The British Frozen Food Federation

&

Local Authority Caterers Association

2009 Report

Frozen Foods -

Use and Nutritional Acceptability in Primary School

Lunch Provision

Sheffield Hallam University

FOOD INNOVATION

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Foreword

This report has been jointly commissioned by the British Frozen Food Federation (BFFF) and Local Authorities Caterers Association (LACA).

The British Frozen Food Federation (BFFF) is the trade association of the frozen food industry. Its' mission statement is '*to promote and protect the interests of the Frozen Food Industry*'.

The Local Authorities Caterers Association is the professional body representing 1000 catering managers and suppliers who provide catering services to all sectors of Local Authorities in England, Wales and Scotland. Local authority caterers are responsible for providing more than 2.5 million school meals a day.

The report was managed and written by Charlotte Harden on behalf of the Centre for Food Innovation at Sheffield Hallam University.

With thanks to: David Johnson, Centre for Food Innovation

Contribution by: Holly Wilson, Placement Student, BSc Food and Nutrition

Project Aims

The aims of this project are to establish:

- current use of frozen food in the provision of primary school meals
- the ratio usage of fresh, dry and tinned food items
- the nutritional variation between fresh and frozen versions of the same product
- the nutritional impact of using frozen produce for school meal provision

The objectives of this project are to:

- visit 4 UK primary schools to review current meal provision
- conduct NetWISP V3.0 analysis to establish the nutritional content of various food items served in primary schools
- conduct independent-sample t-tests to determine if there is a significant difference between the average values of fresh and frozen food
- evaluate the results of the statistical analysis to establish the nutritional impact of using frozen food for primary school meal provision

Executive Summary

An investigation was conducted to examine the current use of frozen food in UK primary schools. Subsequent nutritional and statistical analysis showed no significant difference between fresh and frozen food classification for the 37 nutrients tested. This study supports the findings of similar reports that frozen vegetables are nutritionally comparable to fresh versions.

The common assumption that fresh food has greater nutritional value than its frozen counterpart is misconceived. Rapid and highly organised methods of harvest/slaughter to freeze have evolved with the express purpose of minimising nutrient losses. In contrast, fresh produce has been shown to spend up to a month in the chain of producers, wholesalers and retailers before consumers have access to store and prepare them. During this time significant deterioration occurs to the extent that they can have lower nutritional value than their frozen equivalent.

The result of this investigation correlates well with findings by other investigators. Frozen food can be effective in providing adequate nutrition for primary school children. Other advantages of using frozen food on a catering scale such as its contribution towards reduction in food waste, availability, convenience and improved price stability are also evident.

Care must be taken to ensure, that frozen food intended for use in primary school meal provision, is chosen on the basis of the producers and manufacturers use of quality raw ingredients and well organised processing techniques. Kitchen staff should be advised to ensure food is stored correctly, preparation and cooking times are minimised and long periods of hot-holding are avoided.

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Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 1

1.0 BACKGROUND

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 1

1.0 BACKGROUND

1.1 UK School Meals Policy - A History in Brief

The 1906 Education (Provision of Meals) Act was the first legislation to make public provision of school meals available. It was devised in recognition of concerns over the ill state of health of the poorest members of the population, as revealed during recruitment to the Boer War. Free school meals were only provided to children who were deemed, by medical experts, to be suffering from malnutrition. This 'feeding' intervention has subsequently been described as a form of medical treatment [1].

The 1944 Education Act was borne out of the success of Second World War rationing policy and the popularity of the type of approach to nutrition and health adopted by scientists at this time [2]. Although this legislation was not standardised until 1965, the Local Education Authority (LEA) were duty bound to provide school meals based on clear nutritional guidelines devised by experts. These meals were intended to supply around one-third of the daily allowance of nutrients and energy for each child and a set price was stipulated for this provision.

A 1970s report by the DES Working Party noted that in the light of increased wealth and rising consumerism a nutritious meal would only benefit pupils if they ate it. Children had begun to reject 'nutritious' school lunches in favour of more attractive high street options. For the first time, concerns were raised over consequences of the excesses of children's diets.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

The 1980 Education Act brought about radical change regarding school meal policy [3]. The duty of the LEA to provide school meals was removed along with nutritional standards and fixed pricing systems. The subsequent 1986 Local Government Act introduced competitive tendering, whereby contracts were given to the caterer offering the cheapest standards. This Act affected the majority of secondary school meal provision. Schools sought to emulate the high street and 'cash cafeterias' were created, where pupils were allowed to choose from a range of options.

Since the deregulation of national nutritional guidelines in the 1980s, UK school meals policy has sparked intense debate. In 1992, over 50 organisations joined together to form the School Meals Campaign. They called for the reintroduction of nutritional standards for school meals, citing the reduction in uptake of school meals along with evidence to suggest children's diets had deteriorated as proof of the detrimental effects of deregulation [4].

The awareness of an exponential increase in obesity and its co-morbidities no doubt accelerated political action for change regarding school meal provision. In 2002, the Chief Medical Officer referred to obesity as "a health time bomb" [5] and in the same year the World Health Organization predicted "a third increase in loss of healthy life over the next 20 years as a direct result of overweight and obesity" [6].

In 2005, the School Food Trust was set up with £15 million of funding to promote the education and health of children and young people by improving the quality of food supplied and consumed in schools.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

In May 2006, following consultation on the report ‘Turning the Tables: Transforming School Food’ published by the School Meals Review Panel in October 2005, and the 'Food Other than Lunch' report published by the School Food Trust in February 2006, the Government announced the standards it intended to apply to school food and charged the Trust with taking forward these standards.

In September 2008, the final food-based and nutrient-based standards for school lunches become mandatory in primary schools.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 2

2.0 EXPLAINING FOOD & NUTRIENT BASED STANDARDS

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 2

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The 2008, final food and nutrient based standards apply to all local authority maintained primary schools in England. They apply to all school lunch services, including hot, cold and packed lunch services provided on a school day up to 6pm, including food provided by the school or local authority for a school trip.

2.1 Explaining the Final Food-Based Standards for Primary School Lunches*

*See appendix [1] for a summary of the final food-based standards for school lunches

The food-based standards provide guidelines on the provision of 12 'food group' categories. These are; fruit and vegetables, oily fish, meat products, starchy food cooked in fat or oil, bread, deep fried food, salt and condiments, snacks, confectionary, cakes and biscuits, drinking water and healthier drinks.

The standards outline how often a food group should be served (if at all) and provide guidance on portion sizes. Serving suggestions and tips for general good practice for each food group are also provided.

2.2 Explaining the Final Nutrient-Based Standards for Primary School Lunches**

**See appendix [2] for a summary of the final nutrient-based standards for school lunches

Nutrient based standards apply to the overall provision of an average school lunch rather than individual consumption. Choice of drink, food items and portion size (when variability is available) will impact individual intakes.

In the UK, estimated requirements for particular groups of the population are based on advice given by the Committee on Medical Aspects of Food and Nutrition Policy (COMA). COMA examined the available scientific evidence

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

and estimated nutritional requirements of various groups within the UK population. These were published in the 1991 report *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*.

The final nutrient-based standards for primary school lunches are based on these Dietary Reference Values (DRVs). Dietary recommendations set the standard for an adequate intake of each essential nutrient. DRVs are set for energy and 33 nutrients of known importance to human health.

DRVs are an umbrella term for:

1. ***Estimated Average Requirement (EAR)*.** This is an estimate of the average (mean) requirement of a nutrient or energy for a group of people. About 50% of the group will need more than the EAR; about 50% will need less.

For primary schools, the standards for energy are based on an average value, rather than a minimum or a maximum value. They equate to approximately 30% of the total daily energy requirements (EAR) of a child attending primary school. An average energy value has been used to reflect the range of energy requirements of pupils attending primary schools. Energy and nutrient requirements differ according to age, gender, development and growth rates and activity levels. An average school lunch must provide the amount of energy stipulated with 5% tolerance.

2. ***Reference Nutrient Intake (RNI).*** The RNI is set at a level that is considered to be enough or more than enough for 97.5% of the population. By consistently consuming more than the RNI, it is extremely likely that a person's requirements will be met. The lower a person's intake is below the RNI, the greater the probability it will be inadequate. RNIs are set for vitamins and minerals.

The nutrient-based standards set minimum standards for; vitamin A, vitamin C, folate, calcium (Ca), iron (Fe) and zinc (Zn). These are equivalent to approximately 35% of the total daily requirements (RNI) of a child attending primary school. An average school lunch must provide no less than the minimum amount stipulated.

The nutrient-based standards set maximum standards for sodium (Na). This is equivalent to approximately 30% of the Scientific Advisory Commission on Nutrition's guidelines for total daily requirements of a child attending primary school. An average school lunch must provide no more than the maximum of the amount stipulated.

DRVs for macronutrients (carbohydrates, fat and protein) are population average figures. They are expressed as a percentage to which they contribute to total food energy.

The nutrient-based standards set minimum standards for carbohydrates, protein and non-starch polysaccharides (NSP). For carbohydrates and protein, this is equivalent to 50% and 15% of food energy respectively. For NSP, this is equivalent to 30% of the calculated reference value. An average school lunch must provide no less than the minimum amount stipulated.

The nutrient-based standards set maximum standards for non-milk extrinsic sugars (NMES), fat and saturated fat. This is equivalent to 11%, 30% and 11% of food energy respectively. An average school lunch must provide no more than the maximum of the amount stipulated.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 3

3.0 THE USE OF FROZEN FOOD IN SCHOOL MEAL PROVISION

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Since alterations have been made to improve the nutritional value of school meals, so have opinions as to what type of food is 'healthy' and good quality. Whilst the consumer views 'fresh' food as natural, wholesome and nutrient rich, 'processing' food, even when using the relatively mild process of quick freezing, is considered to substantially reduce quality and nutrient value.

In 2006, Bath and North East Summerset County Council set targets for the purpose of improving their school meals service. A target of 'moving away from the use of processed foods' resulted in 'a reduction in frozen food' usage [7]. A case study from the Cheshire County Council website states 'Instant, frozen food is not cheap as well as being unhealthy' [8].

The quality and deterioration of foods are influenced by the growing conditions and varieties of plants, feeding conditions of animals, conditions of harvest and slaughter, sanitation, damage to tissues, storage temperatures and many other variables.

Fresh produce is typically available to the consumer after a period of 3-7 days in retail distribution and storage [9]. Increasingly, fresh food such as fruit and vegetables are stored at refrigeration as oppose to ambient temperatures, thus fresh produce can be exposed to a variety of environments which potentiate changes in quality characteristics, including nutrient content, before it is cooked and prepared [10].

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

Produce intended for commercial freezing is frozen quickly post harvest or slaughter. Typically, the freezing process preserves food without causing major disruption to its size, shape, texture, colour and flavour. Changes which do occur, particularly during the blanching process, are necessary to inactivate natural enzymes, but little further alterations are expected during deep frozen storage. It is postulated that the nutrient content of fresh produce may continue to fall, possibly below that of frozen versions.

Historically, frozen food has played an important part in the provision of school meals.
The benefits of using frozen food on a catering scale are numerous, specifically in terms of its contribution towards reduction in food waste, all year-round availability, convenience, improved price stability and extended shelf life.

It is important to investigate the use of frozen food in school meals, especially in terms of its nutritional contribution to the final food and nutrient based standards.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 4

4.0 A DESCRIPTION OF THE NUTRIENTS - FOOD SOURCES, DIETARY REFERENCE VALUES, KEY BIOCHEMICAL FUNCTIONS, DEFICIENCY AND TOXICITY, BIOCHEMICAL MEASURES OF NUTRIENT STATUS AND DEFICIENCY PREVELANCE

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 4

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In order to understand the implications of affecting the nutrient content of a food a synopsis of the nutritionally important macronutrients and micronutrients follows.

4.1 Macronutrients

Macronutrients are substances that provide energy, they are metabolic fuels. They are carbohydrates, fats and proteins.

4.1.1 Carbohydrates

Nutrient: carbohydrates. Dietary carbohydrates are usually broken down into three major subdivisions; sugars, starches and non-starch polysaccharides
Major food sources starch: cereals, potatoes
Major food sources sugar: sweetened drinks and cereals products, preserves, sugar, cakes and biscuits
Major food sources non-starch polysaccharides: cereal foods, fruit and vegetables
DRV total carbohydrate: 50% total food energy
DRV non-milk extrinsic sugars: 11% total food energy
DRV intrinsic and milk sugars and starch: 39% total food energy
Key biochemical functions: energy provision

Carbohydrates are always the preferred source of energy. Sugars and starches are readily digested and absorbed in the small intestine and provide approximately 3.75kcal of energy per gram. Non-starch polysaccharides are resistant to digestion but may yield up to 2kcal of energy per gram if fermented by bacteria in the large intestine.

The frequency of sugar consumption is of particular importance in the aetiology of dental caries. Numerous studies indicate dental caries increase with augmented non-milk extrinsic sugar consumption [11, 12]. The 2003, Children's Dental Health Survey showed dental caries remain a problem in the UK. Since 1993, the proportion of children with plaque, calculus and gingivitis has risen [13, 14]. The increasing trend amongst children to consume large quantities of acidic soft drinks and confectionary [15] is potentially detrimental to dental health [16].

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

A number of experts have proposed associations with consumption of sugar products and rising obesity rates [17, 18, 19].

Refined sugar consumption may exacerbate or be the cause of hyperactivity. During a 5hr glucose tolerance test, hyperactive children produced 74% abnormal curves (half of which resembled hypoglycaemia); this purportedly resulted in increased adrenaline production and stimulation of nervous or restless action. Trials involving low-sugar diets have been shown to increase concentration; better sleep patterns have also been noted. White et al. [20] examined the effects of sugar on behaviour/cognition and concluded sugar could have a small effect on child behaviour.

The International Centre for Child Studies collected dietary data from a sample of 4760 children. The DRV for NSP intake of 18g [21] was achieved by 25% of boys and 10% of girls; 13% of boys and 30% girls achieved intakes of only half the current recommendations [22]. The object of a study conducted by Caterson et al. [23] was to examine evidence on the causes of obesity. Evidence that NSP was a protective factor against obesity was considered ‘convincing’.

Constipation in childhood is very common, affecting around 10 per cent of children at any one time [24, 25]. The most common cause of childhood constipation is a lack of dietary fibre [26, 27].

4.1.2 Fats

Nutrient: fats. Dietary fats are usually broken down into three major subdivisions; saturated, monounsaturated and polyunsaturated. All dietary fats contain a mixture of these fatty acids but the proportions vary.
Major food sources saturated fat: animal products such as meat and dairy produce, palm and coconut oils
Major food sources monounsaturated fat: olive and rapeseed oil
Major food sources polyunsaturated fats: fish and fish oils, sunflower, corn and vegetable oils
DRV total fat: no more than 35% total food energy
DRV saturated fat: no more than 11% total food energy
Key biochemical functions: fats are the most energy dense of the macronutrients and provide approximately 9kcal of energy per gram.
The fat soluble vitamins (A, D, E, and K) are predominantly found in fat-containing foods, they are also absorbed along with dietary fat in the gut.
There is an essential dietary requirement for polyunsaturated fatty acids; these are known as essential fatty acids (EFAs). EFAs are important for maintaining the function and integrity of cellular and sub-cellular membranes and are also involved in cholesterol regulation.
Children are consuming more than the recommended DRV values for fat [15, 21, 28]. Fat is a concentrated source of energy; if energy intake and expenditure are unbalanced the excess energy is stored in the body as fat; over time this may result in obesity. There are a number of social and psychological effects of obesity including low self-esteem, depression, and body dissatisfaction [29, 30].
The body can make all the fatty acids it needs except alpha-linolenic acid and linoleic acid. Generally, children's diets are too high in saturated and trans-fats and too low in long-chain polyunsaturated fats, especially alpha linolenic acid [15, 21, 28]. Trans-fatty acids disturb the metabolism of essential fatty

Food Innovation, Sheffield Hallam University
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Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

acids in children. The availability of long-chain polyunsaturated fatty acids is essential for tissue growth and development [31].

High saturated fat intakes are associated with an increased risk of developing hypercholesterolemia, cardiovascular disease and certain types of cancer.

Deficiency: a deficiency in linoleic acid has been demonstrated in children. A lack of essential fatty acids has been repeatedly cited as a possible cause of hyperactivity, poor cognitive development, neurodevelopmental disorders and depression in children [32, 33, 34, 35, 36].

4.1.3 Protein

Nutrient: protein. Protein is the only major nitrogen-containing component of the diet. It is composed of long chains of amino acids that are linked together by peptide bonds. The body cannot synthesise all amino acids so we must obtain these essential amino acids (EAAs) from our diets.

Major food sources: animal products such as meat and dairy produce, eggs and plant proteins such as cereals, beans and nuts

RNI:

4-6yrs 19.7g/d,

7-10yrs 28.3g/d,

Males 11-14yrs, 42.1g/d,

Females 11-14yrs, 41.2g/d

Key biochemical functions: formation of all body cells, enzymes, some hormones, neurotransmitters and other nitrogen containing compounds, transport of substances in the blood, key component of the immune system, maintaining the acid-base balance, energy provision.

Protein provides approximately 4kcal of energy per gram. Animal proteins tend to have a higher biological value, net protein utilisation and digestibility than plant proteins. They also however, tend to contain more fat. In the UK, we generally consume too many animal proteins and too few plant proteins. Individuals following vegetarian and vegan diets should ensure they consume a range of protein foods in order to obtain the EAAs.

High protein diets may contribute to obesity, water loss, deteriorating renal function and demineralisation of the bones.

Deficiency: protein deficiency in the UK is very rarely observed. Protein energy malnutrition in the form of Marasmus and Kwoshiorkor is a major cause of death in developing countries.

4.2 Micronutrients

Micronutrients are substances which support metabolism. They are vitamins and minerals.

4.2.1 Vitamins

Vitamins are a group of indispensible organic compounds. Most vitamins cannot be synthesised at all, or can only be synthesized from specific dietary precursors. They are therefore required in the diet in relatively small amounts of less than 1g a day. They do not provide energy but do have clearly defined roles, in particular in biochemical pathways or physiological processes. The absence of a certain vitamin/s leads to specific deficiency diseases, while excessive intakes can lead to toxicity.

There are divided into two categories based on their solubility characteristics. Water soluble vitamins are vitamin C and the B vitamins. Fat soluble vitamins are A, D, E and K.

4.2.1.1 Water Soluble Vitamins

Water soluble vitamins include: vitamin C also known as ascorbic acid, vitamin B_1 also known as thiamin, vitamin B_2 also known as riboflavin, vitamin B_3 also known as niacin, vitamin B_6 also known as pyridoxine, vitamin B_{12} also known as cobalamin, biotin, folate also known as folic acid and pantothenic acid

Features of water soluble vitamins:

- not stored extensively in the body, as excess is excreted readily in the urine
- required regularly in the diet as deficiency states (with the exception of B_{12}) tend to manifest after relatively short periods of deprivation
- toxicity uncommon due to water solubility and urinary excretion: toxicity is virtually impossible from natural foodstuffs
- most are readily destroyed during processing

4.2.1.1.1 Vitamin B_1

Nutrient: thiamin

Major food sources: whole grain cereals, liver, pork, yeast and dairy

RNI:

4-6yrs, 0.7mg/d,

7-10yrs, 0.7mg/d,

Males 11-14yrs, 0.9mg/d,

Females 11-14yrs, 0.7mg/d

Key biochemical functions: thiamin gives rise to thiamin pyrophosphase, a co-enzyme for pyruvic oxidase, thus ensuring a steady and continuous release of energy from carbohydrates

Deficiency: Beri-Beri, Wernicke-Korsakoff syndrome

Toxicity: rare, 100mg/day regarded as safe

Biochemical measure of nutrient status: erythrocyte transketolase activation coefficient (ETKAC), values >1.25 indicative of deficiency

UK deficiency prevalence: average intake is double RNI, 1% of tested populations have less than the lower reference nutrient intake (LRNI)

4.2.1.1.2 Vitamin B_2

Nutrient: riboflavin

Major food sources: milk, eggs & liver

RNI:

4-6yrs, 0.8mg/d,

7-10yrs, 1.0mg/d,

Males 11-14yrs, 1.2mg/d,

Females 11-14yrs, 1.1mg/d

Key biochemical functions: riboflavin acts as a co-enzyme in many reactions, including the utilisation of energy from food

Deficiency: riboflavin deficiency is rare but if occurs can result in angular stomatitis, cheilosis and nasolabial seborrhoea

Toxicity: very rare and this could be because its low solubility prevents absorption of sufficient amounts to cause toxicity. Regular 40mg/d intakes should be safe and maximum intake from food is estimated to be 4mg/d.

Biochemical measure of nutrient status: erythrocyte glutathione reductase activation coefficient (EGRAC), values >1.23 taken as upper limit of normality

UK deficiency prevalence: in the UK, mild to moderate deficiency is common. Around 3% of men and 8% of women have intakes below the LRNI. The highest numbers of those with deficiencies are observed to be in the youngest age groups.

4.2.1.1.3 Vitamin B_3

Nutrient: niacin, nicotinic acid

Major food sources: whole grains, meat & fish. It can also be synthesised from the amino acid tryptophan.

RNI:

4-6yrs, 11mg/d,

7-10yrs, 12mg/d,

Males 11-14yrs, 15mg/d,

Females 11-14yrs, 12mg/d

Key biochemical functions: component of nicotinamide nucleotide coenzymes, NAD and NAPD, which are involved in many oxidation-reduction reactions

Deficiency: pellagra. Diets heavily dependant on maize and not supplemented by high protein foods may create a deficiency hazard.

Toxicity: rare. High pharmaceutical doses of nicotinic acid have been used to lower plasma cholesterol. Adverse symptoms such as flushing, itching, nausea and vomiting have been observed. Doses of nicotinic acid of up to 500mg/d should not result in adverse effects.

Biochemical measure of nutrient status: urinary nitrogen methyl nicotinamide excretion mg/nicotinamide/g creatine, values above 1.6mg/g indicate normality, values of less than 0.5 indicate absolute deficiency

UK deficiency prevalence: high protein diets are typical, making deficiency highly unlikely

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.1.1.4 Vitamin B_6

Nutrient: pyridoxine

Major food sources: liver, cereals, meats, fruit and vegetables

RNI:

4-6yrs, 0.9mg/d,

7-10yrs, 1.0mg/d,

Males 11-14yrs, 1.2mg/d,

Females 11-14yrs, 1.0mg/d

Key biochemical functions: precursor of pyridoxal phosphate, a coenzyme involved in metabolism of amino acids, including conversion of tryptophan to niacin

Deficiency: overt deficiency is rare; convulsions have been reported in babies fed on B_6 depleted formula

Toxicity: in animal studies, high doses have been shown to be neurotoxic with abnormalities in gait and balance and peripheral nerve damage. Some reports of sensory neuropathy when high supplementary doses are consumed, early symptoms include tingling in the hands and feet. A lifetime intake of 10mg/d should pose no risk.

Biochemical measure of nutrient status: erythrocyte aspartate aminotransferase activation coefficient (EAATAC). Values >2.0 indicative of deficiency.

UK deficiency prevalence: 5% of young women have intakes below the LRNI

4.2.1.1.5 Vitamin B_{12}

Nutrient: coblamins

Major food sources: offal, meat, fermented foods or foods contaminated with mould or other micro-organisms

RNI:

4-6yrs, 0.8µg/d,

7-10yrs, 1.0µg/d,

Males 11-14yrs, 1.2µg/d,

Females 11-14yrs, 1.2µg/d

Key biochemical functions: interacts with folate in methylation reactions necessary for DNA synthesis and cell division, required for nerve myelination

Deficiency: megaloblastic anaemia. Degeneration of the spinal cord leading to progressive paralysis. Those at risk of deficiency include; vegans, the elderly and individuals with pernicious anaemia.

Toxicity: high oral intakes are poorly absorbed and excessive amounts are readily excreted in the urine, therefore risk is very low. Long-term consumption of 2mg/d should pose no risk.

Biochemical measure of nutrient status: serum concentration of B_{12} with a value 118pmol/L is the lower limit of normality

UK deficiency prevalence: average UK intakes are 3 or 4 times the RNI

4.2.1.1.6 Folate

Nutrient: folic acid

Major food sources: liver, nuts, green leafy vegetables, wholegrains

RNI:

4-6yrs, 100µg/d,

7-10yrs, 150µg/d,

Males 11-14yrs, 200µg/d,

Females 11-14yrs, 200µg/d

Key biochemical functions: involved with B_{12} in methylation reactions necessary for DNA synthesis, therefore important in cell division

Deficiency: megaloblastic anaemia and neural tube defects. Risk factors for deficiency include marginal diets and poor absorption due to gastrointestinal disorders. Some drugs may interfere with folate functioning.

Toxicity: direct toxicity risk is very low but high doses can mask the haematological effects of B_{12} deficiency. Doses of up to 1.5mg/day should not have any adverse effects.

Biochemical measure of nutrient status: red cell folate (RCF) concentration with values less than 230nmol/L indicates severe deficiency. Values < 345nmol/L indicates marginal deficiency.

UK deficiency prevalence: 4-5% of the UK population have RCF levels indicative of marginal folate status. Less than 1% of the UK population have values indicating severe deficiency.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.1.1.7 Biotin

Nutrient: biotin

Major food sources: liver, offal, egg yolk, whole grains, yeast

RNI: safe intake, 10-200μg/d

Key biochemical functions: cofactor for several carboxylase enzymes that add carboxyl or -COOH groups

Deficiency: dermatitis. Simple dietary deficiency is rare but it can occur as a side effect of medical treatments or as a result of rare genetic abnormalities.

Toxicity: little evidence with oral consumption. Doses of up to 0.9mg/day should not have adverse effects; doses 10 times higher than this have no reported adverse effects.

Biochemical measure of nutrient status: plasma biotin values below 1.02nmol/L indicates deficiency, rarely measured

UK deficiency prevalence: nutritional deficiency is very rare

4.2.1.1.8 Pantothenic Acid

Nutrient: pantothenic acid
Major food sources: present as part of the coenzyme A molecule in most animal and plant cells, therefore widely distributed in foods
RNI: safe intake, infants 1.7mg/d, adults 3-7mg/d
Key biochemical functions: precursor of CoA and CoA-containing compounds that are key intermediates in many biochemical pathways
Deficiency: 'Burning Feet Syndrome', deficiency is extremely rare
Toxicity: no reports of toxic effects. Supplemental doses of 200mg/d should not have any harmful effects; doses 10 times this amount have not shown any adverse effects.
Biochemical measure of nutrient status: plasma pantothenic acid concentration of less than 100µg/L is indicative of low intake, rarely measured
UK deficiency prevalence: overt dietary deficiency is rarely seen

The National Diet and Nutrition Survey [15] showed children had low intakes of thiamine, riboflavin and folate. All B vitamins act as enzymes in metabolic pathways; the amount of B vitamins required is related to the amount of substrates consumed.

Thiamin is involved in the function of the nervous system and heart. It has been suggested that dietary inadequacy of thiamin may contribute to increased risk of congestive heart failure [37].

Riboflavin is involved in the transport and metabolism of iron and is needed to normalise the structure and function of mucous membranes and skin [38, 39]. Low intakes of riboflavin lead to dryness and cracking of the skin around the mouth and nose. A significant number of children, especially girls have low intakes of riboflavin [40].

Folate is essential for normal cell division and the formation of blood cells. Deficiency of folate leads to megaloblastic anaemia [41]. Folate is also involved with the maintenance of normal blood homocysteine levels. Low folic acid intakes and status are associated with increased levels of homocysteine, a risk factor for heart disease and stroke [40, 42, 43]. Folate is required for the structure of the nervous system, specifically in the development of the neural tube in the embryo. There is conclusive evidence that increasing intake of folate before conception and during the first twelve weeks of pregnancy can prevent the majority of neural tube defects in babies [44].

4.2.1.1.7 Vitamin C

Nutrient: ascorbic acid

Major food sources: fruit and vegetables, fortified drinks

RNI:

4-6yrs, 30mg/d,

7-10yrs, 30mg/d,

Males 11-14yrs, 35mg/d,

Females 11-14yrs, 35mg/d

Key biochemical functions: synthesis of collagen, promotion of non-haem Fe absorption, cofactor in carnitine synthesis, synthesis of several nerve transmitters and peptide hormones, antioxidant

Deficiency: scurvy. Living on preserved foods or having a diet low in fruit and vegetables increases the risk of developing deficiency.

Toxicity: several grams can cause diarrhoea and GI discomfort. High doses may increase risk of Ca oxalate kidney stones. 1g/d unlikely to cause ill effects even in susceptible groups, higher doses are often ingested without ill effects.

Biochemical measure of nutrient status: plasma vitamin C concentrations of less than 11µmol/L are indicative of biochemical depletion

UK deficiency prevalence: 5% males and 3% females in the UK population have plasma levels below the threshold value

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Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.1.2 Fat Soluble Vitamins

Vitamins A, D, E and K are insoluble in water but soluble in fat or fat solvents, they are therefore classified as fat soluble vitamins.

In general fat-soluble vitamins are stored in the liver so daily consumption is not required provided that the average consumption over a period of time is adequate.

Clinical deficiency states usually manifest only after chronic deprivation. Excesses are not readily excreted and so toxic overload is possible from rich food sources. Low fat diets or an inability to absorb fat can precipitate deficiency diseases.

4.2.1.2.1 Vitamin A

Nutrient: retinol; β-carotene

Major food sources:

Retinol; dairy fat, liver, eggs, fatty fish and supplemented foods like margarine

β-carotene; dark green, red, orange and yellow fruits and vegetables

RNI:

4-6yrs, 400µg/d,

7-10yrs, 500µg/d,

Males 11-14yrs, 600µg/d,

Females 11-14yrs, 600µg/d

Key biochemical functions: component of visual pigments; maintains the integrity of the epithelial tissues and immune system, synthesis of glycoproteins

Deficiency: night blindness, xerophthalmia, leading to permanent blindness, poor growth, reduced immunocompetence. A poor diet based on little dairy fat, fatty fish or fruit and vegetables, low fat diets and fat malabsorption are risk factors for deficiency.

Toxicity: retinol is teratogenic in high doses. Acute poisoning results in abdominal symptoms, blurred vision, headaches, anorexia. Chronic toxicity leads to cracked lips, dry hard skin, conjunctivitis, liver damage, headaches, bone mineral loss and joint pain.

Biochemical measure of nutrient status: retinol concentrations below 0.35µmol/L are considered severely deficient

UK deficiency prevalence: average UK intakes are less than 8% of the RNI

4.2.1.2.2 Vitamin D

Nutrient: cholecalciferol

Major food sources: dairy fat, eggs, liver, fatty fish and supplemented foods such as margarine and some cereals

RNI: none in the UK if exposed to natural light

Key biochemical functions: precursor of calcitriol, a hormone produced in the kidney which increases the capacity of the gut and kidney tubule to transport calcium; it regulates deposition of bone mineral. It may have a role in regulating immune responses.

Deficiency: Rickets/osteomalacia with skeletal abnormalities, increased risk of osteoporosis, low plasma calcium, muscle weakness, growth failure, increased risk of infection. Inadequate exposure to sunlight coupled with a limited intake of vitamin D rich food increases risk of deficiency. Risk is increased in people with pigmented skin.

Toxicity: the most acutely toxic of vitamins. Overdose leads to elevated calcium concentrations in the blood and urine with calcification of soft tissue and a high risk of developing kidney stones.

Biochemical measure of nutrient status: plasma 25-OHD concentration of less than 25nmol/L is taken as poor status

UK deficiency prevalence: evidence of widespread poor vitamin D status has been reported in children living in the UK

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4.2.1.2.3 Vitamin E

Nutrient: a-tocopherol

Major food sources: vegetable oils, wheat germ, whole grain cereals, dark green leafy vegetables, seeds and nuts

RNI: safe intake, males above 4mg/d, females above 3mg/d, infants 0.4mg/g polyunsaturated fatty acids

Key biochemical functions: antioxidant in the lipid phase, scavenges free radicals and prevents lipid peroxidation

Deficiency: progressive degeneration of nerves, muscle atrophy and retinopathy. Overt deficiency almost never occurs and is usually confined to individuals with a medical disorder that impairs fat and/or fat-soluble vitamin absorption.

Toxicity: little evidence of toxicity even at very high intakes

Biochemical measure of nutrient status: the lower limit of normality is deemed to be a tocopherol:cholesterol ratio of at least 2.25μmol/mmol

UK deficiency prevalence: overt deficiency is rare

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Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.1.2.4 Vitamin K

Nutrient: phylloquinone

Major food sources: liver, green leafy vegetables, some vegetable oils, milk

RNI: safe intake, adults 1µg/kg/d, infants 10 µg/d

Key biochemical functions: a cofactor for enzymes involved in the synthesis of several clotting factors, may have a role in bone metabolism

Deficiency: excessive bleeding, especially brain haemorrhage in new born infants. Risk factors for deficiency include premature infants, poor fat absorption and overdoses of warfarin and other coumarin-type drugs.

Toxicity: few reports of any toxic effects

Biochemical measure of nutrient status: No reliable indicator available

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Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.2 Minerals

In the UK, DRVs are given for eleven minerals and safe intakes are listed for another four. It is internationally accepted that ingestion of these minerals is essential to maintain human health, although some are required in only trace amounts and in some cases requirements are difficult to establish with confidence.

The incidence of clinically recognizable dietary deficiency states is extremely rare for most essential minerals. Only two such deficiency diseases have been observed. They are goitre, caused by a lack of dietary iodine, and iron deficiency anaemia. Debate continues to exist over whether suboptimal intakes of calcium, selenium and zinc are widespread.

4.2.2.1 Chromium

Nutrient: Cr

Major food sources: processed meats, wholegrain cereals and pulses

RNI: safe intake, infants and children 0.1-1.0µg/kg/d

Key biochemical functions: potentiates the actions of insulin

Deficiency: impaired glucose uptake, reduced fat utilization

Toxicity: very low toxicity, doses of 10mg/day should not have any adverse effects

Biochemical measure of nutrient status: no reliable indicator available

UK deficiency prevalence: overt deficiency is almost never seen

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4.2.2.2 Copper

Nutrient: Cu

Major food sources: nuts, seeds, shellfish, offal, cocoa

RNI:

4-6yrs, 0.6mg/d,

7-10yrs, 0.7mg/d,

Males 11-14yrs, 0.8mg/d,

Females 11-14yrs, 0.8mg/d

Key biochemical functions: involved in transmitter synthesis, iron metabolism, electron transport and disposal of free radicals

Deficiency: not well documented in humans, but in animals experimental deficiency results in anaemia, low white cell count and osteoporosis

Toxicity: acute poisoning is rare as copper compounds have an unpleasant taste and an emetic effect; they also cause abdominal pain and diarrhoea. An upper limit for lifetime consumption has been set at 10mg/d.

Biochemical measure of nutrient status: no reliable indicator available

UK deficiency prevalence: only seen in special circumstances such as patients on total parental nutrition

Copper deficiency is recognized as a potential health problem for children worldwide [45]. It has a number of important functions; it helps produce red and white blood cells and triggers the release of iron to form haemoglobin. It is also thought to be important component in brain development and the immune system [46]. Common clinical features of copper deficiency in children include anaemia, impaired growth and increased susceptibility to infection [47].

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Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.2.3 Fluoride

Nutrient: F

Major food sources: tea, fish, seafood, drinking water, toothpaste, mouthwash and other dental products

RNI: safe intakes, children over 6 months, 0.12mg/kg/d, children over 6 years and adults 0.5mg/kg/d

Key biochemical functions: fluoride is incorporated into the tooth enamel in young children and makes teeth more resistant to acid demineralization. It may also protect the teeth in other ways.

Deficiency: increased risk of dental carries (decayed, missing and filled teeth), although frequent consumption of NMES and inadequate dental hygiene regimes play a significant role in dental health

Toxicity: mottling and pitting of the teeth, increased bone density, calcification. Some areas have artificially fluoridated water to a level of 1mg/L. There has been resistance to widespread fluoridation because of unsubstantiated concerns about the long-term effects of this level of intake. In areas with naturally high fluoride content in the drinking water (1mg/L) rates of child dental disease are low and there are no indications of adverse effects.

Biochemical measure of nutrient status: no reliable indicator available

UK deficiency prevalence: may be on the incline due to increased consumption of bottled as opposed to tap water

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Sheffield, SW1 1WB
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4.2.2.4 Magnesium

Nutrient: Mg

Major food sources: leafy vegetables, wholegrains, nuts, seafood and legumes

RNI:

4-6yrs, 120mg/d,

7-10yrs, 200mg/d,

Males 11-14yrs, 280mg/d,

Females 11-14yrs, 280mg/d

Key biochemical functions: many magnesium dependant enzymes exist and most biochemical pathways have magnesium-dependent enzymes

Deficiency: muscle weakness, spasms, personality changes, anorexia, nausea and vomiting. Those with uncontrolled diabetes, renal disease and gastrointestinal disorders are more at risk from deficiency.

Toxicity: low risk, although diarrhoea may result from excessive intake

Biochemical measure of nutrient status: assessment of status is difficult as only 1% is extracellular, normal serum concentration is 16-26mg/L

UK deficiency prevalence: primary symptomatic deficiency is rare, but many children in Britain have intakes below the LRNI

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Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.2.5 Manganese

Nutrient: Mn

Major food sources: leafy vegetables, wholegrains, nuts, seafood and legumes

RNI: safe intake, infants and children, above 16 μg/kg/d

Key biochemical functions: there are several important manganese containing enzymes

Deficiency: none seen in humans

Toxicity: very low risk

Biochemical measure of nutrient status: rarely measured

UK deficiency prevalence: not seen, average UK intake is three times above the 'safe intake'

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4.2.2.6 Molybdenum

Nutrient: Mo

Major food sources: widespread in foods, quantities dependant on soil content

RNI: safe intake infants, children and adolescents, 0.5-1.5µg/kg/d

Key biochemical functions: at least three molybdenum requiring enzymes exist

Deficiency: reduced activity of molybdenum requiring enzymes

Toxicity: low toxicity, symptoms include vomiting, abdominal pain and diarrhoea

Biochemical measure of nutrient status: not usually measured

UK deficiency prevalence: only observed in patients on total parental nutrition

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T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.2.7 Phosphorus

Nutrient: P

Major food sources: phosphate is a major component of all plant and animal cells, it is therefore found in all natural foods

RNI:

4-6yrs, 350mg/d,

7-10yrs, 450mg/d,

Males 11-14yrs, 775mg/d,

Females 11-14yrs, 625mg/d

Key biochemical functions: about 80% is present in bones as a calcium salt that gives rigidity to the skeleton, component of phospholipids (which are important in membranes and some buffering systems) phosphorylation and dephosphorylation reactions, which are an important feature of biochemical reactions

Deficiency: disruption of calcium homeostasis

Toxicity: diarrhoea, nausea, and vomiting

Biochemical measure of nutrient status: not usually measured

UK deficiency prevalence: not observed

4.2.2.8 Potassium

Nutrient: K

Major food sources: fruit and vegetables

RNI:

4-6yrs, 1,100mg/d,

7-10yrs, 2,000mg/d,

Males 11-14yrs, 3,100mg/d,

Females 11-14yrs, 3,100mg/d

Key biochemical functions: the main cation in intracellular fluid, nerve impulse transmission, contraction of muscle and heart, acid-base balance

Deficiency: primary deficiency is rarely observed, but secondary hypokalaemia leads to muscle weakness, changes in cardiac function, reduced gut motility, alkalosis, depression and confusion

Toxicity: not reported

Biochemical measure of nutrient status: normal serum concentrations are 3.6-5.0mmol/L

UK deficiency prevalence: many children in the UK have recorded intakes below the LRNI

Potassium and magnesium deficiencies are common and are associated with risk factors for heart failure [48]. Symptoms of potassium deficiency include fatigue, slow reflexes, muscle weakness and dry skin [49, 50]. Several studies suggest diets low in potassium is associated with poor lung function and asthma in children [51, 52]. Low potassium diets are associated with an increased risk of stroke [53] and may play an important role in the genesis of high blood pressure. Appel et al. [54] suggest increased potassium intake should be considered as a recommendation for the prevention of hypertension.

4.2.2.9 Selenium

Nutrient: Se

Major food sources: meat (particularly organ meat) eggs, fish and cereals

RNI:

4-6yrs, 20µg/d,

7-10yrs, 30µg/d,

Males 11-14yrs, 45µg/d,

Females 11-14yrs, 45µg/d

Key biochemical functions: component of enzyme system involved in free radical disposal, involved in thyroid function

Deficiency: Keshan disease, a progressive cardiomyopathy

Toxicity: selenosis leads to skin lesions, changes to the hair and nails followed by a range of neurological symptoms

Biochemical measure of nutrient status: plasma or serum selenium is a good short-term indicator of selenium intake, red cell selenium is a long-term measure of intake

UK deficiency prevalence: estimates of intake are unreliable. There are probably a number of individuals in the UK who have intakes below the LRNI although symptomatic deficiency does not occur.

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Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.2.10 Zinc

Nutrient: Zn

Major food sources: meats, wholegrain cereals, pulses and shellfish

RNI:

4-6yrs, 6.5mg/d,

7-10yrs, 7.0mg/d,

Males 11-14yrs, 9.0mg/d,

Females 11-14yrs, 9.0mg/d

Key biochemical functions: numerous zinc containing enzymes are involved in DNA synthesis and in the synthesis and metabolism of fats, carbohydrates and proteins, forms part of an enzyme involved in free radical disposal

Deficiency: experimental deficiency results in anorexia, growth reduction, reduced immune function; poor wound healing, hypogonadism and delayed sexual maturation, skin lesions and hair loss. Diets high in phytates may reduce zinc absorption.

Toxicity: excess interferes with copper absorption and precipitates symptoms of copper deficiency. It may also interfere with iron absorption. Excess zinc can depress the activity of an enzyme involved in free radical disposal. Zinc supplements can cause gastrointestinal distress.

Biochemical measure of nutrient status: serum or plasma concentrations with a value of less than 700µg/L are indicative of deficiency

UK deficiency prevalence: average UK intakes are around the RNI but there is a prevalence (more than 5%) of children with intakes below the LRNI

Zinc has a fundamental role in cellular metabolism and has profound effects on the immune system and intestinal mucosa [55]. Subclinical zinc deficiency in children is widespread [56]. Marginal zinc status or deficiency has been shown to impair immune function and the modulation of host resistance to infectious agents, thus increasing the risk, severity and duration of infectious diseases [57]. Zinc supplementation can reduce the incidence and improve

the outcome of pneumonia and diarrhoea infections, especially in children, and improve hand and eye coordination [58, 59]. Zinc deficiency may have adverse effects on physical growth, neurodevelopment, cognition, motor activity and responses to stress and emotion [60, 61]. Many ADHD suffers are deficient in zinc. Akhondzadeh et al. [62] found supplementation with zinc sulphate (55mg/kg/d) whilst using Ritalin significantly improved parent & teacher ADHD ratings compared to Ritalin alone.

4.2.2.11 Iodine

Nutrient: I

Major food sources: seafood, the amount in fruit, vegetables and meat depends on the soil iodine content

RNI:

4-6yrs, 100µg/d,

7-10yrs, 110µg/d,

Males 11-14yrs, 130µg/d,

Females 11-14yrs, 130µg/d

Key biochemical functions: a component of thyroid hormones

Deficiency: goitre/iodine deficiency diseases including cretinism and myxoedema

Toxicity: high intakes can lead to thyroid function disturbances, which usually manifest as hyperthyroidism and toxic nodular goitre, but occasionally may manifest as hypothyroidism

Biochemical measure of nutrient status: usually based on clinical assessment

UK deficiency prevalence: when iodine intake is consistently low, stores of iodine in the thyroid gland become quickly depleted and deficiency can develop. Iodine deficiency causes goitre, hyporthyroidism and cretinism [63]. Iodine deficiency disorders are one of the major causes of preventable mental disabilities. They affect 13% of the world's population and unlike other diseases of poverty they are not uncommon in developed countries [64, 65]. Requirements for iodine are high in adolescents as well as during pregnancy. This poses a serious public health problem for pregnant teenagers; in 2001 there were an estimated 7,891 conceptions to girls aged under the age of 16 [66]. The iodine status of an unborn child depends on the mother's diet. Maternal subclinical hypothyroidism is a cause of poor neurodevelopment in children [67].

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Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.2.12 Iron

Nutrient: Fe

Major food sources: meat (particularly offal) fish, cereals, green vegetables. The bioavailability (the extent to which a nutrient is digested, absorbed and utilized by the body) of meat sources of iron is the highest.

RNI:

4-6yrs, 6.1mg/d,

7-10yrs, 8.7mg/d,

Males 11-14yrs, 11.3mg/d,

Females 11-14yrs, 14.8mg/d (insufficient for females with high menstrual losses)

Key biochemical functions: component of haemoglobin, myoglobin and cytochromes, there are also several iron-containing enzymes

Deficiency: iron deficiency anaemia (IDA). Those at risk of deficiency are individuals who follow a vegetarian or vegan diet that is low in iron, low in bioavailable iron sources and low in promoters of iron absorption such as vitamin C.

Toxicity: acute effects include constipation or diarrhoea, nausea and vomiting Severe and/or chronic overload will cause tissue damage, especially cirrhosis of the liver.

Biochemical measure of nutrient status: low haemoglobin concentrations are indicative of anaemia. World Health Association lower limits are 130g/L for males and 120g/L for females. Serum ferritin concentration is used to indicate level of iron stores; the normal range is 20-300µg/L for 15-150µg/L for males and females respectively.

UK deficiency prevalence: IDA is the most prevalent micronutrient deficiency globally, in the UK 9% of females are anaemic and a further 12% have depleted iron stores

Iron-deficiency anaemia is the most common nutritional disorder of childhood, occurring in 12% of children in the UK [68, 69]. Iron deficiency during development adversely affects the growth and functioning of multiple organ systems [70]. Iron deficiency was once presumed to exert most of its deleterious effects if anaemia were present. It is now clear that many organs show morphological, physiological and biochemical changes before there is any drop in haemoglobin concentration [71, 72].

Perhaps the most concerning effect of iron-deficiency is on the developing brain. It causes an alteration in cognition; impact can be determined by the severity and duration of deficiency [73, 74]. Neurophysiological studies suggest early iron deficiency has an adverse effect on cognitive functioning in infants and that these effects appear to be long-lasting [75, 76, 77].

A number of intervention trials have examined the effects of iron-deficiency on neural functioning in pre-adolescent boys and girls. These studies indicate iron deficiency can have adverse affects on cognitive functioning, they also suggest depression and learning are sensitive to iron status. Importantly, in most cases, interventions for 2 to 4 months were sufficient to return performance to levels similar to those of controls [78, 79, 80, 81]. Iron deficiency is a preventable disease with preventable consequences. The dependence of brain development and function on iron supply, strongly support the public health importance of ensuring an adequate iron status in childhood [82].

4.2.2.13 Calcium

Nutrient: Ca

Major food sources: milk and milk sources (high bioavailability) fish (particularly if bones are eaten as part of a tinned product) green vegetables, pulses, nuts, wholegrain cereals (white flour is fortified in the UK)

RNI:

4-6yrs, 450mg/d,

7-10yrs, 550mg/d,

Males 11-14yrs, 1,000mg/d,

Females 11-14yrs, 800mg/d

Key biochemical functions: 99% of body calcium is in bone mineral but the other 1% plays vital roles in nerve and muscular function, release of hormones and nerve transmitters, blood clotting and intracellular metabolic regulation

Deficiency: overt, primary deficiency is rare. Vitamin D deficiency leads to poor calcium absorption and the diseases rickets/osteomalacia. Osteoporosis may be a long-term consequence of calcium insufficiency, vitamin D deficiency and poor absorption.

Toxicity: gastrointestinal symptoms, hypercalcaemia, calcification of the tissues, alkalosis, hypertension, neurological symptoms and renal impairment

Biochemical measure of nutrient status: no routine method available

UK deficiency prevalence: 12.5% British women have inadequate intakes with higher prevalence in older children

Children constitute a major section of the population at risk of calcium deficiency [83]. It is known that the risk of osteoporosis can be reduced by achieving maximum peak bone mass and minimising the rate of bone loss [84]. About 20-40% of an individual's susceptibility to osteoporosis is lifestyle related [85]. While lifestyle factors are less influential in the disease process than genetic factors they are very important, since unlike genotype they are

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Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

potentially modifiable. Lifestyle risk factors include a poor diet with inadequate calcium and vitamin D intake [86, 87].

The WHO [88] suggests vitamin D deficiency is common and represents a global health problem. Vitamin D inadequacy is becoming an increasing concern in the UK; especially in young individuals [15]. Vitamin D sufficiency is essential for maintaining normal calcium metabolism; vitamin D deficiency causes insufficient calcium absorption. In childhood, this results in poor mineralization of the collagen matrix, increasing the risk of osteoporosis, rickets and fractures [89]. Poor dental health and dental abnormalities are common in children with poor status or deficiency of vitamin D and calcium [90]. Dental caries affect 60-90% of schoolchildren in the developed world. A major priority of the WHO's Global Oral Health Programme is to address modifiable risks such as a lack of calcium and vitamin D [91].

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Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

4.2.2.14 Sodium

Salt (sodium chloride) is made up of the two minerals sodium and chloride. It is the sodium component that is regarded as significant in terms of causing hypertension (high blood pressure).

Nutrient: Na

Major food sources: processed food, salt added in cooking/at the table. Regularly consumed foods such as bread products, breakfast cereals, soups and ready meals frequently contain high levels of sodium.

RNI:

4-6yrs, 700mg/d,

7-10yrs, 1,200mg/d,

Males 11-14yrs, 1,600mg/d,

Females 11-14yrs, 1,600mg/d

Key biochemical functions: the major cation in extracellular fluid, it maintains fluid and electrolyte balance and is important in nerve transmission and acid-base balance

Deficiency: dietary deficiencies do not usually occur

Toxicity: high salt intake is involved in the aetiology of essential hypertension; prolonged excess sodium intake can lead to excess salt retention and therefore increased fluid retention and hypertension. High salt intakes have also been implicated in the aetiology of gastric cancer and osteoporosis.

Biochemical measure of nutrient status: urinary excretion rate is generally regarded as the best way of measuring salt intake

4.2.2.15 Chloride

Nutrient: chloride

Major food sources: processed food, salt added in cooking/at the table

RNI:

4-6yrs, 1,100mg/d,

7-10yrs, 1,800mg/d,

Males 11-14yrs, 2,500mg/d,

Females 11-14yrs, 2,500mg/d

Key biochemical functions: the major anion in the body and is important in maintaining fluid and electrolyte balance

Toxicity: it has been argued that chloride and sodium interact in inducing hypertension

Biochemical measure of nutrient status: plasma chloride is usually maintained at 95-106mmol/L

In response to evidence suggesting salt intake amongst children is too high, the FSA [92] published specific requirements for maximum daily levels of salt intake for children aged 4 to 6 years (3g salt/1.2g sodium/day) and 7 to 10 years (5g salt/2g sodium/day).

Most foods naturally contain low levels of sodium but the majority comes from processed or manufactured foods to which salt has been added. Salt naturally present in food = 10%, salt in manufactured foods = 75%, salt added in cooking/at the table = 15% [93].

Preference for salty food is learned. The recommendation that the adult population should reduce sodium intake will be more successful if children do not develop a liking for salt in the first place; this can only be achieved if children are given a low salt diet [94]. A number of studies show high intakes of dietary sodium are related to a rise in blood pressure in childhood and may

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Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

be important in the early pathogenesis of primary hypertension [15, 95]. Evidence also suggests a high salt diet can act as a major aggravating factor for asthma [96, 97].

Feng et al. [98] demonstrated high salt diets made children thirstier whilst at school and that children did not always drink enough fluid to prevent dehydration. Dehydration can lead to a number of medical problems including urinary tract infections, constipation, bed wetting and a dry cough. Low levels of dehydration can have deleterious effects on mental performance [99].

CHAPTER 5

5.0 Examination of Current Provision

CHAPTER 5

5.0 EXAMINATION OF CURRENT PROVISION

In order to make an in-depth investigation into the current provision of primary school meals, visits were made to four UK primary schools.

The purpose of these visits was to interview the kitchen managers and establish information relating to manufacturers, distribution, storage conditions, preparation and cooking techniques and portion sizes.

The area 1 school meals are provided on a 3 week rotational basis. The menu changes twice yearly to represent a 'summer' and a 'winter' menu. The manufacturers and distributors of the food used in the school meals are the same throughout the area.

The area 2 school meals are provided on a 3 week rotational basis. The menu changes twice yearly to represent a 'summer' and a 'winter' menu. The manufacturers and distributors of the food used in the school meals are the same throughout the area.

An initial point of analysis was to examine the current use of frozen food produce within these schools [see appendix 7, 8]. The tables in appendix 9, 10, 1, 12 13 and 14 show the provision type (fresh, frozen, dried or tinned) of the various food items served. These tables are split into categories as follows:

1. **Individual Single Items**. These items are those which are served as a single menu item, for example peas or chips.
2. **Individual Composite Items.** These items are those which are served as part of a composite dish, for example the mince in a pasta bake.
3. **Composite Dishes.** These items represent dishes that are made up from single items by kitchen staff on the school premises.

The tables highlight the current provision type of each item; fresh, frozen, dry or tinned. The possibility of changing the current provision type to a frozen version is also shown, for example fresh cabbage to frozen cabbage.

This conversion is not a possibility for all produce, for example flour. However, the **Composite Dishes** table highlights where menu items, which are currently made on the school premises, could be made elsewhere and bought in to the kitchen as a frozen food item.

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Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

5.1 Results Summary - Current Provision Area 1 Schools

In area 1 schools the current provision of the 45 single item foods were as follows:

1. **Individual Single Items:**

   Fresh: 8

   The number of food items where a viable conversion from fresh to frozen is possible is 7.

   Frozen: 30

   Dry: 4

   The number of food items where a viable conversion from dry to frozen is possible is 1

   Tinned: 3

   The number of food items where a viable conversion from fresh to frozen is possible is 2

For single food items current provision of frozen foods represents **67%**. Of the items currently provided as 'fresh', 'dry' or 'tinned' , 10 could be converted to frozen provision. This would increase provision of frozen foods to **89%** [see appendix 9].

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2. **Individual Composite Items:**

In area 1 schools the current provision of the 83 composite item foods were as follows:

Fresh: 21
The number of food items where a viable conversion from fresh to frozen is possible is 13.
Frozen: 4
Dry: 52
The number of food items where a viable conversion from dry to frozen is possible is 9
Tinned: 6
The number of food items where a viable conversion from fresh to frozen is possible is 5

For composite food items current provision of frozen foods represents **5%**. Of the items currently provided as 'fresh', 'dry' or 'tinned', 27 could be converted to frozen provision. This would increase provision of frozen foods to **37%** [see appendix 10].

3. **Composite Dishes**

The number of composite dishes (those which are made on the school premises from a range of single item foods) currently made in area 1 schools are 46. The number of these composite dishes which could be made elsewhere and bought in to the kitchen as a frozen food item is 39 [see appendix 11].

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

5.2 *Results Summary - Current Provision Area 2 Schools*

In area 2 schools the current provision of the 39 single item foods were as follows:

1. **Individual Single Items:**

   Fresh: 7

   The number of food items where a viable conversion from fresh to frozen is possible is 6.

   Frozen: 25

   Dry: 5

   The number of food items where a viable conversion from dry to frozen is possible is 4.

   Tinned: 2

   The number of food items where a viable conversion from fresh to frozen is possible is 0.

For single food items current provision of frozen foods represents **64%**. Of the items currently provided as 'fresh', 'dry' or 'tinned', 10 could be converted to frozen provision. This would increase provision of frozen foods to **90%** [see appendix 12].

2. **Individual Composite Items:**

In area 2 schools the current provision of the 95 composite item foods were as follows:

Fresh: 31
The number of food items where a viable conversion from fresh to frozen is possible is 19.
Frozen: 12
Dry: 44
The number of food items where a viable conversion from dry to frozen is possible is 9
Tinned: 8
The number of food items where a viable conversion from fresh to frozen is possible is 4

For composite food items current provision of frozen foods represents **13%**. Of the items currently provided as 'fresh', 'dry' or 'tinned', 32 could be converted to frozen provision. This would increase provision of frozen foods to **46%** [see appendix 13].

3. **Composite Dishes**

The number of composite dishes (those which are made on the school premises from a range of single item foods) currently made in area 2 schools are 43. The number of these composite dishes which could be made elsewhere and bought in to the kitchen as a frozen food item is 33 [see appendix 14].

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 6

6.0 NUTRITIONAL ANALYSIS

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

6.0 NUTRITIONAL ANALYSIS

NetWISP V3.0 (Tinuveil Software) dietary analysis software was used to analyse and convert the primary school menus into energy, macronutrient and micronutrients. The food composition databank supplied is from HMSO/OPSI, McCance and Widdowson's *The Composition of Foods* - 6th Edition (2002), 5th Edition plus supplements.

The Composition of Foods is widely acknowledged as the key reference tool for examining the nutritional value of foods consumed in the UK. There can however, be no guarantee that a particular item will have precisely the same composition as that described due to the natural variability of foods.

In addition, NetWISP V3.0 contains data from the following manufacturers:

- Tillery Valley Foods, 2008
- Calypso Soft Drinks Ltd, 2008
- Brakes, foodservice (catering) products, 2008
- Nutricia, tube and sip feeds, 2008
- Abbott, tube and sip feeds, 2006
- Glycaemic index of foods, 2005
- Better Hospital Food, 2005
- Pasta & Pasta Sauces, Food Standards Agency (FSA), 2004
- Catch-Up Project, FSA, 2004
- AOAC fibre content of foods, USDA, 2004
- Non-milk extrinsic sugars content of foods, calculated by Registered Nutritionist, 2003

The food composition database contains a total of about 6,000 food records and up to 125 nutrients.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

6.1 Nutritional Analysis Area 2 Schools

single food items	a comparable nutritional analysis was available for 13 out of the 45 items
composite food items	a comparable nutritional analysis was available for 2 out of the 84 items
composite food dishes	a comparable nutritional analysis was available for 3 out of the 46 dishes

See appendix [15, 16, 17] for food item details and NetWISP V3.0 analysis.

6.2 Nutritional Analysis Area 2 Schools

single food items	a comparable nutritional analysis was available for 12 out of the 39 items
composite food items	a comparable nutritional analysis was available for 1 out of the 95 items
composite food dishes	a comparable nutritional analysis was available for 1 out of the 43 dishes

See appendix [18, 19, 20] for food item details and NetWISP V3.0 analysis.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 7

7.0 STATISTICAL ANALYSIS

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

CHAPTER 7

7.0 STATISTICAL ANALYSIS

Using the nutritional analysis data obtained from NetWISP V3.0, independent sample t-tests were performed in order to identify the effect of fresh versus frozen food classification (SPSS; version 15.0 for Windows, SPSS Inc., Chicago, IL, USA). This is a commonly used statistical procedure used to determine if there is a significant difference between the average values of the same measurement made under different conditions. Graphical presentations [appendix 21-42] were produced using SPSS (version 15.0 for Windows, SPSS Inc., Chicago, IL, USA). Results are reported as the mean±standard deviation. Values of $P < .05$ are classed as significant.

Nutrients tested:
Protein g; Total fat g; Carbohydrate g; Energy in kcals; Energy in kJ; Saturated fat; Monounsaturated fat g; Polyunsaturated fat g; Cholesterol mg; Sugars g; Non milk extrinsic sugars g; Starch g; AOAC fibre g; Englist fibre g; Sodium in mg; Potassium in mg; Calcium in mg; Magnesium in mg; Phosphorous in mg; Iron in mg; Copper in mg; Zinc in mg; Chloride in mg; Manganese in mg; Selenium in µg; Iodine intake in µg; Vitamin A (r.e.) in µg; Carotene in µg; Vitamin D in µg; Vitamin E in mg; Thiamin in mg; Riboflavin in mg; Niacin in mg; Vitamin B6 in mg; Vitamin B12 in µg, Folate in µg; Pantothenienic acid in mg; Biotin in mg; Vitamin C in mg

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

7.1 Results - Statistical Analysis Area 1 Schools

An independent-samples t-test was conducted to compare the macronutrient and micronutrient content of fresh and frozen versions of the same food products. There was (equal variances assumed and equal variances not assumed (vitamins A, D and E)) no significant difference in scores for fresh and frozen foods. See appendix 43 for group statistics.

7.2 Results - Statistical Analysis Area 2 Schools

An independent-samples t-test was conducted to compare the macronutrient and micronutrient content of fresh and frozen versions of the same food products. There was (equal variances assumed and equal variances not assumed (vitamins A, D and E)) no significant difference in scores for fresh and frozen foods. See appendix 44 for group statistics.

7.3 Results - Statistical Analysis All Schools

An independent-samples t-test was conducted to compare the macronutrient and micronutrient content of fresh and frozen versions of the same food products. There was (equal variances assumed and equal variances not assumed (magnesium and vitamins A, D and E)) no significant difference in scores for fresh and frozen foods. See appendix 45 for group statistics.

7.4 Results - Statistical Analysis All Vegetables

An independent-samples t-test was conducted to compare the macronutrient and micronutrient content of fresh and frozen versions of the same vegetable products. There was (equal variances assumed) no significant difference in scores for fresh and frozen vegetables. See appendix 46 for group statistics.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

7.5 Results Statistical Analysis All Meat and Fish

An independent-samples t-test was conducted to compare the macronutrient and micronutrient content of fresh and frozen versions of the same meat and fish products. There was (equal variances assumed) no significant difference in scores for fresh and frozen meat and fish. See appendix 47 for group statistics.

CHAPTER 8

8.0 RESULTS EVALUATION

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

8.0 RESULTS EVALUATION

8.1 Processing

Processing food can improve its palatability, make it safer and extend its shelf-life. Whilst the benefits are numerous processing can also have detrimental effects on the nutritional and sensory quality of food. Product composition and the time and temperature of processing and storage are the predominant factors which impact food quality.

8.2 Processing for Safety

Food safety can be enhanced by processing methods designed to eliminate harmful bacteria. Heat treatments such as pasteurization rid juice and milk of organisms such as E. coli and Salmonella. Cooking and other heat treatments can make foods shelf-stable by destroying spoilage micro-organisms [100].

Freezing contributes to food safety by slowing the movement of molecules, causing microbes (bacteria, yeasts and moulds) to enter a dormant stage. It is used effectively for example, to destroy the trichinosis parasite in pork products [101]. A major advantage of freezing meat and fish is to extend its shelf life by slowing or preventing the growth of spoilage and pathogenic microorganisms. Freezing has proven to be a suitable procedure to prolong the shelf life of many food products [100, 102, 105].

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

8.3 Quality of Raw Materials

Regardless of the type of product, the initial quality of the raw materials substantially affects the quality of the final product. Food intended for freezing should be 'on the day fresh' and of the highest nutritional and sensory quality. Determining the initial properties of raw material is essential because with few exceptions frozen storage will not improve the quality of the food, only maintain it [103].

8.4 Meat and Fish

The type of meat consumed in human diets is derived primarily from muscle tissue. The contribution of all forms of meat to the protein content of the average British diet is approximately 29%. Meat is a source of all the essential amino acids and many vitamins, minerals and essential fatty acids [102]. Whilst it is a highly nutritious and bioavailable food, red meat in particular should not be consumed excessively as it can make a significant contribution to fat and saturated fatty acid intake.

Fish is an important source of protein; it contains all the essential amino acids, is an excellent source of polyunsaturated fatty acids and is rich in vitamins A and D. Fish and shellfish also contain B vitamins. Fish is eaten less frequently than meat and contributes approximately 5% of total protein intake in the British diet. The British Heart Foundation recommends eating two portions of fish a week, one of which should be oily fish. Evidence suggests regular fish consumption may be cardio protective and preventative against strokes and prostate cancer.

Meat and fish are highly perishable foods, they spoil easily if incorrectly stored and can cause food poisoning. The number of cases of salmonella and campylobacter in England and Wales was estimated to be 117,600 from June to August 2006. Freezing is considered to be one the best processes for

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

preventing the growth of spoilage and pathogenic microorganisms present on and within meat and fish products [100]. If the freezing and storing process is correctly executed, it causes virtually imperceptible changes to sensory, nutritional and microbial quality. Frozen foods have a very good safety record, with few associated outbreaks of food borne illness. In most cases where outbreaks have occurred, contaminated raw materials or post process contamination, as opposed to freezing, have been implicated [100].

Factors affecting the quality of frozen meat and fish depend on freezing methods, temperatures and storage time. The effect of storage time on the functional attributes of meat was assessed by Farouk et al. [104]. Storage times of 0, 3, 6, 9 and 12 months were examined and increases in pH, emulsion activity and stability were recorded. They found that whist total protein stability decreased with storage time, tenderisation increased. Subsequent reviews have concluded there to be no significant difference in nutritional value between fresh and frozen meat [103].

Some findings suggest prolonged frozen storage increases the toughness and disruption of fish muscle proteins [105]. Conversely, fresh fish deteriorates rapidly, spoiling within days of being caught and resulting in off odours and flavours. Providing quality fresh fish is logistically problematic in cases where fish has to be transported from area of harvesting to the geographically remote customer.

8.5 Fruit and Vegetables

Fruit and vegetables play an important role in the human diet. They are characteristically low in fat, salt and energy, high in carbohydrates and fibre and provide significant levels of micronutrients. Thus incorporating fruit and vegetables into meals fits in well with UK government guidelines to eat a healthy balanced diet. Scientific evidence which suggests high intakes of fruit and vegetables may reduce the risk of developing chronic diseases such as coronary heart disease and certain types of cancer [106] has led to the implementation of initiatives such as the School Fruit and Vegetable Scheme.

Vegetables provide approximately 30% of the vitamin C, 20% of the β-carotene and 10% of the thiamin and iron content of the average UK diet. These attributes are associated with fresh produce, yet commercially frozen versions are not readily accepted as an appropriate alternative. This is despite 5 A DAY programme advice that frozen fruit and vegetables are an acceptable alternative to fresh. Regardless of nutrient degradation during processing, storage and cooking, fresh, frozen, chilled, canned and dried fruit and vegetables are all typically good sources of certain vitamins, minerals and fibre. The Food Standards Agency stipulates that a 'Source' should contain 15% of the European Recommended Daily Amount (RDA) and a ‘Rich’ or ‘Excellent’ source should contain at least half the European RDA or 2 or more vitamins or minerals.

Blanching is common practice in the manufacture of frozen vegetables. Its purpose is to inactivate enzymes that can cause product spoilage. It also prevents the formation of large ice crystals which can rupture the plant cell walls. Vegetables are typically scalded in boiling water or steam for a brief, timed period and then rapidly cooled and centrifuged. Blanching itself causes certain losses in nutrients, yet as a pre-treatment for fruit and vegetables intended for long-term frozen storage, it has been shown to limit vitamin losses and deterioration of organoleptic qualities [107].

Kimiecik and Lisiewska [108] examined the effects of blanching on the preservation of vitamin C, β carotene and chlorophylls in chives. Chives were chosen as, among the onion vegetables, they have the highest quantifies of these nutrients. They found blanching reduced the levels of vitamin C, β carotene and chlorophylls by 29%, 20% and 21% respectively. A 12 month period in frozen storage (-20°C) resulted in further (minimal) nutrient losses for the blanched chives, yet these losses were significantly higher for the non blanched chives. These investigators concluded that if blanching is omitted the preservation of nutrients is not possible even during short periods of freezing. In contrast they suggest blanching ensures good nutrient conservation.

Fresh vegetables have poor durability and are exposed to conditions that rapidly destroy their quality. The seasonality and perishability of vegetables dictate the necessity of applying preservation technologies, such as freezing.

Numerous studies show processed foods to be as nutritious or in some cases more nutritious than their unprocessed counterparts [109,110,111]. Frozen vegetables retain their high vitamin and mineral content because they are processed within hours of harvest and when stored at temperatures below -18°C there are practically no decreases in micronutrient content for up to a year. For fresh vegetables, however, the time needed for packing and transporting usually translates into days or weeks before they are consumed, resulting in a gradual loss of nutrients over time.

The vitamin C content varies considerably between different plants due to the nature of the food as a biological material; citrus fruit and brassicas contain high levels whilst root crops tend to contain relatively little. Even within plant type's inherent vitamin variability occurs, for example peas can contain between 20-40mg per 100g at harvest depending on variety, agronomy etc [109]. Vitamin C content is not an indicator of food quality per se, but since it is vulnerable to chemical and enzymatic oxidation and is highly water soluble it is frequently used as an appropriate marker for monitoring quality changes.

Favell [110] conducted an investigation to examine the nutrient content of fresh and frozen vegetables (peas, broccoli, green beans, carrots and spinach). Using vitamin C as the 'marker' for nutrient alteration, a direct comparison of vegetables at various stages of storage and processing was conducted. Vitamin C status was examined in fresh vegetables (at harvest

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

and over a period of days and weeks in storage) and those of the corresponding conventionally quick-frozen vegetables (post-process and stored up to 12 months). The nutrient status of the frozen peas and broccoli was similar to that of the fresh 3 day old samples. The frozen peas were superior in nutrient content to the fresh samples that had been stored at ambient temperatures for several days. The nutrient status of frozen carrots and green beans was similar to the fresh vegetables at the point of harvest (0 days old). Frozen spinach was nutritionally comparable to freshly harvested vegetables and superior to all stored ambient and chilled samples.

Rickman et al. [111] conducted an extensive review of 56 recent and classical studies that had examined the nutritional differences between fresh and frozen fruit and vegetables. They concluded that the loss of nutrients in fresh products during storage and cooking were clearly more substantial than is commonly perceived and that frozen fruit and vegetable consumption should continue to be promoted as part of national and international food based guidelines.

The literature suggests fresh fruit and vegetables usually lose nutrients more rapidly than frozen products [109,110, 111]. Rather than diminishing our diets, frozen food can actually facilitate the selection of a balanced diet, as they enable school catering staff to shop less frequently and to stock a wide range of foods on which to base varied and nutritious meals.

8.6 Post-processing Issues

Although, fresh and frozen food comparability is accepted by experts, other factors significantly affect the final quality of food items served in a school setting. These factors include post-processing distribution, storage and kitchen-handling.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

Post freezing, foods are often not immediately available for consumption. Several months may elapse before purchase followed by a significant time in catering freezers before final consumption. Fluctuating temperature conditions may occur in this period, often deviating from the ideal. Post-processing temperature conditions and fluctuations can determine degradation rate and shelf life. Improper storage causes evident changes in sensory characteristics and nutritive value that influence consumer acceptability [112].

Considerable research into the degradation of frozen food during distribution and storage has been published and reviewed [113]. Investigators tend to use vitamin C as a representative index for estimating quality deterioration from the point of distribution to final destination. Kimiecik and Lisiewska [108] examined the effect of storage temperatures on the preservation of ascorbic acid in several green vegetables. They conclude that temperature abuse is recognised to be one of the primary causes of quality and safety loss in frozen foods.

Temperature abuse is a term that describes conditions of fluctuation temperature such that there are periods during which a product may be subject to temperatures higher than the range at which it was designed to be kept optimally. Partial thawing may occur, resulting in some loss of sensory quality and shelf life with each episode of increased temperature. Unfavourable conditions primarily occur during transportation. Such conditions also apply to frozen foods kept in catering refrigeration, where frequent opening and closing of the freezer case causes temperature fluctuations that can adversely affect product quality over a period of time [100].

Quality checks when receiving delivery of frozen produce and prior to use should include checking for unpleasant smells, stained packaging or large ice crystal formation surrounding the product.

8.7 Food Preparation

Most foods are prepared and cooked before they can be eaten. For some foods the process might be very simple (washing an apple or peeling an orange) for others is it a complex and time consuming procedure. At each stage of processing some of the nutrients will be discarded or destroyed. Nutrients may be further reduced if food is stored for a long period of time, especially when conditions are not ideal. These losses are not usually significant if a healthy mixed balanced diet is habitually consumed. Nevertheless, it is desirable to keep nutrient losses to a minimum.

Heat causes chemical and physical changes which can make the flavour, texture and digestibility of food more acceptable. It can also increase the availability of some nutrients by destroying enzymes and anti-digestive factors. Usually however, cooking results in the loss of nutrients, especially when food is cooked at high temperatures for a long time or if excessive amounts of liquid are used.

General guidelines for minimising nutrient losses in the kitchen:

Nutrient stability is affected by physical action, pH, the presence or absence of air/oxygen, light and temperature. Leaching occurs when the cell walls of a food are disrupted, nutrient losses occur to a greater extent when food is finely chopped. The losses of soluble vitamins and minerals are reduced if meat juices and cooking waters are retained, for example when making stews, soups and gravies. The effects of microwave cooking on nutrients are deemed to be similar to traditional methods, yet when used for reheating they cause little additional nutrient losses.

Retinol and βeta-carotene are stable throughout most cooking procedures, but at high temperatures in the presence of air there will be minor losses. Losses also occur during prolonged storage if light and air are not excluded. Vitamin D is stable in normal cooking procedures. Vitamin E is insoluble in water and heat stable, but can oxidised in the presence of air.

Vitamin C is one of the least stable nutrients. It is water soluble and very readily destroyed by air; this destruction is accelerated by heat, alkali and presence of copper and iron. Cooking fruit and vegetables for a long time at high temperatures using sodium bicarbonate (to maintain colour) then keeping warm before serving can result in the complete destruction of vitamin C.

B vitamins are all water soluble and most are heat sensitive. Thiamin is the least stable nutrient. It is readily dissolved in cooking water and easily lost from meat juices. It is fairly stable to heat if the food is acid, but losses can be considerable under alkaline conditions (e.g. by adding sodium bicarbonate). An estimated 20% of the thiamin content of all food is lost during cooking and reheating. Food preserved by sulphur dioxide (sausages, wine, some potato products) will contain no thiamin. Riboflavin is lost particularly in discarded cooking water and meat juices. It is unstable in alkali conditions and is especially light sensitive. Niacin is an exceptionally stable vitamin, lost only through solubility in water. B6, folate and pantothenic acid are also heat sensitive and can therefore be lost during cooking procedures.

Minerals are generally unaffected by heat processing, but can be lost by leaching into water during moist cooking or processing procedures.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

8.8 Food Service

Food preparation and cooking cause substantial yet unavoidable nutrient losses but in a school setting 'normal' cooking losses are compounded by problems of meal service. Most primary schools use cook and hot-hold systems for meal service. Hot-holding is a major cause of deterioration of sensory and nutrient quality [114]. Reviews examining the effect of hot-holding on nutrient changes show vitamin C, B_6 and folate are most unstable in these conditions and the longer the hot-holding time, the greater the nutrient losses. [115]. Studies exploring vitamin C retention have reported rapid destruction, even during relatively short periods. For example, when broccoli was held a 63°C for 10, 20 and 30 mins, vitamin C losses were 16%, 27% and 39% respectively (36mg/100g) [116].

References

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

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REFERENCES

[1] Sharp I. Nutritional Guidelines for School Meals. Report of an Expert Working Group. London: Caroline Walker Trust. 1992.

[2] Lupton D. Food, the Body and the Self. London: Sage. 1996.

[3] Gustafsson U. School Meals Policy: the Problem with Governing Children. Social Policy and Administration. 2002;36(6): 685-697.

[4] White J, Cole-Hamilton I, and Dibb S. The Nutritional Case for School Meals. London, School Meals Campaign. 1992.

[5] DoH. Annual Report of the Chief Medical Officer, 2002. [cited 2009 Jan 19] . Available from: http://www.dh.gov.uk/assetRoot/04/08/18/60/04081860.pdf

[6] WHO [Internet] . The World Health Report 2002 - Reducing Risks, Promoting Healthy Life. [cited 2009 Feb 10]. Available from: http://www.who.int/mediacentre/news/releases/pr84/en/index.html

[7] Bath and North East Summerset Council [internet] . School Meal Provision - Case Study 1. [cited 2009 Feb 10] . Available from: http://www.bathnes.gov.uk/BathNES/educationandlearning/Schoolsandcolleges/schoolCatering/School+Meal+Provision.htm

[8] Cheshire County Council. [Internet]. [cited 2009 Feb 10]. Case Studies - tackling local food or organic issues. Available from: http://www.cheshire.gov.uk/ecoschools/Eco_schoolcasestudies.htm

[9] Bushway RJ, Helper PR, King J, Perkins B. Comparison of ascorbic acid content of supermarket versus roadside stand produce . Journal of Food Quality. 1989;12:99-105.

[10] Shewfelt RL. Sources of variation in the nutrient content of agricultural commodities from the farm to the consumer. Journal of Food Quality. 1990;13: 37-54.

[11] Duante CA, Kassu A, Lucas M, Nakamori M, Velandria FV, Yabao RN, and Yamamoto S. Prevalence of dental caries and sugar consumption among 6-12-y-old schoolchildren in La Trinidad. Benguet, Philippines. European Journal of Clinical Nutrition. 2005;59(12):1429-1439.

[12] Bradnock G, Nunn JG, Walker JA, and White D. National Diet and Nutrition Survey: young people aged 4 to 18 years. Volume 2: Report of the oral health survey. 2002. TSO: London.

[13] National Statistics Online. [Internet] .Children's Dental Health. [Cited 2009 Feb 10]. Available from: http://www.statistics.gov.uk/cci/nugget.asp?id=975

[14] British Dental Association [Internet] 2003 Children's Dental Health Survey. [Cited 2009 Feb 10] Available from: http://www.bda dentistry.org.uk/advice/news.cfm?ContentID=1367

[15] Bates CJ, Farron M, Gregory J, Jackson L, Lowe S, Prentice A, Smithers G, and Wenlock R.. National Diet and Nutrition Survey: young people aged 4-18 years. Volume 1: report of the diet and nutrition survey. The Stationery Office. 2000.

[16] Food Standards Agency. [Internet] [Cited 2009 Feb 10th] Available from: http://www.eatwell.gov.uk/healthydiet/nutritionessentials/fatssugarssalt/sugars/

[17] Gortmaker SL, Ludwig DS, and Peterson KE. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. Lancet. 2001; 357: 505–508.

[18] Hill J, and Prentice J. Sugar and Body Weight Regulation. American Journal of Clinical Nutrition. 1995:62,;264-273.

[19] Bolton-Smith C, and Woodward M. Dietary composition and fat to sugar ratios in relation to obesity. International Journal of Obesity Related Metabolic Disorders. 1994:18(12);820-828.

[20] White JW, Wilson DB, and Wolraich ML.The effect of sugar on behaviour or cognition in children; A meta-analysis. JAMA. 1995:274(20); 273-278.

[21] DoH. Dietary Reference Values for Food Energy and Nutrients for the United Kingdom. London: H.M. Stationery Office.1991.

[22] Crawley HF. The energy, nutrient and food intakes of teenagers aged 16-17 years in Britain. British Journal of Nutrition. 1993:70(1);15-26.

[23] Caterson I, James, WPT, Seidell JC, and Swinburn BA. Diet, nutrition and the prevention of excess weight gain and obesity. Public Health Nutrition. 2004:7(1);123-146.

[24] NHS. [Internet]. Constipation [Cited 2009 Feb 10] Available from: http://www.nhsdirect.nhs.uk/articles/article.aspx?articleId=111&sectionId=6282

[25] Adamidis D, Constantopoulos A, Messaritakis J, Nikolara R, and Roma E. Diet and Chronic Constipation in Children: The Role of Fibre. Journal of Pediatric Gastroenterology & Nutrition. 1999:28(2);169-174.

[26] BNF. [Internet] . Dietary Fibre. [Cited 2009 Feb 10] Available from: http://www.nutrition.org.uk/home.asp?siteId=43&sectionId=609&subSubSectionId=324&subSectionId=320&parentSection=299&which=2#1368

[27] FSA. [Internet] Children and Babies.[Cited 2009 Feb 10] Available from,: http://www.eatwell.gov.uk/asksam/agesandstages/childrenandbabies/#A219857

[28] FSA. [Internet] Fats. [Cited 2009 Feb 10] Available from: http://www.eatwell.gov.uk/healthydiet/nutritionessentials/fatssugarssalt/fats/

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk

[29] Griffiths L, Horwood JP, Page AS, Wolke D, and the ALSPAC Study Team.Obesity and bullying; different effects for boys and girls. Archives of Disease in Childhood. 2006:91;121-125.

[30] Dietz WH, Gortmaker SL, Must A, Perrin JM, and Sobol AM. Social and Economic Consequences of Overweight in Adolescence and Young Adulthood. The New England Journal of Medicine. 1993:329(14);1008-1012.

[31] Decsi T, and Koletzko B. Do trans fatty acids impair linoleic acid metabolism in children? Annals of Nutrition and Metabolism. 1995:39(1);36-41.

[32] Wainwright PE. Dietary essential fatty acids and brain function: a developmental perspective on mechanisms. Proceedings of the Nutrition Society. 2002:61(1)61-69.

[33] Burgess JR, Peck L, Stevens L, and Zhang W .Long-chain polyunsaturated fatty acids in children with attention-deficit hyperactivity disorder. American Journal of Clinical Nutrition. 2000:71(1);327-330.

[34] Innis SM. The role of dietary n-6 and n-3 fatty acids in the developing brain. Developmental Neuroscience. 2002:22;474–48.

[35] Carlson SE, and Neuringer M. Polyunsaturated fatty acid status and neurodevelopment: a summary and critical analysis of the literature. Lipids. 1999:34;171–178.

[36] Bunday S, and Colguhoun I. A lack of Essential Fatty Acids as a possible cause of hyperactivity in children. Medical Hypotheses. 1981:7(5);673-679.

[37] Brady JA, Horneffer MR, and Rock CL. Thiamin status, diuretic medications, and the management of congestive heart failure. Journal of American Dietetic Association. 1995:95(5);541-544.

[38] British Nutrition Foundation [Internet] Teenagers [Cited 2009 Feb 10] Available from: http://www.nutrition.org.uk/upload/teenagers%20pdf(1).pdf

[39] Powers HJ. Riboflavin (vitamin B-2) and health. American Journal of Clinical Nutrition. 2003:77 (6);1352-1360.

[40] Brady MC. Addition of nutrients: the importance to public health. British Food Journal. 1996:9(9); 3–11.

[41] Davis RE and Icke GC. Clinical chemistry of thiamin. Advanced Clinical Chemistry. 1983:23;93-140.

[42] Markus HS, Molloy J, Powell J, Sankaralingam A and Swaminathan R. A common polymorphism in the methylenetetrahydrofolate reductase gene, homocysteine, and ischemic cerebrovascular disease. Stroke. 1997:28(9);1739-1743.

[43] Rosenberg ICH, Selhub J, Tucker KL, and Wilson PW. Dietary intake pattern relates to plasma folate and homocysteine concentrations in the Framingham Heart Study. Journal of Nutrition. 1996:12 (12);3025-3031.

[44] BNF [Internet] Vitamins [Cited 2009 Feb 10] Available from: http://www.nutrition.org.uk/home.asp?siteId=43&sectionId=604&subSubSectionId=324&subSectionId=320&parentSection=299&which=2#1055

[45] Araya M, Koletzko B, and Uauy R. Copper deficiency and excess in infancy: developing a research agenda. Journal of Pediatric Gastroenterology and Nutrition. 2003:37(4);422-429.

[46] FSA [Internet] Copper [Cited 2099 Feb 10] Available from:http://www.eatwell.gov.uk/healthydiet/nutritionessentials/vitaminsandminerals/copper/:

[47] BNF [Internet] Adequate Copper Intake [Cited 2009 Feb 10] Available from: http://www.nutrition.org.uk/home.asp?siteId=43&sectionId=725&subSubSectionId=656&subSectionId=328&parentSection=301&which=6#1212

[48] Iezhitsa I. Potassium and magnesium depletions in congestive heart failure – pathophysiology, consequences and replenishment. Clinical Calcium. 2005:15(11);123-133.

[49] Demigné C, Meneton P, Rémésy C and Sabboh H. Protective effects of high dietary potassium: Nutritional and metabolic aspects. Journal of Nutrition. 2004:134(11);2903-2906.

[50] Rodriguez-Soriano J. Potassium homeostasis and its disturbances in children. Practical Paediatric Nephrology. 1995:9(3);364-374.

[51] Berhane KT, Gilligand FD, Kim DH, Margolis HG, and Yu-Fen L. Dietary magnesium, potassium, sodium and children's lung function. Amerian Journal of Epideiology. 2002:155(2);125-131.

[52] Balfour-Lynn I. Difficult asthma: beyond the guidelines. Archives Disability in Childhood. 1999:80;201-206.

[53] Bazzano LA, He J, Loria C, Myers L, Ogden LG, Vupputuri S, and Whelton PK. Dietary Potassium Intake and Risk of Stroke in US Men and Women. Stroke. 2001:32;1473.

[54] Appel LJ, Brancati FL, Cutler JA, Follmann D, He J, Klag MJ, and Whelton. Effects of oral potassium on blood pressure. Meta-analysis of randomized controlled clinical trials. JAMA. 1997:277(20);227-239.

[55] Bhatnagar S and Natchu UM. Zinc in child health and disease. Indian Journal of Pediatrics. 2004:71;991-995.

[56] Rosado JL. Zinc and Copper; proposed fortification levels and recommended zinc compounds. Journal of Nutrition.2003:133(9);2985 -2989.

[57] Hornig DH, Maggini S. and Wintergerst ES. Immune-enhancing role of vitamin C and zinc and effect on clinical conditions. Annals of Nutrition and Metabolism. 2006:50(2);85-94.

[58] Baker-Henningham H, Cole TJ, Gardner JM, Grantham-McGregor S M, Powell CA and Walker SP. Zinc supplementation and psychosocial stimulation: effects on the development of undernourished Jamaican children. The American Journal of Clinical Nutrition. 2005:82(2);399-405.

[59] Cuevas LE and Koyanagi A. Zinc and Infection: A Review. Annals of Tropical Paediatrics. 2005:25(3);149-160.
[60] Black MM. Micronutrient Deficiencies and Cognitive functioning. British Journal of Nutrition. 2003:133;3927-3931.

[61] Bhatnagar S and Taneja, S. Zinc and Cognitive Development. British Journal of Nutrition. 2001:139-145.

[62] Akhondzadeh S, Mohammadi MR and Khademi M. Zinc sulfate as an adjunct to methylphenidate for the treatment of attention deficit hyperactivity disorder in children: A double blind and randomized trial. BMC Psychiatry. 2004:4;9.

[63] WHO. [Internet] Micronutrient Deficiency – Iodine Deficiency Disorders.[Cited 2009 Feb 10] Available from: www.who.int/nut/idd.htm.

[64] Delange F, Dunn JT and Glinoer D. Iodine Deficiency in Europe, a Continuing Concern. New York: Plenum Press. 1993.

[65] Carter AM, Saikat JE, Smith B, Sohel Q and Stewart A. Goitre and environmental iodine deficiency in the UK – Derbyshire: a review. Environmental Geochemistry and Health. 2004:26;395–401.

[66] NHS [Internet] Teenage Pregnancy [Cited 2009 Feb 11] Available from: http://www.nhsinherts.nhs.uk/hp/health_topics/teenage_pregnancy/teenage_pregnancy.htm

[67] Tunbridge WMG and Vanderpump MPJ. Epidemiology and prevention of clinical and subclinical hypothyroidism. Thyroid : official journal of the American Thyroid Association. 2002:12(10);839-47.

[68] Hagen J, Jimenez E, Lozoff B, Mollen E and Wolf AW. Poorer behavioural and developmental outcome more than 10 years after treatment for iron deficiency in infancy. Paediatrics. 2002:105(4);51.

[69] Yip R. Prevention and Control of Iron Deficiency: Policy and Strategy Issues. The Journal of Nutrition. 2002:132(4);802-805.

[70] Aukett MA and Booth IW. Iron deficiency anaemia in infancy and early childhood. Archives of Disease in Childhood. 1997:76; 549-554.

[71] UNICEF [Internet] The State of the World's Children [Cited 2009 Feb 11] Available from: http://www.unicef.org/sowc98/fs03.htm

[72] Beard JL and Connor JR. Iron status and neural functioning. Annual Review of Nutrition. 2003:23; 41-58.

[73] Georgieff MK and Rao R. Neonatal iron nutrition. Semin. Neonatol. 2001:6(5);425-435.

[74] Idjradinata P and Pollitt E. Reversal of developmental delays in iron-deficient anaemic infants treated with iron. Lancet. 1993:341;1–4.

[75] Garrido M, Roncagliolo M and Walter T. Evidence of altered central nervous system development in infants with iron deficiency anaemia at 6 months: delayed maturation of auditory brainstem responses. American Journal of Clinical Nutrition. 1998:68;683–90.

[76] Lozoff B. Prenatal iron deficiency and the developing brain. Paediatric Research. 2000:48(2);137-139.

[77] Walter T. Effect of iron-deficiency anaemia on cognitive skills in infancy and childhood. Clinical Haematology. 1994:7(4);815-827.

[78] Albonico M, Chwaya HM, Kvalsvig JD, Montresor A, Stoltzfus RJ and Tielsch JM. Effects of iron supplementation and antihelminthic treatment on motor and language development of preschool children in Zanzibar: double blind, placebo controlled study. British Medical Journal. 2001:323;1389-1393.

[79] Hathirat P, Kotchabhakdi NJ, Pollitt E, Missell L and Valyasevi A.Iron deficiency and educational achievement in Thailand. American Journal of Clinical Nutrition. 1989:50; 687-696.

[80] Gopaldas T and Seshadri S. Impact of iron supplementation on cognitive functions in preschool and school-aged children: the Indian experience. American Journal of Clinical Nutrition. 1989:50;675-686.

[81] Ani C and Grantham-McGregor S. A review of studies on the effect of iron deficiency on cognitive development in children. Journal of Nutrition. 2001:131;649-666.

[82] Grantham-McGregor SM and Simeon DT. Nutritional deficiencies and children's behaviour and mental development. Nutrition Research Reviews. 1990: 3;1-24.

[83] WHO. [Internet] Calcium [Cited 2009 Feb 11] Available from: http://search.who.int/search?ie=utf8&site=default_collection&client=WHO&proxystylesheet=WHO&output=xml_no_dtd&oe=utf8&q=calcium

[84] Hardman AE and Stensel D.Physical Activity and Health - The Evidence Explained. Routledge Publications. 2003.

[85] Barr R, Chow R, Faulkner A and Prior JC. Prevention and management of osteoporosis: consensus statements from the Scientific Advisory Board of the Osteoporosis Society of Canada.5.Physical activity as therapy for osteoporosis. Canadian Medical Association Journal. 1996:155(7);940-944.

[86] DiRienzo DB, Huth PJ and Miller GD. Major scientific advances with dairy foods in nutrition and health. Journal of Dairy Science. 2006:89(4);1207-1221.

[87] Eastell R and Peel N. ABC of Rheumatology: Osteoporosis. British Medical Journal. 1995:310;989-992.

[88] WHO. [Internet] Food and Health in Europe: a new basis for action [Cited 2009 Feb 12] Available from,: http://www.euro.who.int/document/E82161.pdf

[89] Holick MF. The Vitamin D Epidemic and its Health Consequences. The Journal of Nutrition. 2005:135(11); 2739-2748.

[90] Chaussain-Miller C, Garabédian M, Godeau G, Lasfargues JJ, Sinding C and Wolikow M. Dental abnormalities in patients with familial hypophosphatemic vitamin D-resistant rickets: prevention by early treatment with 1-hydroxyvitamin D. Journal of Pediatrics. 2003:142(3);324-331.

[91] WHO. [Internet] WHO releases new report on global problem of oral diseases.[Cited on 2009 Feb 12] Available from:http://www.who.int/mediacentre/news/releases/2004/pr15/en/

[92] FSA. [Internet] Salt; Children and Babies. [Cited 2009 Feb 12] Available from: http://www.salt.gov.uk/babies_and_children.shtml

[93] FSA. [Internet] Fats, sugars and salt.[Cited 2009 Feb 12] Available from: http://www.eatwell.gov.uk/asksam/healthydiet/fssq/#A242245

[94] CASH. [Internet] Salt and Children Information. [Cited 2009 Feb 12] Available from: http://www.actiononsalt.org.uk/salt_in_children.htm

[95] Geleijnse JM, Grobbee DE and Hofman A. Sodium and potassium intake and blood pressure change in childhood. British Medical Journal. 1990:300;899-902.

[96] Antonis TFT and Macgregor GA. Salt- more adverse effects. Lancet. 1996:348;250-251.

[97] Burney PGJ. A diet rich in sodium may potentiate asthma: epidemiological evidence for a new hypotheses. Chest. 1987:91;143-148.

[98] Feng JH, Giuseppe A, MacGregor GA, Markandu S and Nirmala D.
Effect of Salt Intake on Renal Excretion of Water in Humans. Hypertension. 2001:38;317-320.

[99] BNF. [Internet] Fluid in Schools. [Cited 2009 Feb 12] Available from: http://www.nutrition.org.uk/home.asp?siteId=43&sectionId=522&subSubSectionId=356&subSectionId=310&parentSection=300&which=4#963

[100] Da-Wen Sun. Handbook of Frozen Food Processing and Packaging. CRC Press, Taylor and Francis Group. 2006.

[101] Potter NN and Hotchkiss JH. Food Science. 5th Edition. Springer Science. 1998.

[102] Proudlove K. The Science and Technology of Foods. 4th Edition. Forbes Publications. 2001.

[103] Gaman PM and Sherrington KB. The Science of Food. 4th Edition. Butterworth-Heinemann, Reed Elsevier plc. 1996.

[104] Farouk MM, Wieliczko KJ and Merts I. Ultra-fast freezing and low storage temperatures are not necessary to maintain the functional properties of manufacturing beef. Meat Science. 2004:66(1);171-179.

[105] Bennion M. The Science of Food. Harper and Row. 1980.

[106] DoH. Information for Schools - Schools Fruit and Vegetable Scheme. NHS, 5-A-DAY. Department of Health. 2002.

[107] Leino ME. Effect of freezing, freeze-drying and air drying on odour of chive characterised by headspace gas chromatography and sensory analyses. Journal of Agriculture and Food Chemistry. 1992:40;1379-1384.

[108] Kmjecik W and Lisiewska Z. Effect of pretreatment and conditions and period of storage on some quality indices of frozen chives. Food Chemistry.1999:67;61–66.

[109] Lee CY, Downing DL, Tredale HD and Chapman JA. The variations of ascorbic acid content in vegetable processing. Food Chemistry. 1976:1;15-22.

[110] Favell DJ. A comparison of the vitamin C content of fresh and frozen vegetables. Food Chemistry. 1998:62(1);59-64.

[111] Rickman JC, Barrett DM and Bruhn CM. Nutritionalcomparison of fresh, frozen and canned fruits and vegetables. Part 1 Vitamins C and B and phenolic compounds. Journal of the Science of Food and Agriculture. 2007:87(6);930-944.

[112] Giannakourou MC and Taoukis PS. Kinetnic Modelling of vitamin C loss in frozen green vegetables under variable storage conditions. Food Chemistry. 2003:83(1);33-41

[113] Pilar Cano M. Vegetables. In: L.E. Jeremiah, Editor, Freezing effects on food quality, Marcel Dekker. New York. 1999;247–297.

[114] Williams PG. Vitamin retention in cook/chill and cook/hot-hold hospital food services. Journal of the American Dietetic Association. 1996:96(5);490-498.

[115] Synder, PO and Matthews ME. Effect of hot-holding on the nutritional quality of menu items in food service systems: a review. School Food Service Res Rev. 1984:8;6-16

[116] Carlson BL and Tabacchi MH. Loss of vitamin C in vegetables during the food service cycle. Journal of the American Dietetic Association.

Food Innovation, Sheffield Hallam University
Enterprise Centre, Howard Street
Sheffield, SW1 1WB
T: 0114 225 5000 E:foodinnovation@shu.ac.uk