional status of the infants.

Elderly

The number of individuals aged 60 years or older is increasing rapidly worldwide. The United Nations Population Division estimated that by the year 2050, the absolute number would be more than 2 billion. Body composition changes with age and a normal part of ageing is the gradual decrease in muscle mass, and with it strength, known as sarcopenia.[22] Elderly are susceptible to protein deficiency, and protein adequacy is important for maintaining lean tissue, immune function and muscle function.[23] However, a vast majority of the countries in Asia, Latin America, Northern Africa and the Middle East have now experienced ‘nutritional transition’ whereby diets high in unrefined carbohydrates and fibre are replaced by diets containing a higher proportion of fats, particularly saturated fatty acids, and sugars,[24] and as a result the proportion of the overweight or obese population is already increasing rapidly. This double burden of undernutrition and obesity in an ageing population poses tremendous challenges for developing countries. As already mentioned earlier, obesity is strongly associated with chronic diseases, and the leading cause of death among older people worldwide is vascular disease and associated chronic conditions. There is great potential for prevention of these diseases through healthy lifestyles that include physical activity and nutritious diets.

There is evidence that micronutrient deficiencies are very common among elderly populations, even in the most developed countries, and they have increasingly been linked to risk of chronic diseases.[25] Among the micronutrient deficiencies, calcium, zinc, folic acid, vitamins B_6, B_{12} and D are common. Vitamins B_6, B_{12} and folate are required to prevent the accumulation of homocysteine, which is associated with risk of vascular disease.[26] Subclinical vitamin and mineral deficiencies may also contribute to the pathogenesis of declining neurocognitive function with age.[27] With age, declining renal function leads to malabsorption of calcium and accelerated bone loss. Osteoporosis affects the majority of older people, including an estimated 33% of postmenopausal women.[28] Anti-oxidant vitamins including vitamins C and E, and some phytochemicals are important in maintaining effective anti-oxidant defences against oxidant stress-related diseases, including cancer, cataract and Alzheimer’s disease.[25] There has been a suggestion that for some countries food fortification or possibly supplementation of food products with unbound vitamin B_{12} may be needed for the elderly, due to diminished bioavailability of B vitamins from normal food sources.

Novel food and its scope in improving nutritional status

In the present context, novel foods include any foods or food ingredients that have not been previously consumed by the population in general. They may include foods with ingredients that offer health benefits and usually involve the use of ingredients in higher levels than are traditionally found in the food, or the introduction of ingredients that are not typically found in the traditional food. In recent years, the number of novel foods that have potential benefits for health has grown tremendously. Phytochemicals (carotenoids, flavonoids and isoflavonoids etc.) and functional foods that are high in dietary fibre have been found to be associated with the prevention and/or treatment of a good number of the leading causes of death in developed countries, such as cancer, diabetes, cardiovascular disease, hypertension and obesity, and with the prevention and/or treatment of other medical ailments including neural tube defects, osteoporosis, abnormal bowel function and arthritis.[29–31] Dietary resistant starch has desirable physiological effects on gut health and bowel function.[32] Certainly these foods can play an important role in preventing non-communicable diseases in adults and in the elderly population. Increasing the nutritional content of staple food by genetic manipulation may also play a critical role in preventing various micronutrient deficiencies in different stages of lifespan among people living in the developing countries. One of the most recent examples of genetically modified novel foods is ‘Golden Rice’, which clearly has the potential to help millions in rice-eating populations where vitamin A deficiency is still a major public health problem. There has also been work in progress to develop improved rice varieties with high iron and zinc contents.[33]

Although the fortification of foods with vitamins and minerals has been practised in developed countries for a long time, there are still many opportunities for novel foods with added vitamins and minerals. Food fortification programmes have also been implemented in a number of developing countries to alleviate or prevent some of the major micronutrient deficiencies in the region. Studies have shown that iron fortification of infant formulas and cereals have the potential to combat iron deficiency in the target population.[34] However, there are some technical issues that need to be considered before large-scale implementation. One of the major problems of iron salt fortification is that it may give a metallic taste. There can also be discoloration of foods with the addition of ferrous sulphate.[34] The relatively new development of the addition of microencapsulated iron salts in place of soluble iron salts in infant formulas fortified with iron has potential. Fortification of multiple micronutrient in foods such as instant noodles, fortified drinks, biscuits and breakfast cereals could be one of the options to prevent micronutrient deficiencies in different stages of the lifecycle, such as during school age, adolescence, the pre-pregnancy and pregnancy period and even in elderly people. Different minerals and vitamins can have different stabilities under the same conditions, and this could be one of the potential problems in the development of multiple micronutrient-fortified foods. Recently, microencapsulated vitamins and minerals have been developed that enable the addition of the mixtures of these nutrients to foods.

In developing countries, PEM is the most common form of nutritional deficiency and it affects almost all stages of the lifespan. It is generally accepted that increasing production of staple foods can reduce the prevalence of PEM. Thus genetically modified novel foods with a higher yield potential, higher yield stability and greater production efficiency have the potential to prevent PEM. In general, beans tend to be full of proteins with an extremely high fibre content. Soybeans are considered to be an excellent source of protein with a relatively high lysine content. Although soybean is one of the major crops in the Western world and some Eastern countries, a large number of the countries do not consume soy products. Thus the use of soybean as a novel food for some developing countries may have potential for the alleviation of PEM. Furthermore, soy protein as part of a diet low in saturated fat and cholesterol may also reduce the risk of heart attacks.

Long-chain polyunsaturated fatty acids (PUFA), primarily the omega-3 fatty acids, eicosopentaenoic acid (EPA) and docosahexaenoic acid (DHA) are found to be associated with reducing the risk of heart disease and aiding brain and eye development in children. Food products that have been fortified with oils containing PUFA include milks, yoghurts, desserts, infant formulas, and bread and cereal products. More recently, a number of companies have developed microencapsulated PUFA/fish oils that are more stable and have allowed the development of PUFA-enriched foods with a longer shelf-life. The new product has the potential to play a role in preventing infant undernutrition and to reduce the risk of cardiovascular disease in adults and in elderly people.

Conclusion

Novel foods and/or foods containing novel food ingredients seem to have great potential and scope for alleviating and/or preventing malnutrition in different stages of the lifespan. These foods can also play an important role in reducing the risk of chronic diseases in adults and the elderly population, and thereby may help to contribute in maintaining a healthy lifestyle. However, it is important to note that all the commercial research efforts in developing functional or novel foods is targeted at the consumers in developed countries. Although some efforts have been made to improve the situation, the magnitude of the problems makes it clear that the real need for functional or novel foods is for those who live in developing countries, where there is a large majority of the population deprived of the basic amenities of life and health-care facilities. Therefore, the present challenge for the public health nutritionists is to ensure that these foods are available and affordable to the population most at risk, and only then will it be possible to achieve a noticeable impact of novel foods on public health.

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