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Food carbohydrates: Forms, functions and choices²

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ABSTRACT⁴

Carbohydrates have multiple and important roles in nutrition. Various properties of food carbohydrates⁵ can be traced to their different molecular structures, and to the roles that they played in plants – energy storage, hydration, support, protection, transport. When plants are consumed, carbohydrate properties become nutritional attributes that our bodies have become dependent on in evolution. In a natural diet consisting of a variety of whole foods – fruits, vegetables and grains – carbohydrates provide a balance of properties. With advanced food processing functional balance has been disrupted. Carbohydrates that regulated digestibility and provided roughage have been removed, along with associated nutrients and phytochemicals. Diets have become enriched in carbohydrates that are easily procured and consumed, and readily digested. At the same time, the average person has become somewhat constipated, obese, and glucose intolerant, with an increased chance of dying prematurely of colorectal cancer, heart disease or of some other complication of diabetes. Carbohydrates have unjustifiably been blamed. Now, with the benefit of hindsight, food scientists and technologists are trying to put nature back together again in an avalanche of “functional” foods. Unfortunately, there is still no consistently predictable way for consumers to tell which foods will really provide the benefits that are expected or claimed of them, and by how much one food is better than another. There is a need for new types of information that will assist choice of healthy foods by communicating functional efficacy. Virtual food components representing food effects may fill this role.

INTRODUCTION⁶

The structure of sugars and their ability to act as units in a vast range of polymeric⁷ combinations, each with different properties, gave them a central role in the evolution of plant life as we know it. And similarly, with plants forming the base of human diets, the persisting properties of plant carbohydrates have shaped the structure and function of the human gut.

Food carbohydrates have recently been maligned as the source of many of the health problems⁸ that afflict the modern world, such as obesity and type 2 diabetes. Yet, with a gastrointestinal system so obviously designed for the presence of carbohydrates, it cannot be carbohydrates *per se* that are a problem, but behaviors that determine the patterns in which carbohydrates are provided and consumed in the modern human diet. Indeed, the many properties and arrangements of carbohydrates in plants that influence how foods are digested are now recognized as more than nutritionally incidental; they are nutritional attributes that our bodies and digestive systems depend on for good health (Schneeman, 2001).

Functional characteristics of natural polysaccharide associations⁹

In the foregut¹⁰

Properties of the different forms of carbohydrates consumed in plant-based foods can be¹¹ traced to their molecular structure, and to the various functions that they have been asked to perform in the plant kingdom – energy storage, hydration, support, protection, transport. Table 1 summarizes some of the functions of carbohydrates in plants, and the response of the gut to these properties. Of the polysaccharides, only starch, α -1,4-1,6 linked glucose can be digested by human enzymes. The structure of the human gut reflects the processes used to obtain nutrients from within the polysaccharide skeleton of the plant, and to then make use of the residue. At the front end teeth coarsely but incompletely crush the food to release a proportion of soluble components and allow access of digestive enzymes. The mouth, stomach and small intestine are the gut sites where human enzymes digest accessible and soluble nutrients.

Table 1 Dietary benefit from properties of plant carbohydrates in the diet

| Carbohydrate type and form | Role in plant | Properties in gut | Health benefit |
|--|--|--|--|
| Starch | Energy storage | Susceptible to human α -amylase digestion to glucose. | Readily digested energy |
| Hydrated, gel or viscous polysaccharide | Hydration | Dilution, bulk, volume, physical consistency, in small intestine. Fermentation substrate in colon. | Satiation. Moderation and extension of food digestion and absorption. Colonic fermentation |
| Mixed function cell walls | Compartmentalization, of stored carbohydrate | Restriction of digestive enzyme access. | Reduced rate of digestion. Restricted extent of digestion. Partial colonic fermentation. |
| Linear, associated as supporting structures (eg cellulose) | Tissue structure, physical support, protection | Bulk, partial resistance to or slow colonic fermentation | Partial colonic fermentation Faecal bulk effects due to retained plant tissue structure (Table 2) |
| Lignified and suberised, cellulosic | Support, resist bacteria and fungi | Bulk in diet and in colon – faecal bulk. Binding of genotoxins | Faecal bulk benefits (Table 2), Prevention of colonic stagnation. |

In the foregut the cell wall residue remains chemically intact and retains most of its properties. Important amongst these is the hydrated volume of the cell wall material. Bulky, hydrated, gel-like plant cell wall and tissue particles in the gut have the important net effect of reducing the rate and extent of nutrient absorption, not only by diluting nutrients and extending their digestion along the small intestine (Schneeman, 1998), but by simultaneously stimulating secretion of mucins, which may further retard absorption by increasing viscosity at the gut-lumen boundary (Tanabe *et al.*, 2005). Apart from the simple effects of bulk, cell wall particles can act as pectic gels reinforced by the cellulose and hemicellulosic polysaccharides embedded in them, so they possess a porosity that can retard the movement of molecules (Pena *et al.*, 2001).

As well as attenuating the absorption of mono- and disaccharides, dietary fibre in the form of encapsulating cell walls limits the digestion of starch in any cells that have escaped crushing. Not surprisingly, a strong negative relationship has been found between dietary fibre content and the glycemic impact of foods (Englyst *et al.*, 1996).

In the hind gut

As food residues move into the colon the gut environment changes drastically. In the colon, undigested materials enter an ecosystem in which a complex and diverse population of bacteria attacks most organic food components, to an extent limited by the properties of the material and the time for which it resides in the colon.

Rather than being simple a waste storage and disposal unit, the colon is a large and active organ that makes an important contribution to health, especially under the dietary conditions for which it evolved – a high intake of cell wall residues representing a valuable energy and mineral resource for the body.

In the colonic environment a new range of cell wall properties exert their influence:

Carbohydrate, mainly polysaccharide, that is susceptible to bacteria provides a substrate for fermentation to short chain fatty acids (SCFA). SCFAs are absorbed to provide a biologically significant source of energy to the body (Wolf, 2006), as well as specifically nourishing the colon and stimulating its own protective mechanisms, including immune and apoptotic responses (Gibson, *et al.*, 2005). The low pH environment induced by SCFA production facilitates mineral uptake so that the colon makes an important contribution to calcium and magnesium recovery (Coxam, 2005), while the low pH inhibits pathogenic pH-sensitive bacteria (Bruno *et al.*, 2002)

Cell wall and plant structures, such as wheat bran and plant xylem tissues, may contribute to faecal bulk by remaining largely intact during passage through the colon. The contributing polysaccharides are those which fulfill a structural role in the plant, so include cell wall polysaccharides that are organized into strong, slowly digested semi-crystalline associations, such as cellulose microfibrils, or in which polysaccharides are protected by resistant coatings such as lignin and suberin. Faecal bulk is important in stimulating defecation, which has a number of indirect benefits, summarized in Table 2 (Monro, 2000a).

Table 2 Direct and indirect effects of bulk provided by fermentation-resistant polysaccharide associations in the large intestine

| Property/Effect | Consequent effect |
|------------------------|--|
| Bulkiness | Bulk transfer, replenishment |
| Bulk transfer | Toxin removal, colonic exposure reduced, decreased transit time. |
| Decreased transit time | Less protein putrefaction to genotoxic nitrogenous products. Less time for dehydration. |
| Increased water load | Diluted colon contents, stool softening, pressure distribution. |
| Replenishment | Substrates for bacterial growth and fermentation to short chain fatty acids: butyrate (protection) and decreased pH (calcium uptake, pathogen suppression) |
| Binding | Reduced toxin/carcinogen activity. |
| Distension | Defecation stimulus. |
| Defecation | Comfort and maintained colonic flow. |

Functional consequences of physically disrupting natural carbohydrate associations in processing

Food processes such as milling, refining and juicing have been designed to release digestible polysaccharides from their natural packaging of cell walls, and usually to discard the cell wall residue. The functional balance in carbohydrates for which the digestive system was designed has been disrupted. Carbohydrates with important structural and hydrating roles in the plant, and which constrained digestibility and provided roughage in the gut, have been removed along with their associated nutrients (Atwell, 2002). The benefits outlined in Table 1 have been diminished.

Some examples of the effect of various forms of refining are to be seen in Figures 1 to 3. In Figure 1 the swelling of insoluble vegetable (carrot, swede, asparagus, broccoli pith) material prepared by a mild water-extraction is shown after gastric and ileal digestion *in vitro*. Compared with the vegetable material, cell wall material in the form of sugar beet fibre, and apple fibre, both of which have been highly processed, show a much lesser degree of swelling. Nonetheless, commercially available dietary fibre sources are commonly promoted as ingredients that will confer the functional benefits of dietary fibre on foods containing them as an ingredient.

The nutritional influence of the simple food refinement step of removing the rind from vegetables is seen in Figure 2, which shows results of a faecal bulking trial in which dietary fibre sources were included at 12.5% of the diet by replacing sucrose. The broccoli rind contains vessels and fibres constructed of secondarily thickened cell walls, so can partially resist fermentation and retain its anatomical integrity through the colon. The polysaccharides and the interstices within fibres of the rind confer a considerable water holding capacity, greater than that due to wheat bran, which translates into a 212% increase in colonic water load per 100 g intake of the rind enriched food, compared with the baseline (Figure 2). The complete stem is not far behind, giving a 187 % increase, but the increase

drops to a mere 30 % increase in response to the diet containing 12.5% pith with rind removed. The pith consists of thin-walled cells with little secondary thickening that are readily fermented in the colon. The results show that a simple strategy, not peeling, aimed at retaining a natural polysaccharide association considerably enhanced functional efficacy.

FIGURE 1 Swelling of native vegetable cell walls under post-gastric ileal conditions in vitro compared with swelling of highly processed fibre sources (orange QF10, sugar beet fibre, apple fibre AF400) under the same conditions.

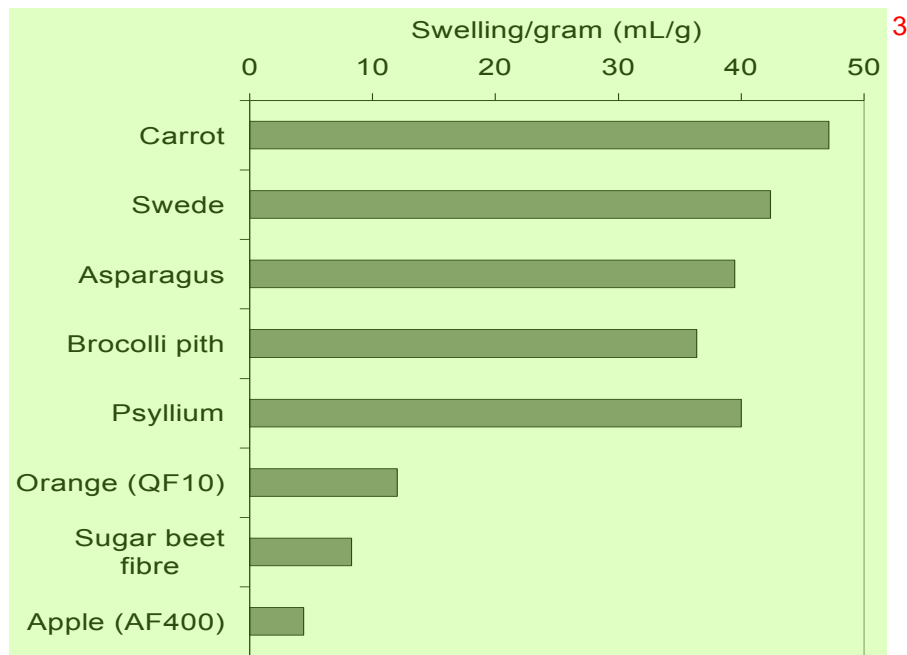
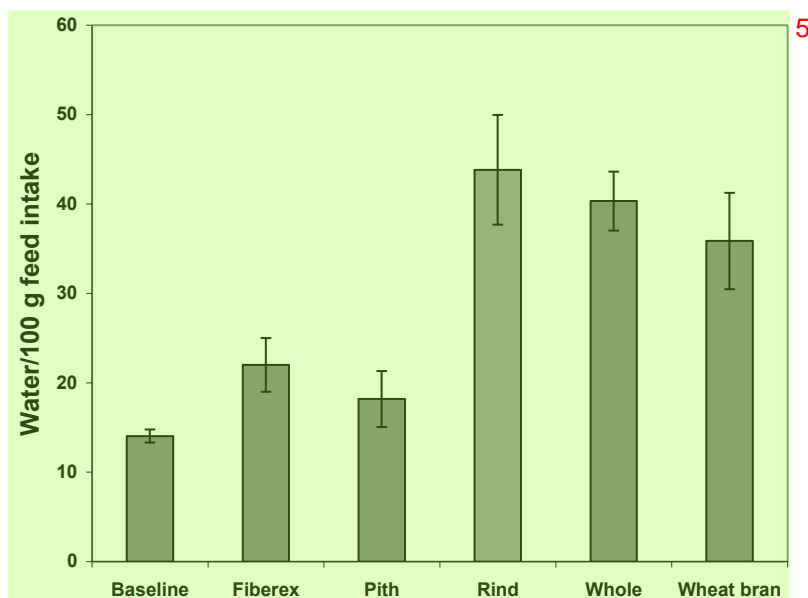


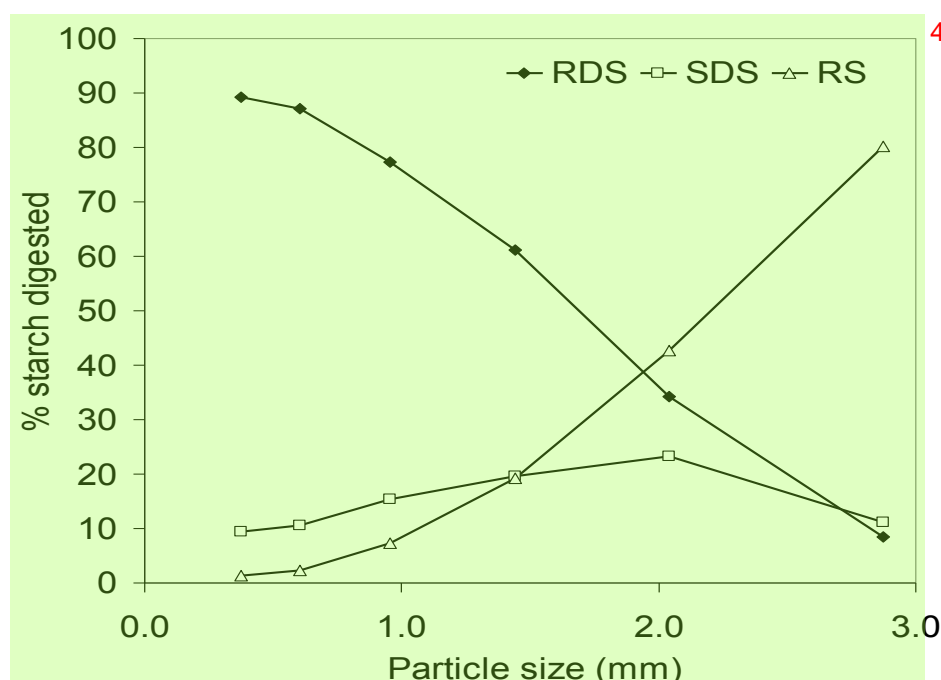
FIGURE 2 The effect of removing the rind from broccoli stem on the theoretical water transfer through the colon. Percentage increases over baseline were Fiberex™ (sugar beet fibre), 57 %; broccoli pith fibre, 30 %; broccoli rind fibre, 212 %; whole broccoli stem fibre, 187.2 %; wheat bran, 155.4 %.



Another important food processing influence is the effect of milling on the glycaemic impact of foods. Refined flour makes up a substantial proportion of processed foods and is responsible for a large proportion of the glycaemic loading of modern diets (Liu, 2002). Figure 3 shows the relationship between size of cooked cereal particles and the content of rapidly digested (highly glycaemic), slowly digested and non-digested (resistant) starch in cereal grains. As particle size increases the content of rapidly available starch drops abruptly, and it is replaced more by an increase in resistant starch than by an increase in slowly digested starch.

The results in Figure 3 provide another example of how the maintenance of natural structure, in the form of semi-intact endosperm fragments, can have a profound effect on the functionality of a food. Increasing particle size has changed the cereal starch from being highly digested, with little remaining to act as a fermentable substrate for colonic bacteria, to a less digestible starch source with a large proportion of starch remaining in the grain to act as colonic substrate. In other words, the increase in intactness has converted the cereal from a highly glycaemic material of low prebiotic potential to a material that is less glycaemic but prebiotic – the dangers of hyperglycemia are avoided and colonic benefits obtained.

FIGURE 3 Effect of size of cooked cereal particles on the proportion of rapidly digested (RDS), slowly digested (SDS) and resistant (RS) starch in cereal grain



Communicating the functional benefits of carbohydrate associations in foods

Physiological effects of food carbohydrates that are modulated by cellular, food, or tissue structure cannot be represented in nutrient informational panels, because standard nutrient analysis of foods always destroys food structure (Monro, 2000b). Samples for analysis are routinely finely ground to ensure that all potentially digestible nutrients are extracted. Rates and degrees of carbohydrate digestion *in vivo* are, however, determined by many structural features of foods (Venn and Mann, 2004). Enzyme access to carbohydrate, colonic loading of starch encapsulated within cells, inaccessibility of cell walls to colonic bacteria, water holding capacity of interacting polysaccharide chains or of plant tissue remnants in the ileum and colon, are important properties that depend on structure, but are not accounted for in the measurements obtained from food analysis.

To consume a diet with a balance of the healthy attributes conferred by the properties of carbohydrates in foods, it is necessary to choose foods, not carbohydrates, according to the degree to which the food expresses the property. The results of simple nutrient analysis do not provide such information. Nutritional attributes such as moderate digestibility, fermentability, faecal bulking,

satiation, even when associated with a carbohydrate component, are emergent properties of the whole food and cannot be represented by a quantity of isolated food component. 1

With an emphasis now being placed on the connection between nutrition and health, and the rampant exploitation of this link in food marketing, consumers (including health and nutrition professionals) need some objective means to assess the efficacy of foods with respect to health benefits. The concept of virtual food components (VFC) was introduced to provide consumers with the means to discriminate between foods in the enormous range that are claimed in one way or another to be healthy (Monro, 2004a). Equally, a VFC may be used by food manufacturers as a means of accurately promoting their “functional” products according to efficacy. 2

A VFC expresses the effect of a food as the weight of a reference material required to induce the same amount of effect as a given weight of the food. A VFC is, therefore, expressed in terms of an equivalent weight of the reference material. For instance, to say that a muesli bar has a relative glycaemic impact of 15 glycaemic glucose equivalents (GGE), means that the muesli bar will induce the same glycaemic response as 15 g glucose (Monro 2002a). Similarly, if the same bar contributes four wheat bran equivalents (WBE), it will augment faecal bulk by the same amount as 4 g wheat bran (Monro 2001). 3

Because a VFC is expressed as a weight of reference, it may be presented in the same terms as other food components in food composition databases and nutrient information panels, as g/serving or g/100 g food, or as grams per specified food quantity (Monro, 2005). However, because VFCs represent responses to foods, it is likely that their values will be modulated by the presence of other food components and foods in the diet. Nonetheless, if one assumes that response to the reference and to food will be similarly affected by the food/digesta matrix, and remembering that a VFC is a relative value, it is possible to say that VFCs may be used as guides to selecting foods that are relatively more efficacious or healthy than others within a range of diets. 4

Recommended levels of functional food components do not necessarily provide functional balance. 5

One of the reasons why there is a need for VFCs is that a single nutrient value in a nutrient information panel, such as dietary fibre, can represent a class of components with quite diverse properties, and be used as such in marketing without allowing for functional diversity, because food standards are based on a single criterion value. Calci Trim® “Liquid breakfast”, “High in Calcium and Fibre” is one of many examples. As a “liquid breakfast” the consumer could reasonably expect a healthy balance in a main meal, but examination of the NIP of the product reveals that of the 3.75 g per serving of dietary fibre present, 3.25 g is oligosaccharide, so will have little direct rheological effect in the ileum, and will be completely fermented in the colon, so make little contribution to faecal bulk. Thus although the criterion level of 3g/serving required for a claim of “high in fibre” is reached the vague term “dietary fibre” provides no information about the level of benefit achieved (Monro, 2002b). If the functionality could be represented by VFCs, the information could be more informatively presented as 3.25 g inulin equivalents, to show its relative prebiotic potential, and 0.3 g wheat bran equivalents (WBE) to show its relative faecal bulking capacity (Monro, 2002c). Such data would alert the nutritionist, if not the consumer, to the fact that although the product may have some prebiotic effect, it would probably contribute little to an adequate daily intake of about 60 WBE (Monro, 2004b). 6

Virtual food components in personal well-being based on genotypic and holistic analysis – the future? 7

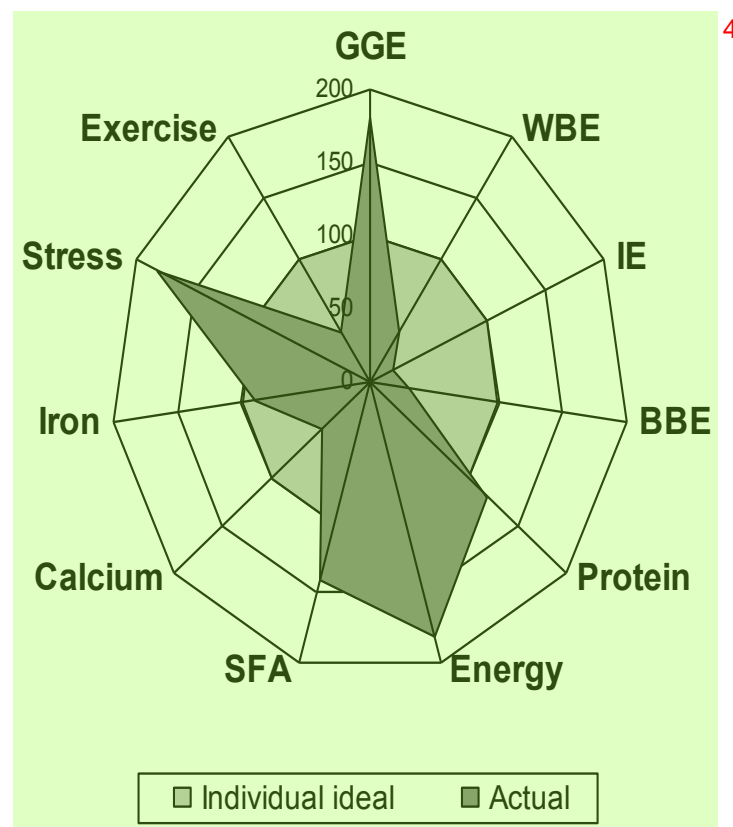
Improved public health is seen increasingly to be dependent not only on improved nutrition and food choices *per se*, but also on many dimensions of life that constitute ‘well-being’. Food choices, stress, exercise, and social inclusion, for instance, are all lifestyle factors that impinge on well-being. Furthermore, with the advent of genotyping, a list of susceptibilities may be added to the dimensions of well-being that could be addressed at the level of individual nutrition and living. 8

Helping people towards the goal of well-being is heavily dependent on communication, to which virtual food components are well suited: they express food effects in relative terms that can be translated into an informed food choice based on efficacy, and they express functionality in the same gram weight format as real nutrients, so they may be stored in a food composition database and used concurrently with nutrients in individualised meal design (Monro and Williams, 2000). 9

An example of how nutrients, VFC's representing food functions, and lifestyle factors could be displayed against the assessed needs of an individual with diabetes is shown in Figure 4. Real food components linked to complications of diabetes, such as saturated fatty acids, GGE as a virtual food component representing glycaemic impact, and aspects of lifestyle, including stress and exercise, may all be shown in a multidimensional display which shows, in percentage terms, how well the individual's lifestyle matches their targets for well-being (Monro, 2006).

Figure 4 Multidimensional representation of nutrients, virtual food components including GGE and lifestyle factors that collectively determine well-being. The value of 100 on each dimension would be set as the optimum for an individual after personal assessment of individual requirements and

responsiveness. In the above example light grey is the ideal and dark grey is typical of a modern lifestyle. GGE, glycaemic glucose equivalent (glycaemic impact); WBE, wheat bran equivalent (faecal bulk); IE, inulin equivalent (prebiotic efficacy); BBE, blueberry equivalent (antioxidant efficacy); SFA, saturated fatty acids.



CONCLUSION

Carbohydrates confer a wide range of beneficial properties on the foods that contain them, and this range reflects the diverse functions of carbohydrates within plants. Modern food processing has separated plant components and in so doing has disrupted the balance of attributes. Food developers are now trying to restore some of these attributes, or at least meet criterion levels of food components required to make health claims. However, until the relative impact of foods on specific health endpoints or biomarkers is expressed, perhaps as virtual food components, there will be limited opportunity for consumers to base food choices on the functional efficacy of foods.

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"Foods for the Future — An Innovation Approach"¹

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INTRODUCTION⁴

Consumers are increasingly looking for solutions to manage their health, to protect against⁵ illness and to delay the onset of age-related ailments. They are also looking to aid quality of life when ill health strikes or when health is compromised (e.g. when cancer is diagnosed). It is a widely held belief that, as the proportion of older consumers increases, there will be new demand for products that support healthy aging — to slow the onset of age-related disorders that impact on our quality of life. One of the largest targets of the functional foods and nutraceuticals business may well be those in the 50–65 year age group who have disposable income to spend but are also motivated to manage their health and wellness. Trends in sales of dietary supplements and so-called functional foods and beverages grew through the late 1990s and early this century (Euromonitor, 2004), suggesting a growing belief in the benefits of these “natural” approaches to disease prevention or management. However, more recent surveys suggest a slowing in that growth. This review discusses some of the hurdles to success in functional foods and provides some suggestions for managing innovation to maximise the chances of success.

Current Market Issues for Functional Foods⁶

Current estimates of the size of the global functional foods market are up to US\$50–60 billion⁷ (Table 1), and some have predicted that the market will grow to US\$167 billion by 2010 (Anon, 2004). Within current estimates of the market, growth is predicted to increase in dairy products and to decline in most other categories in the US, but to decline across all categories in Europe (Datamonitor, 2005). The European market is a smaller and perhaps a maturing market, or it may be that the lack of growth reflects stifling by regulatory barriers.

Table 1. Total market value sales of functional foods and beverages, 1998–2008 (Euromonitor, 2004)⁸

| | Market size (US\$m) | Annual growth (%) |
|------|------------------------|-------------------|
| 1998 | 27,650.20 | — |
| 1999 | 31,023.50 | 12.2 |
| 2000 | 34,193.30 | 10.2 |
| 2001 | 35,229.40 | 3.0 |
| 2002 | 38,930.20 | 10.5 |
| 2003 | 44,120.80 | 13.3 |
| 2004 | 47,987.10 | 8.8 |
| 2005 | 51,931.60 | 8.2 |
| 2006 | 55,623.40 | 7.1 |
| 2007 | 58,885.70 | 5.9 |
| 2008 | 61,788.00 | 4.9 |

*Functional Foods: Foods or food components that provide a health benefit beyond basic nutrition*¹⁰ (IFIC, 2002).

There is no single definition of functional foods, and therefore no clearly defined food¹¹ category. Finland is often referred to as the birthplace of functional foods. However, the functional foods regulatory framework originated in Japan, which is the only country to have a specific regulatory process to define, and approve, foods or food ingredients for specific health use (FOSHU). Other

countries are following, setting up their regulatory framework to address concerns around health claims, the approval process, labelling and safety issues for functional foods and dietary supplements. The regulatory environment, a key element of infrastructure development, clearly lags both the market and the food industry interest in health products.

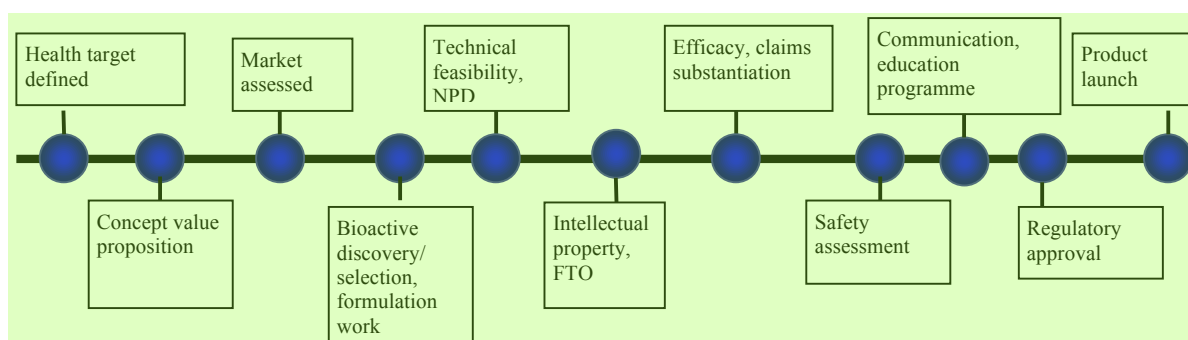
Increasing consumer understanding of their health needs and the benefits of the foods and beverages available to them will help to generate greater “market pull” in the future. However, consumers find it difficult to understand hard, scientific health claims (Mellentin, 2005). Thus, as the market for these products increases, so will consumers’ requirements for understandable, robust scientific proof for “hard” claims. The onus on relevant, understandable and accurate consumer education and marketing will be great. Overlaying this is the requirement to meet regulatory criteria including substantiating health claims and demonstrating the safety of new dietary ingredients (e.g. bioactives). This ensures that any risks associated with the consumption of new “foods” or ingredients — perhaps at doses not traditionally observed — will be eliminated or minimised.

It is important to understand the target market before starting the innovation process for a new product. The size of the market is needed to calculate the predicted future value, so allowing some way of choosing one opportunity from another for investment and development. Understanding the market will also allow you to analyse the competition, and this will be in the form of other foods, bioactives, supplements and pharmaceuticals. Knowledge of the target market, channels to market and consumer characteristics will also help to shape the type of product and claims needed. For example, a blood-cholesterol-lowering probiotic that needs to be delivered as a yoghurt product may not be successful with older adults who do not traditionally consume yoghurt, or for the US where the concept of probiotics is still not well understood or accepted.

Innovation Management

Developing a successful food for the future is more than just developing a product that you can demonstrate confers some benefit. Although this is clearly important, there are many other criteria that must be met and factors that must be managed through the process of idea to commercialisation (Figure 1). There are many ways to go about the development of a new product concept, and the steps and the order of the stages may differ with each opportunity. Some activities, such as reassessing the market, managing the regulatory issues and protecting intellectual property, will continue throughout the process.

Figure 1. Journey from idea to proof of concept and commercialisation: success signposts for functional food development.



Gaining some protection from competitors in the market is attractive, and the process of managing intellectual property is important, although it can be expensive and lengthy. If there is a programme of discovery of new bioactives, or perhaps a novel process is invented in the course of developing the product, then intellectual property can be captured through a patent or trade secret. Often a more pragmatic approach is to get into the market first with your new product and capture the benefits first. Of course, there is an element of risk in this, as you may need to make the largest investment in consumer education if the concept is new. Also, if you have had to make a large investment in clinical trials to demonstrate efficacy, then some protection against second comers is always desired. Another aspect to managing intellectual property that is less well appreciated and understood is being able to demonstrate that you have “Freedom to Operate”. Although your idea may

be great and the market need high, if someone else has already covered your idea in a patent, then you will be infringing their intellectual property if you commercialise the idea without being granted a licence. Therefore, an assessment of your ability to both protect your idea and avoid infringement is an important part of innovation management.

Technical feasibility is also obviously important. There are many aspects to this, not only in the product development or process development phases but also in terms of the cost of the product. A simple example is the cost of adding a bioactive into a food product. If the cost of the dose of the ingredient needed to deliver the claimed benefit is too high, then the product will not be successful unless the consumer is prepared to pay the premiums required. Furthermore, the dose of the active components may affect the food matrix, reducing stability or shelf life, affecting taste, colour and flavour or in fact reducing the properties of other bioactive components such as vitamins and minerals. It is well known that increasingly consumers will not compromise on taste, convenience and, to a lesser extent, price, just to get a health benefit from their food.

Health Targets³

A commercially focused innovation programme to deliver a pipeline of commercialisable new functional food product options will need to have clearly defined health targets. But how are those targets determined? Many different sources of information are available to help to define the most appropriate targets for functional food ingredients. We can either look at current health concerns or attempt to predict future concerns and unmet needs by analysing the data available. For example, mortality statistics such as the World Health Organisation (WHO) population-based summaries consider both leading causes of death and the trends (Table 2). Cardiovascular diseases are still the leading causes of death in the developed world, but there is a growing trend in deaths due to some types of cancer.

Table 2. Global mortality statistics and ranking of cause of death in adults (Beaglehole *et al.*, 2004)

| Adults aged 15–59 years | | Adults aged 60+ years | |
|--|---------------|---|---------------|
| Rank/Cause | Deaths (000s) | Rank/Cause | Deaths (000s) |
| 1 HIV/AIDS | 2279 | 1 Ischaemic heart disease | 5825 |
| 2 Ischaemic heart disease | 1332 | 2 Cerebrovascular disease | 4689 |
| 3 Tuberculosis | 1036 | 3 Chronic obstructive pulmonary disease | 2399 |
| 4 Road traffic injuries | 814 | 4 Lower respiratory infections | 1396 |
| 5 Cerebrovascular disease | 783 | 5 Trachea, bronchus, lung cancers | 928 |
| 6 Self-inflicted injuries | 672 | 6 Diabetes mellitus | 754 |
| 7 Violence | 473 | 7 Hypertensive heart disease | 735 |
| 8 Cirrhosis of the liver | 382 | 8 Stomach cancer | 605 |
| 9 Lower respiratory infections | 352 | 9 Tuberculosis | 495 |
| 10 Chronic obstructive pulmonary disease | 343 | 10 Colon and rectum cancers | 477 |

It may be more relevant to consider what conditions or diseases consumers are trying to avoid or manage. This may provide insights in order to provide solutions to prevent disease or reduce the risk of disease. Table 3 lists the leading causes of morbidity, or disease burden, calculated as disability-adjusted life years (DALYs), which combine years of life lost through premature death with years of life with disability. One DALY can be thought of as one lost year of “healthy” life. Again, heart disease and stroke lead for impact on quality of life in older adults, whereas infectious/immune system disorders, such as AIDS and tuberculosis, and depression are greater causes of morbidity in younger adults.

Taken together, the WHO statistics demonstrate that ischaemic heart disease and cerebrovascular disease are the two primary causes of mortality and disease burden, especially among older adults (Beaglehole *et al.*, 2004). In developed countries, these two diseases are responsible for 36% of deaths, and death rates are higher for men than for women. It is interesting to note that the

WHO is actively calling for consumers to use prevention as a tool against heart disease, underlying the opportunities for food and beverage manufacturers developing heart health products. Given the prevalence of HIV/AIDS and related deaths in younger adults, in developed countries, this may also provide new opportunities for functional foods targeted at management of the condition.

Table 3. Ranking of disease burden in adults and impact calculated as disability-adjusted life years (DALYs) (Beaglehole et al., 2004)

| Adults aged 15–59 years | | Adults aged 60+ years | |
|---------------------------------|--------------|--|--------------|
| Rank/Cause | DALYs (000s) | Rank/Cause | DALYs (000s) |
| 1 HIV/AIDS | 68661 | 1 Ischaemic heart disease | 31481 |
| 2 Unipolar depressive disorders | 57843 | 2 Cerebrovascular disease | 29595 |
| 3 Tuberculosis | 28380 | 3 Chronic obstructive pulmonary disease | 14380 |
| 4 Road traffic injuries | 27264 | 4 Alzheimer and other dementias | 8569 |
| 5 Ischaemic heart disease | 26155 | 5 Cataracts | 7384 |
| 6 Alcohol use disorders | 19567 | 6 Lower respiratory infections | 6597 |
| 7 Hearing loss, adult onset | 19486 | 7 Hearing loss, adult onset | 6548 |
| 8 Violence | 18962 | 8 Trachea, bronchus, lung cancers | 5952 |
| 9 Cerebrovascular disease | 18749 | 9 Diabetes mellitus | 5882 |
| 10 Self-inflicted injuries | 18522 | 10 Vision disorders, age-related and other | 4766 |

Consumer research is another important source of information to help to determine consumer-relevant targets for functional food/ingredient development. Heart disease tops the list for consumer concern. Several consumer surveys in the US have indicated that weight issues, heart disease, cancer and joint pain are the most common conditions that consumers are trying to manage or prevent with food purchase (IFIC, 2000; 2002; Sloan, 2002; 2003). A survey of leaders in the food industry also ranked obesity, heart disease, cancer, diabetes, anti-aging and bone health as the most important consumer concerns (Lewis, 2004).

Perhaps it is not surprising to find that products aimed at heart health are predicted to be among the leading functional food trends in coming years (Datamonitor, 2005), along with the more predictable bone, gut and immune health products (Table 4). The predicted trends are as follows:

heart and cardiovascular health;
bone health and osteoporosis;
gut health and immunity;
cancer and preventative health;
prevention of neural tube defects;
age- and gender-related health;
mental acuity and brain health;
physical performance and sports health.

Table 4. US and European functional foods market trends, Compound Annual Growth Rate (%) by claimed health benefit (Datamonitor, 2005)

| Benefit | US market | | European market | |
|--------------------|-----------|-----------|-----------------|-----------|
| | 1999–2004 | 2004–2009 | 1999–2004 | 2004–2009 |
| Bone health | 6.0 | 4.9 | 7.5 | 7.4 |
| Heart health | 8.5 | 6.3 | 7.4 | 6.9 |
| Gut health | 23.4 | 14.0 | 7.4 | 7.2 |
| Energy | 7.0 | 6.1 | 6.7 | 6.2 |
| Other health needs | 6.1 | 4.0 | 7.9 | 4.2 |
| Overall | 7.2 | 5.7 | 7.4 | 6.4 |

Mellentin (2005) has also made some predictions for health trends in the more immediate future. Included in this list are intrinsic health benefits for everyday foods, personalised nutrition and the transition of supplement ingredients into foods. Discovery of novel bioactives for targeted health uses can underpin each of these trends.

Proof of Concept: Efficacy and Safety

Whether discovering new bioactive components or investigating the nutritional and health benefits of traditional foods, we need to manage the process of generating the evidence to underpin consumer messages and health claims. The discovery process through to commercialisation, following the drug development models, is made up of five stages.

Discovery, including production or synthesis of the test compounds and screening in bioactivity assays.

Preclinical investigation, including animal trial, dose/response, mechanism of action investigation.
Phase I human trials using small numbers of normal healthy subjects to investigate bioavailability, metabolic fate, safety, dose/response. In pharmaceutical development in the US, this stage is registered as an Investigational New Drug Application with the USFDA.
Phase II clinical trials, using patients with the target disease, are larger than Phase I trials and are designed to generate safety data and preliminary efficacy data.
Phase III clinical trials are typically large and multi-centred, and provide confirmation of efficacy and further safety data (e.g. side effects from use). In pharmaceutical development, this is the pre-approval stage.

The process is less clearly defined for functional foods, dietary supplements and bioactive ingredients, and will depend on the market, the nature of the desired claim and the format of the product (supplement versus food). However, in the absence of prescribed criteria for demonstrating efficacy, increasingly companies are using the drug development model for functional food ingredients, although perhaps on a smaller scale at Phases II/III. The closer we move to the pharmaceutical model for demonstrating efficacy, the greater will be our investment in research and development for functional foods and nutraceuticals. Therefore, we need to have clearly defined criteria for focusing on our best chances for success, and to manage our investment in a staged way.

It is difficult to really value a future opportunity without knowing what your active ingredient does or at what level it needs to be consumed to give a clear consumer benefit. So, gaining early proof of concept is important for filtering out the less promising opportunities and selecting the more favourable. What defines appropriate or adequate “proof of concept”? Early in discovery, the confirmation that a new component or fraction has some bioactivity is an early indicator and may be enough to warrant a provisional patent. However, evidence from in vivo studies is more convincing and generally gives some sense of the effective dose required. This information can be used to firm up any calculations of potential financial value. In vivo data are also usually preferred to robust any patents at the final filing and patent claims stage. Animal model data may also be required before taking a novel ingredient into human studies, to demonstrate safety. Formal safety and toxicological testing is also required for new ingredients in most markets, and increasingly food companies are requiring that authorised safety approval has been attained, e.g. FDA GRAS approval.

Communication is a key part of the commercialisation strategy. Communication of the science will underpin the consumer education and the eventual marketing and promotion of the functional ingredient, but it needs to be timed appropriately. All intellectual property capture needs to be initiated before public disclosure of an invention. Part of the communication strategy may be trademarking to further protect your commercial utility. This may help to avoid the situation whereby another company can add the component to its product and make a content claim, and by association benefit from all the hard work done by the owner or licensee of the intellectual property in terms of consumer education of the benefits of that component. As consumers relate the component to the benefit, each product appears to be equally efficacious once consumers are aware of the component’s benefits. So, communication needs to co-ordinated and managed alongside other commercialisation activities, and having the right marketing message can make or break a new product launch. Again, the cost of these activities should not be underestimated.

Gaining health claim approval is currently one of the hardest steps in the process to commercialising a novel functional food or ingredient. The regulatory processes differ across countries and jurisdictions, and the level of substantiation required for each target market may be quite different (Rowan *et al.*, 2005; Arvanitoyannis and van Houwelingen-Koukaliaroglou 2005). As the regulatory guidelines limit what can be claimed for a product, it is important to be aware of the constraints on marketing messages before designing research trials to generate the clinical evidence. Again, the innovation management process needs to be integrated across all the workstreams to be most efficient and effective.

CONCLUSIONS²

Before commercialising new functional food components, a number of scientific, technological, regulatory and marketing issues need to be addressed. There are many problems to overcome to turn the discovery of a novel functional food component into a product that will deliver a clear health benefit to the consumer. Proof of concept is different at the different stages of the process, and is dependent to a large extent on the positioning of the final product, the market into which it will be sold and the application. Nutrition marketing commentator Julian Mellentin (2005) points out that successful brands are often more about packaging and marketing than about scientific breakthroughs and strong health claims — which are often not well understood by the consumer anyway. Above all, consumers will not compromise on taste. Thus, to complement the scientists' best efforts in terms of discovery, many factors other than excellence in technology and food science must be taken into account to guarantee commercial success.

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Sensory evaluation of Earth Gems™ grown in different media¹

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ABSTRACT⁴

Ulluco (*Ullucus tuberosus*) is a South American root crop that has recently been released in New Zealand under the name Earth Gems™. It contains high levels of carbohydrate, moderate levels of protein and very low levels of fat and so will be a valuable addition to the New Zealand diet. Ulluco are widely eaten in South American countries bordering the high Andes, where they are commonly used in stews in combination with other local vegetables and meat. Previous sensory evaluation trials in New Zealand have confirmed the presence of a mild after-taste in locally grown tubers. In this research two different ulluco cultivars, principally red and yellow skinned, were grown in a glasshouse in three different types of media; soil, potting mix and sand to determine whether the problem was genetic or related to the medium they were grown in. Thirty five panellists taste-tested the cooked ulluco and evaluated the two cultivars grown in the three different mediums. The evaluations comprised skin colour, hardness of the flesh measured by biting the cooked tissue, waxiness, sweetness, bitterness, the amount of earthy taste and overall acceptance. Statistical analysis of the taste preference data recorded under standardised conditions by the 35 panellists showed that no statistical differences between the evaluation of the red and yellow colours or the evaluations of the different growth mediums could be identified. In this experiment the panellists did not report any significant comments with regards to a previously reported earthy flavour.

INTRODUCTION⁶

Ulluco (*Ullucus tuberosus*) is a tuber that is a staple food of people living in the high Andes of South America. As one of the “lost crops” used by the Incas, it is still grown and eaten today, mainly by subsistence farmers, but is largely unknown outside the Andean region (Sperling and King, 1990). In 1993, a number of ulluco cultivars were brought to New Zealand where they were quarantined to remove viruses. On release from quarantine a number of these colourful (magenta and yellow) and exotic looking (magenta spots on yellow and green spots on yellow) tubers have been grown at Pukekohe, Feilding and Lincoln, in New Zealand, to find out the most preferred site for growing.

In South America, ulluco are commonly used in stews in combination with other local vegetables and meat. Cooked ulluco tubers have been reported as having a smooth texture and a slight earthy taste (Pietilä and Jokela, 1988) and others describe the flavour as mucilaginous and similar to okra (Sperling and King, 1990). Some cultivars contain mucilage which can be removed by soaking or preboiling before cooking (Arbizu and Tapia, 1997). This tuber contains high levels of carbohydrate, moderate levels of protein and very low levels of fat (Busch and Savage, 2002). As such, they will be a valuable addition to the New Zealand diet. Other tubers from South America such as potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*) (called kumara in New Zealand) and oca (*Oxalis tuberosa*) (called yam in New Zealand) have been successfully grown in New Zealand and this suggests that ulluco may also grow successfully in the right environment in New Zealand. Popenoe (1992) notes that ulluco could enjoy profitable niches in supermarkets and health food stores.

Ulluco have recently been released commercially in New Zealand and are sold under the name of Earth Gems™. Previous studies in New Zealand have confirmed the presence of a mild earthy after-taste in some locally grown tubers (Busch *et al.*, 2000). This study compares ulluco grown in three different growth media (soil, river sand and potting mix) in order to find out whether the taste problem is genetic or related to the growth medium.

MATERIALS AND METHODS¹

Fifteen accessions of ulluco (*Ullucus tuberosus*) were collected in Bolivia and Argentina² during 1993 as part of the biodiversity programme of the New Zealand Ministry of Agriculture and Fisheries (now part of the New Zealand Institute for Crop & Food Research Ltd's New Crops Programme). All accessions were examined for virus contamination at Crop & Food Research, Lincoln in May 1993 using herbaceous indicator hosts. All lines were found to be infected with several viruses. Virus elimination in five cultivars was carried out following the procedures of Fletcher *et al.*, (1998). One vigorously growing virus-free plant of each cultivar with no morphological differences from the originally imported cultivars was released from quarantine in July 1998.

Tubers of five cultivars of ulluco (U2, U3, U9, U13 and U15) were all individually planted in³ 8.5 litre pots on 30th November 2004 at Lincoln, in a heated glasshouse with an average temperature of 20°C. The skin colour of each cultivar was as follows: predominantly red- U2 and U15, and predominately yellow- U3 (with red spots), U9 and U13. Three media selected were soil, potting mix and sand. Each pot was filled up to about 4 cm below top with sand, soil or potting mix before planting. The tubers planted were graded prior to planting and had an average weight of 5 g. Tubers were planted 3 cm deep in the middle of each pot. The trial was replicated five times and the pots were randomly moved around twice during the growing season as to avoid any shade effect in the glasshouse. All the plots regularly received water and fertiliser to avoid stress to the plants. Slow release fertiliser (nitrogen-20%, phosphate-10%, potash-5%, calcium- 2.6%, sulphur-2.6%, iron-0.36%) by the trade name of Grotabs was applied at the rate of 5 g/plant on 20th December 2005. Plants were top dressed with Crop 20 (nitrogen-19.5%, potash-10%, sulphur-12.5%) at the rate of 5 g/plant. Each individual pot was harvested separately on 25th July 2005. Tuber number and the total weight per pot were recorded. Due to the limited number of tubers from each pot, red and yellow cultivars were bulked separately according to the colour for the taste test.

Sensory Analysis⁴

Cooking⁵

For each cultivar, 200 g of ulluco were added to 600 mL of tap water in a covered container⁶ with a sealing lid. They were brought to the boil and then cooked for a further 15 minutes until tender. Samples were drained of water and allowed to cool to room temperature before use.

Panellists and sensory procedures⁷

The 35 panel members consisted of staff and students from Lincoln University. There were 15⁸ males and 20 females, aged between 19 and 55. One piece of each sample was placed on identical white plates coded with a 2-digit random number (www.randomnumber.org) and served at room temperature. Six different samples were presented to panellists in a random order. Panellists evaluated the samples in individual white booths. Between each sample, panellists were encouraged to rinse their mouth out with water. Taste testing took place in the morning and afternoon of the same day.

Panellists were asked to evaluate skin colour, texture, flavour and overall acceptability of the cooked⁹ ulluco. Two types of scale, intensity and preference, were applied for rating either (a) the intensity of the attributes, or (b) the preference for skin colour and overall acceptability (Meilgaard *et al.*, 1987). A 5 point scale with 1 = very soft and 5 = very hard, 1 = non-waxy and 5 = very waxy, 1 = not sweet at all and 5 = extremely sweet, 1 = no bitter taste and 5 = very strong bitter taste, was used to evaluate hardness, waxiness, sweetness and bitterness, respectively. The preference rating was scored on a hedonic scale of 5 with 1 = dislike very much and 5 = like very much for skin and flesh colour and with 1 = like very much and 5 = dislike very much for overall acceptability.

RESULTS¹⁰

Mean data for the sensory evaluation for each cultivar for each of the three treatments are¹¹ shown in Table 1. Statistical analysis of the data showed that no significant differences between the growing mediums or the skin colour could be detected for any of the parameters assessed by the panellists. Overall, the panellists did observe “a slightly earthy taste” for all of the cultivars with no marked difference between the red and yellow cultivars. The panellists gave an overall rating of “not very sweet” and “slightly bitter” for both the red and yellow skinned cultivars.

Table 1: Mean data for each sensory evaluation descriptor for the three treatments.

| Tuber colour | Soil medium | Skin colour | Hardness | Waxiness | Sweetness | Bitterness | Earthy taste | Overall acceptance |
|--------------|-------------|-------------|----------|----------|-----------|------------|--------------|--------------------|
| Yellow | Soil | 3.2 | 2.7 | 3.2 | 2.1 | 1.6 | 2.6 | 2.5 |
| Yellow | Potting mix | 3.4 | 2.3 | 3.2 | 2.1 | 1.7 | 2.1 | 2.5 |
| Yellow | Sand | 3.0 | 2.5 | 2.8 | 1.7 | 1.8 | 2.4 | 4.5 |
| Mean yellow | | 3.2 | 2.5 | 3.1 | 2.0 | 1.7 | 2.4 | 3.2 |
| Red | Soil | 3.6 | 2.8 | 3.0 | 1.9 | 1.5 | 2.3 | 2.0 |
| Red | Potting mix | 3.1 | 2.7 | 2.8 | 1.6 | 1.9 | 2.5 | 1.5 |
| Red | Sand | 3.4 | 2.4 | 2.4 | 1.8 | 1.6 | 2.2 | 2.3 |
| Mean red | | 3.4 | 2.6 | 2.7 | 1.8 | 1.7 | 2.3 | 1.9 |

The data show that panellists liked the colour of the red ulluco grown in soil best, followed by the yellow grown in potting mix and the red grown in sand. The red ulluco grown in soil and potting mix and the yellow grown in soil were ranked as hardest by the panellists. Overall, the yellow ulluco were ranked lower for hardness than the red ulluco. For waxiness and sweetness the yellow ulluco were ranked higher than the red ulluco. Both the red and yellow ulluco were ranked the same for bitterness, with a mean of 1.7. The yellow ulluco grown in soil and the red ulluco grown in potting mix had the highest ranking for earthy taste, while the yellow ulluco grown in potting mix and the red ulluco grown in sand had the lowest ranking for earthy taste. Panellists made few negative comments with regards to an earthy taste and gave a mean ranking of 2.4 (for yellow and red) that was between 'slight earthy taste' and 'moderate after taste'. There were no differences in taste between the two different skin colours of the ulluco or the medium they were grown in. However, for overall acceptability (where the ranking was opposite; 1 = like, etc to 5 = dislike, etc) the red skinned ulluco were ranked much lower than the yellow ulluco, mean results were 1.9 and 3.2 respectively.

DISCUSSION

Growing the ulluco in different media appears to have little effect on the sensory evaluation results. The most common comment made by the panellists was about liking the colour of the cooked ulluco. Previous research has shown that ulluco still retained their colour after cooking (Busch and Savage, 2000). Based on their answers to the preference to buy data (shown as skin colour in Table 1) the panellists liked the red cultivars best, a similar result to previous studies (Busch *et al.*, 2000). This may be as a result of the popularity of other red vegetables commonly available in New Zealand.

Interestingly, studies in South America (Espinosa and Crissman, 1999 and Pietelä and Jokela, 1988) show that consumers preferred the yellow tubers. In New Zealand, there are few other yellow tubers that consumers are familiar with, although this situation is changing with the release of two new types of oca being released recently, Inca Gold by Crop & Food Research Ltd and another yellow oca sold by Halford's of Palmerston North. It would be interesting to undertake a repeat sensory analysis of ulluco in five years or so to see if this preference changes.

In South America ulluco are traditionally washed and/or soaked overnight in water before cooking to remove the mucilage present in some cultivars. The ulluco in this experiment were not soaked to remove mucilage before cooking. The overall plan in this experiment was to reflect the most likely way the tubers would be treated by New Zealand consumers. In fact, no mucilage exuded from these particular ulluco when they were prepared for the sensory evaluation or, were any comments

made about the presence of mucilage by panellists. This is in contrast to previous studies in New Zealand (Busch *et al.*, 2000).

In the absence of any media effect, as well as pursuing a possible genetic link for this problem, it would be interesting to explore whether the perception of the earthy taste is idiosyncratic to the panellist concerned. Other research has shown that some people are “tasters” or “non-tasters” of particular chemicals (Prescott *et al.*, 2001). Previous authors have also reported that ulluco may contain compounds such as saponins, which are known to have a bitter taste (Sperling and King, 1999). In the meantime, it may be useful to suggest that ulluco should be soaked in water for a short period before cooking.

CONCLUSIONS

This study shows that growing ulluco in different media has no effect on the taste descriptors measured, particularly the development of an earthy taste. Further research to see if there is a genetic component in identifying an earthy taste by consumers and analysing ulluco to identify possible compounds involved in the earthy taste would be useful. Overall, the panellists made positive comments about the attractive colours of this vegetable, and this reinforces the comment made by other researchers who called ulluco “underground rainbows” (Flores *et al.*, 2003). The overall acceptance of the red ulluco in this taste-test was considerably higher than for the yellow skinned ulluco. With their low fat, content, attractive colours and “exotic” origin (Busch *et al.*, 2000), ulluco should be an interesting and nutritional addition to the New Zealand diet.

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Functional anti-diabetic foods of the future: Traditional plants¹ and health claims.

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ABSTRACT³

Diabetes mellitus and 'syndrome X' are areas of immense health concerns. Both conditions⁴ carry an appalling consequence of chronic macro- and micro-vascular complications. Currently there is a resurgent interest in alternative anti-diabetic plants that has long history of usage to complement the conventional treatment therapies. In this context, the anti-diabetic properties of three such plants, namely fenugreek (*Trigonella foenum - graecum*), bitter melon (*Momordica charantia*) and gurmar (*Gymnema sylvestre*) with most research evidence are reviewed.

INTRODUCTION⁵

Diabetes mellitus is a serious endocrine disorder caused by the body's inability to produce any⁶ or enough insulin or by the ineffective use of the insulin produced (insulin resistance). This deficiency results in increased concentrations of glucose in the blood called hyperglycaemia, which if not controlled damage many of the body's organs. Associated with insulin resistance is the collection of symptoms known as Syndrome X or "metabolic syndrome" or 'pre-diabetic syndrome' (abdominal obesity, elevated triglycerides, low HDL cholesterol, high blood pressure and high normal blood sugar). Long-term complications of uncontrolled blood sugar include increased risk of heart disease, stroke, kidney disease, blindness and loss of nerve function. Regulating blood sugar for diabetics is therefore crucial.

The first goal in therapy is to achieve and maintain an optimal fasting blood glucose level.⁷ Lifestyle management (diet control, exercise and weight control, stress management), oral glucose-lowering drugs and injections of insulin are the conventional strategic treatment therapies for improving glucose homeostasis. Food is the primary foundation for blood sugar control, often called glycaemic control. Eating foods that promote glycaemic balance is the key to a healthy diet, especially for those with insulin resistance. Pharmacological treatment is resorted when glycaemic balance is not maintained, but the benefit of medication on blood sugar control is often temporary. Insulin is usually added to an oral agent when glycemic control is suboptimal at maximal doses of oral medications. Although insulin is a life-saver, it is not a cure-all. The majority of type 2 patients are sufficiently insulin-resistant that even supra-normal insulin concentrations, are insufficient to control the hyperglycaemia. Weight gain, increased risk of atherogenesis and hypoglycaemia are common side effects of insulin therapy.

Unfortunately, neither insulin injections nor oral ant diabetic drugs reinstate a normal pattern⁸ of glycaemic control, whether used alone or in combination. As an alternative approach, plants with anti-diabetic activities are increasingly sought by diabetic patients and health care professionals. Although there are thousands of botanicals with anti-diabetic claims, this review will discuss only three such plants (fenugreek, bitter melon and gurmar) with long history of therapeutic use, most research evidence, less side effects and potential for use as functional ingredients in low-glycaemic foods. Knowledge on these plants primarily comes from generations of experience and traditional medicine.

Fenugreek⁹

Fenugreek (*Trigonella foenum - graecum*) is an annual plant from the family Papilionaceae –¹⁰ Leguminosae. Its seeds, inter alia is widely as a condiment in Asian dishes. It is used as a supplement in wheat and maize flour for bread making in India and Egypt, and also therapeutically as a lactation stimulant. Fenugreek seeds contain 23-26% protein with lysine content (5.5 – 6.6 g/16 g N) similar to

that of soybean. It also contains a polar, non-charged, free amino acid, 4-hydroxyisoyserine (4-OH-Ile).¹ This amino acid is present only in plants, especially in *Trigonella* species.

In several clinical trials, fenugreek seeds have been found to lower glucose levels in both,² humans and animals, the effect is gradual and cumulative. It is reported to increase erythrocyte insulin receptors and improve peripheral glucose utilization, thus showing potential pancreatic as well as extrapancreatic effects (Raguram *et al.*, 1994). The hypoglycaemic effects have been attributed to several mechanisms. Sauvaire *et al.* (1998) demonstrated that 4-OH-Ile increased glucose-induced, dose-dependent insulin release through a direct effect on the isolated islets of Langerhans in both humans and rats. The pattern of insulin secretion was described to be biphasic and it was hypothesised that the mode of action was on the β -cells since the levels of somatostatin and glucagons produced by the pancreatic α -cells were not altered. However carbon α -S- configuration, carbon γ hydroxylation and full methylation are essential features required for insulinotropic activity of 4-OH-Ile. It also had no interaction with other agonists of insulin secretion, such as leucine, arginine, tolbutamide and glyceraldehyde. Fenugreek is also reported to inhibit the activities of α -amylase and sucrase enzymes involved in carbohydrate digestion.

A secondary mechanism for its hypoglycaemic action is via the fibre content. Fenugreek³ contains 50% fibre (20% soluble fibre – mainly galactomannans) that can slow the rate of postprandial glucose absorption. Other chemical constituents that are believed to have hypoglycaemic activity include saponins (4.8%), many of which are glycosides of diosgenin, alkaloids such as trigonelline, fenugreekine, gentianine, carpaine and several C-glycosides. Fenugreek is also reported to be rich in chromium, a mineral that plays a role in the uptake of glucose by cells.

In addition to restoring antioxidant balance in diabetes, fenugreek seeds are reported to be⁴ effective at lowering serum triglycerides, total cholesterol, LDL-cholesterol and the mechanism is attributed to saponins which increases biliary cholesterol excretion, leading to low cholesterol levels. Seed powder normalized the altered creatinine kinase activity in heart, liver and skeletal muscle of diabetic rats to the values of control rats (Genet *et al.*, 1999). It also normalized alteration in hepatic and renal glucose-6-phosphatase and fructose-1,6-bisphosphatase activity (Gupta *et al.*, 1999). There is no evidence that fenugreek produces any acute or cumulative toxicity.

Bitter Melon⁵

Bitter melon or bitter gourd (*Momordica charantia*) belongs to the family Cucurbitaceae. Its⁶ general nutritional composition is similar to that of cucumber, but it contains several chemical constituents, which are characteristic to bitter melon. The bitter principle, for which the fruit is named, is due to the alkaloid momordicine and charantin, and not cucurbitacins as in other members of the Cucurbitaceae. Amongst the dazzling array of medical conditions (possible anti-tumour, anti-mutagenic, anti-viral and other activities) documented for bitter melon, its hypoglycaemic effect has received the most attention. The fruit is eaten as a vegetable, but as a treatment for diabetes, it is typically the juice or an extract of the unripe fruit (50 to 200 mL per day) that is most effective. The darker coloured, small varieties are more potent in being hypoglycaemic than the modern produce that has been bred for less bitterness.

A large body of research now confirms the hypoglycemic effects of bitter melon in animal⁷ models, both acutely and chronically. In separate studies, 73-86% of type 2 diabetic animals showed hypoglycaemic response to bitter melon juice (Ahmad *et al.*, 1999; Wellihinda *et al.*, 1986). Two compounds, namely charantin, a mixture of steroidal glycosides and an insulin-like protein referred to as polypeptide-P or plant insulin, have been isolated from bitter melon and are believed to be responsible for its hypoglycemic activity. It is believed that bitter melon acts on both the pancreas and non-pancreatic cells, such as muscle cells. Bitter melon also contains the alkaloid momordicine. Other proposed actions include extra-pancreatic activity, such as increased tissue glucose uptake, liver/muscle glycogen synthesis and, decreased blood glucose synthesis through depression of the enzymes glucose-6-phosphatase, fructose-1, and 6 bisphosphatase, and enhanced glucose oxidation by enzyme G6PDH pathway.

In an investigation of *M. charantia* in streptozotocin induced diabetic mice, bitter melon not⁸ only reduced plasma glucose levels, but also significantly reduced renal hypertrophy compared to untreated diabetic controls (Grover *et al.*, 2001). Bitter melon extracts were also able to reduce oxidative stress and reverse the effects of chronic diabetes. Additionally, bitter melon extracts show

triglyceride and cholesterol lowering activity in diabetic animals, as well as non-diabetic animals fed cholesterol-rich diets. More studies need to be conducted to confirm the efficacy of these extracts in humans, although the generations of dietary use suggests that safety is unlikely to be an issue

Gurmar²

Gymnema (*Gymnema sylvestra*) is a woody plant whose leaves have been used for centuries to treat diabetes. Chewing the leaves impairs a person's ability to discriminate sweet taste, hence its name 'gurmar' or 'sugar destroyer' (in Hindi). Gurmarin, a polypeptide of 35 amino acids is reported to be responsible for this sweetness inhibitory activity. Though one mechanism of action is by suppressing the desire to eat sweet foods, the hypoglycaemic activity of gymnema is reported to reside primarily in a group of compounds called gymnemic acids. They are a mixture of acid insoluble triterpenoid saponins present in an aqueous ethanolic extract, GS4 of the leaves.

Gymnema extract GS4 has been reported to reduce hyperglycaemia in diabetic rats, rabbits and humans, both type 1 and type 2 diabetes, increase serum insulin levels in vivo and in vitro, and increase β -cell number in streptozin-induced diabetes. Fasting blood glucose levels as well as insulin requirements were reported to be reduced in type 1 individuals, perhaps by increasing the utilization of insulin (Shanmugasunderam *et al.*, 1990). Significant reductions in blood glucose, glycosylated haemoglobin (HbA1c), plasma proteins and conventional drug requirement were reported in 22 type 2 diabetic patients after an oral treatment with 400 mg/day GS4 extract for 18-20 months. Five patients totally discontinued conventional drug therapy and maintained glucose homeostasis entirely with this plant extract. In this study, lipids also decreased significantly. Patients on placebo had no significant changes in HbA1c, FBG, or lipids. (Baskaran *et al.*, 1990). In these studies, it was hypothesised that GS4 may stimulate β -cell function, increase β -cell number, and/or increase insulin release by increasing cell permeability to insulin (Persaud *et al.*, 1999). In pancreatectomised animals, it had no hypoglycaemic effect, indicating that its effect may require some residual β -cell function (Shanmugasundaram *et al.*, 1990).

CONCLUSIONS⁵

There is a wider interest in the use of 'natural' dietary adjuncts as functional foods for management of diseases. With syndrome X and diabetes, a low-risk, food-based intervention that can modulate glucose homeostasis and potentially improve lipid parameters is desirable. In this respect, the three plants examined in this review hold promise as functional ingredients. They also enrich the diet with natural fibre, antioxidants, vitamins and minerals. Added value occurs through other compounds such as alkaloids and glycosides, and unique amino acids which do not lend themselves for pharmacological development in an effective form. Besides such an ethnomedical approach for diabetes is practical, safe, cost-effective and logical for its treatment

There is some evidence that these botanicals may have synergistic benefits for controlling diabetes. They act on the cellular metabolic level, beyond the simple physical effect of lowering glucose. They stimulate insulin secretion and/or action, improve insulin binding and prevent hyperlipidemia, though exact mechanisms are yet to be elucidated. All three plants have traditionally been considered safe and well tolerated by humans. Available literature also reveals no reports of clinically significant harmful adverse effects. However one cannot rule out the possibility for drug-interactions and hypoglycaemia in diabetic individuals.

This is an interesting area and also one that is relatively underdeveloped to date for functional foods, and shows strong promise for further research.

"Let food be your medicine and medicine be your food" Hippocrates (460-380 BC)

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Tomatoes as a functional food¹

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INTRODUCTION³

The maintenance of human health has been an important area of research over the last few decades and so a major focus of nutritional studies has been to examine foods for their disease-preventing potential. Some foods are now called functional foods, foods that are capable of providing additional physiological benefits, such as preventing or delaying onset of chronic diseases, in addition to meeting basic nutritional requirements (Kaur and Kapoor, 2001). The antioxidant compounds present in certain functional foods help to scavenge free radicals formed in the body, and to prevent oxidation of lipids, proteins and genetic material at a cellular level (Basu, 1999). In addition to endogenous antioxidants synthesised by the body, the diet *also* supplies a significant amount of the antioxidants required by the body (Parke, 1999). Tomatoes have been identified as an important functional food as they contain a number of antioxidants, such as, carotenoids (especially lycopene), phenolics, and ascorbic acid (Abushita *et al.*, 2000; Djuric and Powell, 2001; Martinez-Valverde *et al.*, 2002). Because a significant amount of tomatoes and tomato products are consumed in the diet, they make a valuable contribution to the supply of antioxidants required in the body. Regular consumption of tomatoes and processed tomato products has been related to a reduced risk of various chronic diseases such as cancers, especially prostate cancer (Basu, 1999; Giovannucci, 1999; Rao and Agarwal, 1999; George *et al.*, 2001) and coronary heart diseases (Arab *et al.*, 2000; Bramley, 2000).

Antioxidant components of tomatoes⁵

Tomato fruit contains a wide range of antioxidant molecules, such as carotenoids, flavonoids, phenolic acids and ascorbic acid (Giovanelli *et al.*, 1999; Raffo *et al.*, 2002; George *et al.*, 2004). The antioxidant compounds help scavenge free radicals and, thus, prevent abnormal oxidative changes in the human body. Free radicals can be formed spontaneously in the body by many biological processes and their production may increase as a result of environmental sources such as cigarette smoke, UV radiation and oxidizing agents (Scheffler *et al.*, 1992). Excessive accumulation of these pro-oxidants and free radicals may damage cells by the oxidation of lipids, proteins and DNA, and induce peroxidation and DNA strand-breaks (Sun, 1990; Kamimura, 1992). To prevent accumulation of free radicals in the body, antioxidant compounds which inhibit oxidation should be present (Basu, 1999). Apart from the various endogenous antioxidants synthesized in the body, such as catalase, glutathione peroxidase and transferrin (Halliwell, 1996), the diet *also* makes an important contribution to the levels of antioxidants in the body. Tomatoes and their products make a significant contribution to the supply of antioxidants required in the body (Heber, 2000; Leonardi *et al.*, 2000; Martinez-Valverde *et al.*, 2002). Tomatoes and tomato-based products account for more than 85% of the dietary intake of lycopene in the USA (Rao and Agarwal, 1999). Fresh tomatoes account for 51% of the total daily dietary lycopene intake, with the rest coming from processed products (Rao and Agarwal, 2000).

Studies have shown that lycopene is a powerful antioxidant *in vitro* (Di Mascio *et al.*, 1989) and numerous investigations have revealed possible links between tomato consumption and a decreased risk of certain cancers, in particular prostate and lung cancers (reviewed by Giovannucci, 1999). It is thought that the free radical scavenging ability of lycopene is one of the mechanisms responsible for its beneficial properties. Sharoni *et al.* (2000) reviewed the molecular mechanisms for the anti-cancer role of lycopene. At a cellular level, lycopene interferes with the mitogenic pathway of IGF-1 levels and slowed cell cycle progression. However, it has been observed that the anti-cancer effects of lycopene, together with other micronutrients like α -tocopherol, lipoic acid and curcumin, were much greater than lycopene alone (Liu *et al.*, 1997; Pastori *et al.*, 1998; Amir *et al.*, 1999). Lycopene also increased gap-junction communication between cells and induced the synthesis of connexin-43 (Shi and Le Maguer, 2000). Loss of gap-junction communication may be important for malignant transformation, and its restoration may reverse the malignant process (Shi and Le Maguer, 2000).

Lycopene content of tomatoes⁸

Carotenoids are only one of the antioxidants found in tomatoes but they are considered to be the most important. Tomatoes contain more than 21 carotenoids, including lycopene, phytoene, phytofluene, neurosporene, α -, β -, γ -, δ - and ξ -carotene and lutein (Shi and Le Maguer, 2000).

Lycopene is the most abundant carotenoid present in ripe red tomatoes, comprising up to 90% of the pigments present. Lycopene from natural plant sources exists, predominantly, in an all-*trans* configuration, which is the most thermodynamically stable form (Nguyen and Schwartz, 1999).

Although different varieties of tomatoes contain varying levels of lycopene the average level ranges from 1.6-11 mg/100 g fresh weight (FW) (Kerkhofs *et al.*, 2003) (Table 1). Lycopene is concentrated in the layer of 4-5 cells under the thin cuticle of the tomato (most often, the skin plus the next 4-5 layers of cells are referred to as the skin), which contains little lycopene (Davies & Hobson, 1981). Darker coloured varieties of tomatoes tend to contain higher levels of lycopene than paler varieties (Shi and Le Maguer, 2000). Smaller sized varieties, for example cherry and cocktail tomatoes, generally contain higher levels of lycopene (Leonardi *et al.*, 2002; Raffo *et al.*, 2002; see Table 1). Conversely, larger tomatoes usually contain lower levels of lycopene (Shi and Le Maguer, 2000). Yellow tomatoes contain little or no lycopene (Hart and Scott, 1995; Shi and Le Maguer, 2000) and have β -carotene as the major carotenoid.

Table 1: Lycopene concentration of fresh tomatoes (Kerkhofs *et al.*, 2003).

| Total lycopene (mg/100 g FW) | Reference |
|------------------------------|--|
| 1.6-5.6 | Hart and Scott (1995) |
| 1.8- 6.5 | Martinez-Valverde <i>et al.</i> , (2002) |
| 3.1-7.7 | Nguyen and Schwartz (1999) |
| 5.2-8.5 | Abushita <i>et al.</i> , (2000) |
| 5.8 | Kozukue and Friedman (2003) |
| 4.6, 6.8 | Lavelli <i>et al.</i> , (2000) |
| 10.4 | Raffo <i>et al.</i> , (2002) |
| 10.8 | Leonardi <i>et al.</i> , (2000) |
| 2.0-3.9 | Molyneux <i>et al.</i> , (2004) ^a |
| 2.5, 3.7 | Sahlin <i>et al.</i> , (2004) ^a |
| 2.2-2.7 | Kerkhofs (2003) ^a |

^aNew Zealand data

In processed tomato products, all-*trans* lycopene accounts for 90-98% of the total lycopene present and very small amounts of *cis*-lycopene have been detected (Böhm *et al.*, 2002).

Health benefits of tomato and tomato products

Antioxidant functions of lycopene, phenolic compounds, and ascorbic acid are associated with reductions in DNA damage, malignant transformation and biological oxidative damage of proteins, lipids, and other cell components *in vitro* (Shi and Le Maguer, 2000). Many tissue culture studies and animal studies have also shown that lycopene helps to inhibit tumour formation (Rao and Agarwal, 1999). The interest in tomato antioxidants and their potential protective role in prevention of chronic diseases stems largely from the epidemiological observations on normal and at risk populations (Rao and Agarwal, 1999). Many epidemiological studies have suggested that a diet rich in a variety of fruits and vegetables results in a lower risk of cancer and other chronic diseases (Steinmetz and Potter, 1996; World Cancer Research Fund, 1997). Epidemiological investigations to study the role of tomatoes and tomato products in relation to chronic diseases have found a reduction in risk of various cancers and ischaemic heart diseases. Some of the major studies have been summarized in Table 2 (Rao and Agarwal, 1999). Based on consumption of more than 10 servings of tomato products per week, an almost 35% reduction in risk of prostate cancer has been observed, and the protective effect was even stronger, when the analysis focused on more advanced or aggressive prostate cancer (Giovannucci, 1999).

Table 2: Epidemiological studies related with intake of tomato and processed tomato products (Rao and Agarwal, 1999).

| Type of study | Summary of the major observations | References |
|--|--|------------------------------------|
| Prostate cancer Prospective cohort study | Inverse association between dietary intake of tomato products and risk of prostate cancer | Giovannucci <i>et al.</i> , (1999) |
| Cervical cancer Case control study | Lycopene showed an inverse association with cervical cancer risk | VanEewyck <i>et al.</i> , (1991) |
| Digestive tract cancer Case control study | High intake of tomatoes was associated with a reduced risk of all types of digestive tract cancers | Franceschi <i>et al.</i> , (1994) |
| Bladder cancer Case control study | Serum lycopene associated with decreased risk of bladder cancer | Helzlsouer <i>et al.</i> , (1989) |
| Breast cancer Case control study | Inverse association between serum lycopene and breast cancer risk | Dorgan <i>et al.</i> , (1989) |
| Myocardial infarction risk Case control study | Adipose tissue lycopene associated with lowered risk | Kohlmeier <i>et al.</i> , (1997) |

Oxidatively modified low-density lipoproteins have been reported to be involved in ischaemic heart disease due to atherosclerosis of the coronary arteries (Rao and Agarwal, 1999). It has been suggested that dietary antioxidant vitamins, flavonoids and carotenoids may protect low-density lipoproteins from oxidative damage and may, thus, contribute to a reduction in the risk of ischaemic heart disease (Halliwell, 1996).

Increased consumer awareness about the health benefits of antioxidant compounds present in tomatoes provides an opportunity for growers and processors to produce tomatoes and processed tomato products containing higher levels of antioxidants particularly lycopene. Most research studying the antioxidant components in tomatoes has been carried out overseas and there is limited data concerning the antioxidant composition of tomatoes grown in New Zealand except for the studies carried out by Molyneux *et al.*, (2004) and Kerkhofs *et al.*, (2005). A number of factors- varietal, agronomic and environmental have been reported to influence the resulting antioxidant composition of tomatoes (McCollum, 1954; Bajaj *et al.*, 1990; Buta and Spaulding, 1997; Abushita *et al.*, 2000; Dumas *et al.*, 2003). In order to improve the level of antioxidants in tomatoes and their processed products, it is important to understand how different factors, ranging from growing to processing, could influence their levels.

In some earlier studies, tomatoes have been obtained from consumer markets without any control or information about the growing conditions (Vinson *et al.* 1998; Crozier *et al.*, 1997; Stewart *et al.*, 2000; Martinez-Valverde *et al.*, 2002) while, in other studies, the cultivars were harvested at different stages of maturity (Leonardi *et al.*, 2000); therefore, it is not possible to directly compare these results. To make a valid comparison of the effect of cultivar, there is a need to study the antioxidant composition of tomatoes grown under identical conditions and harvested at the same stage of maturity. It is known that the growing conditions (e.g. field vs. greenhouse) and stage of maturity play an important role in determining the level of antioxidant components (Abushita *et al.*, 2000; Arias *et al.*, 2000a; Gómez *et al.*, 2001). Because exposure to higher light intensity field grown tomatoes have been reported to contain higher levels of flavonoids, ascorbic acid and lycopene compared to greenhouse grown tomatoes (Herrmann, 1976; Abushita *et al.*, 2000; Shi and Le Maguer, 2000; Gómez *et al.*, 2001). A more than 20-fold increase in lycopene content of tomatoes occurs between the green stage and the red-ripe stage of maturity (Gómez *et al.*, 2001; Raffo *et al.*, 2002). Molyneux *et al.*, (2004) noted that the lycopene content of different cultivars of greenhouse grown tomatoes ranged from 1.7 to 4.2 mg/100 g even though they were grown under similar conditions. Overall, the lycopene content of the five different cultivars investigated increased by 34% after only 5 days storage at 15°C.

Environmental factors such as solar radiation can also influence the antioxidant components of tomato. High light intensity have also been reported to improve the levels of ascorbic acid and lycopene in tomatoes (Hamner *et al.*, 1945; McCollum, 1954; Davey *et al.*, 2000). Toor *et al.*, (2006)

have shown that the lycopene content of tomatoes harvested from the same plants grown in a greenhouse over an 8 month harvest season varies considerably. Overall, there appears to be an increase in lycopene content in two of the cultivars studied (Tradiro and Flavourine) while the levels in the cultivar Excell remained relatively constant. All of the tomatoes were harvested at the same level of maturity. Almost all of the earlier studies on the lycopene content of tomatoes have been conducted on field grown tomatoes. The light conditions, i.e. the amount of solar radiation received inside the greenhouse may vary at different times of the year, as occurs in the field which, in turn, could play an important role in determining the levels of antioxidants in tomatoes produced at different times of the year, and this requires further investigation.

Fertiliser treatments of the growing plants are also of importance, however, the data available on the effects of fertilisers on the antioxidant components of tomato is limited (Dumas *et al.*, 2003). Application of greater amounts of potassium than usual has been reported to increase the synthesis of lycopene in tomatoes, however the rates of potassium applied in studies were very high and not consistent with modern agricultural practices (Dumas *et al.*, 2003). Both organic and synthetic fertilisers can be used for growing tomatoes. In New Zealand, organic farming is being considered as an alternative to conventional farming, which uses synthetic fertilisers, pesticides and growth regulators. The use of organic fertilisers like vermicompost has been reported to increase the amount of ascorbic acid content in tomato (Premuzic *et al.*, 1998), but their influence on other antioxidant components has not been widely studied. Toor *et al.*, (2006) showed that growing greenhouse tomatoes organically using either chicken manure or a grass-clover mulch led to a reduction in yield of tomatoes. The lycopene content of the tomatoes grown on chicken manure was comparable to the inorganic fertiliser treatments. However, the lycopene contents of the tomatoes grown on a grass-mulch were very much lower than all the other treatments. Toor *et al.*, (2006) suggest that this might have been caused by limitation in S supply to these plants. Low levels of sulphur are known to inhibit the biosynthesis of lycopene in tomatoes.

Studies have demonstrated that fruits accumulate higher levels of phenolic compounds in the skin as their protection mechanism against ultraviolet radiation, to act as attractants in fruit dispersal, and as defence chemicals against pathogens and predators (Strack, 1997). Tomato skin has been reported to contain higher levels of lycopene and flavonoids than pulp (Al-Wandawi *et al.*, 1985; Sharma and Le Maguer, 1996; Stewart *et al.*, 2000; George *et al.*, 2004). The skin and seeds of tomatoes are often discarded during cooking or commercial processing. Toor and Savage (2005) showed that the skin of greenhouse grown tomatoes contained significantly larger amounts of lycopene compared to the pulp and the seeds.

Post harvest handling such as storage and processing of tomatoes, is another factor that can influence the antioxidant composition of tomatoes. Storage of tomatoes, and other products of tropical or subtropical origin, at below critical but non-freezing temperatures (up to 12°C), predisposes them to chilling injury (Grierson and Kader, 1986; Efiuvwevwe and Thorne, 1988; Yanuriati *et al.*, 1999). In addition, storage of tomatoes at 22°C for 14 days resulted in an increase in antioxidant components such as lycopene due to an increased rate of conversion of chloroplasts into chromoplasts, whereas, storage at 4°C produced no significant changes in lycopene content (Ajlouni *et al.*, 2001). However, there is limited research about the effect of storage temperature and time on the other antioxidant components of fresh tomato. Processing of tomatoes can also affect their antioxidant components. For example, frying of tomatoes and treatment with oil and vinegar mixture has been reported to cause a significant reduction in the ascorbic acid, total phenolic content and antioxidant activity of tomatoes (Sahlin *et al.*, 2004). Takeoka *et al.* (2001) observed an 82% decrease in ascorbic acid, and a 9 to 28% decrease in lycopene content during processing of tomatoes into tomato paste. Fresh tomatoes are usually dried, using high temperatures, into different forms such as halves, slices, quarters and powders and are used as a component for pizza and various vegetable dishes (Giovanelli *et al.*, 2002). Drying of tomatoes at high temperature has been reported to cause considerable losses of ascorbic acid, and browning (Zanoni *et al.*, 1999; Dewanto *et al.*, 2002; Giovanelli *et al.*, 2002). Zanoni *et al.* (1999) proposed that use of low temperature for drying and production of an intermediate moisture product can help to reduce the oxidative damage in the final product. Kerkhofs *et al.*, (2005) suggest that drying tomatoes above 60°C will lead to significant losses of lycopene in the dried product. Their studies showed that drying at 42°C yielded a product appeared to contain 33% more extractable lycopene than the original fresh product. Kerkhofs *et al.*, (2005) suggest that the early part of the drying process, which lasted two days, was more like a slow gentle cooking process which allowed

more lycopene to be released from the tomato matrix. The final colour of the dried product was bright red suggesting that no appreciable oxidation had taken place during drying.

Another important factor that can influence the biological activity of antioxidants is bioavailability, the degree to which antioxidants are released from the food matrix and absorbed by the human body. Bioavailability studies give an indication of the fraction of an ingested nutrient that is available to the body through absorption for utilization in normal physiological functions (Shi and Le Maguer, 2000) and these are conducted by measuring the concentrations of nutrients in plasma and urine after ingestion of either pure compounds or foodstuffs of interest (Scalbert and Williamson, 2000). Several researchers (Gartner *et al.*, 1997; Pateau *et al.*, 1998; Porrini *et al.*, 1998; Pellegrini *et al.*, 2000) have noted an increase in the lycopene concentrations in plasma after ingestion of tomato puree, tomato paste and tomato juice, but not after ingestion of fresh tomatoes (Gartner *et al.*, 1997; Böhm and Bitsch, 1999). Studying bioavailability using animals and humans is time consuming and costly. Therefore, *in vitro* digestion model is an alternative method, which simulates the conditions of human digestive tract and can be used to determine the amount of antioxidants that are released from tomatoes under physiological conditions (Hedrén *et al.*, 2002). Preliminary studies carried out by Toor *et al.*, (2006) confirm that the amount of lycopene released during an *in vitro* digestion of three different cultivars of fresh tomato was very low (mean 3.8%).

CONCLUSIONS

Foods that provide health benefits in addition to their nutritive value, or that have a role in disease risk prevention, can be called functional foods. Fresh tomatoes and processed tomato products have been identified as important functional foods because they contain various antioxidant components such as carotenoids, mainly lycopene, phenolics and ascorbic acid. The regular consumption of tomatoes has been associated with reduced risk from various forms of cancer and heart diseases. The challenge for the future is to find a way to concentrate tomatoes so that it is possible to consume sufficient lycopene to meet the daily requirement to lower the risk of various chronic diseases such as cancers, especially, prostate cancer and coronary heart disease.

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Effect of Inulin and sucrose esters on reducing sugar levels of breads¹

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ABSTRACT⁴

The effects of inulin (Inulin TEX and Inulin HD), together with sucrose ester (SP 50 and SP 70), inclusions on Reducing sugar release (RSR) were studied. RSR values from in vitro degradation studies showed a decrease in starch digestion and the release of reducing sugars following the inclusion of inulin, sucrose esters and a combination of inulin and sucrose esters. Increased concentration of inulin TEX reduced RSR levels after 40 min of the digestion where as inulin HD did not show this pattern. Combinations of inulin fibre (TEX, HD) with sucrose ester (SP50, SP70) were not significantly different to breads with inulin fibres only. Inclusion of sucrose esters alone had a significant impact on reducing RSR levels when compared to control. This indicates a potential nutritional benefit of inulin enhanced breads.⁵

INTRODUCTION⁶

Ever since the early description of dietary fibre by Trowel in 1974, the terminology and definition of dietary fibre has been debated. The most recent definition regarding dietary fibre classifies it as a remnant of edible plant cell polysaccharides and associated substances resistant to hydrolysis by human alimentary enzymes (Cherbut *et al.*, 2002; Trowel and Burkitt, 1986). Significantly, this definition includes undigestible material such as oligosaccharides, (for instance inulin) which have been shown to be important sources of fermentation substrates for the large intestinal micro flora(Asp, 1996). Research has also indicated these oligosaccharides may influence the digestion process in the upper intestine, and affect transit and stool output as well as integrity of the mucosal barrier in large intestine (Brennan *et al.*, 2004).⁷

Inulin is considered fructo-oligosaccharides and is widely used in the food industry both to add fibre to food products, and also as a sweetener. Unlike other fibres, inulin generally has no “off flavours” and is highly soluble, hence reducing the negative effects of other viscous non-starch polysaccharides used in the food industry.⁸

Chain length, distribution of the chains, and how the inulin chain is branched, all have a significant influence on the behaviour of the inulin ingredient. Simplistically, short chain inulin molecules show a different technological behaviour than long chain inulin molecules. Thus, long chain Inulin molecules are able to bind water and even form weak particle gels, whereas short chain Inulin molecules do not exhibit these properties.⁹

The importance of dietary fibre in relation to obesity, diabetes and other chronic illnesses has been subject to much scrutiny recently. Recommendations of the food pyramid consumption for dietary fibre range from 25 to 30 g/day, and the Food and Drug Administration has set the daily reference values to 25 g for labelling purposes (Park *et al.*, 1997). This has prompted efforts by the food industry to add dietary fibre into various food products.¹⁰

Bread has been targeted as an important food item to enrich with fibre, and has been the focus of attention by the industry and researchers in trying to incorporate higher levels of dietary fibres (Symons and Brennan 2004; Brennan 2005). However the main problem of dietary fibre addition in baking is the important reduction of loaf volume and the different texture of the breads obtained which¹¹

has been reported previously (Pomeranz *et al.*, 1977). Some evidence suggests that the use of food emulsifiers (such as sucrose esters) can mitigate these responses (Sangnark and Nookhorm, 2004).

MATERIALS AND METHODS

Commercial high-grade wheat flour (Elfin High Grade, Goodman Fielder, Auckland New Zealand) was used for the base doughs. This flour contained approximately 76.8 g CHO; 1 g sugar; 3.5 g dietary fibre (according to manufactures specifications). Inulin TEX and HD were obtained from Suiker Unie & Sensus (Dinteloord, The Netherlands). The sucrose esters (SP 50, SP 70) were obtained from Sisterna.

Bread dough was made according to the straight dough / bread making method (AACC 1995). Ingredients for the doughs are detailed in Table 1. Doughs were divided into 70g portions and baked in test-tins (pan height 60 mm; dimensions 150 mm length by 50 mm width top; and 140 mm length by 40 mm width bottom). Doughs were baked at 220C for 20 minutes and allowed to cool for bread analysis. Eight loaves were made per batch, and triplicate batches were produced.

In order to investigate the relative contributions of type of Inulin (Inulin TEX, Inulin HD), and type of sucrose ester (SP50, SP70) and to determine their optimum level, an experimental design was carried out. Each Inulin (TEX, HD) was used at two concentrations 5 and 10%, and each emulsifier (SP50, SP70) was used at 1% (all % are on flour bases wet basis).

In Vitro Analysis

Digestion of bread samples were conducted using the in vitro starch digestion process of Symons and Brennan (2004) involving digestion of the bread samples in protease and amylase enzymatic solutions. The production of reducing sugars was assessed by the DNS method (as used by Symons and Brennan, 2004) and the results are reported as reducing sugars released on a starch basis. Samples are crushed to a size of 1 cm³, placed in sodium phosphate buffer (pH 6.9), reduced to pH 1.5 (with 8M HCL), and digested with 5 mL porcine pepsin and allowed to digest for 30 mins at 37°C. Then the pH was adjusted to 6.9 (with 10 % NaOH), and the volume of the liquid made up to 50 mL with sodium phosphate buffer to which porcine pancreatic α amylase had been added. The mixture was transferred to dialysis tubing and placed in 450 mL of sodium phosphate buffer for 5 h. Duplicate aliquots (1 mL) of dialysate were taken every 30 min and analysed for total sugars by the 3, 5-dinitrosalicylic acid(DNS) method. Reducing sugars released (RSR) were expressed in maltose equivalents as a total available carbohydrates present in the sample using following calculation.

$$A_{\text{sample}} \times 500 \times 0.95 / A_{\text{maltose}} \times \text{SS} \times 100 = \text{RSR}$$

Where A sample is the value of absorbance at 540 nm; A maltose is the value of absorbance of a solution containing 1 mg of pure maltose per mL/ phosphate buffer; SS is the amount of starch plus sugars(in milligrams) contained within the sample; 500 is the total volume; and 0.95 is the conversion from maltose to starch.

Statistical Analysis

The data collected from all experiments were calculated as means ± S.D. All determinations were made, unless otherwise stated, in triplicate. Analyses of variance of the results (ANOVA) were performed using the Minitab 14 statistical software package. Significance was defined as P< 0.05.

RESULTS AND DISCUSSION

The effect of fibre and ester inclusion on starch degradation is illustrated in Figure 1 (a-d). It is of interest to note that the time 0 determination of RSR from the bread samples is higher in the fibre and ester adulterated samples than the control. This may in part be due to reducing sugars present inulin samples, although the effect observed with the addition of the sugar esters is unexpected and has not been reported previously. However, inulin, sugar ester, and the combination of inulin and sugar

ester addition to the breads resulted in a decrease in overall sugar release following digestion (on a comparative starch basis). This indicates that starch degradation and sugar release during the in vitro process is reduced compared to the control samples.

Addition of Inulin Tex (Figure 1a) to the breads appeared to have a greater effect in the reduction of sugar release compared to the Inulin HD additions (Figure 1b). This is especially evident for the 10 % addition of Inulin Tex. When the sugar esters were also included in these breads, the RSR levels were similar to the samples without sugar esters. This indicates that there is little potential benefit, in terms of lowering sugar release, by adding a combination of sugar esters and Inulin. In all samples there seemed to be a peak in starch digestion between 80-120 minutes.

Inclusion of the sugar esters themselves (at a 1% level) appeared to elicit a similar RSR reduction as the 5 and 10% addition of the Inulin (Figures 1 c and d). Thus it is possible that the degree of starch degradation of breads may be regulated by either the inclusion of fibre components, or sugar esters. The decision to use a particular source could be made on economic basis. However it should be borne in mind that the addition of sugar esters to the bread doughs did not have negative effects on the loaf volumes of the resulting breads.

Previous research by Jenkins *et al.*, (1981) has demonstrated the potential uses of non-starch polysaccharides as modulators of the glycaemic response to bread intake. Several researchers have attempted to determine the mechanisms in which this is achieved (Brennan *et al.*, 1996; Brighenti *et al.*, 1995; Schweizer *et al.*, 1988). It is unlikely that the mode of action of the inulin was as a result of viscosity altering abilities of the inulin enriched doughs as inulin is a relatively short chained molecule which does not significantly alter the viscosity of systems through gelling properties. However it is possible that the inulin formed some competition with the starch and the protein within the system for the limited amount of water, and that this competition for water availability resulted in the reduction of starch degradation.

CONCLUSION

The addition of inulin TEX and HD reduced RSR levels effectively when compared to control bread. The increase in the concentration of inulin TEX had shown to reduce RSR levels after 40 minutes of the digestion where as inulin HD did not reduce RSR levels effectively upon increase in the concentration. The combinations of inulin fibres (TEX, HD) with sucrose esters (SP50, SP70) were not effectively reduced RSR levels when compared to breads with inulin fibres only. Interestingly inclusion of sucrose esters alone had large impact on reducing RSR values when compared to the control.

Sucrose ester SP50 had decreased RSR values by 72.5 % at the end of the digestion comparing to that of 63.9% by Sucrose ester SP70. From the graphs it was observed that RSR values were going down during the last 60 minutes of the incubation in the breads with inulin and sucrose ester. The reason might be due to the above variability's and also when looked at carefully after 160 min sampling time, in most of the samples there did not appear to be statistically differences between the samples. This will show a slowing down of starch digestion over incubation time, which would be expected.

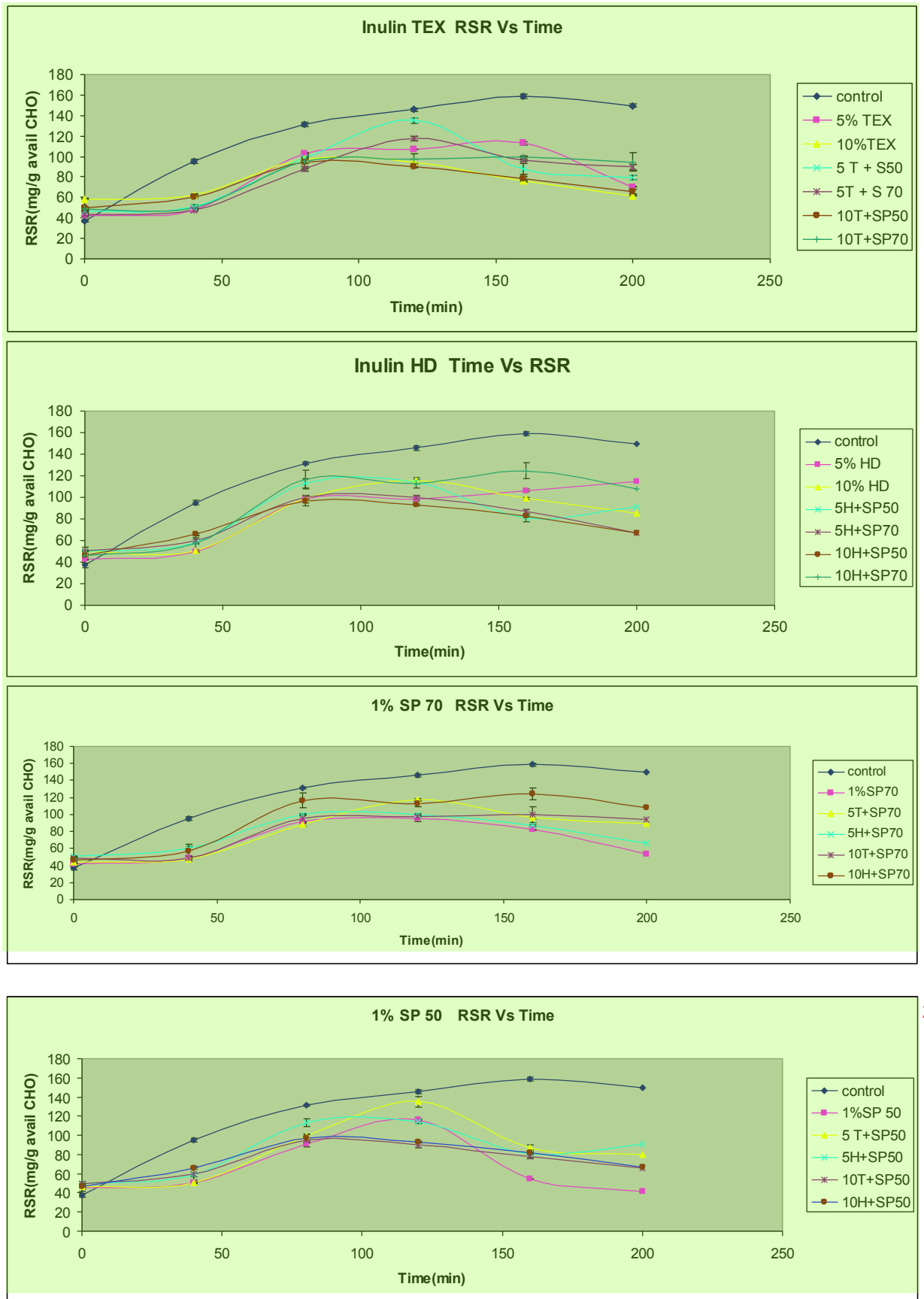


Fig 1: a) Inulin TEX breads, b) Inulin HD breads, c) SP 50 breads, d) SP 70 breads

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Sensory evaluation of different levels of roasting of New Zealand grown hazelnuts¹

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ABSTRACT³

Hazelnuts (*Corylus avellana* L.) are a very recent addition to commercial horticulture in New Zealand and Whiteheart has been selected as the primary commercial cultivar. No published information is available on the optimum temperatures needed to roast the dried nuts. An experiment was designed to investigate three different roasting treatments, blanching, light roast and full roast using a conveyer type roasting oven set at 200°C. The roasted samples were then analysed for proximate contents and evaluated using a taste panel. The appearance, texture, flavour and overall appearance was evaluated by 63 tasters at one time. The blanched nut was appreciated for its colour but it was considered too chewy and bland in taste compared to the roasted nuts. Each one of the heat treatments gave an improved rating for all of the attributes measured. Roasting in the oven set at 200°C for 6 minutes (full roast) was the treatment appreciated most by all tasters. Analysis of the correlation coefficients showed that the overriding impression about the hazelnuts comes from the flavour of the nut followed by its texture. The overall appearance of the nut was not highly rated by the tasters once the hazelnuts had been heat treated.

INTRODUCTION⁵

Hazelnuts (*Corylus avellana* L.) are widely used as a luxury food especially when incorporated into chocolate confectionary and muesli products. The taste and flavour of hazelnuts is due to the occurrence of several compounds whose presence affects both quality and nutritional value. However, the beneficial characteristics of hazelnuts and hazelnut oil should not be overlooked.

Hazelnuts are a very recent addition to commercial horticulture in New Zealand. Many blocks of trees have been planted in the last 10 years and crops of more than 40 tonnes/annum have been projected for the Canterbury region when the planted crop reaches full production. The aim of this work is to discover the form in which hazelnuts are most preferred to be eaten. This research is concerned with evaluating various levels of roasting of hazelnuts from no roasting to well roasted.

There appears to be no published papers on the sensory evaluation of the different levels of roasting of hazelnuts. In the paper "New hazelnuts selections for direct consumption" Valentini *et al.*, (2001), different hybrids were compared to find the most favoured raw nuts and the most favoured roasted nuts. They were rated on degree of liking alone. In another study McNeil *et al.*, (1994), compared consumer preferences of 22 walnut cultivars. These were compared for taste, aftertaste, flavour strength and sweetness. In a study by Zeppa *et al.*, (2000) Italian and foreign cultivars of hazelnuts were compared by morphological and sensory analysis. Using a taste panel the Lansing 35 selection gave the best results for the fresh hazelnut but Tonda Geentil delle Langhe gave the best overall result for the roasted kernel. The intensity of its sweetness and overall intensity of aroma was the best features of Tonda Geentil identified in the taste test. Sinesio and Moneta (1997) carried out a sensory evaluation of walnuts by geographical region. The seven trained and experienced panellists assessed the nuts for external appearance, taste and flavour and oral texture. Only one study involved roasted hazelnuts and this did not compare levels of roasting. There is also a need to evaluate the New Zealand variety Whiteheart as it is a recent selection.

METHODS⁹

Treatments¹⁰

Twenty kg of hazelnuts (*Corylus avellana* L. cv Whiteheart) were harvested from a Canterbury orchard in June 2001. The nuts were dried and stored in their shell at ambient temperatures until the experiment commenced. The kernels were removed from their shells in April 2002 using a Kempe Cracker and the kernels were stored in a sealed plastic bag in a fridge at 4°C until roasting commenced in June 2002.

Some initial experiments took place to identify the temperature/time characteristics of an electric high-intensity infrared conveyer oven (Lincoln Impinger 1300, Fort Wayne, Indiana, USA). In the final experiment the oven was set at 200°C and the degree of roasting was determined by the speed

of the conveyer. 200°C was chosen because temperatures in excess of this scorched the outside of the nuts. Three speed settings were chosen to correspond to the three levels of required roasting:

Blanch – conveyer set to 1.75 min setting
Light roast – conveyer set to 5 min setting
Full roast – conveyer set to 6 min setting

The nuts were roasted the day before the sensory evaluation took place and the roasted nuts were put in sealed containers and stored overnight at 4°C. The kernels were placed in an oven for 16 hours at 105°C to determine their dry matter content (AOAC, 2002).

Taste tests

A sensory evaluation environment was set up with white booths and four small plastic containers to hold each of the four test samples (raw hazelnuts compared with the three levels of roasting) and a glass of water. The containers contained five nuts per cup. The samples were evaluated from left to right and the order was randomised in each booth. The tasters were invited to eat as many nuts as they wished from each treatment then to fill in the evaluation of that nut before moving to the next sample.

The first part of the questionnaire contained questions on factors, which were identified as potentially having an effect on each tasters decision-taking. The factors collected were gender, age, smoker/non-smoker, coffee and tea intake, nationality and previous hazelnut eating experience. For the tasting section a response on a 9-point Hedonic scale was requested (ranging from like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much, dislike extremely). This scale was applied to the four nut attributes, namely appearance, texture, flavour and overall impression. The tasters were simply required to tick the appropriate box. The nuts were sampled in a random order and the volunteers were given no information about the samples. The tasters were also encouraged to record their written comments about attribute for each of the treatments. A summary of these comments is shown in Table 2.

Statistical analysis

Demographic information of each of the 63 tasters and their responses for each attribute on the raw and three roasting treatments were recorded and the data from the taste tests were analysed using the GLM procedure (analysis of variance) in SAS V8.2 to determine differences between each treatment. The taster was included as a blocking factor. The factor was not significant for all but the texture result. The Bonferroni (Dunn) t-test at $\alpha = 0.05$ was used to calculate the LSD.

RESULTS AND DISCUSSION

The 1.75 min conveyer setting supplied just enough heat to allow the pellicle to be removed from the raw hazelnuts. A 5 minute conveyer setting changed the nuts to a light brown colour and produced a crisper texture in the nuts. Six minutes of cooking caused the nuts to brown further; cooking beyond 6 minutes caused the hazelnuts to begin to burn. The moisture level of the raw nuts was 4.5% and after roasting for 6 minutes the level dropped to 1.5%.

Table 1: Taste test values for each attribute at each level of roasting, (mean \pm S.E.),

| Treatment | Appearance | Texture | Flavour | Overall impression |
|-----------------|-------------------|-------------------|-------------------|--------------------|
| Raw | 6.0 b \pm 0.21 | 5.4 c \pm 0.22 | 5.8 c \pm 0.26 | 5.7 c \pm 0.24 |
| Blanch | 6.1 b \pm 0.19 | 6.4 b \pm 0.18 | 6.2 bc \pm 0.22 | 6.3 bc \pm 0.18 |
| Roast 5 minutes | 6.5 ab \pm 0.18 | 7.0 ab \pm 0.15 | 6.7 ab \pm 0.18 | 6.6 ab \pm 0.18 |
| Roast 6 minutes | 6.9 a \pm 0.20 | 7.5 a \pm 0.14 | 7.1 a \pm 0.23 | 7.2 a \pm 0.20 |
| p = | 0.005 | <0.001 | 0.001 | <0.0001 |

Different letters within each attribute indicate significant differences between treatments (Bonferroni t-test at $\alpha = 0.05$).

The results in this table show a remarkably consistent pattern. Without exception, as the treatment level increased so did the score for each of the four attributes. All but five of the 63 tasters made some comments about the nuts on their evaluation sheets and these are summarised in Table 2.

The numbers in the table relate to the number of tasters who made that comment. Again, the comments give a clear picture. They also give a rationale for the consumer preferences. A raw hazelnut is generally not liked as much as a roasted hazelnut. This is in spite of a majority of the tasters liking the appearance of the skin. A common comment was the bitterness of the skin and the difficulty in chewing it.

The blanched nut was appreciated for its white colour but was considered too chewy and bland. These factors led to a low overall impression of the blanched nuts. The light roast and the full roast nuts received similar comments. The full 6-minute roasted nuts were more appreciated for each attribute except for its overall impression. It is unclear why more tasters commented positively on the light roast than the full roast in this category, though many of those who did comment on the full roast said they were the best tasting nuts. Both treatments of the nuts were considered to have a good appearance, a number of tasters commenting that this was how a hazelnut should look. A few tasters felt the nuts looked burnt. Many tasters commented on how they liked the crunchy texture. Comments supported the tasters liking for the flavour of the roasted nuts. There was a particularly strong response for the flavour of the full roast nuts. Though the majority wrote comments on just a few categories, more than 50% felt strongly enough to comment on the good flavour of the full roast nuts. An unavoidable complication of the tasting session was that some individual nuts were rancid and these could not be identified before the tasting session commenced. The negative feedback from a few of the tasters regarding flavour of some of the nuts was almost certainly due to this occurrence. It should be noted that the occurrence of individual rancid nuts would be expected to occur in equal numbers across the raw and three roasting methods.

Table 2: Summary of the main comments made by the tasters.

| Appearance | Raw | Blanched | Light roast | Full roast |
|-----------------------|---------|--------------------|-----------------|-------------------------------------|
| Liked the colour | 12 | 10 | 11 | 13 |
| Don't like the colour | 9 | 6 | 4 | 4 |
| Texture | | | | |
| Crunchy and crisp | 0 | 4 | 22 | 25 |
| Chewy/stuck in teeth | 29 | 8 | 0 | 0 |
| Dry | 0 | 2 | 2 | 0 |
| Oily | 0 | 1 | 1 | 1 |
| Smooth | 0 | 3 | 4 | 0 |
| Flavour | | | | |
| Nice strong flavour | 5 | 10 | 17 | 32 |
| No flavour | 9 | 9 | 1 | 1 |
| Bad flavour/bitter | 11 | 3 | 6 | 4 |
| Raw | 0 | 3 | 0 | 0 |
| Overall | | | | |
| Best | 0 | 1 | 4 | 6 |
| Good | 1 | 0 | 13 | 8 |
| OK | 0 | 5 | 0 | 2 |
| Bad | 15 | 6 | 2 | 3 |
| Taste resembled: | peanuts | peanuts walnuts | almonds eggs | hazelnuts cashews (2) peanuts |

CONCLUSIONS¹

The Whiteheart cultivar of hazelnuts has been selected to be the main commercial cultivar in New Zealand. This experiment showed that the blanched nut was appreciated for its colour but it was considered too be chewy and bland in taste compared to the roasted nuts. Each heat treatment received an improved rating for all of the attributes measured. Roasting in the oven set at 200°C for 6 minutes (full roast) was the most appreciated treatment by all of the tasters. Analysis of the correlation coefficients showed that the overriding impression of the hazelnuts comes from the flavour of the nut followed by its texture. The overall appearance of the nut was not highly rated by the tasters once the hazelnuts had been heat treated.

ACKNOWLEDGEMENTS³

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A comparison between capillary blood sampling and the Minimed® Continuous Glucose Monitoring System Gold™ for determining the blood glucose response of foods ¹

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ABSTRACT ⁴

The aim of the study was assess the Minimed Continuous Glucose Monitoring® System Gold™ as a possible alternative method to capillary blood sampling for determining blood glucose response to foods. Eight individuals without diabetes took part in the study. The Glycaemic Glucose Equivalents (GGE) for eight foods were determined by capillary and CGMS® blood sampling methods. The GGE was determined as the incremental area under the curve for two hours after consumption of the food compared to the incremental area under the curve for a 25 g glucose reference drink. The only GGE found to be significantly different by the CGMS® and capillary blood sampling methods was the mixed grain bread, with a GGE of 17.2 by the capillary method and a GGE of 7.8 by the CGMS® method. Individuals were ranked differently by the CGMS® and capillary method for three of the eight foods. Additionally, there was significantly more variability in the ranking of foods for the eight individuals when the GGE of the food was ranked by the CGMS® than capillary blood sampling method. This study suggests that, at this stage, the CGMS® shows too much variability to replace capillary blood sampling as a method of determining blood glucose response of foods in normal individuals. ⁵

INTRODUCTION ⁶

The ability of foods to raise blood glucose levels in individuals is estimated by measuring individuals' blood glucose responses to consumption of a food from fasting for 2-3 hours. Glycaemic Glucose Equivalents (GGE) represents a food's effect on blood glucose in terms of the weight of glucose an individual would need to eat to produce the same effect as the food (Monro, 2002). Blood samples are often collected using capillary blood sampling. Capillary blood sampling results in a large number of finger pricks to participants over a short period of time (eight in two hours) and can therefore be painful. The method also limits the length of time foods can be followed and makes it difficult to study the blood glucose profile of food and meals over the whole day. ⁷

An alternative to capillary blood sampling for determining the blood glucose response of foods may be the Minimed® Continuous Glucose Monitoring® System Gold™ (CGMS®). This monitors glucose values in the interstitial tissue fluid. The monitor records an average glucose value every five minutes. The CGMS® has been used in a number of clinical trials and the correlation between blood glucose measurement and the CGMS® has been reported to be high (0.8-0.9) (Gross & Mastrototaro, 2000). However, when glucose values are changing rapidly, there may be a lag between blood and interstitial fluid measurements (Rebrin *et al.*, 1999). Since measurements of blood glucose response to foods are based on the area under the curve of blood glucose response following consumption of a food, a lag may not affect the overall area under the curve, but could affect the timing of the response. ⁸

The present study examined whether capillary and CGMS® methods estimated the same GGE values for foods with a range of GGE values. If the CGMS® could be used to determine the blood glucose response of foods, it would replace the need for continual blood sampling. ⁹

MATERIALS AND METHODS¹

Eight individuals, five males and three females without diabetes, took part in this study. The average age (\pm s.d.) of participants was 42.8 ± 18.7 years; their average BMI was 25.8 ± 6.3 kg/m²; and the average fasting capillary glucose was 4.9 ± 0.4 mmol/L. This study was approved by the Canterbury Ethical Committee and all participants gave their informed consent.

Participants came into the Lipid and Diabetes Research Centre late one afternoon in order to have the Minimed® CGMS® fitted. The CGMS® monitor was fitted on the back of each participants hip area. The CGMS® was worn for up to 72 hours continuously. After wearing the CGMS® for one hour, participants carried out a self-monitoring blood glucose test (SMBG, similar to the capillary test) and entered this value into the CGMS®. The participant carried out this procedure again three times before midnight.

The following morning, participants came into the clinic after fasting and remained there for about three hours. Capillary blood samples were taken using a lancet. A drop of blood was collected in a HemoCue® cuvette and blood concentration measured using a HemoCue® Glucose 201 Analyzer (Helsingborg, Sweden). Two fasting blood glucose concentrations were taken, then the participant consumed a test food within fifteen minutes, and further blood samples were taken at 15, 30, 45, 60, 90 and 120 minutes after the participant had begun eating. If the blood glucose concentration had not returned to within 0.2 mmol/L of the baseline concentration at 120 minutes, further blood samples were taken at 150 and 180 minutes. Self-monitoring blood glucoses were also taken at 0, 30 and 120 minutes and entered into the CGMS®.

At the end of the morning, participants left the clinic to continue their normal activities but continued to wear the CGMS®. This procedure was then repeated on the following two days. While individuals were away from the clinic they carried out two further SMBG measurements. At the end of the third day the CGMS® was removed.

The effect of consuming four 25 g reference drinks and eight foods was investigated over a 4-5 week period. In each week, two foods (Table 1) and a 25 g glucose reference were measured in random order. The incremental area under the blood glucose response curve (AUC) for both capillary and CGMS® blood sampling methods was calculated geometrically to 180 minutes (Wolever & Jenkins, 1986). Areas where the curve dropped below baseline were excluded. For the CGMS®, the blood glucose levels were measured every five minutes up to a maximum of 180 minutes. Using the capillary sampling method, measurements were available at 0, 15, 30, 45, 60, 90, 120, 150 and 180 minutes.

The GGE of the test food was calculated as GGE/portion size by dividing the $AUC_{\text{test food}}$ by the $AUC_{\text{average glucose}}$ and multiplying the result by 25 g (glucose concentration of reference). The average GGE/serve for each food was taken as the average of the eight individuals. The average GGE values were compared using paired t-tests. The rankings of the foods for each method were compared using the non-parametric Wilcoxon matched-pairs signed-rank test.

RESULTS⁸

Table 1 shows the GGE values measured by capillary and CGMS® blood sampling methods for the various foods, as well as the mean difference in values between the two methods. Differences between the CGMS® and capillary methods ranged from an overestimation of 6.3 g by the CGMS® method compared to capillary method to an underestimation by the CGMS® method of 9.4 g. The mean differences between the two methods were not consistently overestimated or underestimated. The Pita bread, crackers, yoghurt and pear halves were all overestimated by the CGMS® methods compared to the capillary method whereas the mixed grain bread, breakfast bar, sweet bar and sweet breakfast cereal were all underestimated by the CGMS® method compared to capillary blood sampling. The mixed grain bread was the only food to show a significant difference in GGE values between capillary and CGMS® sampling methods, with a difference of 9.4 g between the two methods.

Table 1. GGE values for eight foods measured by capillary blood sampling and the CGMS® system.

| Food | Capillary GGE/serve (sd) (g) | CGMS® GGE/serve (g) | Mean difference in GGEs (Capillary – CGMS®) |
|------------------------------------|---------------------------------|------------------------|---|
| Bar, sweet (50g) | 18.0 (8.8) | 12.8 (7.2) | 5.1 |
| Bar, breakfast (50g) | 21.2 (8.6) | 16.0 (10.5) | 5.2 |
| Bread, mixed grain, heavy (90g) | 17.2 (3.1) | 7.8 (8.2) | 9.4 * |
| Bread, pita, white (90g) | 19.2 (11.5) | 22.4 (20.1) | -3.2 |
| Breakfast cereal, sweet (40g) | 24.3 (9.2) | 16.0 (9.2) | 8.3 |
| Crackers, plain (25g) | 10.4 (3.1) | 16.7 (10.4) | -6.3 |
| Pear halves, canned (192g) | 6.8 (4.8) | 8.5 (8.4) | -1.7 |
| Yoghurt, fruit (125g) | 5.5 (1.8) | 9.4 (6.2) | -3.9 |

* significant difference between capillary and CGMS®, $p = 0.01$

For each individual the GGE's for each of the eight foods were ranked from the highest to lowest GGE, for both capillary and CGMS® sampling methods. Three of the eight foods were ranked significantly differently by the CGMS® than by the capillary method. The standard deviations of the rankings were larger for the CGMS® than the capillary method ($p=0.01$), meaning that there was less consistency in the rankings for individuals using the CGMS® method.

DISCUSSION

This study investigated whether it was possible to use CGMS® as a method to determine the blood glucose response to foods rather than capillary blood sampling. Currently capillary blood sampling is accepted as the preferred method for determining the blood glucose response of foods. This study indicated that the CGMS® was a more variable measure of blood glucose response to foods. A possible reason why similar GGE values were not seen for the foods may be because the calculation of blood glucose values by the CGMS® relies on a retrospective calibration approach whereby, when a self-monitoring blood glucose value is entered into the CGMS®, the programme software uses the value to retrospectively determine linear calibration constants, which are then used to generate sensor glucose values (Mastrototaro, 2000). The problem with this approach is that it means blood glucose values are not based on real time monitoring. The person's blood glucose in the previous 12 hours and the accuracy between the CGMS® and the self-monitoring blood glucose will all affect the calculation of the blood glucoses in the period the study was interested in – the two hours after the food was eaten. Given that the study measured the area under the blood glucose response curve, not the actual blood glucose values, a system where blood glucose values were not adjusted retrospectively may work better. Additionally, the manufacturers state that for optimal efficacy, there needs to be a range in blood glucose values during a 24 hour period of greater than 5.6 mmol/L (MiniMed 2004). In normal individuals, because their glucose control is well regulated, it can be difficult to achieve these differences. In this study, measurements were taken both when participants were fasting and half an hour after meals but often differences in blood glucose levels of 5.6 mmol/L were not achieved.

There are other techniques being developed using the principle of continuous glucose monitoring that may have more accuracy than the CGMS®, such as techniques based on near infra-red spectroscopy. Being able to continuously monitor blood glucose response levels would be useful for determining blood glucose response for foods, and may help to reduce the variability in these measurements as well as make studies of foods over longer periods of time and in the context of meals and at other time periods of the day easier to conduct.

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2

Impact of gut microflora on the bioavailability of soy isoflavones¹

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ABSTRACT³

Soy is increasingly used as a food ingredient. In an average New Zealand diet, bread, beer and processed meats are major contributors to soy intake. Soy consumption is promoted for a number of claimed health benefits including reducing the risk of heart disease and some cancers (breast, prostate and lung), and providing relief from menopausal symptoms. The functionality of soy foods for disease prevention and health benefits is dependent upon *in vivo* bioavailability of the active estrogenic compounds – including the isoflavones genistein and daidzein. It is established that the gut microflora has a role in isoflavone metabolism that can influence bioavailability. This study investigates the nature and extent of the microbial metabolism of isoflavones by faecal microflora from New Zealanders of European origin. The rates of isoflavone degradation by human faecal microflora exposed to daidzein and genistein, both alone and in combination, were studied by high performance liquid chromatography. The degradation rate was variable and unpredictable both within (over 15 weeks) and between individuals (5 subjects). Given the available data, end point health effects associated with the functionality of soy foods are currently unpredictable.

INTRODUCTION⁵

Soy is associated with a range of positive health effects, namely stimulation of the immune system, prevention of bone loss and higher bone mineral density, reduced risk of heart disease, relief from menopausal symptoms and protection from certain cancers (breast, prostate and lung) (COT, 2003). Selected health claims for soy may now be legally promoted in the USA (Harland, 2002), increasing soy as a target ingredient for functional foods (Squires, 2005). Key bioactives in soy are the isoflavones genistein and daidzein that mimic the female hormone estrogen. A food can only be functional if the bioactive constituents reach the target cell at an effective dose and our studies of dietary exposure to genistein and daidzein show that serum levels are only 0.5 to 1% of the amount ingested (Thomson, 2005, Thomson, Cressey and Shaw, 2003). The gut microflora has been implicated as having a role in the bioavailability of isoflavones from soy containing foods (Hendrich et al., 1998, Rowland et al, 1999, Lampe et al 1998, Turner et al, 2003). This paper reports on studies of the degradation of isoflavones by human faecal microflora as a possible explanation for the low levels in serum compared with intake, and to better understand the role of gut microflora on the bioavailability of soy isoflavones.

MATERIALS and METHODS⁷

*Chemicals and media*⁸

Genistein ($\geq 98\%$ pure) and daidzein ($\geq 98\%$ pure) were purchased from Sigma (St Louis, MO). Stock solutions were prepared in HPLC grade methanol at concentrations of 1.49 mmol/L and 1.34 mmol/L respectively following the method of Klump et al (2001). Standards were made for each isoflavone to produce a concentration series from 7 to 120 $\mu\text{mol/L}$. Brain Heart Infusion (BHI) Broth (Difco) was prepared according to the manufacturer's instructions with water treated by the ElixTM system (Millipore, Molsheim, France).

*Subjects*¹⁰

All subjects were voluntary, healthy New Zealand residents who gave their informed consent. The main subject who participated in all experiments was a European New Zealand female (referred to as Subject A), 47 y of age with a Body-Mass Index (BMI) of 25 kg/m^2 . Other subjects who participated in parts of the study were all European New Zealanders, 1 female (Subject B) and 3 males (C-E), between 31-50 y of age. Four of the participants followed an average omnivorous Western diet with no

intentional soy food consumption, the other participant was a vegetarian male who occasionally consumed soy products (Subject E).

Collection, preparation, incubation and sampling of faeces/isoflavone solutions

Fresh, aseptically collected faecal samples were processed within 3 hours. A 5% faecal slurry was made in a whirlpak bag with BHI broth as the diluent, homogenised in a Bagmixer® (Interscience, St Nom, France) for 30 s, and centrifuged at 1660 x g for 2 min. Four ml aliquots of faecal slurry supernatant were pipetted into sterile tubes containing the appropriate isoflavone preparation. To account for inter-individual variation (all 5 subjects), three series of tubes were prepared containing 59.8 µmol/L genistein, 64.5 µmol/L daidzein, or a mixture of both at a concentration of 124.3 µmol/L total isoflavones. A separate incubation tube was removed at each of 4 sampling times over 72 h. Controls consisted of tubes containing mixed isoflavones in BHI broth (no inoculum). All tubes were incubated at 37°C with anaerobic sachets (Oxoid AnaeroGen™) to create microaerophilic conditions. To assess intra-individual variation with time, the results over 15 weeks from several repetitions of the experiment on Subject A were compared.

Isolation and preparation of isoflavones

Isolation of isoflavones was modelled on the method of Xu et al (1995). Samples were quickly vortex mixed and 1 ml passed very slowly through a Maxi-Clean (Alltech, Deerfield, IL) C18 cartridge (300 mg, 50 µm particle size, 6 nm pore size), pre-wetted with 1 ml 100% methanol, followed by 2x2 ml water. The isoflavones were eluted with 2 ml 80% methanol, reduced in volume by rotary evaporation and made up to 2 ml in volumetric tubes, with 80% methanol, for analysis by HPLC.

HPLC protocol

HPLC analysis was performed on a Waters WISP 712 coupled with a Waters 600 multisolvent delivery system and Waters Lambda-Max 481 spectrophotometer. Separation was achieved on a Spheri-5 MPLC ODS (Brownlee; Applied Biosystems, Melbourne, Australia) C-18 column (4.6 x 220 mm, 5 µm particle size) protected by a RP-18 ODS NewGuard (PerkinElmer, Melbourne, Australia) prefilter column. Methanol/water was used as the mobile phase, employing a gradient of 40% to 65% methanol over 30 min at a flow rate of 1 ml/min. Detection was by UV absorbance at 260 nm. Isoflavone standards used for each HPLC run had mixed genistein and daidzein at final concentrations of 29.9 µmol/L and 32.3 µmol/L respectively.

Quality control

Reproducibility of the incubations was assessed from triplicate incubations of one faecal supernatant from Subject A for the three isoflavone conditions (each alone and mixed), and sampled over 72 h. Efficiency of the Maxi-Clean cartridge extraction method was determined for genistein and daidzein solutions at (59.8 and 64.5 µmol/L respectively).

RESULTS

The mean extraction recovery was 67% ± 12 (1 SD) and 64% ± 13 for genistein (n = 34) and daidzein (n = 31), respectively. Losses were not accounted for by the water rinses or 80% methanol elution and therefore most likely to be associated with lack of, or irreversible, absorption onto the cartridge. The HPLC response to the standards of genistein and daidzein was linear ($R^2=1.00$) over the concentration range analysed (0-128 µmol/l).

The reproducibility of degradative characteristics of triplicate faecal samples is shown in Figure 1. Whilst two of the replicates were similar, the third replicate was different, with variability ascribed to a combination of analytical and microbiological components. The negative degradation for daidzein (in combination with genistein) is indicative of analytical variability in the order of ±15% since the isoflavones cannot be synthesized by the microbes. The greater variability observed for 72 compared with 24 hours of incubation suggests a microbial component to the variability since more replications give a greater chance for microbial sub-populations to emerge. The limited reproducibility at longer incubation times means that differences observed in subsequent studies are preliminary only.

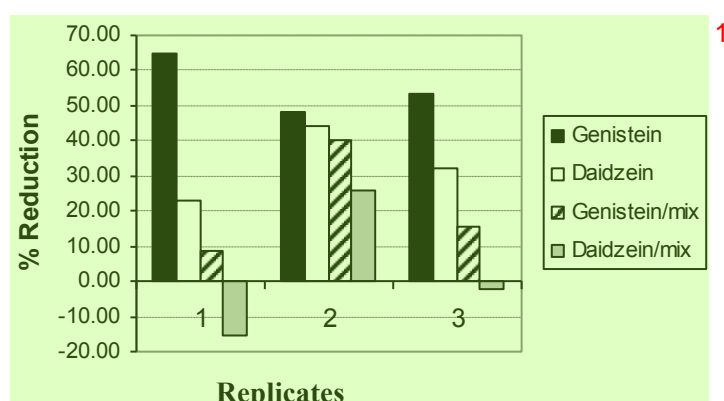


Figure 1: Reproducibility of degradation of isoflavones relative to time 0 for three replicates of a faecal sample incubated up to 72 hours. Genistein 59.8, daidzein 64.5 and total mixed isoflavones at 124.3 $\mu\text{mol/L}$.

Intra-individual variation

In four out of five faecal samples taken over a 15 week period, the gut microflora in the faeces of Subject A showed ability to degrade the isoflavones (Figure 2) although the extent of degradation was variable. Little (within error) or no degradation of any isoflavone combination was observed at week 7, in contrast to week 14 where the isoflavones were almost completely degraded. The week 14 incubations differed in that initial concentrations of the individual isoflavones equaled 30 $\mu\text{mol/L}$ (total of 60 $\mu\text{mol/L}$ in mixtures) – half the concentration of the other trials. For the remaining three trials, microflora from Subject A consistently degraded genistein alone within 30 h, but showed variable degradation ability for daidzein alone (30 and 90% where the experiment was allowed to run for 72 h, degradation had not occurred after 28 h). When present in an isoflavone mixture, little to no degradation of daidzein was seen, and degradation of genistein was up to 65% only where the experiment was allowed to run to 72h.

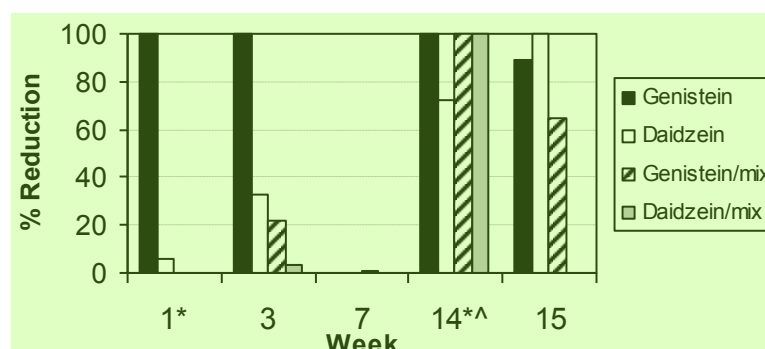


Figure 2: Total percentage change in concentration of isoflavones relative to time 0 h due to degradation by faecal microflora from Subject A in 5 experiments over 15 weeks. 'Mix' indicates where daidzein and genistein were present in combination. In all cases the initial concentration of isoflavone was 60 $\mu\text{mol/L}$ (total 120 $\mu\text{mol/L}$ when mixed), and experiments were concluded at 72 h. Exceptions are denoted with an (*) where the experiment was concluded at 28 h, and (^) where the starting concentration was 30 $\mu\text{mol/L}$ (60 $\mu\text{mol/L}$ mixed).

Inter-individual variation ¹

The results in Figure 3 show the change in isoflavone concentration relative to time 0 h for the 5 NZ European subjects. The experiment was concluded at 30 h (genistein), and 72 h for daidzein, genistein/mix (in combination with daidzein) and daidzein/mix (in combination with genistein), except where 100% degradation was detected beforehand. The results demonstrate both the ability for each individual's faecal microflora to degrade isoflavones, and differences between individuals in the extent of degradation for faecal samples collected at one time point. Other than Subject A, who showed no isoflavone degradation ability in this trial, all subjects completely metabolised genistein within 24 h and daidzein to variable extents (100% detected at 36 h and 60 h for Subjects B and D respectively). In the mixtures, significant degradation of genistein was only observed in Subject C, and no daidzein metabolism was detected in the microflora of any participant.

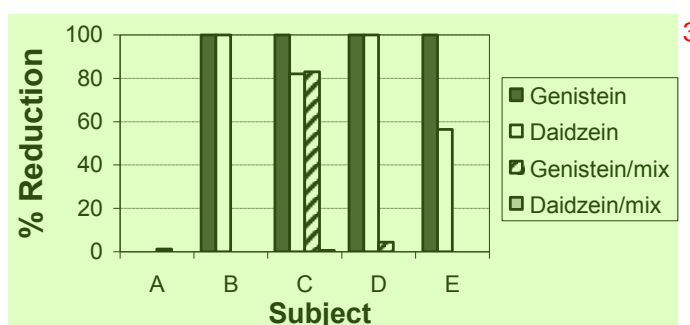


Figure 3: Percentage change in concentration of isoflavones relative to time 0 after 30 h (genistein) or 72 h (daidzein and mixtures) due to degradation by faecal microflora from 5 NZ European subjects. Genistein 59.8, daidzein 64.5 and total mixed isoflavones at 124.3 $\mu\text{mol/l}$.

DISCUSSION ⁵

Ideally, microflora would be obtained from the small intestine where the majority of absorption is likely to occur (Turner et al, 2003) but the use of faecal material as a source of gut microflora is a pragmatic approach increasingly being used (Xu et al, 1995, Setchell et al, 1984, Zhang et al, 1999, Zheng et al., 2003, 2004, Wiseman et al, 2004, Simons et al., 2005). Faecal incubations for Subject A demonstrated considerable variability in gut microfloral degradation activity when sampled 5 times over 3 months, despite no intentional soy consumption or antibiotic use during this time. This variability within an individual, also observed for one of the other European New Zealand subjects, is at variance with the "stable-microflora metabolism" opinion of others (Hendrich et al, 1998, Zheng et al, 2003, Wiseman et al. 2004). Although preliminary, there is no evidence that the methodology failed as simultaneous incubations for other subjects showed degradation. No other investigators have reported more than duplicate studies for an individual. The intra- and inter individual variability observed means that the bioavailable dose of isoflavones, hence, health outcome, is highly likely to be variable and at this time, unpredictable. These findings have important implications for the promotion and prescription of soy foods and supplements for disease prevention and health benefits. How can the consumer be assured that what they are consuming will provide a functional dose?

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The implication of fenugreek incorporation into foods on the potential glycaemic response of fenugreek fortified breads.

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ABSTRACT

Fenugreek seeds were ground to a fine flour and incorporated into a bread dough mixture at three different levels. Assessments were conducted upon the effect of the incorporation of the fenugreek flour on loaf volume and also the starch digestibility of the breads, following an in vitro analysis of starch degradation. Although the fenugreek material had a negative aspect on the volume of the bread, the amount of starch degradation observed in the fenugreek enriched breads was lower than that observed in the control white bread. This indicated that the addition of fenugreek material had a potential to retard the rate and extent of starch digestion, and hence the potential to affect the glycaemic response to the ingestion of fenugreek enriched breads.

INTRODUCTION

The role of dietary fibre in the attenuation of glycaemic response of individuals is well documented and the efficacy of dietary fibre appears to be dose related. The term dietary fibre refers to the collection of ingredients which are of plant origin and which resist degradation by human enzymes during digestion. Thus they appear as having zero (or very little) calorie value in foods, and have the additional beneficial role in passing through the digestive tract to act as sources of fermentation for gut microflora (Brennan 2005).

A tremendous amount of research has been conducted on the use of non-starch polysaccharides such as guar gums (a galactomannan based polysaccharide) in reducing the amount and rate of starch degradation (Brennan *et al* 1993, 1996) and the incorporation of similar non starch polysaccharides in model food systems (Tudorica *et al* 2002). Thus, of interest to today's food industry is the possibility of utilising novel plant based ingredients to manipulate food structure, texture and human nutrition.

In recent years attention has focussed on a range of novel dietary fibres, one of these is the polysaccharide fraction obtained from the seeds of the fenugreek plant (genus *Trigonella*). This polysaccharide is similar to guar gum in that it is a highly viscous material which can be used in the food industry as a thickener and stabiliser (Brummer *et al.*, 2003). The seeds of the fenugreek plant have been regarded as having anti-diabetic properties (Sharma *et al.*, 1986, 1990; Sowmya and Rajyalakshmi, 1999). One of the mechanisms by which such a modulation in glycaemic response is achieved could be by the alteration of the viscosity of digested foods and potential subsequent impairment of nutrient availability (Bowling *et al.*, 1981). Another possible mechanism is that the polysaccharide can affect effective starch degradation time by restriction of starch accessibility to starch degrading enzymes, and the reduction of starch gelatinisation events.

The current study looked at the utilisation of commercially available sources of ground fenugreek seeds in a bread product and the effect of fenugreek additions on both loaf characteristics and the amount of reducing sugars released from the products.

MATERIALS AND METHODS

High-grade wheat flour (Champion brand, approximate composition being 76.8 g carbohydrate, 1 g sugar, and 3.5 g dietary fibre) was purchased from local supermarket. Fenugreek seeds were purchased from supermarket and were ground using a hammer mill to pass through 300µm sieve mesh. The fenugreek flour was stored in an airtight container until used.

Bread making method: straight dough method

Bread loaves were made to a standard recipe (flour-250g, water-137.5g, yeast-8.33g, sugar-8.33g, salt-4.16g, canola oil-8.33g). Ground fenugreek material was added to the standard recipe at 10, 15 and 20% levels (based on dry ingredient weight). The ingredients were mixed in a commercial food processor (Kenwood- USA) and the dough left to rise at 30°C for 45 mins. Subsequently 75g portions of the dough were shaped into test-bread moulds, rested for 30 mins at 30°C and then baked in an fan oven at 180°C for 20 mins. The bread loaves were then removed from the pans, and cooled for 60 mins prior to analysis.

Loaf height and volume

Loaf height was determined using calibrated callipers and reported in centimetres. Measurements were taken from the centre of each loaf. Loaf volume was measured using AACC Approved method 10-05, volume by rapeseed displacement (AACC 2000). Eight (8) loaf samples were tested and calculated as mean \pm SD (n = 8).

Chemical composition of the loaves¹

Moisture contents of the loaves were calculated by standard AACC methodology (AACC² 2000). Total starch analyses of bread samples was conducted by Amyloglucosidase/ α -amylase method (AOAC method- 996.11, AACC method- 76.13). Protein analysis was conducted by the Dumas method (Leco model FB-428) and expressed using the conversion factor ($N \times 5.7$).

In vitro Starch Digestion³

A modified multi-enzymatic method of Brighenti *et al* (1995) was used involving mixing of⁴ bread samples with proteolytic and amylolytic enzymes. Reducing sugar release (RSR) was estimated by 3, 5- Dinitrosalicylic acid method (DNS) at 546 nm as described in Tudorica *et al* 2002.

Statistical analysis⁵

The data collected from all experiments were calculated as mean \pm S.D and all determinations⁶ were made at least in triplicate. Analyses of variance of the results (ANOVA) were performed using the Minitab 14 statistical software package. Significance was defined as $p < 0.05$.

RESULTS⁷

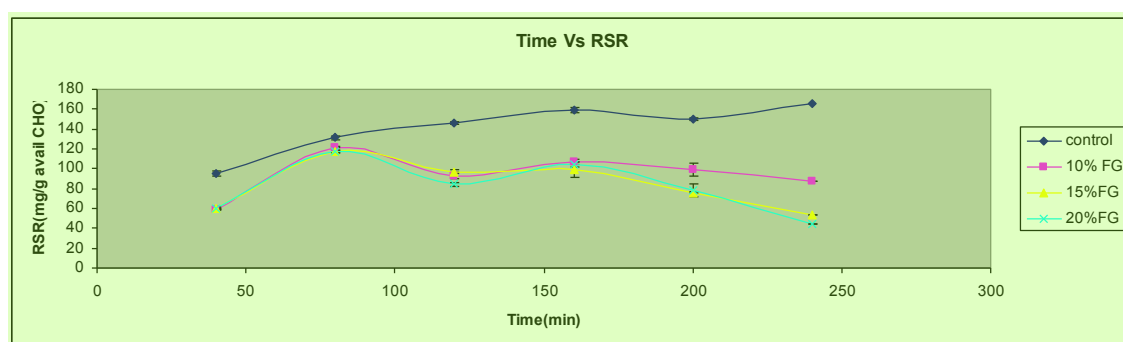
The addition of fenugreek to the control bread had a significant impact on loaf volume and⁸ also loaf height. Higher levels of fenugreek flour addition resulted in greater reductions in both of these parameters (Table 1). Such a reduction in loaf volume and height could be related to the incorporation of galactomannans (from the fenugreek material) and the thickening action associated with galactomannans in carbohydrate based systems. The formation of such a gel-like network would impede the carbohydrate – gluten network developed in breads during mixing and fermentation, thus leading to a less elastic network.

Table 1 Effect of fenugreek addition on loaf volume⁹

| Sample | Loaf volume (ml) | Loaf height (cm) |
|-----------------------------|-----------------------------|------------------------------|
| Control | 345 \pm 6.63 ^a | 8.65 \pm 0.13 ^a |
| 10% fenugreek (FG) addition | 307 \pm 4.02 ^b | 7.70 \pm 0.11 ^b |
| 15% fenugreek (FG) addition | 305 \pm 3.73 ^b | 7.34 \pm 0.20 ^c |
| 20% fenugreek (FG) addition | 281 \pm 2.50 ^c | 6.73 \pm 0.18 ^d |

In vitro analysis of the samples based on the digestibility of the starch with alpha-amylase illustrated variations in the release of reducing sugars due to the incorporation of fenugreek material in the bread loaves. Figure 1 illustrates that the incorporation of Fenugreek material significantly reduced the amount of starch hydrolysis during the *in vitro* digestion process when compared with the control bread sample. Similar results have been observed in other non-starch polysaccharide materials when incorporated into breads. For instance the addition of beta-glucans into breads at levels of 2.5- 15% significantly reduces the rate of sugar release following digestion and hence the potential glycaemic index of those breads (Symons and Brennan 2004).

Figure 1 Evolution of reducing sugars released during a 240 mins *in vitro* digestion process.



The magnitude of reduction of starch hydrolysis did not appear to be related to the level of fenugreek addition to the bread samples. It is clear that the incorporation of ground fenugreek material has similar effects to other NSPs. This is most likely due to the presence of galactomannan in the fenugreek seed. Previous studies have illustrated that guar galactomannan inhibits starch degradation by forming a barrier around starch granules (Brennan *et al* 1996) probably due to thermodynamic incompatibilities of the two polysaccharides (Tudorica *et al* 2002). Further research is needed to establish if this is the case for the use of fenugreek material.

CONCLUSION

The data presented in this paper indicates the potential use of ground fenugreek material in reducing the release of sugars from carbohydrate rich foods, following hydrolysis of starch. Incorporation of fenugreek into bread doughs did appear to have negative effects on the quality of the bread loaves produced. This may be due to the actual incorporation of galactomannan rich material into the bread, the use of relatively unpurified fenugreek material, or a dilution of the gluten network during dough development. Thus, although there exists an opportunity to manipulate the glycaemic impact of starchy foods by the incorporation of fenugreek material careful attention to the mode of addition of the fenugreek is required to avoid deleterious consumer acceptance scores.

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Antioxidant content of fermented products made from brassica waste¹

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ABSTRACT⁴

Edible plant parts are a major source of dietary antioxidants required for health and well-being. The potential to utilise crop harvest residue and process waste by producing a fermented product is investigated. This novel fermented product can act as an additional source of antioxidants as well as adding value for the grower. In this study the content of vitamin C and total phenolic in broccoli and cauliflower stalks was measured before and after a fermentation process. Further, consumer acceptability for the processed product was determined by three groups from different cultural backgrounds.

The pith of fresh broccoli stalks had high vitamin C concentrations (mean \pm SEM were 714.9 ± 7.1 and 633.5 ± 7.1 mg/100 g dry matter (DM), for large and small stalks, respectively). The outer-layers of fresh broccoli stalks had vitamin C concentrations of 269.9 ± 7.1 and 290.1 ± 7.1 mg/100 g DM, for large and small stalks, respectively. Large cauliflower stalks had significantly ($P < 0.001$) lower vitamin C concentrations in the pith (481.0 ± 7.1 mg/100 g DM) and higher vitamin C concentrations in the outer-layers (355.8 ± 7.1 mg/100 g DM). Total phenolic concentration in the pith of fresh broccoli was 187.8 ± 3.3 and 188.4 ± 3.3 mg/100 g DM, for large and small stalks, respectively. The outer-layers of fresh broccoli stalks had total phenolic concentrations of 124.5 ± 3.3 and 116.6 ± 3.3 , mg/100 g DM, for large and small stalks, respectively. Cauliflower had total phenolic concentrations of 205.5 ± 3.3 and 175.2 ± 3.3 mg/100 g DM, for pith and outer-layer, respectively. Fermentation decreased ($P < 0.001$) vitamin C concentration to about 55% of that found in fresh stalks of broccoli and cauliflower (range 54.3-64%). Also, fermentation caused a reduction in total phenolic concentrations (about 28% and 15% for cauliflower and broccoli, respectively). The results from the taste panel indicated that the fermented broccoli and cauliflower could be acceptable condiments for consumers familiar with fermented products.

INTRODUCTION⁷

Over the last few years there has been a plethora of biomedical research on antioxidants and active compounds derived from plants. Epidemiological studies have linked the increased consumption of plants products with reduced incidence of pathological diseases (Block *et al.*, 1992). Edible plant parts are the major source of dietary antioxidants required for health and well-being. Thus, the majority of published studies have been of the parts of plants considered edible. These edible parts in many cases represent a small fraction of the plant and the remainder is considered harvest residue or processing waste. These materials have an economic cost and disposal may cause environmental concern.

As a result of global environmental changes, urbanization and increased natural disasters, arable land is decreasing and food shortages are becoming chronic in many countries. Furthermore, in the light of increased populations, there is need to revise the current usage of raw material available for food and too utilize them to minimise waste. Many parts of plants have significant amounts of biologically active compounds (Peschel *et al.*, 2005). Crop harvest residue can be used as a dietary antioxidant source. This use may improve financial return, as well as reduce organic waste.

Of the many plants evaluated for their health benefits much attention has been focused on brassica vegetables. Biologically active compounds from brassica have been shown to prevent or interfere with progress of many diseases (for two good reviews see Beecher, 1994 and Podsedek, 2005). Therefore, the present study was undertaken to investigate the possible use of broccoli (*Brassica oleracea* var. *Italica*) and cauliflower (*Brassica oleracea* var. *botrytis*) stalks as a fermented condiment.

The study also measured vitamin C and total phenolic changes in broccoli and cauliflower stalks before and after fermentation to measure the change in nutritional value.

MATERIALS AND METHODS

Samples

Standing harvest residue of broccoli was collected from a mid Canterbury commercial grower in April 2005, one week after saleable broccoli florets were harvested. Plants were cut about 5 cm from the soil surface and taken to the lab for preparation. The plants were divided into edible florets, leaves, stalks, flowered buds and woody parts and trimmings (Table 1). Broccoli stalks were grouped into large and small sized stalks based on their morphology (each plant had a large stem with branched small stalks).

Table 1: Composition of broccoli harvest remains and cauliflower processing waste.

| | Broccoli harvest residue | | Cauliflower | |
|---------------------------|--------------------------|-------|-------------|-------|
| | kg | % | kg | % |
| Edible Florets | 1.49 | 9.57 | 11.84 | 62.55 |
| Leaves | 3.04 | 19.56 | 4.44 | 23.45 |
| Stalks | 3.38 | 21.75 | 2.25 | 11.89 |
| Flowered buds | 1.96 | 12.60 | - | - |
| Woody parts and trimmings | 5.67 | 36.51 | 0.40 | 2.11 |
| Total | 15.54 | - | 18.93 | - |

Ten whole cauliflowers (average weight \pm SD was 1.58 ± 0.55 kg) were purchased from a Christchurch supermarket. Cauliflower has a large stem with no branching thus cauliflower stems were classed as large stalks. Cauliflowers were divided into different parts similar to broccoli harvest residue. Stalks from both plants were washed under warm running water ($\approx 45^\circ\text{C}$), patted dried with paper towel and then fermented. Stalks from broccoli and cauliflower were placed in separate clean glass containers with other ingredients (herbs, spices and whole garlic cloves) and the mixture was topped with 6% brine solution at a stalk to brine ratio of 4:1 w/v. The mixture was left to ferment at room temperature ($\approx 20^\circ\text{C}$) for 3 weeks.

Before analysis both fresh and fermented broccoli and cauliflower samples were peeled and divided into pith and outer-layer (contained epidermis, cortex and the vascular bundles tissues) reflecting the edible and non-edible parts, respectively (Table 2). This resulted in the following samples for broccoli: fresh large broccoli pith, fresh large broccoli outer layer, fresh small broccoli pith, fresh small broccoli outer layer, fermented large broccoli pith, fermented large broccoli outer layer, fermented small broccoli pith and fermented small broccoli outer layer. Cauliflower had the following samples: fresh large cauliflower pith, fresh large cauliflower outer layer, fermented large cauliflower pith and fermented large cauliflower outer layer. Fermented pith from large broccoli and cauliflower were sliced and used for the sensory evaluation. Samples for chemical analysis were frozen, freeze dried, pulverized, vacuum packed and stored at -20°C until analysis.

Table 2: Processing yield and edible yield of fermented broccoli and cauliflower stalks as a percentage of original raw materials.

| | Broccoli stalks (%) | | Cauliflower (%) |
|-------------------|---------------------|-------|-----------------|
| | large | small | large |
| Fermented yield | 97.26 | 95.50 | 97.60 |
| Edible pith yield | 43.10 | 41.23 | 53.85 |

Measurement of Vitamin C

The vitamin C content was determined by AOAC method (AOAC, 1990) using a 670 Titrprocessor (Metrohm, Switzerland). Vitamin C content was determined in triplicate and expressed as mg/100 g dry matter (DM).

Measurement of total phenolic compounds.¹

Total phenolic were determined in triplicates using Folin-Ciocalteu reagent method (Singleton² and Rossi, 1965). A sample (200 mg) was extracted with 2 mL of 80% methanol containing 1% hydrochloric acid for 2 h at room temperature on an orbital shaker set at 200 rpm. The mixture was centrifuged at 2000 g for 15 min and the supernatant was transferred into 10 ml tube. The resultant pellet was extracted again as before and the combined supernatants were used for total phenolic assay. Extracts were appropriately diluted and then oxidized with 2.5 ml of freshly prepared 0.2 M Folin-Ciocalteu reagent. The reaction was neutralized by adding 2 mL of 7.5% w/v sodium carbonate and the samples were vortexed for 20 sec. The samples were incubated at 45°C for 15 min and then the absorbance was measured at 765 nm using a spectrophotometer (UV300, Unicam Ltd, UK). Total phenolic were corrected for the contribution of vitamin C and expressed as gallic acid equivalents (GAE) per 100 g DM (Toor *et al.*, 2006).

Consumer's perception of the fermented product³

The fermented products were tested in a consumer type panel to determine the acceptability of⁴ the products. The panellists recorded their ethnicity and results were then split into three groups; New Zealander; Asian and others (Table 3). The panellists were asked to evaluate the physical and flavour characteristics as well as the overall acceptability of the products on a 1 (dislike very much) to 5 (like very much) scale. They were asked to rate, again on a 1-5 scale, their likelihood of purchase each fermented product. In addition, the panellists were asked directly which product they preferred most.

Table 3: Structure of panellists for consumer's perception of fermented⁵ broccoli and cauliflower stalks.

| | New Zealanders | Asian | Others | ⁶ |
|----------------------|----------------|------------|------------|--------------|
| Number of panellists | 20 | 22 | 6 | |
| Males | 5 | 13 | 4 | |
| Female | 15 | 9 | 2 | |
| Age (average; range) | 24 (18-56) | 33 (20-48) | 30 (21-37) | |

Statistical analysis⁷

Data for vitamin C and total phenolic were analysed using analysis of variance (ANOVA)⁸ using PROC GLM in MINITAB (Release 14.1). Differences between means were determined using Fisher's least significant difference. Data for consumer's perception of the fermented products were analysed using the restricted maximum likelihood estimation (REML) routine in GenStat (Release 7, Lawes Agricultural Trust, VSN International Ltd., Rothamstead, U.K.), and the significance of model terms were determined by Wald tests. Means presented were those estimated by the REML routine.

RESULTS AND DISCUSSION⁹

Raw material and processing¹⁰

After the broccoli was harvested the residue still contained 9.5% of edible florets. About 22%¹¹ of the residue was stalks that can be utilized as a raw material for further processing (e.g. fermentation). These materials are normally mulched into the soil as picking the secondary florets is not a financially viable practice and currently there is no economical use for harvest residues. Cauliflower had lower percentage of stalks (about 12%) because of the trimming process prior to retail sale (Table 1). This percentage would increase if the harvest remains were included. While broccoli and cauliflower stalks had similar processed yield after fermentation, the edible pith yield for cauliflower was at least 10% higher than that of broccoli (Table 2). This higher pith yield seems to have resulted from differences in the geometrical properties and the ratio of out-layer to pith for the two crops.

Vitamin C¹²

Fresh large broccoli stalks had higher ($P < 0.001$) concentrations of vitamin C compared with¹³ small ones (Table 4). Vitamin C concentrations in the pith of fresh broccoli (714.9 ± 7.1 and 633.5 ± 7.1 mg/100 g DM, for large and small stalks, respectively) were considerably higher ($P < 0.001$) than in

outer layers. It is well known that broccoli florets contain high levels of vitamin C (Davey *et al.*, 2000; Podsedek, 2005). The reported values for vitamin C in the edible portion of broccoli ranged from 34-146 mg/100 g wet weight (WM). This variation was attributed to environmental (eg. climatic, geographical conditions) and agricultural practices (e.g. irrigation conditions; fertilization), (Podsedek, 2005). In the present study, the freeze dried pith of fresh broccoli stalks had 43 mg/ 100 g WM, which is slightly lower than the average reported for broccoli florets. There are two reasons for this; firstly, a 29% loss in vitamin C due to preparation and freeze drying was observed (fresh pith before freeze drying was 61.17 ± 3 mg/100 g WM). This is in agreement with results of Favell (1998) who reported a 20% loss of vitamin C in broccoli florets due to freezing. Secondly, cultivation in April meant that the plants were not exposed to light and temperature conditions that enhance vitamin C accumulation. Seasonal effects on vitamin C accumulation in plants are well documented (Davey *et al.*, 2000; Podsedek, 2005). Large cauliflower stalks had significantly ($P < 0.001$) lower vitamin C concentrations in the pith (481 mg/100 g DM) and higher vitamin C concentrations in the outer-layers (356 mg/100 g DM) than broccoli. Fermentation decreased ($P < 0.001$) vitamin C concentration in the edible portion (pith) to about 55% of that found in the pith of fresh stalks of broccoli. Also, there was about 44% loss in vitamin C content in cauliflower pith as a result of fermentation. Although almost 50% of the original vitamin C content in stalks was lost due to fermentation, this process is more efficient than storage at room temperature or partial chilling for longer periods. According to Favell (1998) broccoli florets lost 80% of its vitamin C during ambient or partial chilling/ambient storage for 3 weeks. Davey *et al.* (2000) listed vitamin C content in 63 fruits and vegetables in which broccoli ranked 7th on that list (after acerola, rosehip, guava, blackcurrant, kale and green pepper). In New Zealand, many of the high vitamin C sources (e.g. acerola, rosehip, guava and kale) are not available fresh to the average consumers. Thus, advice on the use of broccoli and cauliflower and their stalks as rich sources for vitamin C is important.

Table 4: Concentration of Vitamin C (mg/100 g DM) and total phenolic compounds (mg/100 g DM) in Brassica stalks before and after fermentation.

| Brassica | Size | Treatment | Part | Mean vitamin C (mg/100 g DM) | Mean total phenolic compounds (mg/100 g DM) |
|-------------|-------|-----------|-------------|------------------------------|---|
| Broccoli | small | fresh | pith | 633.5b | 188.4b |
| Broccoli | small | fresh | outer layer | 290.1e | 116.6e |
| Broccoli | large | fresh | pith | 714.9a | 187.8bc |
| Broccoli | large | fresh | outer-layer | 269.9e | 124.5e |
| Broccoli | large | fermented | pith | 366.1d | 161.0d |
| Cauliflower | - | fresh | pith | 481.0c | 205.5a |
| Cauliflower | - | fresh | outer-layer | 355.8d | 175.2c |
| Cauliflower | - | fermented | pith | 268.7e | 158.9d |
| Cauliflower | - | fermented | outer-layer | 227.4f | 111.0e |
| | | | | SEM = 7.1 LSD = 29.1 | SEM = 3.3 LSD = 13.5 |

Within a column for each factor, means that do not have a common letter are significantly different at the 1% level, SEM = standard error of mean, LSD = least significant difference (1%).

Total phenolic compounds

Size did not affect ($P > 0.05$) the total phenolic content of fresh broccoli stalks (187.8 ± 3.3 and 188.4 ± 3.3 mg GAE/100 g DM, for large and small stalks, respectively, Table 4). Total phenolic content of broccoli florets was reported to be in the range of 34.5 to 337 mg of GAE/100 g WM (Podsedek, 2005). This wide variation was due to the use of different extraction methods. However, it seems that soil and environmental conditions (reflected in country of origin) played a role in this variation (Podsedek, 2005). Also, in most of the reported studies, the contribution of vitamin C to total phenolic content was not taken into account. Indeed, when harsh extraction conditions were used, total phenolic content in broccoli (florets and stem) was low (Zhang and Hamauzu, 2004). For instance, in the present study total phenolic content in the broccoli stalks was 11.3 mg GAE/100 g WM compared with 4.5 mg GAE/100 g WM broccoli stems reported by Zhang and Hamauzu (2004).

The pith of fresh cauliflower had similar total phenolic content (205.5 ± 3.3 mg GAE/100 g DM) to the pith of fresh broccoli, whereas the outer layer of the fresh cauliflower had higher ($P < 0.001$)

total phenolic content than the broccoli outer layer (Table 4). Fermentation caused a reduction in total phenolic concentrations (about 28% and 15% for cauliflower and broccoli, respectively). This was expected as polyphenols are known to degrade during fermentation (Svanberg and Lorri, 1997).

Consumer's perception of the fermented product

Forty eight people took part in the consumer panel. The panellists expressed their ethnicity and were then split into three groups: New Zealander, Asian, and other (Table 3). The majority (77%) of the Asian group were Chinese while those in the other group included those of Middle Eastern ethnicity and respondents who did not complete the ethnicity question.

There was a significant difference in the overall acceptability of the fermented products between groups of different ethnicity (Table 5). The Asian and others panellists found that the fermented products were acceptable or very acceptable, while 70% of the New Zealand panellists ranked the products with 1 (dislike very much) or 2 (dislike). This may reflect a cultural background difference in that the Asian and others groups were more familiar with fermented vegetables while in New Zealand the consumption of such products is low.

Fermented cauliflower stalks were perceived as more preferable than broccoli stalks (Table 5). The fermented cauliflower ranked more highly in terms of saltiness, overall flavour, mouthfeel and hardness ($P < 0.05$). Although the pale green colour of the broccoli product attracted comment, there was no significant difference in the acceptability of the colour of the products. Both products attracted scores at both end of the acceptability scale from dislike very much to like very much.

The overall acceptability of fermented products was not significantly different between males and females (Table 5). Female panellists reported higher scores for all the evaluation parameters, but significant differences were found in colour, smell and hardness. When the interaction of sex and type of fermented product was considered (data not shown) females gave a higher ranking to the cauliflower fermented product than the broccoli product. The panellists were also asked about their likelihood to purchase. There was again a significant difference ($P < 0.001$) between the ethnic groups. Using scale of 1 (very unlikely) to 5 (very likely); with 3 the neutral position indicated as "maybe", the predicted means were 1.74, 3.51, 3.67 for New Zealanders, Asians and others respectively. There was no difference in the likelihood of purchase between the broccoli and cauliflower fermented products. This data indicate that these fermented products may have potential in markets with a high proportion of consumers who are familiar with fermented products. These markets could include Asian and Mediterranean countries as well as other countries where there are large populations of these consumers.

Table 5: Average taste panel scores for fermented broccoli and cauliflower stalks.

| | Sweet-ness | Colour | Smell | Salt | Flavour | Hard-ness | Mouth-feel | Accept-ance | |
|-------------|------------|--------|-------|-------|---------|-----------|------------|-------------|--------|
| Ethnicity | | | | | | | | | |
| NZ | 2.13a | 2.64a | 2.33a | 2.36a | 2.14a | 2.77a | 2.46a | 2.32a | |
| Asian | 3.11b | 3.60b | 3.57b | 3.70b | 3.54b | 3.85b | 3.55b | 3.53b | |
| Others | 4.62b | 4.27b | 4.89b | 4.08b | 3.70b | 4.80b | 4.78b | 4.17b | |
| P | 0.001 | 0.003 | 0.001 | 0.001 | 0.001 | 0.003 | 0.001 | 0.001 | |
| Broccoli | 3.43 | 3.44 | 3.60 | 3.61 | 3.36a | 3.86 | 3.87a | 3.53a | |
| Cauliflower | 3.14 | 3.56 | 3.60 | 3.14 | 2.89b | 3.75 | 3.20b | 3.15b | |
| P | NS | NS | NS | 0.034 | 0.004 | NS | 0.001 | 0.002 | |
| Female | 3.40 | 3.78a | 3.99a | 3.45 | 3.33 | 4.11a | 3.87 | 3.50 | |
| Male | 3.17 | 3.23b | 3.21b | 3.03 | 2.92 | 3.50b | 3.32 | 3.17 | |
| P | NS | 0.032 | 0.011 | NS | NS | 0.038 | NS | NS | Within |

a column for each factor, means that do not have a common letter are significantly different at the stated P value.

CONCLUSIONS

The materials obtained from broccoli and cauliflower represents the material that can be recovered at the grower and processor levels, respectively. With the appropriate technology it is feasible to utilize these materials further. After appropriate processing, these materials can be used effectively as a dietary source of nutrients either directly as food or as an ingredient in a functional food product. In the present study, we reported relatively high vitamin C and total phenolics contents in broccoli and cauliflower stalks that were used to produce fermented products and in the fermented products themselves. The results from the taste panel indicated that the fermented broccoli and cauliflower could be a successful product as a condiment for consumers familiar with fermented products. The potential to use harvest residue and processing by-products and target overseas markets is promising.

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The behaviour and susceptibility to degradation of a barley β -glucan, Glucagel™, in a white wheat bread, during fermentation, baking and *in vitro* digestion¹

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ABSTRACT⁴

Soluble fibres such as (1→3)(1→4)- β -glucan (hereafter referred to as β -glucan) have been illustrated to be effective in reducing postprandial glycaemic, insulin, and cholesterol responses in humans. Cereals, such as oat and barley are rich sources of β -glucan, with numerous studies demonstrating their nutritional benefits. Much research has focused upon how these β -glucans can be incorporated into products for human consumption. The nutritional efficacy of β -glucan preparations is in part related to dose, molecular weight, fine structure and rheological characteristics of extracted and native β -glucan. Incorporation of high purity β -glucan extracts in food products may be favourable to native cereals or flours, since larger doses of β -glucan can be incorporated into products at smaller replacement levels, thus possibly reducing negative changes to product quality and consumer acceptance. However, extraction procedures can negatively alter the physical properties of β -glucans, through molecular degradation, thus reducing their nutritional efficacy. There is also evidence to suggest that certain β -glucan extracts may also be also susceptible to degradation during processing and intestinal transit.

This paper provides a profile of the behaviour of a barley β -glucan extract, Glucagel™, and differently isolated beta-glucan material in white wheat bread, during fermentation, baking and *in vitro* digestion, examining not only physico-chemical and nutritional (*in vitro* starch digestibility) changes within the breads, but also the susceptibility of this extract to molecular degradation.

INTRODUCTION⁷

Barley beta-glucan has been the centre of research and legislative attention recently, with the aim of awarding barley beta-glucan with the same functional health claims as those of oat beta-glucans. The association between beta-glucan and its potential to manipulate cholesterol and glycaemic responses in individuals is well established. Previous research has shown that the incorporation of barley beta glucan into starch systems (Symons and Brennan, 2004a), bread and dough material (Symons and Brennan, 2004b), pasta (Brennan *et al.*, 2006) and dairy products (Tudorica et al 2005) can also affect the structural integrity of food. There appears to be a firm link between this structuring ability of the beta-glucan and the way that it modifies food quality (from a consumers acceptance and also nutritional point of view). Thus the visco altering nature of beta-glucans have the potential to be exploited by the food industry to provide truly functional foods to the consumer.

Research has indicated that the molecular weight of beta-glucans has a role in altering the visco-elastic nature of the food matrix

Such information about commercial β -glucan extracts will allow for greater use as nutraceuticals. ¹

Nutritional assessment of 11-14 year old Hawkes Bay swimmers during high volume training¹

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ABSTRACT⁴

Energy expenditure is shown to exceed intake in adolescent swimmers. Comprehensive⁵ nutrition screening identifies adolescents who have poor nutritional status, as well as those who are at risk for developing nutrition-related problems. This study attempts to further understand the nutritional requirements of adolescent athletes participating in competitive sport while maintaining optimal growth and development. Twenty-seven Hawkes Bay swimmers aged 13.3yrs (11.3-15.1) completed four-day estimated diet and activity records. Body composition was assessed using the ISAK restricted proforma. Biochemical indices of nutrient and physiological status included; serum ferritin (F), serum iron (Fe), transferrin saturation (TS), serum folate (SF) and red cell folate (RCF), vitamin B12, creatine kinase (CK), lactate dehydrogenase (LDH), cortisol (C), C-reactive protein (CRP) as well as total cholesterol (TC), LDL-Cholesterol (LDL), HDL-Cholesterol (HDL) and triglycerides (TG). Mean energy intake was found to be 10726 (6649-15313) kJ/d while expenditure was 11138 (7526-16492) kJ/d. Total sugars (23.3 %TE) exceeded national guidelines of 15%TE. Absolute protein intake (1.7 g/kg) was below the recommended 2g/kg. All indices of nutritional status appear normal, however, three were found to have stage 1 and one stage 3 iron deficiency. Serum CK, LDH and C exceeded normal values. Significant differences ($p < 0.05$) were observed between males and females for protein (+23.7g), BMI (-2.7kg/m²), LDH (+84.4U/L) and CK (+135.4U/L). This study provides the foundation for further comparisons of nutritional demands between sports for aspiring athletes and with non-swimming, matched peers.

INTRODUCTION⁶

Children and adolescent's dietary intake influences normal growth, health status, as well as⁷ lifelong nutritional habits (Perks, Roemmich *et al.* 2000). It is well known that negative energy balance in young athletes has far more severe consequences for growth, development, health and sport performance than in adults. Nutritional status measures can provide the foundation for monitoring an athlete's response to training from dietary perspective (Deakin 2000). Comprehensive dietary screening identifies adolescents who have poor nutritional status, as well as those who are at risk for developing nutrition-related problems (Stang 2002).

Although a number of investigators have studied the nutritional status of adolescent swimmers⁸ during peak training (Hawley and Williams 1991) (Berning, Troup *et al.* 1991) but none have examined the status of young adolescent swimmers in New Zealand. It has been widely shown that energy intakes remain constant despite fluctuations in training volume or intensity (Imbeault, Saint-Pierre *et al.* 1997). Constantini has also shown energy expenditure far exceeds energy intake in adolescent swimmers (Constantini, Eliakim *et al.* 2000). Using doubly-labeled water (DLW), Trappe *et al.* (Trappe, Gastaldelli *et al.* 1997) showed that training 5-6 hours per day contributed to 23.4 ± 2.1 MJ/d of expended energy, in contrast to 13.1 ± 1.0 MJ/d of energy intake. Studies of female swimmers have also shown relatively high expenditure in low volume (< 3.3km/d) swimming (Vallieres, Tremblay *et al.* 1989; Jones and Leitch 1993)

Adolescent female athletes have been shown to have both inadequate protein and⁹ micronutrient intakes despite having better nutritional knowledge than non-athletes (Cupisti, D'Alessandro *et al.* 2002). Similarly, sub-optimal micronutrient intakes for iron and calcium have been observed in adolescent swimmers (Berning, Troup *et al.* 1991; Bandini, Must *et al.* 2003) and figure skaters (Ziegler, Sharp *et al.* 2002). A problem commonly encountered in adolescent female, but rarely in adolescent male athletes.

High volume training and competition is known induce physiological stress on muscle tissue. ¹
An early study showed dietary strategies can affect CK and LDH levels post-training (Cade, Reese *et al.* 1991). Nutrient selection during recovery was an important predictor for changes in muscle stress. It was shown CK and LDH levels were reduced with milk protein solutions immediately post-training indicating improved physiological recovery. Thus, the importance of optimal dietary strategies during recovery high volume training, particularly in adolescence, is paramount.

By assessing dietary trends, associated nutrient intakes nutritional status and indices of muscle ²
stress, this study aims to educate young competitive swimmers (and parents) of the consequences food choice and subsequent nutrient intake may have on health and physical performance.

MATERIALS AND METHODS ³

Participants ⁴

Twenty seven (15 male, 12 female) local sub-elite swimmers from a Hawkes Bay swim team ⁵
participated in this study. All data was collected during a period of medium-high volume training in which swimmers were training minimum of two hours per day, five days per week. Participants completed an initial health and demographic questionnaire which included number of sports participated in, nutritional supplement use, source of supplement information and stage of pubertal development (Tanner 1952).

Dietary intake ⁶

Four-day estimated food records were collected to determine nutrient intakes. These included ⁷
three weekdays and one weekend day. To ensure accuracy, swimmers and parents were trained in a group session as well as provided with detailed instructions for reporting serving sizes, food preparation and food/beverage recording. Food records were analysed using SERVE (Serve Nutrition Systems, version 5.01, Sydney, Australia) . Analysed nutrient data were reviewed with individual reports and group results presented during scheduled nutrition counseling sessions.

Energy expenditure ⁸

Four-day self-reported physical activity records were completed immediately after food ⁹
records. Swimmers and parents were trained in a group session and provided with detailed instructions for accurately reporting daily physical activity. Daily energy expenditure was then estimated using metabolic equivalent data using the techniques developed by Ainsworth and colleagues (Ainsworth, Haskell *et al.* 1993; Ainsworth, Haskell *et al.* 2000). All estimations of energy expenditure were calculated in calories (kcal), which were multiplied by a factor of 4.18 for kilojoule (kJ) conversion.

Body composition ¹⁰

The body mass and height of each participant was measured using an electronic scale and a ¹¹
wall-mounted stadiometer. These were determined prior to evening training in their swimsuits. Body composition was assessed using the ISAK Restricted Proforma. Sum of seven skinfolds (S7SF) were measured using Holtain calipers and percentage body fat (%BF) was calculated as a mean of three regression equations for children (Lohman 1986; Slaughter, Lohman *et al.* 1988; Goran, Driscoll *et al.* 1996).

Blood sample collection and analysis ¹²

Fasting blood samples (20mL) were collected prior to a morning training session from the ¹³
antecubital vein. All samples were taken from the antecubital vein. Serum iron and TIBC were measured using Colorimetric Assay (Hitachi 917, Roche Diagnostics NZ, Auckland). Serum Ferritin, SF, RCF and B12 and C were measured using direct chemiluminescence (Advia Centaur, Bayer Diagnostics NZ, Auckland), CRP was measured using Immunoturbidimetric Assay (Hitachi 917, Roche Diagnostics NZ, Auckland), LDH and CK by Photometric Assay (Hitachi 917, Roche Diagnostics NZ, Auckland), T-Chol and TGs by Enzymatic Colorimetric Assay (Hitachi 917, Roche Diagnostics NZ, Auckland) and HDL by Homogenous Enzymatic Colorimetric Assay (Hitachi 917, Roche Diagnostics NZ, Auckland).

Statistics ¹⁴

All descriptive statistics were identified using SPSS for windows version 13.0. Differences in 1
between sex variables (LDH, CK, protein, S7SF and BMI) were analysed using independent samples t-
test with a significant difference identified at $p < 0.05$.

RESULTS 2

The mean (range) age of the swimmers was 13.3 years (11.3-15.1), height was 1.65m (1.45- 3
1.82), weight 58.5kg (38.0-82.0) and BMI 21.2kg/m² (16.9-27.6). Swimmers trained for 3.3 hours per
day (2.0-4.0) per day while 58% participated in two sports or more. Sixty three percent of swimmers
abstained from using nutritional supplements. One was currently consuming a maintenance dose of
Creatine Monohydrate, while others consumed either single vitamin/mineral (21%) or a multivitamin
(13%) supplement. As expected, Tanner stage of pubertal development ranged from 1 to 5 (mean 3.7).
Mean (range) %BF was 16.2% (10.2-31.3) resulting from an 83.6mm (42.4-196.9) S7SF.

Table 1 represents the eating habits of swimmers based on the mean number of food group 4
servings per day. Of importance is the combined number of sugar, confectionary, treats and fast food
which represents an average of 5.5 servings per day. In addition, 3.5 servings of fruits and vegetables
were consumed per day.

Table 1: Mean number of servings per day of major food groups 5

| Food Groups | No. servings mean (range) 6 |
|-----------------------------------|--------------------------------|
| Fruit | 1.8 (0.5-4.5) |
| Vegetables | 1.7 (0.5-3.5) |
| Breads and Cereals | 5.5 (2.3-9.3) |
| Baked Products | 0.9 (0-2.5) |
| Meat, Alternatives, Fish and Eggs | 1.8 (0.8-4.0) |
| Dairy | 1.9 (0.5-3.5) |
| Sugar, Confectionary, Treats | 4.8 (1.5-9.5) |
| Fast Food | 0.7 (0-2.8) |

The descriptive statistics for total macronutrient intake as a percentage of energy consumed 7
and by kilogram of body weight is shown in Table 2. A slight energy deficit of 3.6% was observed in
these swimmers. Although mean total CHO and fat intakes were within the recommended level, sugar
(23%TE) and SAFA (14%TE) intake were above dietary recommendations (<15% and <12%
respectively). Although protein was within recommended levels of 12-15%, consumption based on
body weight (1.7g/kg) was less than recommended (2g/kg).

Table 2: Mean energy and macronutrient intakes based on 4 day estimated food and activity 8
record data

| Characteristic | Mean | Range | Recommended 9 |
|-------------------------|-----------|-----------------|---------------|
| Energy Intake (kJ) | 10726 | 6649-15313 | |
| Energy Expenditure (kJ) | 11138 | 7526-16492 | |
| CHO g (%TE) | 336 (50) | 216-534 (40-57) | 50-55% |
| CHO (g/kg) | 6 | 3.6-9.7 | 4-7 |
| Sugars g (%TE) | 154 (23) | 68-315 (14-33) | <15% |
| Total Fat g (%TE) | 93.8 (32) | 54-155 (25-40) | 30-33% |
| SAFA g (%TE) | 40 (14) | 23-76 (9-19) | <12 (8-12) |
| MUFA g (%TE) | 30 (10) | 17-54 (7-15) | <20 (10-20) |
| PUFA g (%TE) | 14 (5) | 5-24 (2-7) | 8 (6-10) |
| Protein g (%TE) | 97 (15) | 55-151 (9-19) | 12-15% |
| Protein (g/kg) | 1.7 | 1.0-3.2 | 2 |

Table 3 describes the biochemical status of the swim team in terms of nutrient and physical stress indices. All swimmers were identified as having adequate vitamin B12 and folate status. Although mean iron status appears normal, Looker's guidelines for iron status (Looker, Dallman *et al.* 1997) suggest one female swimmers was found to be in stage 2 iron deficiency (SF=10, TS=15%), while three others (2F, 1M) were found to have low iron stores (SF<20, TS<20%)

Table 3: Mean biochemical status of key nutrients and indicators of muscular stress

| Biochemical Indice* | Concentration [‡] | Normal Value |
|-----------------------------|----------------------------|--------------|
| Serum Iron (umol/L) | 16.6 (6.0 - 31.0) | 10-30 |
| Serum Ferritin (ug/L) | 46.4 (10.0 - 96.0) | 20-200 |
| Transferrin Saturation (%) | 30.2 (15.0 - 54.0) | >14 |
| Serum Folate (nmol/L) | 23.2 (10.4 - 43.6) | >10 |
| Red Cell Folate (nmol/L) | 858.5 (663.0 - 1081.0) | 600-2000 |
| Vitamin B12 (pmol/L) | 288.1 (194.0 - 471.0) | 170-600 |
| Lactate Dehydrogenase (U/L) | 439.4 (315.0 - 595.0) | 240-480 |
| Creatine Kinase (U/L) | 211.5 (33.0 - 633.0) | 22-198 |
| Cortisol (nmol/L) | 735.6 (9.4 - 1164.0) | 118-618 |

*1 swimmer (♀) was found to have Stage 2 iron deficiency (SF=10, TS=15%), while 3 others (2♀, 1♂) were found to have low iron stores (SF<20, TS<20%)

[‡] Values shown as mean (range)

Gender differences for health and biochemical variables are shown in Table 4. There was no effect of energy expenditure, tanner stage, age or BMI on serum LDH and CK concentration.

Table 4: Gender differences for health and biochemical variables

| Characteristic | Females | Males |
|----------------------------|------------|------------|
| BMI (kg/m2)* | 22.7 ± 3.1 | 20.5 ± 2.0 |
| Sum 7 SF (mm) [‡] | 117 ± 3.1 | 60 ± 3.1 |
| Protein (g)* | 84 ± 19 | 108 ± 24 |
| LDH (U/L) [‡] | 391 ± 51 | 475 ± 64 |
| CK (U/L)* | 133 ± 55 | 267 ± 134 |

* mean ± SD, p<0.01

[‡] mean ± SD, p<0.001

DISCUSSION

Similar to previous studies (Vallieres, Tremblay *et al.* 1989; Jones and Leitch 1993; Trappe, Gastaldelli *et al.* 1997; Leiper and Maughan 2004) our results confirm the difficulties athletes have in achieving energy balance during periods of high training volume. Recently, Leiper and Maughan (Leiper and Maughan 2004) used diet and activity records to estimate energy balance while swimming four kilometers per session nine times per week. Similar results were observed with an energy deficit of 5.5%. Despite the recognised limitations associated with diet and activity records, the observed mean energy deficit, however small, has future implications, especially when training volume increases and should not be ignored.

Nutritional status 1

Overall, these young swimmers had a relatively good nutritional status. The omission of Haemoglobin (Hb) as an index of iron status presented a major limitation in the assessment of this population. Only estimates of iron status were provided based on previous iron status assessments (Looker, Dallman *et al.* 1997). Providing Hb, in combination with parameters used in this study, enables a more accurate diagnosis of iron status. Also, as protein status was observed to be below that recommended for adolescent athletes, an identification of protein balance may be a better indication of protein status. In future, this can be estimated from daily protein intake and rate of urinary nitrogen excretion (Boisseau, Le Creff *et al.* 2002).

Dietary quality 3

Optimal dietary intake is a major determinant of performance, especially at the elite level. Burke previously reported poor nutritional practices in many athletes (Burke 1999). Other studies have also reported sub-optimal micronutrient intakes in adolescent athletes (Berning, Troup *et al.* 1991; Boisseau, Le Creff *et al.* 2002; Cupisti, D'Alessandro *et al.* 2002; Bandini, Must *et al.* 2003). Mean dietary data in this study showed micronutrient intake met recommended levels. However, macronutrient intake, in particular protein and sugars, did not meet recommended values. Numerous overseas studies in adolescent soccer players (Boisseau, Le Creff *et al.* 2002) and swimmers (Ousley-Pahnke, Black *et al.* 2001; Paschoal and Amancio 2004), have shown protein intake was less than the recommended 2g/kg per day. Quality of carbohydrate intake may also be of concern. Although sugars provide the basis for energy intake in times of high carbohydrate demand, exceeding the recommended 15%TE provides some nutritional concern, especially when total energy intake is not particularly high.

Recovery nutrition 5

In addition to providing education on food choices for nutritional quality, strategies aimed at timing of food choices around training may be important for recovery in these swimmers. Swimming has been shown to increase levels of muscle damage in swimmers during high volume training (Cade, Reese *et al.* 1991). Cade showed that milk protein solutions post-training significantly reduced indices of muscle stress. This may have significant implications, especially when muscle damage has been implicated in impaired muscle glycogen restoration post-exercise. Therefore, may warrant further investigation in young swimmers (Burke 2000).

Food sources and eating habits 7

A review of suitable nutritional interventions for adolescents identified excessive consumption of fats (particularly saturated fat), sugar and salt while inadequate amounts of fruits and vegetables, whole-grains, calcium foods and iron (Hoelscher, Evans *et al.* 2002). Closer to home, 11 to 14 year old children showed similar trends in the National Children's Nutrition Survey (NCNS) (Parnell, Scragg *et al.* 2003).

The current swimming population consumed only 3.5 FV and 5.5 BC servings per day (6.4 incl. bakery products) compared to the recommended 5+ and 6 to 11 serves of FV and BC respectively. Our swimming population consumed 5.5 servings per day of sugar, confectionary, 'treats' or fast food, possibly contributing to the higher than recommended contribution of sugar (23%) and saturated fat (14%) to energy intake. More than 90% of adolescents report eating snacks between meals which are classified as 'junk' food or 'high fat' fast food items and can contribute to one third of total energy intake (Wahl 1999). Often, consumers are unaware of what constitutes 'healthy' snack foods, providing direction for education of these swimmers and parents.

Nutrition education vs nutrition practice 10

Many authors stress the importance of nutritional education to adopt dietary strategies that will subsequently optimise health as well as athletic performance (Burke 1995; Grandjean 1997; Metz 1999). However, nutrition knowledge may not always be converted into actual dietary behaviour (Chapman, Toma *et al.* 1997). A recent study found nutritional intake was poorer among adult soccer players than in adolescents (Ruiz, Irazusta *et al.* 2005), further supporting the fact knowledge may not lead to optimal food choice. In contrast, sports participation in adolescent females had a positive influence on dietary habits and nutrition knowledge (Cupisti, D'Alessandro *et al.* 2002).

Our study sampled young adolescents, for whom dietary intake, is often beyond their control. Both Cupisti *et al.* (2002) and Ruiz *et al.* (2005) (Cupisti, D'Alessandro *et al.* 2002; Ruiz, Irazusta *et al.*

2005) suggest providing nutritional education at an early age while others believe the application of this knowledge is related to the stage of behaviour change (King 2005). Either way, the environment in which we educate our adolescent athletes about nutrition must be all encompassing to include the child (athlete) as well as coaches, schools and parents, focusing on ways we can put education into practice.

Overall, the nutritional status of this population is in line with recommended levels. However there are dietary trends that may be implicated in poor recovery and result in suboptimal health and swimming performance for some participants. This study provides the foundation for comparisons between sports for adolescent athletes and with non-swimming, age and sex-matched peers.

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Foetal Alcohol Spectrum Disorder and the Barker Hypothesis: 1 Do We Know The Difference?

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ABSTRACT 3

The Barker hypothesis proposes that correlations between small body size at birth and 4 subsequent poor health outcomes indicate that foetal nutrition can 'programme' the health status of an individual in later life. However many studies in the field have not included detailed information on the reasons for low birth weight, other than assumption of 'poor nutrition'. Some studies mention smoking as a possible contributing cause to low birth weight, but few make any reference to the effects of alcohol intake during pregnancy. Current evidence indicates that ethanol exposure is a nutritional factor that must be considered in assessing the relationship between low birth weight and subsequent health outcomes.

INTRODUCTION 5

The Barker Hypothesis (Barker, 1992) proposes that low birth weight correlates with 6 subsequent development of adverse health outcomes, such as diabetes and hypertension, in later life. Low birth weight has been viewed as an indicator of poor fetal nutrition, and thus the connection has been made that poor fetal nutrition can 'programme' for poor health in later life. Some studies, however, have not shown clear correlations between birth weight and subsequent poor health outcomes. It has been suggested that other factors, such as the rate of body weight increase relative to birth size, may also be important, and that a range of different regression models should be used to test data (for a discussion, see Lucas *et al*, 1999). There is still, however, much support for the Barker Hypothesis (Cunningham and Cameron, 2003; Gluckman and Hanson, 2004; Ozanne *et al*, 2004), and more recent information is beginning to suggest links between birth weight of mothers and outcomes for children in terms of predisposition to poor health outcomes such as high blood pressure, insulin resistance and Type 2 diabetes (Barker *et al*, 2000; Gluckman and Hanson, 2004). This suggests that adverse fetal nutrition may affect not only one generation, but succeeding generations as well. This possibility has been supported by some animal experiments (Reusens and Remacle, 2005), but not by others (Rogers *et al*, 2003).

Molecular mechanisms and confounding factors 7

Research in the area of long-term effects of fetal nutrition is beginning to move to the study of 8 molecular mechanisms, such as changes in insulin (Plagemann, 2005), insulin-like growth factors (Cutfield *et al*., 2004) other hormones (Davies and Norman, 2002) or DNA methylation (Allegrucci *et al*, 2005), which might explain the effects of maternal diet on health outcomes over immediate and subsequent generations. However, it is becoming apparent that phenotypically similar outcomes (for example predisposition to diabetes) may result from different nutritional insults (for example maternal calorie or protein restriction, maternal diabetes and uterine blood flow restriction) (Reusens and Remacle, 2005). Whether a single underlying molecular mechanism can be identified remains to be seen.

Studies using animal models for fetal programming provide a possible explanation of the 9 difficulty in the interpretation of the studies that have been carried out in human populations. In many of these population-based studies, low birth weight has been taken as an indicator of 'poor fetal nutrition', but there has been no detailed analysis of the maternal diet or other physical or physiological factors that have led to the low birth weight, so the exact cause of the low birth weight (eg calorie restriction, protein restriction, specific vitamin deficiencies, high carbohydrate diet, placental insufficiency) is not known. The outcome of low birth weight may be similar in each case, but longer-term changes in health status may differ depending on the original nutritional problem. In many studies, confirming the underlying nutritional problem would be difficult, as it would mean asking

mothers for retrospective information about their health and diet from many years in the past. Studies¹ are required in which dietary analysis is maintained through pregnancy, and physical or physiological factors that could result in low birth weight are assessed, and then outcomes are monitored. However, even this may not be sufficient to fully clarify the effects of maternal nutrition on human development. Intergenerational effects may also apply, which would entail following families for several generations to fully understand the consequences of maternal nutrition. An additional problem in human studies is that maternal alcohol intake may be a confounding factor of prime importance. There is a large amount of evidence that indicates that ethanol affects fetal growth and development, and prior to pregnancy about 80% of women in Western countries consume alcohol as part of their diet, with between 10 and 80%, depending on age group and country of origin, continuing to consume alcohol during pregnancy (Parackal, 2001)¹. Including this as a factor to be considered in any detailed dietary analysis throughout pregnancy presents an ethical dilemma, in that a pregnant mother should be strongly advised not to consume any alcohol since there is no known safe level during pregnancy. With the understanding that is now developing of the effects of ethanol on fetal development and of fetal nutritional programming and intergenerational effects, it is timely to assess whether there could be underlying common, or related, molecular explanations for these effects.

The effects of alcohol on fetal development²

Effects on fetal growth.³

It is well recognised that maternal ethanol consumption leads to decreased birth weight. That⁴ this is not just a result of associated maternal smoking or poor nutrition has been confirmed using studies in model animals (U.S. Government, 2000). The deficit in fetal growth caused by alcohol intake is probably largely attributable to interference with macronutrient metabolism. Alcohol can cause changes in carbohydrate, lipid and protein metabolism, and has the potential to do this in both the mother and the fetus. The effects of ethanol on carbohydrate metabolism are likely to be of particular importance in terms of pancreatic development. A single large dose of ethanol can cause mobilisation of glycogen stores from the liver in the well-fed state, and can inhibit gluconeogenesis that is required to restore circulating glucose concentrations during low food intake. Ethanol thus has the potential to cause larger than normal fluctuations in glucose supply to the developing fetus – abnormally high if the mother is well-fed when intake occurs, and abnormally low if alcohol intake occurs without recent food intake. Model animal studies are now confirming that prenatal alcohol exposure can induce β -cell dysfunction and insulin resistance in offspring (Chen and Nyomba, 2003). Additional factors that may lead to deficits in fetal growth with alcohol exposure are interference with oxygen supply and utilisation and absorption and metabolism of specific vitamins and micronutrients, notably thiamine, folate and zinc (Lieber and Abittan, 1999).

Other effects of ethanol on fetal development.⁵

In addition to ethanol intake during pregnancy leading to low birth weight and small size,⁶ ethanol exposure can also cause physical, developmental and behavioural abnormalities, a syndrome termed ‘Fetal Alcohol Syndrome (FAS)’. Even moderate alcohol exposure during pregnancy may lead to some abnormalities and the inclusive term used for such effects is ‘Fetal Alcohol Spectrum Disorder (FASD)’. Cellular mechanisms that cause these effects are beginning to be clarified (U.S. Government, 2000). Alcohol can affect the process of apoptosis, or programmed cell death, and can interfere with the actions of growth factors and cell adhesion molecules – all vital to the correct growth and development of the fetus, in particular of complex organs such as the brain and the pancreas. Underlying molecular mechanisms may include interference by ethanol in the retinoid signalling system, and the actions of ethanol on cellular redox state and mitochondrial metabolism.

Effects of ethanol on the actions of retinoic acid.⁷

Retinoic acid binds to retinoic acid receptors, and the complex acts as a transcription factor to⁸ switch genes on or off during fetal and cellular development. Retinol (vitamin A) is converted to retinal by enzymes related to those involved in ethanol metabolism and the presence of ethanol can interfere with retinoid metabolism (U.S. Government, 2000). Retinoic acid is crucial in guiding the correct formation of craniofacial features and limb buds – hence the physical deformities that may be observed with fetal exposure to ethanol. Animal studies have confirmed that deformities are specific to

¹ It is notable that the 80% statistic is derived from New Zealand teenagers.

² Standard milk can be purchased at a lower unit price than trim milk, although there is no independent

the particular developmental stage of ethanol exposure. In addition, however, retinoic acid is crucial to the correct development of neuronal cells and the cellular processes that interconnect them, and of glial cells. Interference by ethanol in these processes may well explain the mental and behavioural changes that are observed with FASD (Grummer *et al*, 2000). Evidence is now also becoming available to suggest that the retinoid signalling system is important in early pancreatic development (Kadison *et al*, 2001) thus providing a route through which ethanol could specifically interfere with pancreatic development.

The actions of ethanol on cellular redox state and mitochondrial metabolism.

The enzymes that convert ethanol to acetaldehyde and acetaldehyde to acetate require NAD^+ , which is converted to NADH. As with other metabolites that are oxidised, such as glucose, this NADH is re-oxidised via the mitochondrial electron transport chain. As indicated above, ethanol metabolism increases the ratio of $[\text{NADH}]$ to $[\text{NAD}^+]$ in many tissues, thus potentially affecting all metabolic processes that depend on the redox state of the cell. In liver cells, for example, the altered redox state due to ethanol metabolism can inhibit gluconeogenesis from lactate, and the function of the citric acid cycle. The latter effect will slow the oxidation of fatty acids, and contributes to the accumulation of fat in the liver during ethanol metabolism (Lieber and Abittan, 1999). The changed ratio of NADH to NAD^+ may also contribute to the formation of reactive oxygen species by the mitochondrial electron transport chain and this may damage the mitochondrial DNA. It is probable that such damage occurring in developing fetal tissues would have long-term metabolic consequences. As an example, correct electron transport chain function is required for pancreatic cells to release insulin in response to elevated blood glucose concentrations, and damage to mitochondrial DNA may contribute to pancreatic dysfunction that continues after precipitating hyperglycemia has been resolved, leading to the phenomenon that has been referred to as 'hyperglycemic memory' (Brownlee, 2001).

CONCLUSION

Reusens and Remacle (2005) have suggested that a common theme of reprogramming of mitochondrial function may explain susceptibility to metabolic disorders after fetal exposure to both early malnutrition and maternal diabetes. A similar explanation could account for vulnerability to metabolic disorders arising from prenatal exposure to ethanol. It is therefore possible that mitochondrial damage due to oxidative stress may provide a unifying molecular mechanism to explain fetal developmental changes and long-term health effects arising from ethanol exposure, maternal diabetes or other maternal dietary influences such as calorie and/or protein restriction.

Since mitochondrial DNA is almost exclusively maternally inherited, this also provides a mechanism for intergenerational transmission of metabolic effects. Abnormal mitochondrial function, with consequent generation of oxidative stress and abnormalities in cellular redox state, would also lead to disruption of other cellular processes, some of which would provide further possible routes for intergenerational transmission of metabolic changes. For example, oxidative stress due to ethanol metabolism may alter S-adenosyl methionine concentrations (Mato *et al*, 1997), which may in turn alter DNA methylation, which may lead to transmission of epigenetic changes.

A further concern related to both ethanol exposure and hyperglycemia resulting from maternal diabetes and/or excessive carbohydrate intake is that it is possible that mitochondrial DNA damage due to oxidative stress could occur in oocytes prior to pregnancy. If this can occur, it is not sufficient to recommend strict adherence to an alcohol-free, well balanced diet just when pregnant or when pregnancy is possible. Such precautions would be necessary throughout the lifetime of a woman until the end of the reproductive years.

Owing to the ethical difficulty of undertaking appropriately controlled studies in human populations, we may never be able to conclusively prove to what extent maternal ethanol consumption can be a contributing cause for adverse long-term health outcomes in low birth-weight babies. However, the evidence accumulating from animal studies is compelling enough to indicate that New Zealand should move to a universal recommendation of abstinence from alcohol during pregnancy or when pregnancy is possible, as has been done in the United States since the early 1980's. Alcoholic beverages should also be labelled with a specific warning about the danger of alcohol consumption during pregnancy.

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A method for measuring dietary similarities and its application to the process of dietary acculturation¹

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ABSTRACT⁴

The term “dietary acculturation” refers to the process whereby individuals of one culture adopt the eating patterns and dietary choices of another culture. The development of a new food-based method for the assessment of similarities between diets among individuals undergoing acculturation is presented in this paper. An ecological data analysis technique known as similarity coefficient analysis is piloted on dietary data collected from the multicultural community of East Oxford, UK. The method determines the amount of ethnic overlap between foods listed in food diaries collected from 155 middle school children. Results indicate that the diets of British and W. Indies children were significantly more similar to each other than were diets of British and Pakistani children (similarity coefficients 0.402 vs. 0.263; $p < 0.05$). In conclusion, conducting similarity coefficient analysis on the diets of ethnic groups residing in the same community provides a novel way to measure dietary similarity, and may be an indication of degree of dietary acculturation.

INTRODUCTION⁶

“Dietary” acculturation is the process whereby individuals of one culture adopt the eating patterns and dietary choices of another culture as a result of exposure to the new culture (Satia *et al*, 2001). Dietary acculturation in Western societies with the adoption of Western eating habits has proven to be a risk factor for chronic diseases, such as is seen among Cambodian refugees in the US (Palinkas and Pickwell, 1995). Depending upon the degree of dietary acculturation of an ethnic group, dietary recommendations will vary; therefore, the ability to measure dietary acculturation may help in the development of appropriate dietary intervention strategies (Satia *et al*, 2001). While there are some sophisticated measures of general acculturation, such as the Acculturation Rating Scale for Mexican Americans, often these scales do not measure dietary practices specifically and provide little information about dietary habits (Satia-Abouta *et al*, 2002). Recent efforts to develop measures of dietary acculturation have resulted in some food-based scales that have proven useful in specific settings for specific ethnic groups (Yang and Fox, 1979; Lv and Cason, 2004; Satia *et al*, 2001; and Kim and Chan, 2004). However, there are several limitations to these food-based dietary acculturation scales. First, they depend upon respondent memory of recall dietary intakes when they first came into the host country. Secondly, they cannot be used to compare the acculturation process between multiple groups residing in a multicultural community, nor between those members of the same ethnic group residing in different communities. Lastly, they fail to recognize the bi- and multicultural dietary exchanges occurring during the acculturation process. The development of new measures to address some of these limitations has been recommended (Satia-Abouta *et al*, 2002). The purpose of this paper is to present a new method for the rapid assessment of dietary similarities between ethnic groups, which if applied appropriately, may be used as a measure of dietary acculturation.

MATERIALS AND METHODS⁸

Similarity coefficient data analysis⁹

Ecologists use similarity coefficient analyses as a measure of niche overlap (Schoener, 1970), and have modified these to measure the amount of dietary overlap occurring between species residing in the same habitat, enabling them to measure the extent to which species use the same food resources (Abrams, 1980; Weaver and Garman, 1994; Mansfield and Mcardle, 1998). In our research, we’ve used similarity coefficient analyses (Ludwig and Reynolds, 1988) to determine the similarity in diets between ethnic groups taken in pairs. As a descriptive statistic, similarity coefficients can be quite

useful in measuring dietary overlap. The values range from 0 to 1, where 0 indicates no overlap between types of foods eaten by ethnic groups (if ethnic group A ate only A foods and ethnic group B ate only B foods) and 1 indicates complete overlap between ethnic groups (if ethnic groups A & B ate the same proportion of A and B foods).

The formula for similarity coefficients for ethnic groups A & B is as follows: Similarity Coefficient AB = $1 - \sqrt{[2(1 - \text{ccosAB})] / [2]}$; where the chord cosine (ccos) is computed by: $\text{ccosAB} = \frac{\sum X_{iA} X_{iB}}{\sqrt{[\sum X_{iA}^2 \sum X_{iB}^2]}}$ and where X_{iA} is the number of foods from ethnic group i consumed by people of ethnic group A, and X_{iB} is the number of foods from ethnic group i consumed by people of ethnic group B.

Chord distances were computed because these put greater importance on relative proportions of foods in various ethnic groups and less importance on the absolute quantities (Ludwig and Reynolds, 1988). Bootstrapping was used (Resampling Stats, 2004) to determine 95% confidence intervals (CIs) between values (Dixon, 2001; Efron and Tibshirani, 1993). It does this by randomly resampling from a sample distribution similar to the original sample. It has been estimated that at least 1000 resamplings must be conducted in order to determine 95% CIs (Efron, 1987). It is important to note that this analysis is very robust at small sample sizes.

East Oxford Pilot Data

The pilot data set being used to test the method was collected in East Oxford UK in 1994. A convenience sample of 163 children between the ages of 9 and 12 years was recruited to complete 4-7 day food diaries. Classes were chosen based upon the willingness of class teachers to have the students complete the food diaries. Children were instructed to complete the food diaries throughout the day by filling in all foods and drinks as they were ingested. Eight children were excluded from the analyses because they did not submit at least four completed days of food intake. The final sample size was 155.

Children were classified by ethnic groups based on parent report of ethnic origins, teacher's report of ethnic origins or child report of ethnic origins. Although most of the ethnic minority children were first or second generation, data on this and other measures of acculturation were not uniformly collected at the time of the study.

Coding of the foods was conducted on foods ingested on three days during the week and one weekend day. Most of the foods in the diaries were categorized as ethnic dishes rather than as individual food items. Foods were classified as Pakistani, West Indian or European (British) using several references from the literature. For example, foods such as fish and chips, crisps and biscuits were categorized as "European," foods such as chicken creole and spicy coconut bean dishes were categorized as "W. Indian" and foods such as chapattis, pakorahs or ghee were classified as "Pakistani." Ethical approval was provided by the University Ethics Officer at Oxford Brookes University.

RESULTS

Ethnic groups

The ethnic makeup of our final sample of 155 children is shown in Table 1. Mixed ethnic groups are also included in the analyses. In references to a mixed group, the first name is the ethnicity of the children's mothers (female symbol) and the second name is the ethnicity of the children's fathers (male symbol). There was only one subject with a Pakistani mother and British father, and no subjects with a British mother and Pakistani father, hence no analyses were conducted on these ethnic mixes.

Classification of most frequently consumed foods

Classification of the most frequently consumed foods is shown in Table 2. In many instances, foods were categorized as ethnic dishes rather than as individual food components. It was possible for foods to be classified in more than one ethnic category. This occurred in those cases where the food item is traditionally eaten by more than one ethnic group. For example, when a Pakistani child recorded aubergine it was categorized as a Pakistani food for that child, whereas when an indigenous British child recorded aubergine it was categorized as "European/British." The percentage of ethnic foods recorded for each ethnic group or mix is shown in Figure 1.

Table 1. Ethnic groups¹

| Ethnic group/mix | n | % of total sample ² |
|-----------------------|-----|--------------------------------|
| British | 129 | 83.2 |
| British♀/W. Indies♂ | 7 | 4.5 |
| W. Indies ♀ /British♂ | 2 | 1.3 |
| W. Indies | 5 | 3.2 |
| Pakistani ♀ /British♂ | 1 | 0.7 |
| Pakistani | 5 | 3.2 |

Table 2. Classification of most frequently consumed foods⁴

| European ³ | Pakistani | W. Indies |
|-----------------------------|---------------------|------------------|
| fish and chips | curry | chicken creole |
| fish fingers | rice | spicy beans/fish |
| chips | peas | cassava |
| crisps, biscuits | chapatti | yams |
| baked beans | dhal/lentils | rice |
| sausages | pakorah | coconut dishes |
| rst chicken/beef & potatoes | ghee | breadfruit |
| ham sandwiches | chicken curry | barbecue chicken |
| pizza | fish curry | dumplings |
| beef burgers | samosa | hot chocolate |
| spaghetti/pasta | aubergine | popcorn |
| chicken Kiev | jalebi | orange juice |
| shepherd's pie | pilao | pulses |
| wheetabix, corn flakes | chicken Tikka | plantains |
| aubergine | meat & potato curry | dasheen |
| chocolate bars | | mangos |
| misc sweets | | |

The results of the similarity coefficient analyses are shown in Table 3. In each case, a similarity coefficient statistic is generated by comparing two ethnic groups. British compared to Pakistani has a similarity coefficient of 0.263 whereas British vs. W. Indies is 0.402. Recall that the smaller the number, the less the overlap in diets whereas the higher the number, the greater the overlap in diets.

Table 3. Similarity coefficients and 95% confidence intervals (C.I.) for comparisons of diets of different ethnic groups⁷

| Ethnic Groups Compared | Similarity Coefficient* | 95% C.I. |
|---------------------------------------|-------------------------|---------------|
| British vs. Pakistani | 0.263 | (0.208-0.320) |
| British vs. West Indies | 0.402 | (0.352-0.455) |
| British♀/W. Indies♂ mix vs. W. Indies | 0.616 | (0.524-0.719) |
| British ♀ /W. Indies♂ mix vs. British | 0.773 | (0.700-0.837) |
| W. Indies ♀ /British♂ mix vs. British | 0.479 | (0.332-0.629) |
| W. Indies ♀ /British♂ mix vs.W.Indies | 0.91 | (0.747-1.089) |

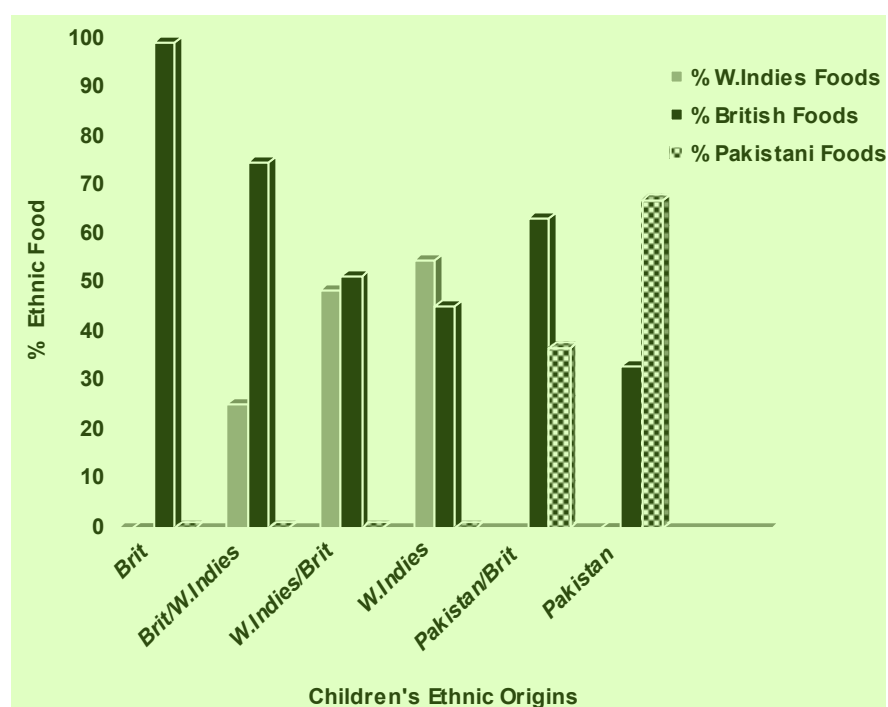
*Similarity coefficients are statistically significantly different from each other (p<0.05) wherever the confidence intervals don't overlap

Previous research has demonstrated clear relationships between acculturation level and dietary habits. Among African Americans ranked by acculturation level, those who are less acculturated tend to eat higher fat diets, and less fruits, vegetables and dairy products than those who are more acculturated (Ard *et al*, 2005). Conversely, among Korean-Americans, those more acculturated eat diets higher in fat and lower in fruits and vegetables whereas those less acculturated eat a more traditional diet that incorporates greater amounts of fruits and vegetables (Park *et al*, 2005). Recommendations to encourage healthful dietary patterns and to discourage less healthful patterns will depend in part upon degree of acculturation.

The similarity coefficient analyses of the pilot data found that the diet of W. Indies children was more similar to the British than the diet of the Pakistani children (similarity coefficients 0.402 vs. 0.263 respectively; $p < 0.05$; Table 3). However, these findings do not allow us to conclude with certainty that the W. Indies children exhibit a greater degree of dietary acculturation than the Pakistani. It is difficult to measure acculturation without knowing what the groups ate prior to coming to the host country. Individuals may have already been eating diets with some overlap between their own and the host country's ethnic foods. If, however, a group is followed longitudinally, it would be possible to see whether the similarity in diets has changed and as such, to determine the degree of dietary acculturation.

In the case of mixed groups, the mother's ethnicity appears to have a stronger influence on types of foods eaten by the children than does that of the father (Table 3). For example, in the case of British / W. Indies, the children ate a greater percentage of British foods as compared with W. Indies /British children, who incorporated more W. Indies foods in their diets. Children solely of W. Indies origin incorporated the highest proportion of W. Indies foods in their diets (Figure 1). Children of West Indian mothers and British fathers had diets significantly more similar to West Indian (0.91) than British children (0.479, $p < 0.05$). Children of British mothers and West Indian fathers had diets more similar to British (0.773) than West Indian children (0.616), although the difference was not significant ($p=0.09$). In this research, we do not know who the primary caregiver was in each household of mixed ethnicity and can only conjecture that it was the mother. Further research into how ethnicity and gender of primary caregivers influence children's diets during the acculturation process may help shed light on these findings.

Figure 1. Percentage of ethnic foods recorded for each ethnic group / mix



Similarity coefficient analyses allow for the determination of dietary overlap between immigrant and host country diet. This may be used as a measure of dietary acculturation and as such, may help determine appropriate dietary intervention strategies. We are unaware of any studies to date looking at the degree of general acculturation of Pakistani or W. Indies groups in the UK with which to compare our dietary acculturation data. When considering these results, it is important to remember that similarity coefficient analyses need to be conducted in tandem with other measures of acculturation in order to place in context not only whether the diets are similar, but how they are similar and what processes have made them similar. Many factors influence the acculturation process in general, and dietary acculturation specifically.

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Dietary intakes and iron status of non vegetarian women aged 18-40 years living in the Manawatu region¹

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ABSTRACT³

Iron deficiency is relatively common in young women and several dietary factors are known to influence iron bioavailability and status. The aim of this study was to assess the dietary intakes and iron status of non vegetarian women aged 18-40 years living in the Manawatu region. Exclusion criteria included pregnancy or breastfeeding in the past 12 months, smoking, high alcohol consumption and recent blood donation. Dietary intakes were estimated using a 24 hour recall. A non validated food frequency questionnaire was used to determine the intake of foods containing iron or factors known to enhance or inhibit iron absorption. Weight and height were measured. Biochemical iron status was determined using serum ferritin (SF) and haemoglobin (Hb). Of the 45 women recruited, 2 women (4.4%) had iron deficiency anaemia (SF<12 µg/L and Hb<120g/L) and 2 women (4.4%) had depleted iron stores (SF<20 µg/L). All other women had normal iron stores (SF>20µg/L). The median and mean SF levels were 39µg/L and 42.24±20.89µg/L respectively. Daily mean and median iron intakes were 14.21±7.15mg and 13.65mg. 20 women (44.4%) consumed less than the Recommended Dietary Intake of 12-16mg iron per day. These findings are similar to those of the National Nutrition Survey where 4 - 7% of menstruating women had low iron stores, despite a much higher estimated prevalence of inadequate intakes. Multiple regression analysis showed that SF was positively associated with age and total dietary iron intake and negatively associated with tea and Vitamin C intake. Age explained 16.0% (p<0.001) of the variation (partial coefficient of determination; partial R²) in SF, iron 8.4% (p<0.03), Vitamin C 8.0% (p<0.005) and tea 8.2% (p<0.03). No statistically significant relationship was found between SF and daily energy, protein, haem iron, vitamin A, fibre, calcium or coffee intake (p>0.05).

INTRODUCTION⁵

Iron deficiency anaemia has severe health consequences while iron deficiency without anaemia has been linked to delayed cognitive development (Grantham-McGregor and Ani, 2001) and reduced work capacity (Haas and Brownlie, 2001). In New Zealand low iron stores, iron deficiency and iron deficiency anaemia mainly affect women aged 15 to 44 years (Russell *et al.*, 1999). A New Zealand study found that factors associated with an increased risk of mild iron deficiency (SF 12–20µg/L and normal Hb) in women of child bearing age included high menstrual blood loss, recent blood donation, nose bleeds, a low body mass index and a low intake of meat, fish and poultry (Heath *et al.*, 2001). Other risk factors for iron deficiency include high parity, previous diagnosis of iron deficiency anaemia, low iron intakes (including vegetarian and vegan diets) and the use of intra-uterine contraceptive devices which induce blood loss (Ministry of Health, 2003). There are a number of dietary factors known to influence the absorption of iron in the body. Haem iron found in meat products is better absorbed (~10-40%) (Hallberg *et al.*, 1997) than the non haem iron found in meat and plant foods (~1-15% absorbed) (Hunt, 2003). Several dietary factors influence the absorption of non haem iron. Ascorbic acid and meat are strong enhancers of non haem iron absorption, while polyphenols, phytates, calcium and some proteins inhibit non haem iron absorption. The aims of this study were to assess the dietary intakes and iron status of non vegetarian women aged 18-40 years of age living in the Manawatu region, and to determine which dietary factors influenced iron status.

METHODS⁷

Subjects were recruited from the Manawatu region between August 2004 and September 2005 as part of a larger study. The study was advertised through posters, local newspapers and a radio interview. Interested subjects were sent an information sheet explaining the study and were asked to contact the researcher if wanting to take part in the study. Exclusion criteria included being vegetarian

or vegan, allergies to iron containing products, donation of blood in the past 12 weeks, smoking, a high alcohol intake (>2 glasses of wine or 1 pint of beer/day), pregnancy or breastfeeding in the past year, or planning to become pregnant in the next 6 months. All subjects took part in a dietary interview and had their iron status assessed. Written informed consent was obtained at the initial dietary interview. Subjects were asked to describe their activity levels and use of supplements. Standing height and body weight were measured. Dietary intake was assessed using a 24 hour recall, with subjects recalling their food intake from the previous day. The booklet "Food Portion Sizes: A Photographic Atlas" (Nelson *et al.*, 2002) was used to help estimate portion sizes. A non validated food frequency questionnaire was used to determine subject's intake of foods containing iron and foods known to enhance or inhibit iron absorption. Dietary intakes were analysed using FoodWorks Professional Edition Version 4.00. All subjects had a blood test taken at MedLab Central in Palmerston North. Biochemical iron status was determined on a non-fasting venipuncture blood sample using SF and Hb. Subjects with an abnormal C-Reactive Protein level had their bloods retested at a later stage. Subjects were sent a letter and explanation informing them of their blood test results. This project was reviewed and approved by the Manawatu-Whanganui Human Ethics Committee and the Massey University Human Ethics Committee. The results were analysed through stepwise multiple regression analysis using MINITAB (Minitab Inc, 2003).

RESULTS²

A total of 53 women were recruited over a 13 month period. Blood results were available for 45 of these women. The mean age of this group was 25.6±6.6 years and the mean BMI 23.2±2.7. Two women (4.4%) had iron deficiency anaemia (SF<12µg/L and Hb<120g/L) and two women (4.4%) had depleted iron stores (SF<20µg/L). All other women had normal iron stores (SF>20µg/L). The mean and median SF levels were 42.24±20.89µg/L and 39µg/L respectively. The daily mean and median iron intakes were 14.21±7.15mg and 13.65mg, both which met the RDI of 12-16mg iron / day. Eight women (17.7%) did not meet the United Kingdom's lower reference nutrient intake for iron of 8mg iron/day. Twenty women (44.4%) consumed less than 12mg iron per day and a further 10 women (22.2%) consumed less than 16mg iron per day. Multiple regression analysis showed that SF was positively associated with age and total dietary iron intake and negatively associated with tea and Vitamin C intake. Age explained 16.0 % (p<0.001) of the variation (partial coefficient of determination; partial R²) in SF, iron 8.4% (p<0.03), Vitamin C 8.0% (p<0.005) and tea 8.2% (p<0.03). No statistically significant relationship was found between SF and daily energy, protein, haem iron, vitamin A, fibre, calcium or coffee intake (p>0.05).

DISCUSSION⁴

The incidence of iron deficiency and depleted iron stores was lower than women in other New Zealand studies, but the incidence of iron deficiency anaemia was similar (Fawcett *et al.*, 1998; Russell *et al.*, 1999; Heath *et al.*, 2001). In a Dunedin study of women aged 18–40 years, 2% had iron deficiency anaemia (SF<12µg/L and Hb<120g/L), 4% had iron deficiency (SF<12µg/L, >40µmol zinc protoporphyrin/mol haem) and 19% had mild iron deficiency (SF<20µg/L) (Heath *et al.*, 2001). Six percent of women aged 19 to 24 years in the National Nutrition Survey had low iron stores or iron deficiency (<12µg/L) and 1% had iron deficiency anaemia (SF<12µg/L and Hb<120g/L). For women aged 25–44 years, the figures were 10 and 2% (Russell *et al.*, 1999). The lower incidence of depleted iron stores in our subjects may have been due to the exclusion of subjects who had donated blood in the past 12 weeks, the exclusion of vegetarians and a higher intake of dietary iron. Recent blood donation (in the past 4 months) is a risk factor for mild iron deficiency (Heath *et al.*, 2001) and blood donors have a lower SF concentration than non blood donors (Leggett *et al.* 1990; Brussard *et al.*, 1997). Vegetarian females tend to have lower SF concentrations than non vegetarian females, but do not appear to have a higher incidence of iron deficiency anaemia (Hunt, 2003). This may be due to a higher level of dietary iron absorption in vegetarians. The daily mean iron intake of 14.21±7.15mg was higher than that of the National Nutrition Survey (10.8 and 10.5mg for females aged 19–24 and 25–44 years respectively) (Russell *et al.*, 1999) and higher than that in a study with women of a similar age group (10.7mg) (Heath *et al.*, 2001).

Total dietary iron intake was the only dietary factor to show a statistically significant positive relationship with SF concentration. This finding is supported by two large European studies (Galan *et*

al., 1998; Preziosi *et al.*, 1994), however, most studies have not found this association (Galan *et al.*, 1985; Razagui *et al.*, 1991; Brussard *et al.*, 1997; Rangan *et al.*, 1997; Heath *et al.*, 2001). Haem iron intake had no effect on the iron status in this group. Several studies have found iron status to be positively correlated with haem iron and meat intake (Leggett *et al.*, 1990; Brussard *et al.*, 1997; Rangan *et al.*, 1997; Galan *et al.*, 1998; Heath *et al.*, 2001). This finding may have been more significant if we had included vegetarians in our study population.

Tea and vitamin C intake were negatively associated with iron intake. In single meal studies, the addition of tea to a meal strongly inhibits non haem iron absorption (Hurrell *et al.*, 1999), while Vitamin C increases non haem iron absorption, but only when taken at the same time as the meal (Cook and Monsen, 1977). Negative associations have been found between serum ferritin and tea consumption (Galan *et al.*, 1985), however, a meta-analysis found that tea consumption does not appear to affect iron status in populations who have an adequate iron status (Temme and Van Hooijdonck, 2002). The majority of studies in young women have not shown any association between total daily ascorbic acid intake and iron status (Galan *et al.*, 1985; Preziosi *et al.*, 1994; Rangan *et al.*, 1997; Galan *et al.*, 1998; Heath *et al.*, 2001) and no study has found Vitamin C intake to be negatively associated with iron status. Razagui *et al.* (1991) found that daily Vitamin C intake was less important than the amount of Vitamin C consumed at meal times in determining iron status. This may partly explain our findings.

No statistically significant relationship was found between SF and daily energy, protein, haem iron, vitamin A, fibre, calcium, alcohol or coffee intake. There were several limitations to this study. We did not consider the effect of blood loss through menstruation on iron status (Heath *et al.*, 2001; Harvey *et al.*, 2005) and a 24 hour recall may not provide an accurate or valid representation of what an individual normally eats. In addition, errors may occur through reliance on memory, over or underestimation of food intakes or recording errors. A diet record or a validated food frequency questionnaire may have been more appropriate to use to estimate dietary iron intake. Our method of recruiting was based on subjects volunteering for the study, which may have had an influence on the results.

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Impact of diet on satiety and body weight regulation: A review¹

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ABSTRACT⁴

Obesity is increasingly being recognized as a significant health challenge facing all ages of the population and it is a risk factor for several chronic disorders. The inclusion of foods in our diet that may enhance energy expenditure or improve satiety could be a practical way to maintain a stable body weight or assist in achieving weight loss. Protein is a satiating nutrient, and literature evidence suggests that when offered un-restricted in either animal or human studies, total dietary intake will be lower with a high protein diet compared to a diet rich in carbohydrates or lipids. The intent of this review is to shed some light on the role of protein and high-protein diets on satiety and bodyweight regulation with particular reference to dairy proteins. Carefully conducted clinical studies are needed to firmly ascertain the effect of dairy proteins on body weight maintenance, to assess their potential to assist in weight-loss efforts and to ascertain dose-response relations and mechanisms of action.

INTRODUCTION⁶

Obesity is increasingly being recognized as a significant health challenge facing all ages of the population and may soon replace smoking as the number one cause of preventable death (Peters *et al.*, 2003). Moreover, it is a risk factor for several chronic disorders such as diabetes, cardiovascular disease, hypertension, sleeping apnoea, osteoarthritis of weight-bearing joints, reduced fertility, asthma, and some cancers (Rippe *et al.*, 1998) and hence, effective treatment of obesity can lead to a reduction of risk factors for these diseases and may result in decreased morbidity and mortality. The etiology of obesity is multifactorial. Genetic, environmental, metabolic, and behavioral issues may all contribute to the development of obesity (Rippe *et al.*, 1998). The culture of over-eating and sedentary lifestyle is compounding the effects of a dietary profile that contains a large percentage of energy-dense processed and conventional foods (WHO, 1998). Another change that has aligned with the current obesity crisis in children and younger adults is the reduction in milk consumption with one study showing that between 1965 and 1996, milk intake decreased in American adolescents by 36% (Cavadini *et al.*, 2000).

Currently, there is no functional food available for obesity, such as there is for cardiovascular disease or cancer (St-Onge, 2005) and hence efficient, effective and satisfying treatments are required. Nutritional research strategies that target aspects of the physiology of obesity are critically important if a workable solution to this health challenge is to be found. One area identified as showing potential is the possibility of creating food choices that, through physiological modulation, can induce greater satiety, and therefore reduce intake.

It is well known that if body weight is to remain stable over time, energy intake (food intake) must match energy expenditure (the sum of metabolic activity and physical exercise) over long durations. Any chronic deviation from this equilibrium will result in weight gain or loss (Woods, 2005). The objective of the present review was to shed light on the role of protein and high-protein diets on satiety and bodyweight regulation, and in particular the role dairy proteins may play in inducing satiety.

Effects of proteins, carbohydrates and lipid on food intake and body weight management¹⁰

The macronutrients protein, carbohydrate and fat exert different satiating efficiencies with protein being the most satiating and fat the least satiating (Westerplantenga *et al.*, 1999; Anderson and Moore, 2004). The relationship between perception of satiety and metabolic rate, with varying macronutrient composition, was assessed in man in a controlled situation over 24 h in a respiration chamber (Westerplantenga *et al.*, 1999). Satiety and fullness were significantly higher in subjects on the high protein/high carbohydrate diet, than on the high fat diet, while hunger, appetite, desire to eat,

and estimated quantity to eat, were significantly lower. Moreover, a higher diet-induced thermogenesis (DIT) with a high protein/high carbohydrate diet, compared to the DIT with high fat diet was observed and that satiety was positively related to 24 h DIT. Increased satiety on a high protein diet, under similar energy intake conditions was also shown in the longer term, during a weight maintenance/weight regain period (Westerplantenga *et al.*, 2004). 1

The impact of high protein diets on body-weight loss have been assessed in different studies with contradictory results. The effects of 25% versus 12% energy intake from protein on weight loss in obese subjects was examined. Weight loss and fat loss were significantly higher in the high protein group, most likely due to a lower energy intake (Skov *et al.*, 1999). On the other hand, Due *et al.* (2004) conducted a follow-up study and found that after 12 months weight loss was not significantly greater among subjects in a high protein group, but they had a greater reduction in intra-abdominal adipose tissue. 2

A stronger short-term satiety effect of protein, compared with that of fat and carbohydrate, is evidenced by the delay in time at which food is requested after a protein load. For example, when young men were fed ad libitum lunch followed 4 h later by mandatory snacks containing the same amount of energy but were either high in protein (77% of energy), fat (58% of energy), or carbohydrate (84% of energy), the dinner requests were delayed the longest, by 60 min, on the day that a high protein snack was consumed, while requests were only delayed by 35 min when a high carbohydrate snack was consumed and by 25 min on the day that a high fat snack was consumed by the subjects (Marmonier *et al.*, 2000). 3

In another study where the subjects were fed a low fat (30% of energy) diet containing either 25% or 12% of energy as protein, the subjects ate less on the high-protein diet and it was concluded that this was due to the enhanced satiety caused by the high-protein diet (Skov *et al.*, 1999). In addition, the subjects on the 25% protein diet had a greater reduction in body weight than their counterparts consuming the 12% protein diet. Layman *et al.* (2003) conducted a study in which women were given diets containing different carbohydrate to protein ratios for 10 weeks and found that women who consumed a diet with a carbohydrate to protein ratio of 1:4 showed similar weight loss but greater satiety than those eating a diet containing a carbohydrate to protein ratio 3:5 and thus the authors provides further evidence on the role of protein in contributing to satiety. 4

In addition to promoting fat loss, high protein diets maintain lean body mass and a relatively high rate of metabolism, which is a major component of total energy expenditure (Layman *et al.*, 2003). Recently, Lejeune *et al.* (2005) investigated whether the addition of protein to the diet might limit weight regain after a weight loss of 7.5% in moderately overweight subjects and found that subjects who consumed 18% of their energy as protein regained less weight during 6-12 months weight maintenance (0.8 kg), compared with subjects who consumed 15% of their energy intake as protein (3 kg). In addition, the body mass regained in the protein group consisted only of fat-free mass while in the control group the body mass regain was fat mass as well as fat-free mass. The researchers also observed a greater increase in post-absorptive satiety in the protein group during weight maintenance, although their energy intake did not differ significantly from that of the control group and this higher post-absorptive satiety was attributed to increased thermogenesis. 5

Only a few studies have been conducted in order to determine the role of protein source on feeding response in humans, with conflicting results. It has been found, for example that food intake suppression in the next hour of feeding is greater following gavage with whey compared with egg-albumin and soy protein (Morgan, 1998) and this difference in activity was attributed to physiological action of the proteins in the gut and not to their nutritional qualities. In another study, young men fed a meal containing 50 g of protein from lean fish were less hungry over a 3-h period than when they were fed an equivalent amount of protein as either beef or chicken (Uhe *et al.*, 1992). In contrast, some studies report that protein source in a mixed meal is not a factor in food intake suppression at a later meal (Lang *et al.*, 1999). 6

Impact of milk and other dairy products on satiety and body weight regulation 7

Milk proteins (whey and casein) appear to differ in their effects on food intake (for more details see Anderson and Moore, 2004). In one study, monkeys fed a liquid diet using a system that allowed manipulation of the intragastric diet, ate 25% fewer calories when the intragastric diet was 50% casein compared to a 14% reduction in calorie intake with a 50% whey diet (Hannah *et al.*, 1990). 8

Many reasons for these differences were hypothesized such as the peptide products derived from the dietary protein and their physiological effects preabsorptively, where whey protein rapidly enters the jejunum mostly as an intact protein, whereas casein is slow to appear and mainly in the form of degraded peptide (Boirie *et al.*, 1997). Mahe *et al.* (1996) reported that the difference between whey and casein is largely attributed to the clotting and precipitation of the casein (unlike the soluble whey protein) in the acidic media of the stomach, giving it longer exposure to gastric peptic hydrolysis. Hall *et al.* (2003) conducted two studies in order to investigate the effects of casein and whey milk proteins on food intake and subjective ratings of hunger and fullness, and on postprandial metabolite and gastrointestinal hormone response and reported that whey consumption leads to higher plasma concentrations of factors known to contribute to satiety including amino acids, glucose-dependent insulinotropic polypeptide, glucose-like peptide-1 and CCK.

In addition to milk proteins, there is increasing evidence that dairy calcium may play a role in body weight regulation (Zemel, 2002). It is proposed that intracellular calcium plays a role in adipocyte metabolism and that its concentrations are modulated by calcitrophic hormones. An increase in calcium intake in foods would down-regulate 1, 25-dihydroxyvitamin D, which would result in a decrease in the absorption of calcium into adipocytes and pancreatic islet cells. Within the adipocyte, intracellular calcium increases fatty acid synthase transcription and inhibits lipolysis. Within the pancreas, intracellular calcium stimulates insulin release, which further acts to inhibit lipolysis and stimulate fatty acid synthase transcription. Therefore, any reduction in intracellular calcium would lead to a reduction in lipogenesis and the stimulation of lipolysis (Zemel, 2003). The higher activity of dairy calcium compared to elemental calcium may be attributed to the presence of other compounds within dairy products that act in concert with dietary calcium to produce antiobesity effects. Such compounds that have been proposed are whey proteins, conjugated linoleic acid, and branched-chain amino acids (Zemel, 2003).

Recently, a clinical trial has been conducted to examine whether dairy or elemental calcium supplementation enhanced weight loss in obese men and women (Zemel *et al.* 2004). At the end of the weight-loss period, subjects in the low-dairy, high-calcium, and high-dairy groups lost 6.4%, 8.6%, and 10.9% of body weight, respectively. Fat-mass loss followed the same trend: the low-dairy, high-calcium, and high-dairy groups lost 8.1%, 11.6%, and 14.1%, respectively, of total fat mass. Fat loss from the abdominal region represented 19% of the total fat loss in subjects in the low-dairy group and 50.1% and 66.2% for those in the high-calcium and high-dairy groups, respectively. The authors concluded that calcium particularly that from dairy products can enhance weight loss in obese persons.

A RAT model for measuring satiety and preliminary results

Different animal models have been used to measure the satiating effect of various diets. One model developed by Froetschel *et al.* (2001) and found to be very reliable involves providing rats with a premeal 20-30 minutes prior to their daily meal and assessing the impact of that premeal on subsequent food intake. Critical to the success of this model is adaptation of the rats to a daily feeding regimen that restricts their access to food to a given period of time, thus ensuring that the rats will begin feeding as soon as the food is offered. This model has been used successfully at Massey University, with minor modifications, to determine the satiating impact of premeals of various dietary components. In one example (Molan, A; Darragh, A; Rowan, A; Haggarty, N – unpublished), a study was conducted to determine whether milk proteins, given shortly before the onset of a meal, would influence total daily food intake. Female rats aged six weeks were housed individually in hanging wire-mesh stainless steel cages in a room with a temperature of 22 ± 1 °C and a 12-h light: dark cycle and had free access to water throughout the study. All rats were habituated to the same 20-h deprivation schedule whereby a feeder containing more than one day's expected intake of food (AIN-93 diet) was made available to each rat for a total of four hours (1000 - 2000h; 2 hours in light cycle, and 2 hours in the dark cycle) in an attempt to provide a more controlled and exaggerated appetite response at feeding and emphasize gastric mechanisms of intake regulation (Froetschel *et al.*, 2001).

The rats were given a premeal of 1ml of fluid, in which was suspended the milk protein to be tested. This premeal was administered to the rat via gavage (at the back of the throat) using a very soft silicon rubber tube attached to a 1-ml syringe. So that the rats are comfortable with this procedure, during the 7 day adaptation period the rats were handled daily, and for the last three days of the adaptation period, premeals of sterile water were gavaged into each rat once a day prior to the meal being offered. For the remainder of the study rats were put through a design with three experimental blocks. Each block tested three milk protein groups (n=10 per group) against a control group (n=10).

The pre-meal was given to each rat 20 minutes before the normal mealtime, and impact of the pre-meal was determined by monitoring changes in each rat's total food intake for that day. This was repeated for a period of four days. Food intake was determined by the difference in weights of food cups before and after each feeding period and corrected for spillage. A wash-out of three days was scheduled between each test period. On the wash-out days, the rats did not receive any pre-meal, but continued with the four-hourly meal regimen.

During the adaptation period, there were no between-group differences in food intake, water intake and body weight (data not shown). All rats consumed their diets as expected and demonstrated acceptable weight gains. Transition from the normal diet (pelleted chow) to a powdered diet induced a rapid depression in food intake during the first 3-5 days and then gradually adapted to the new diet. The powdered food was used in preference to pelleted chow because its consistency minimized spillage, thereby preventing animal from removing food from the feed for consumption at a later time.

The gavaging technique guaranteed that each rat received orally a define amount of load and prevented any issues arising because of palatability differences in the pre-meal. Nine milk protein mixtures were tested and four of them (MP2, MP4, MP8, and MP9; Figure 1) showed a satiety effect as evidenced by their ability to reduce food intake by 13–17% ($P < 0.05-0.01$) compared with the rats given water as a placebo.

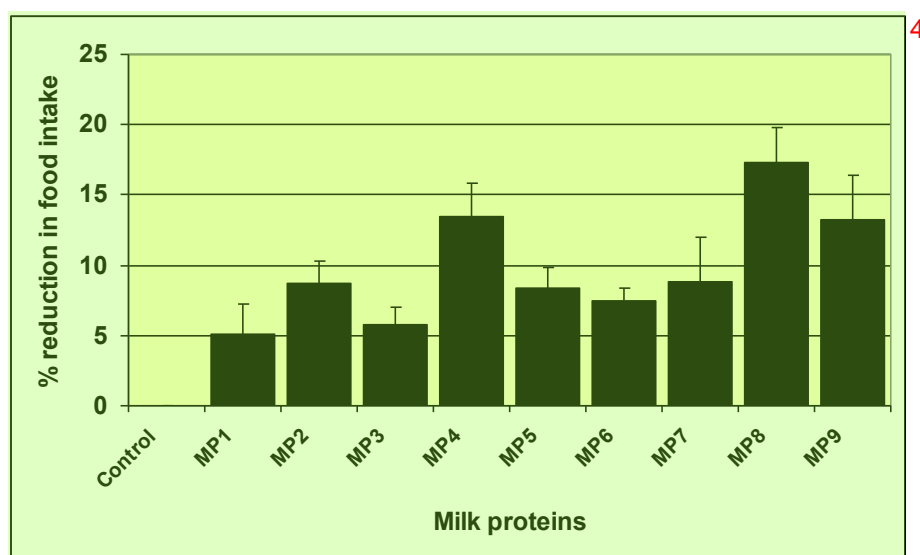


Figure 1. Percentage reduction of food intake in rats preloaded with 9 different milk proteins (MP) relative to control rats preloaded with water only. Vertical bars represent the Standard Error. The % reduction in food intake (FIR%; satiety effect) was calculated by using the following equation:

$$\% \text{ FIR} = \frac{[\text{Food Intake (Control)} - \text{Food Intake (Protein Pre-meal)}]}{\text{Food Intake (Control)}} \times 100$$

The reduction in food intake, observed over four hours in rats given a preload of milk proteins in comparison to rats in a control group given the same preload volume of water, has led to the conclusion that the decrease in food intake was mainly the consequence of a satiating effect of the proteins rather than simply a stomach distension effect.

Recently St-Onge (2005) reported that the inclusion of foods or the replacement of habitual foods with others that may enhance energy expenditure (EE) or improve satiety could be a practical way to maintain a stable body weight or to assist in achieving weight loss; such foods may act as functional foods in body weight control. Although the precise mechanisms which underlie the satiating effects of proteins are not fully understood, they may trigger receptors for amino acids which have been detected in the wall of the upper intestine (Mei 1992). The afferent fibres from these receptors may inform certain brain centres that a source of energy and/or a specific nutrient has been ingested. Alternatively, such receptors may play a role in inducing satiety by triggering the release of hormones such as cholecystokinin (CCK), which might act directly at the central and/or peripheral levels to

stimulate pancreatic juices and reduce gastric emptying. Other post-absorptive metabolic effects of amino acids must also be taken into account, together with direct central signals associated with amino acids. Amongst the metabolic factors which may be responsible for a reduction in food intake during high-protein feeding, two main hypotheses have been suggested: an elevated plasma-free amino acid concentration (Morens *et al.*, 2001) and an increased metabolic rate resulting from the marked thermogenesis induced by ingesting amino acids, a mechanism which underlies several important hypotheses (energetic, metabolic, ischymetric) concerning the control of food intake (Even *et al.*, 2000).

According to Woods and his colleagues (1998, 2005) there are two types of signals that influence food intake and energy expenditure: signals generated during meals that influence the sensations of satiation (i.e., fullness, or signals that contribute to the decision to terminate an ongoing meal) and satiety (i.e., signals that function to prolong the interval until hunger or a drive to eat reappears) and these signals are collectively called “satiety signals,” and the prototypical example is CCK. The second category includes hormones whose secretion is proportional to the amount of fat in the body, and it includes insulin from the pancreatic islets and leptin from adipose tissue, stomach and elsewhere. These hormones are transported from the circulation into the brain through the blood-brain barrier, and once inside the brain they interact with specific receptors on nerve cells.

CONCLUSION

Obesity is increasingly being recognized as a significant health challenge facing all ages of the population and it is a risk factor for several chronic disorders. Increasing the satiety of food and diets is likely to be a more positive approach to weight management, particularly in vulnerable groups such as children, and would help avoid the negative psychological ramifications of caloric-control and “dieting”.

Protein is a satiating nutrient, and literature evidence suggests that when offered un-restricted in either animal or human studies, total dietary intake will be lower with a high protein diet compared to diet rich in carbohydrates or lipids. Increased protein intake sustained weight maintenance by increasing satiety, and therefore sustains reduced energy-intake diets, by favoring regain of fat-free mass at the cost of fat mass at a similar physical activity level. There is evidence that the high satiating effect of protein may be attributed to the ability of high protein diet to imply a high thermogenesis. More studies are needed to explore the reasons behind the satiating activity of protein.

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Preconceptional nutrition and lifestyle in young women in the Manawatu region¹

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ABSTRACT³

78 women aged between 24 and 40 were recruited from the Manawatu area in 2004. 31⁴ women were trying to conceive and the remainder were not intentionally planning to become pregnant in the forthcoming 12-month period. 40% of all women had more than 30% body fat. Half of the women reported an undesirable high alcohol intake per occasion, though this was less common in women intending to conceive. Intake of various micronutrients varied from insufficient to inappropriately high as consumption of fortified foods and nutrient supplements was common in some women. About half the women planning pregnancy consumed folic acid supplements as recommended; the remainder of women planning pregnancy stated they planned to take folic acid supplements when their pregnancy was confirmed.

INTRODUCTION⁵

Increasing evidence suggests that maternal nutrition and lifestyle factors during the⁶ preconceptional period can affect maternal (King 2000) and potential infant health including the infant's later risk of developing some adult-onset disease (Barker 2003). There is increasing recognition that body composition of the mother can affect her fertility and the outcome of pregnancy (de Weerd *et al* 2003). Several lifestyle factors such as smoking, alcohol consumption and caffeine have a negative effect on fertility (Curtis *et al* 1997, Hakim *et al* 1998, Hassan & Killick 2004, Henriksen *et al* 2004, Jensen *et al* 1998). Currently little information or support is available for women planning pregnancy in New Zealand. Before effective nutrition interventions can be planned or designed, it is important to know the nutritional intakes of women who may become pregnant and the factors which affect their nutritional status and their beliefs about nutrition and lifestyle which might impact on conception and pregnancy.

METHODS⁷

We recruited a sample of convenience from the Manawatu area between April and December⁸ 2004. The study design received ethical approval from Massey University Human Ethics Committee and prospective participants were recruited by advertisements in the press, on local radio and on various community notice boards. Subjects were women aged between 20 and 40 who were not pregnant and had no known (declared) history of infertility. 101 women expressed interest in the study and asked for further information. 78 women volunteered to participate in the study; 47 women were not deliberately intending to become pregnant and 31 were planning pregnancy.

Anthropometric measurements including weight and height (using the BodPod weight scales⁹ and a Toleda stadiometer respectively), hip and waist circumference (using a Jobst tape) skinfold thicknesses (triceps, biceps, subscapular and suprailiac skinfold thicknesses using Holtain skinfold calipers) and air-displacement plethysmography (BodPod, Life Measurement Inc) were conducted.

Subjects were also interviewed about their lifestyle using a structured interview which¹⁰ included questions about demographic characteristics (age, occupation, reproductive history), personal health and lifestyle factors. Nutritional intake was determined by 24-hour dietary recall using a photographic atlas (Nelson *et al* 1997) to assess portion sizes and Xyris FoodWorks (version 3.02) to analyse data. Under-reporting was assessed using the Goldberg cut-off values (Goldberg *et al* 1991); 5 women planning pregnancy and 5 women not intending to become pregnant were excluded on the grounds of underreporting intake. Nutritional intake was compared to the New Zealand National Nutrition Survey (Russell *et al* 1999), the New Zealand nutritional recommendations (Truswell *et al* 1990) and to Institute of Medicine recommendations (Institute of Medicine 1997, 2000, 2002, 2004).

RESULTS 1

Although 31 of the 78 women recruited to the study defined themselves as planning pregnancy, 21 women were actively planning pregnancy as soon as possible, were not using contraceptives and had discussed their hopes for pregnancy with their partners. 10 of the subjects were planning pregnancy within 12 months at the time of recruitment but were still using contraception or had not discussed their hopes with their partners.

Table 1 3

| | Control Group (n=47) | Planning pregnancy (n=31) 4 |
|--------------------|----------------------|-----------------------------|
| Age | 26.6 ± 3.64 y | 30.9 ± 4.33 y |
| Previous pregnancy | 21.3% | 51.6% |
| Mean body fat | 28.3 ± 6.65% | 31.15 ± 7.47% |

Lifestyle Factors 5

The percentage of women who smoked cigarettes was 6.4%, considerably less than the estimated 25% of all women who smoke in New Zealand (Barnett *et al* 2004). 2 women also indicated that they were occasional smokers of marijuana. This low incidence of reported smoking probably reflects the high educational level of the subjects. All women but one agreed that women who are trying to conceive should avoid smoking. 93% of all women in the study thought that women who were trying to conceive should avoid alcohol. However, 89% of women not intending to become pregnant, and 71% of women planning pregnancy immediately, drank some alcohol (5.8 and 5.3 standard drinks per week respectively). Half the women not intending to become pregnant did not meet the ALAC (Alcohol Advisory Council of New Zealand) guidelines for alcohol intake per occasion; no more than 4 standard drinks per occasion (Alcohol Advisory Council, 2002). Women planning pregnancy tended to consume alcohol more regularly throughout the week; again this may reflect the slightly higher mean age of this group.

Coffee consumption in women planning pregnancy and women not planning pregnancy was similar (62% and 65%) but 13% of women planning pregnancy drank decaffeinated coffee (none of the women not intending to become pregnant drank decaffeinated coffee). 70% of all women thought women planning pregnancy should avoid coffee; those women who did not drink any coffee were more likely to think that coffee should be avoided at the time of conception and during pregnancy.

Anthropometric measurements 8

34.7% women had a BMI over 25 kg/m² and 38.9% women had more than 30% body fat. 9 There were slight differences between the body composition of women planning pregnancy and those not intending to conceive but these differences are largely attributable to the difference in mean age of the two groups of women. No difference was seen in the waist:hip ratio between the two groups. 53% of women in the study were not satisfied with their current weight and 41% of women were actively trying to lose weight.

Nutrient Intake 10

In general, the women in the study had nutrient intakes in excess of the mean intake from the National Nutrition Survey, possibly reflecting their higher educational background and above average mean income. Purchase and consumption of fortified foods and vitamin and mineral supplements was relatively high; these had a significant impact on micronutrient intake. Of particular note was that women planning pregnancy had a significantly lower energy intake from carbohydrate (53.4±8.2 vs. 48.6± 6.8%; p<0.05) (and energy intake from fat was higher) because they were consuming less complex carbohydrates (monosaccharide and disaccharide intake was similar in both groups). The intake of saturated fat was similar in both groups (average of 46.3% of total fat intake). 78% of women agreed with the statement "I should eat less saturated fat". On average, women consumed an average of 2.6 portions of fruit and 2.8 portions of vegetables per day.

About half of all women took a daily nutrient supplement. None of the women not intending to become pregnant took a folic acid only supplement; supplements that were consumed had lower than the recommended intake of folic acid for women in the periconceptual period. Women planning pregnancy used more supplements and 45% of these women planning pregnancy took a folic acid

supplement designed for the periconceptual period. Predominant reasons for taking supplements were to prevent a dietary deficiency or sickness or because the woman felt tired or low. The consumption of nutrient supplements contributed to the wide range of micronutrient intakes of the women taking part in the study. Excluding the contribution of supplements, the New Zealand recommendations were not met by 34% of women for folate, by 41% of women for iron, by 50% of women for vitamin A and by 50% of women for calcium.

DISCUSSION

The women who took part in this study had a higher incidence of overweight/obesity compared to women of this age group in other New Zealand surveys. This may reflect the timing of the study; the incidence of obesity is increasing (Ministry of Health 2004). Being overweight affects fertility (time to conception) (Mansour 2004) and outcome of pregnancy (Waller & Dawson 2005, Castro & Avina 2002). Generally, women in the study accurately judged their body fat, alcohol intake and consumption of saturated fat; however, behaviour did not reflect their stated concerns. Similarly, of the women who were hoping to become pregnant all were either taking folic acid supplements or planned to do so when they became pregnant. For those women not currently taking the recommended folic acid supplements or consuming high intakes of coffee or alcohol, the point of planned behavioural change was confirmation of pregnancy. The results of this study are similar to the findings of the Dutch explorative study which investigated dietary intake and lifestyle factors in women planning pregnancy (de Weerd *et al* 2003). It was reported that less than half the women planning pregnancy were taking a folic acid supplement and intake of vitamin A, iron and some other micronutrients were particularly low in about 50% of the subjects. Whilst it is known that awareness of nutritional and lifestyle issues does not necessarily affect behaviour (Croghan 2005, Shepherd 2005), some aspects of the lack of awareness of the importance of diet and behaviour before and at conception maybe related to lack of support and information. It is of concern that a large number of women appear not be preparing themselves for pregnancy and are not fully aware of the importance of this periconceptual period for the outcome of pregnancy.

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Nutrition Today, Health tomorrow – Communicating the science.¹

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Introduction³

Nutrition today: health tomorrow is an important message. Health and wellbeing is the outcome of a complex interaction of biology- genetic endowment, uterine environment and external factors including nutrition. Research over the last two decades has provided a substantial amount of data on possible influences of dietary factors on health, especially as regards chronic long effects (Simopoulos, 2005) dispersed in the scientific literature and discussed at seminars and conferences and a basis for different dietary guide lines (Baghurst, 2003; Cooper and Zlotkin, 2003; Dwyer, 2001; Schneeman, 2003). How successfully has this information been disseminated to the general population? A large survey in Britain on changes in physical activity and dietary habits over an 8 year period in a 1958 cohort concluded that life style habits such as dietary intake were slow to change and that current health promotion strategies may need to be supplemented with additional methods to achieve the desired outcomes (Parsons *et al*, 2005). A large American survey of army personnel reported that though physical activity goals were met improvement was needed to meet the nutrition goals (Yore *et al*, 2000). A report by the New Zealand Cancer Society reported that 66% NZ adults know eating fruit and vegetables is important for health, but 48% do not consume the recommended 5+ servings a day (Sullivan *et al*, 2004). Therefore the important questions- and challenges - are: Is the correct message being received? And, more importantly: Is it being acted on?

Nutrition behind our health⁵

In a nutritional context health promotion can be seen as the interface of behavioural psychology, educational theory and nutritional science and different terminology and theoretical frameworks are used including the stages of change (Blackburn, 2005; Verheijden and Kok, 2005). Empowerment, leading to active participation, is a key component of health promotion, defined as “the process which enable people to gain control over their health determinants in order to improve their health” (Koelen and Lindstrom, 2005). A critical requirement for this in conjunction with biological, environmental and psychosocial factors is *health literacy*. This is defined as “the cognitive and social skills which determine the motivation and ability to gain access to information, and to understand and critically use this information in ways which promote and maintain good health” (Nutbeam D, WHO 1998) quoted in (Koelen and Lindstrom, 2005).

Therefore health literacy incorporates both nutritional understanding and efficacy – an understanding of the relevant health implications of dietary choices, as well as the means to put this into practice. This awareness is the first step towards participation, behaviour change, risk change and disease change. So a crucial issue related to this is how effectively nutrition messages are communicated to the wider community. According to Blackburn (2005) “90 million Americans lack basic skills needed to access, understand and use health information and services to make healthy dietary choices”.

In the public arena, the importance of food and nutrition is increasingly recognised as a major factor in short and long term health as well as fitness and performance by the community at large. That nutrition is news, is clear from biannual surveys on news stories about food and health and state by the Centre for Media and Public Affairs for the International Food Information Council Foundation, an American based organization supported by food, beverage and agricultural industries. The same group identified sources of nutrition information for consumers in recent years to be magazines (95%) and books (72%) compared to 25% for nutritionists or dieticians. A small pilot survey in New Zealand likewise identified books, magazines and newspaper as well as family and friends as significant sources. In the use of nutritional supplements, the media have likewise been show to be important (Rowe and Toner, 2003). For the general public there are many books and articles in newspapers and magazines on healthy eating as well as a huge diversity of information from the internet. The problem is that the nutrition messages often do not come from the professionals in the field. Adding to the confusion is that they don’t always appear to agree, even those that do come from the scientific

community and sometimes seem to change, as for example in the recent challenge by the Harvard Medical School scientists of the traditional health pyramid dietary guidelines, appearing in the public press (Consumer, 2003) and the pros and cons of a high protein diet.

Studies reported in the 1980s and early 1990s led to the conclusion that “simply changing knowledge is unlikely to have the desired effect” as regards eating patterns (Shepherd and Trower, 1992 quoted in Wardle *et al*, 2000) These authors argue that this assumption was based on inadequate evaluation and methodology and that the value of nutrition education had been prematurely rejected. Conversely, they reported a strong association between nutrition knowledge and intake of fruit, vegetables and fat (Wardle *et al*, 2000) . Similar results have been reported with respect to cancer prevention dietary behaviour (Harnack *et al*, 1997). An Australian report noted that those with tertiary education tended to know more about food and nutrition and appear to have healthier dietary habits (Worsley *et al*, 2004). In their study of 138 participants Crites *et al* concluded that health evaluations were more strongly associated with attitudes for people with high nutritional knowledge (Crites and Aikman, 2005). Over recent years in Europe, there is an increasing acknowledgement of the importance of effective, informative and appropriate nutrition communication using different channels including family doctors (Koster *et al*, 2005; Truswell *et al*, 2005).

Conclusion

Attitudes, belief systems, barriers, conflicting or/and confusing or/and misleading nutrition messages from a wide diversity of sources in the public arena all need to be factored into the equation for effective nutrition promotion. Likewise communication channels, and the appropriate nutrition message (Reger *et al*, 2000; Worsley, 2002) in addition to an appreciation of the evaluation tools used in nutrition education intervention research (Contento *et al*, 2002). This presentation raises and discusses some of these issues.

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Health tomorrow, for all or some? ¹

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ABSTRACT ⁴

Functional foods have the potential to improve health, but the question is raised as to whether ⁵ a benefit will be gained across the population, or if developments in this area will result in increased health inequities associated with socio-economic status. Are functional foods more expensive and inevitably beyond the reach of families with lower incomes? How does the promotion of some foods as having an 'extra benefit' influence understanding of a 'healthy diet'? Some insight into this question can be provided by examination of products currently on the market and investigation of consumer perceptions. The response of the nutritionist needs to be debated.

INTRODUCTION ⁶

Nutrition research is identifying new ways to reduce disease risk and optimise health, but ⁷ will 'cutting edge' nutrition research improve health for all, or will it only benefit wealthy, health conscious people? In particular, can research in the fields of functional foods and nutrigenomics reduce health inequalities associated with socioeconomic status, or will such research only support the status quo, or perhaps lead to greater inequalities?

Inequalities in health associated with socioeconomic status are a global reality. In New ⁸ Zealand, although death rates associated with a number of chronic diseases are falling across the population, inequality associated with socioeconomic status has remained and relative inequality has increased (Ministry of Health, 2005). An example of this trend is illustrated in Figure 1.

Figure 1: Cardiovascular disease mortality rates by income and sex (Ministry of Health, 2005) ⁹



Diet has been implicated as one of the causes of premature death that can be realistically ¹¹ addressed. Since inability to access the medical sector has been cited as a barrier to health for some people in lower socioeconomic groups diet would seem to be a particularly useful public health intervention towards the reduction of health inequities.

Functional foods and nutrigenomics have been promoted as tools for improving public health (IFT, 2005; Jones, 2002; Darnton-Hill, 2004). While research has shown these to have great potential in terms of identifying and addressing disease risk it is not clear how accessible they will be to those of lower socio-economic status. At present, both are being offered—for a price—by the private sector. Genetic profiling is expensive and is unlikely to be made available as part of freely accessible public health care (Chadwick, 2004). Even if public money were made available for genetic profiling it has been argued that it may not be the wisest use of limited public health funds (Chadwick, 2004).

To date promoting foods as functional is primarily an industry initiative, and doing so is a way to differentiate products, add value and increase profits (Holm, 2003; Euromonitor, 2003). A quick look at the supermarket shelves in New Zealand shows that in some food categories those promoted as having a health benefit, e.g. margarine with added plant sterols and nutritionally differentiated milks, cost more than similar foods without the added nutritional 'benefit'. It is unlikely that people with lower income will be purchasing these more expensive 'functional' options within the food category. Research in the US has shown that people with low incomes are more likely to purchase generic brands and less expensive products within a product class (Ackbay & Jones, 2005) and Otago University assumes "purchase of the 'lowest priced item within each food category' when calculating 'Basic Family Food costs for their annual estimated food costs survey (Department of Human Nutrition, 2005). Thus the benefit of many functional foods is not likely to be obtained by those with low incomes.

If we accept that nutrigenomics and functional foods will not be accessible to the less privileged members of society and so not directly benefit their health, then the question must be asked, 'will they cause any harm?' Mechanisms by which harm may be caused include:

- a) diversion of scarce dollars away from research and public health interventions that are more likely to benefit the broader population (Chadwick, 2004)
- b) distract people from core nutrition messages of 'balanced' diets (Holm, 2003; Mathers, 2000)
- c) increase the perception that 'healthy' foods cost more, so that people who can not afford functional foods or genetic analysis believe that a healthy diet is 'out of their reach' and hence disregard all nutrition messages

In the remainder of this paper I will further examine these potential mechanisms for harm.

Research dollars need to be used so that they achieve the most benefit for the population (Darnton-Hill, 2004). This is not to say that research should not address these new areas, but that we as a research community have an obligation to ensure that a broad range of areas are researched, not just those with clear 'commercial potential'.

Health claims for foods, described as 'the engine' for functional foods, have been promoted partly as a way to educate the consumer (Holm, 2003). While there is some evidence that they can help raise consumer awareness to a small extent (ANZFA, 2000), research in Australia found that many nutrition related claims do not reflect important public health nutrition issues, e.g. "cholesterol free" (Williams *et al*, 2003.) Therefore it is important that public funding for nutrition promotion continue, or even increase, alongside of industry initiatives.

Nutrigenomics and functional foods pose a challenge to traditional nutritional promotion. For example from the point of view of nutrigenomics, general population recommendations do not make a lot of sense. For example, it would be ideal if all people could know if they individually will benefit from consumption of moderate amounts of alcohol, but the reality is that public health messages need to present information in the absence of this certainty. We need to maintain confidence in public health messages in light of publicity about nutrigenomics.

Likewise functional foods appear to be the antitheses of current nutrition education with its focus on total diet as opposed to single foods. Health claims for functional foods are often worded to indicate that the benefit of the product occurs as 'part of a balanced diet', e.g. the health claims for folate fortified foods are required by the Food Standards Code to include a statement related to the 'importance of maintaining a varied diet' (FSANZ, 2005a) In qualitative research commissioned by FSANZ most consumers felt that the inclusion of the term 'healthy diet' or 'healthy, balanced diet' in a health claim was relevant (FSANZ, 2005). But the question remains as to whether consumers hear the entire message or focus on the food that is being promoted as a 'magic bullet'. The food industry has

far more money available for nutrition promotion than does the health sector, so it is possible that the health and nutrition messages from industry could overpower those from the health sector. There is some evidence that US consumers experience information overload, leading to emphasis placed on less important information (Variyam & Golan, 2002). Although this is the case for consumers across the socio-economic spectrum, the fact is that people with less money to spend on food must make wiser food choices (Department of Human Nutrition, 2005). 1

To date promotion of functional foods has come primarily from industry, with the associated marketing aims and premium pricing. Perhaps nutritionists should integrate information about functional foods into current dietary recommendations. Should we be promoting the functional properties of whole foods as a way to promote variety in food groups? One of the few examples of recognition of a 'functional food' in nutrition education material is the inclusion of a glass of wine with the food pyramid proposed by Willet and Stampfer (2003). 2

There is a perception amongst some of the population that 'healthy foods cost more', e.g. Strong (2005). Jetter and Cassidy (2005) showed this to be the case in areas of California. In New Zealand the cost of fruit and vegetables is cited as a barrier to increasing consumption, and consumers in less affluent areas are less likely to meet recommended intakes of fruit and vegetables (Russel *et al*, 1999). They are also less likely to consume trim milk, as opposed to standard milk² (Russel *et al*, 1999). 3

In an attempt to examine the hypotheses that promotion of functional foods may distract people from core nutrition messages and/or contribute to the perception that 'healthy food costs more' and hence leads to resignation by those on a limited income that a 'healthy diet' is unobtainable, I carried out a small qualitative study in a rural area of the North Island (Weber, unpublished data). Using in depth interviews the 'cost of a healthy diet' and 'feeding the family properly' was explored using a questionnaire and in depth interviews with parents of primary school children. In this research, people who reported difficulty in feeding their family 'properly' mentioned fruits, vegetables, dairy products and meat as being prohibitively expensive. They said they did not always purchase as much of these as they would like. Price was the main determinant of what they bought within a product category; health and nutritional aspects of the product were not part of the decision. 4

Normally go for budget and whatever's on special 5

In this group of people of people experiencing food stress³ there did not appear to be much awareness of foods marketed as having a nutritional advantage, although they agreed that some foods might be better nutritionally, e.g. those with the Heart Foundation tick. The foods with Heart Foundation tick were generally recognised as better nutritionally, but not affordable and so not part of their usual food purchase decision making. 6

People who stated that they could feed their family properly also agreed that 'healthy food costs more', but they mentioned specialty oils and spreads, and brown bread as the healthy foods that cost too much. While they recognised some foods as 'better' in terms of nutrition, their inability to purchase them was not seen as a barrier to feeding the family 'properly' because these foods were not considered to be essential. 7

If I bought that [spread with omega 3s] then I wouldn't be able to buy something else. I'm on a tight budget" 8

Vegetables spike in price sometimes, but you need to buy them.... Brown bread would be better, but...

Foods with the Heart Foundation Tick were also considered to be 'better' by this group also, but they are thought to be expensive and again not necessary. 9

There was limited awareness of fortified foods currently for sale in New Zealand, but when products were described to them the parents expressed a belief in the benefit of basic foods to supply needed nutrients. 10

² Standard milk can be purchased at a lower unit price than trim milk, although there is no independent evidence that cost is the determinant of this choice.

³ Food stress is used to refer to people who, in a questionnaire, indicated that they could not always afford to feed their family properly.

“but they’re eating their vegetables, so they’ll get fibre from them” (in response to question about fibre white bread)
“they get that from milk” (in response to description of orange juice with added calcium)

These responses suggest a basic understanding of nutrition/ food composition. Although the parents expressed scepticism about nutritionally enhanced products it remains to be seen if their basic understanding remains after exposure to a large amount of advertising incorporating nutrition messages.

All the parents interviewed described feeding the family properly as consisting of a diet including vegetables, fruits, meat, etc, in other words ‘basic foods’. Thus in this small sample the hypothesis that promotion of functional foods has distracted people from basic nutrition messages or lead them to believe a ‘healthy diet’ was ‘out of reach’ was not borne out. This may be partly due to the low awareness of functional foods in this sample. The recognition of some foods as ‘better’ but not ‘necessary’ may reflect the view that functional foods are a way to ‘optimize diet’ (Milner, 1999) or it may be a way of justifying the food choices that they are able to make within their budget. Interestingly, the people who appeared to be under food stress were less likely to be aware of functional foods currently on the market. Thus, while promotion of functional foods may not detract from their diet in the near future it is also unlikely that health claims will be an efficient way to educate and influence this segment of society to improve nutritional status.

In conclusion, there are a number of ways that emerging research in functional foods and nutrigenomics may increase inequalities associated with socio-economic status. Nutritionists are morally bound to ensure that the benefits of this research are obtained by both rich and poor, especially if government funds are used for the research (Darnton-Hill, 2004; Verschuren, 2002). Moral responsibility can take the form of choosing appropriate areas of research, promoting research findings in ways to benefit the most people, involvement in policy decisions, e.g. decisions related to health claims, and carrying out research into the impact of new technologies.

One opportunity for nutritionists to respond to this moral imperative is in relation to the development of Food Standards. The Australia New Zealand Food Standards Code is soon to be altered to allow health claims. This is likely to result in an increased interest in research related to functional foods. It is also likely to lead to an increase of advertising messages with reference to nutrition and health. It is important that research examines how people incorporate this information into their view of a ‘healthy’ diet, especially the views of people who are currently socio-economically disadvantaged. While they have the most to gain from good nutrition, they are also most vulnerable.

Tim Lang (2005) in support of the New Nutrition Science Project wrote,

“it is a myth that nutrition science was ever neutral. Nutrition has made advances only when engaged with society. Policy-makers have been weak in responding to evidence from nutritional science, but this failure has also been due to nutrition lacking good champions, coherent organisations, and political will to lobby against and with powerful forces”

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Overview of Food Security Status in New Zealand as a Predictor of Nutritional Outcomes. ¹

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ABSTRACT ⁴

Food security (access by all people at all times to enough appropriate food for an active healthy life) is not achieved in New Zealand despite an abundant food supply. Eight aspects of household security were determined for the New Zealand population and used in the National Nutrition Surveys of Adults (1997) (NNS97) and Children (2002) (CNS02). Rasch modelling analysis was used to rank these indices and produce a uni-dimensional measure of the severity of food insecurity. Three categories of household food security were assigned: full/almost full security; moderate security and low security. Using ANOVA (for adults) and linear mixed models (for the children's data to control for clustering within households with multiple participants), food security category was associated with nutrient intakes and body weight status. NNS97 participants in the less food secure households had the highest BMI, higher intakes of fat, vitamin B12 and lactose and the lowest intakes of glucose and fructose and vitamin C. CNS02 participants in the less food secure households had lower intakes of total sugars, vitamin A, β -carotene, vitamin B12 and calcium, and lactose. ⁵

These results are congruent with work reported in the United Kingdom and North America, although there are no directly comparable studies on national data sets. The ability to reliably measure household food security status, and thence to determine nutrition and health correlates is of public health significance in New Zealand. ⁶

INTRODUCTION ⁷

The emergence of 'hunger' within developed countries with a plentiful food supply was first described in the US in the 1980s. Radimer (Radimer, 1996; Radimer *et al.*, 1990), used qualitative methodologies to develop indicators to assess 'hunger', specific to and appropriate for the US environment. Emerging from this work came the now currently accepted definition of food security: access by all people, at all times, to enough appropriate food for an active healthy life (LSRO, 1990). The components of food insecurity—which has a number of manifestations (Parnell *et al.*, 2001), with greater or lesser impact on the life and health of those experiencing it—have been well described by Radimer (Radimer, 1996). At the lowest level it may mean that food choices are less than optimal. At the most severe level, those who are food insecure might access food by socially unacceptable means. Individuals living in food insecure households are able to describe the coping strategies which they employ. ⁸

Strenuous efforts have been made to assess or measure, food insecurity in a valid way. In the US, building on the work of Radimer, a large team of researchers, developed an 18-scale set of indicators of food insecurity, ranked them in order of severity and then developed four 'categories' of food insecurity, suitable to classify households (Hamilton *et al.*, 1997). ⁹

The development of these 'categories' of food insecurity (food secure; food insecure but hunger not evident; food insecure with moderate hunger; food insecure with severe hunger), further enabled researchers to examine the nutrition and health outcomes experienced by those experiencing varying levels of 'severity' of food insecurity (Tarasuk *et al.*, 1999; Vozoris *et al.*, 2003). It is generally accepted that while there is some commonality in the experience of food insecurity across countries or cultures, it is desirable that each population group develop their own food insecurity instrument, particular to their food patterns and wider environment. ¹⁰

The qualitative work documenting the components of food insecurity as experienced in the New Zealand context was carried out by J Reid (Reid, 1997). Eight items were identified—fewer than ¹¹

the 18 chosen in the US. For the National Nutrition Survey (NNS97) these items were further developed into eight indicator statements, presented to respondents and potentially applicable to their household (or themselves in the case of a single person household). The prevalence of these eight aspects or indicators of food insecurity in the New Zealand (NZ) population has been described for all households (Russell *et al.*, 1999) and for households with children (Parnell *et al.*, 2003).

The NNS97 was a voluntary cross-sectional survey of New Zealanders 15 years and above (n=4636). The ethical approval, survey design and methodology are described elsewhere (Russell *et al.*, 1999). The CNS02 was a voluntary cross sectional school based survey of New Zealand children, 5-14 years (n=3276). The ethical approval, methodology and survey design are described in 'New Zealand Food: New Zealand Children' (Parnell *et al.*, 2003). As part of the survey interview, eight statement indices of food insecurity for NZ households were placed before adult participants in the NNS97 and the adult care-givers of children in the CNS02, after an introductory paragraph was read to them.

Statements 1-8, as presented to respondents.

1. I/we can afford to eat properly.
2. Food runs out in my/our household due to lack of money.
3. I/we eat less because of lack of money.
4. The variety of food I am/we are able to eat is limited by a lack of money.
5. I/we rely on others to provide food and/or money for food for my/our household when I/we don't have enough money.
6. I/we make use of special food grants or food banks when I/we do not have enough money for food.
7. I feel stressed because of not having enough money for food.
8. I feel stressed because I can't provide the food I want for social occasions.

Rasch analysis was performed on responses pertaining to households, where some food insecurity was reported. The Rasch modelling approach took a set of attributes or items of the particular construct (food security) and:-

- Examined whether each of the items were unique, contributed meaningfully to the construct, and could be ordered on a uni-dimensional scale (in order of difficulty).
- Explored the pattern of the responses to each of the items, described the patterns into which they fell and placed them on the same scale (Bond *et al.*, 2001).

Three categories of food security were then assigned:

1. Full/almost full food security: Households providing no affirmative response to any of the eight indices of food insecurity and households responding to only one of the indices.
2. Moderate food security
3. Low food security: Households in this group were most likely to report 'relying on others for food or money for food, and that they had to use special food grants or a food bank, to acquire the food they needed.

The Rasch analysis was deemed to be 'successful', in that the relatively small number of indicators of food insecurity (eight), were able to be ranked or scaled with acceptable fit and separation. The responses to the indicators exhibited acceptable 'subject reliability' (Parnell, 2005).

Associations between the three assigned categories of household food security and the intakes of energy and nutrients were explored by ANOVA for adults, controlling for age, sex, ethnicity, Index of Deprivation (by place of residence), urban/rural location, level of education, income and household size. For the children's data (to control for clustering within households with multiple participants) the associations were explored using linear mixed models controlling for age, sex, ethnicity, Index of Deprivation, urban/rural location, and household size.

IMPACT OF FOOD SECURITY ON NUTRIENT INTAKE 1

In the NNS97, for NZ adults, households with lower food security had significantly higher fat intakes (all types), lower intakes of glucose; fructose; lactose; vitamins B6 and C, and higher intakes of lactose and vitamin B12. 2

As reported by the adult care-givers in household with children in the CNS02, lower household food security was significantly associated with a lower intake of total sugars; lactose; vitamin A; β -carotene; vitamin B12; calcium. 3

The relationship between levels of intake of fat and cholesterol with degree of food security is unique to this study, with those in the least food secure households having the highest level of intake. Food insecurity appears to be a barrier to achieving recommended dietary guidelines for adult New Zealanders; namely reducing the proportion of dietary energy from fat in particular, total fat (Department-of-Health, 1991). The lower levels of intake of fructose and glucose (largely supplied by fruits in the diet), of adults in food insecure households demonstrates that food insecurity works against achieving another important aim — to increase the intake of fruits in the diet. A number of studies have provided data illustrating this nutritional disadvantage of the food insecure (Dowler *et al.*, 1995; Gulliford *et al.*, 2003; Tarasuk *et al.*, 1999; Tingay *et al.*, 2003), although none of these studies are population based, or use a fully validated instrument for the measurement of food security. 4

Since the food patterns and relative costs of foods differ between countries and cultures it is to be expected that food security status might be related to food and nutrient intake in a unique way (Drewnowski *et al.*, 2004). Additionally, adults and children even within a country or culture do not necessarily follow the same food patterns. New Zealand children, for example, choose a diet higher in sugars and lower in fat than NZ adults (Parnell *et al.*, 2003; Russell *et al.*, 1999). 5

In NZ, the nutrient intake of children is affected by the level of food security differently to that of adults. The children in most food insecure households have lower intakes of lactose and calcium (a marker of dairy product intake), whereas for lactose food insecurity is associated with the opposite relationship among adults. Children in food insecure households also have lower intakes of β -carotene (from fruits and vegetables) and vitamin A. Together these results indicate poorer quality diets for those in food insecure households. The nutrients affected are those which come from perishable foods: fruits, vegetables, dairy products. 6

Impact of food security on Body Mass Index (BMI) 7

For NZ adults, but not children, adjusted mean BMI was lowest for those living in households within the fully/almost fully food secure category (28.7), compared to those moderately food secure (29.2), and those living in households which had the lowest food security (29.5). 8

The relationship between food security status and BMI for the adult (men and women) population of NZ is of interest. The results for women are congruent with the findings reported elsewhere; where overweight is lowest among the food secure (Townsend *et al.*, 2001). However Canadian men in food insufficient households were found to be less likely to be overweight than their counterparts in food sufficient circumstances (Vozoris *et al.*, 2002). Explanations for an association between food security status and BMI are not immediately obvious. However, this study and other research has indicated that food insecurity is associated with poorer dietary choices among adults (Kendall *et al.*, 1996). Additionally, it is believed to be possible that the food insecure may both fast and feast as a consequence of their economic circumstances which are not constant. McIntyre and Glanville *et al.* (McIntyre *et al.*, 2003) suggest that children in households are protected from fluctuating intake and are given precedence in the family distribution hierarchy by their mothers. Neither the data from this study nor elsewhere confirm any relationship between household food security status and BMI among children in developed countries. 9

CONCLUSIONS 10

The 8-index NZ Food Security Model has been demonstrated to be sufficient and appropriate to assess food security in the NZ population. Not only does the model provide a means of assessing the 11

prevalence of food security/insecurity at a household level, but it demonstrates that there is a clear relationship between level of food insecurity and nutrient intake.

The major conclusion from the examination of the prevalence of household food security in New Zealand is that only 72.8% of households in 1997 (some of which included children) and 50.5% of households with children in 2002 described themselves as food secure. Since the data described here further illustrate that members of food insecure households, both adults and school children consumed diets with poorer nutrient intakes and food insecure adults had less desirable body weight status, it is an inescapable conclusion that food insecurity matters. It impacts on nutritional health and wellbeing. The reasons why a significant proportion of NZ households do not have enough money available to spend on the food they need, need to be explored. For some it will be that their income level or benefit is insufficient for their needs. For others there will be real reasons why the money potentially available for food is expended in other areas. To ignore the social and economic causes of food insecurity is to reap poorer nutritional health.

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Nutrient utilisation in the newly hatched chick¹

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ABSTRACT⁴

This study was undertaken to determine the changes in apparent metabolisable energy (AME)⁵ and nutrient digestibility over the first two weeks of life in broiler chicks fed diets based on different cereals. Three experimental diets were formulated containing wheat, sorghum or maize as the cereal base and fed for two weeks. On days 3, 5, 7, 9 and 14, total excreta collection was undertaken, feed intake measured, and AME calculated. The digestibility of starch, fat and protein was determined on days 5, 7 and 14 using titanium oxide as an indigestible marker. Cereal effects on AME were significant on days 7 and 9 ($P < 0.05$) with values for the wheat diet being lower than those for sorghum or maize diets. Age effects on AME were highly significant ($P < 0.0001$). The AME values were high on day 3, declined on days 5 and 7 and then increasing at day 14. Cereal effect on nutrient digestibility was not significant with the exception of a significantly ($P < 0.05$) higher fat digestibility for the maize diet on day 7. Starch and fat digestibility showed highly significant age effects ($P < 0.0001$), with digestibility decreasing from day 5 to day 7 and then increasing at day 14. In general, the present data are suggestive of digestive inefficiency during the first week of life in the newly hatched broiler chick.

INTRODUCTION⁶

The first week after hatch is the most critical period in the life of a broiler chicken. When the chick emerges from the egg, its digestive and immune systems are still immature and the bird is not well prepared to face the environmental challenges confronting them. First, there is the transition from yolk to oral nutrition. Associated with this are the substantial physical and functional development of the digestive tract and organs and the development of active immunity. The capacity to digest the feed and, absorb and transport nutrients appears to be limiting during the early life of broilers. To achieve their genetic potential, the neonate must quickly adapt to efficiently digesting and utilising nutrients from relatively complex exogenous dietary sources in which energy is supplied predominantly by carbohydrates.

With the first 14 days post-hatch now representing 40% of the total life of the broiler chicken,⁸ a better understanding of the development of digestive capacity of the newly hatched chick is of increasing importance. Studies on the changes with age in the apparent metabolisable energy (AME) in the young broiler chick are limited (Zelenka, 1968; Batal and Parsons, 2002). The present study was undertaken to determine the AME of diets based on wheat, sorghum and maize during the first two weeks post-hatch of broilers. The study also measured changes in the digestibility of starch, fat and protein over the first 14 days of age to test the hypothesis that changes in AME with age are due to limitations in the digestion capacity of specific nutrients.

MATERIALS AND METHODS⁹

Three dietary treatments based on wheat, sorghum and maize were used in the trial. The diets¹⁰ were formulated to have similar levels of AME, amino acids and other major nutrients (Table 1). The wheat-based diet was supplemented with a commercial xylanase. Titanium oxide (BDH Laboratory Supplies, Poole, England) was added to all diets at 0.3% as an inert marker. The diets were formulated to meet or exceed the NRC (1994) requirements for all nutrients. All diets were steam pelleted at 70 °C.

Day old male broilers were randomly assigned to six replicate groups for each dietary¹¹ treatment (8 chicks/ replicate). On days 3, 5, 7, 9 and 14, feed intake was measured and total excreta collected over a 24-hour period. A sample of feed was taken daily and dry matter (DM) contents were determined to correct the feed intake for moisture losses in the feed. Dry matter, gross energy and

titanium oxide contents were determined for the diets and excreta samples from 3, 5, 7, 9 and 14. Starch, crude fat and nitrogen were determined for the diets and excreta samples from days 5, 7 and 14. The data were analysed by the General Linear Model procedure with pen means as the experimental unit. AME values and starch, fat and protein digestibility were subjected to repeated measures analysis.

Table 1. Percentage composition of experimental diets based on wheat, sorghum and maize

| Ingredient | Wheat diet | Sorghum diet | Maize diet |
|----------------------------|------------|--------------|------------|
| Wheat | 65.76 | - | - |
| Sorghum | - | 61.08 | - |
| Maize | - | - | 58.62 |
| Soybean meal | 27.34 | 32.19 | 35.18 |
| Vegetable oil | 2.73 | 2.09 | 1.78 |
| Dicalcium phosphate | 2.03 | 1.91 | 2.17 |
| Limestone | 0.34 | 0.94 | 0.78 |
| Salt | 0.14 | 0.16 | 0.23 |
| Lysine.HCl | 0.34 | 0.29 | 0.18 |
| DL-methionine | 0.24 | 0.33 | 0.25 |
| L-threonine | 0.12 | 0.08 | 0.03 |
| Sodium bicarbonate | 0.36 | 0.33 | 0.18 |
| Vitamin and mineral premix | 0.30 | 0.30 | 0.30 |
| Xylanase | + | - | - |
| Calculated analysis, % | | | |
| AME, MJ/kg | 12.5 | 12.5 | 12.5 |
| Crude protein | 22.0 | 22.0 | 22.0 |
| Lysine | 1.35 | 1.35 | 1.35 |
| Met + cys | 0.95 | 0.95 | 0.95 |
| Calcium | 0.95 | 0.95 | 0.95 |
| Available phosphorus | 0.48 | 0.48 | 0.48 |

RESULTS AND DISCUSSION

AME calculated based on total collection

Cereal effects on AME determined by total collection were significant on days 7 and 9 (Table 2 and Figure 1). This was due to a larger AME reduction ($P < 0.05$) for the wheat-based diet than those based on sorghum and maize. Age effects were also significant ($P < 0.0001$), with the AME declining from day 3 to day 7 and then increasing to day 14.

Table 2. Least square means for AME (MJ/ kg DM) of wheat, sorghum and maize-based diets - calculated by total collection method

| Day | Day 3 | Day 5 | Day 7 | Day 9 | Day 14 | Pooled SEM |
|---------|--------------------|---------------------|---------------------|---------------------|--------------------|------------|
| Wheat | 15.00 ⁴ | 13.12 ² | 11.92 ^{a1} | 13.20 ^{a2} | 14.15 ³ | 0.22 |
| Sorghum | 15.50 ⁴ | 13.64 ² | 12.95 ^{b1} | 14.36 ^{b3} | 14.27 ³ | |
| Maize | 15.00 ³ | 13.58 ¹² | 13.22 ^{b1} | 14.10 ^{b2} | 13.91 ² | |

^{a,b} Different superscripts in a column are significantly different ($P < 0.05$).

^{1,2,3,4} Different superscripts in a row are significantly different ($P < 0.05$).

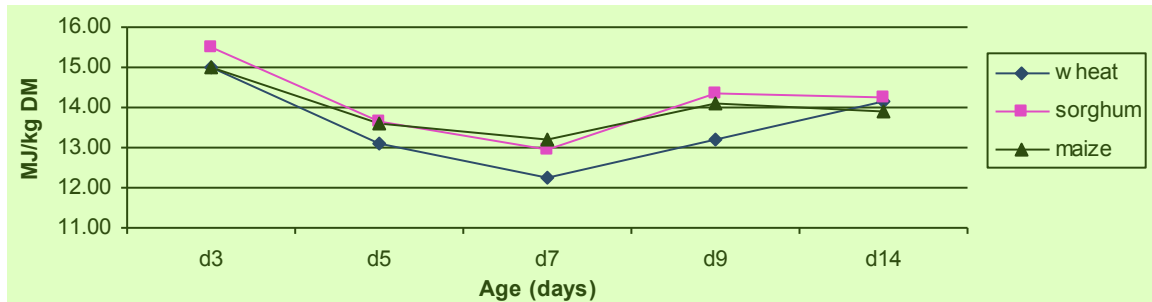


Figure 1. AME values for wheat, sorghum and maize-based diets calculated using total excreta collection method

AME calculated based on marker method

Cereal and age effects on AME values calculated using the marker ratios were somewhat similar to those calculated based on the total excreta collection (Table 3). The trends in AME with advancing age were also remarkably similar (Figure 2). The AME was found to decrease from day 3 to day 7 and then increase to day 14.

Table 3. Least square means for AME (MJ/ kg DM) of wheat, sorghum and maize-based diets calculated by the marker method

| | Day 3 | Day 5 | Day 7 | Day 9 | Day 14 | Pooled SEM |
|---------|--------------------|----------------------|---------------------|---------------------|----------------------|------------|
| Wheat | 14.27 ³ | 12.72 ^{ab2} | 11.88 ^{a1} | 12.30 ¹² | 13.73 ^{ab3} | 0.021 |
| Sorghum | 14.38 ² | 12.49 ^{a1} | 12.53 ^{b1} | 12.84 ¹ | 14.23 ^{b2} | |
| Maize | 14.16 ³ | 13.23 ^{b2} | 13.24 ^{c2} | 12.25 ¹ | 13.59 ^{a2} | |

^{a,b} Different superscripts in a column are significantly different ($P < 0.05$).
^{1,2,3} Different superscripts in a row are significantly different ($P < 0.05$).

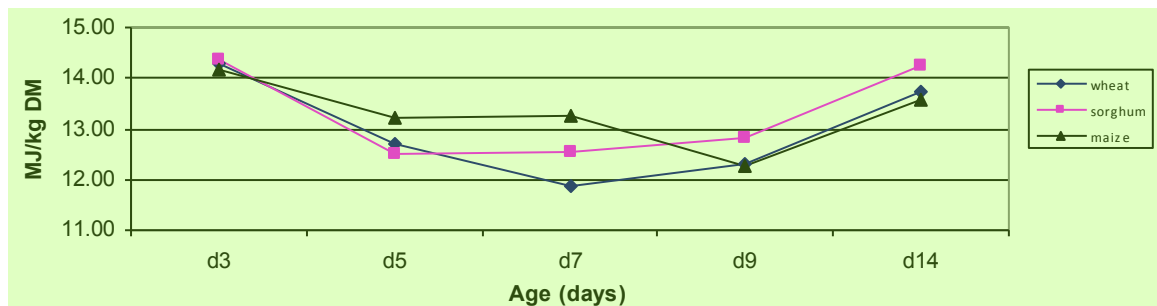


Figure 2. AME values for wheat, sorghum and maize-based diets calculated using the marker method

Starch digestibility

Excreta starch digestibility determined on days 5, 7 and 14 was high (> 0.90) for all three cereals and there were no significant differences between the cereals (Table 4 and figure 3). Significant age effects ($P < 0.0001$) were observed, with average digestibility coefficients of 0.95, 0.92 and 0.97 for days 5, 7 and 14, respectively.

Table 4. Starch digestibility coefficients at 5, 7 and 14 days of age for wheat, sorghum and maize-based diets. ¹

| | Day 5 | Day 7 | Day 14 | Pooled SEM |
|--------------|-------------------|-------------------|-------------------|------------|
| Wheat diet | 0.95 ² | 0.90 ¹ | 0.97 ² | 0.00618 |
| Sorghum diet | 0.95 ² | 0.92 ¹ | 0.97 ³ | |
| Maize diet | 0.96 ² | 0.94 ¹ | 0.98 ² | |

^{a,b} Different superscripts in a column are significantly different ($P < 0.05$). ³

Fat digestibility ⁴

Significant cereal effects ($P < 0.05$) on excreta fat digestibility was observed only on day 7, ⁵ with digestibility in wheat and sorghum diets being lower ($P < 0.05$) than that in the maize diet (Table 5 and Figure 4). Age effects on fat digestibility in wheat and sorghum diets were significant ($P < 0.0001$), with a pattern similar to that observed for AME. Although numerical trends were observed for the maize diet, the differences between the three ages were not significant ($P > 0.05$).

Table 5. Fat digestibility coefficients for 5, 7 and 14 days of age for wheat, sorghum and maize-based diets. ⁶

| | Day 5 | Day 7 | Day 14 | Pooled SEM |
|--------------|-------------------|--------------------|-------------------|------------|
| Wheat diet | 0.62 ² | 0.42 ^{a1} | 0.76 ³ | 0.048 |
| Sorghum diet | 0.52 ¹ | 0.43 ^{a1} | 0.76 ² | |
| Maize diet | 0.69 | 0.65 ^b | 0.78 | |

^{a,b} Different superscripts in a column are significantly different ($P < 0.05$). ⁸

^{1,2,3} Different superscripts in a row are significantly different ($P < 0.05$).

Nitrogen digestibility ⁹

The excreta nitrogen digestibility in wheat, sorghum and maize diets over the 14-day period ¹⁰ ranged from 57-61, 58-62 and 59-64, respectively. The effects of cereal type and age, however, were not significant ($P > 0.05$). These data are in contrast to the trends noted in the AME and the digestibility of starch and fat, and this unexpected. This finding was likely to be related the confounding effects of uric acid nitrogen from urine in the excreta.

CONCLUSIONS ¹¹

In general, the present data are suggestive of digestive inefficiency during the first week of life in ¹² modern fast-growing broilers. Reasons for the poor nutrient utilization during this period may include changes in gut flora, inadequate secretion of digestive enzymes, or inadequate digesta mixing.

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Effect of Selenium Level and Source in Dairy Cattle Diets on Selenium Content of Milk and Milk Products¹

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ABSTRACT⁴

The effect of selenium supplementation on the selenium content of milk and cheese was measured using 12 lactating dairy cows which were assigned to one of three treatments: 6mgSe/d from sodium selenite (ST), 3mgSe/d from Sel-Plex (LS)(Alltech Inc, USA) or 6mgSe/d from Sel-Plex (HS). Cows were offered 7kg/h/d compound and ad libitum access to spring pasture. Individual milk samples were analysed for Se content (weekly) and used to manufacture a whole milk, unripened soft cheese. There were no difference in body weight, milk yield, milk composition between treatments except for milk protein which was significantly lower in the LS group (ST 31.1, LS 29.3, HS 30.7 g/kg; s.e.m. 0.30; P<0.05). Milk selenium content was significantly higher for the HS group (ST 14.7, LS 15.5, HS 21.6 mg/l; s.e.m. 0.65; P<0.001), Se content of cheese was higher in the HS group (0.10, 0.10, 0.16 mg/kg; s.e.m. 0.02), but not significantly. MC, pH, lactic acid levels, cheese yield were not significantly different, though less milk was required to produce 1kg of cheese from the HS group (ST 8.41, LS 8.15, HS 7.31 kg milk/kg cheese). Selenium from Sel-Plex is more bio-available than selenium from sodium selenite and significantly increased the selenium content of human foods such as milk. Although not significant, milk from cows offered 6mg/h/d Sel-Plex tended to have a higher cheese selenium content and a greater cheese yield.⁵

Feeding of whole wheat for broilers: Influence on performance, gizzard size and carcass characteristics¹

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ABSTRACT³

The objectives of this study were to investigate the effects of feeding whole-wheat through mixed feeding (MF) or free choice feeding (FCF) on the performance, digestive tract development and carcass traits in broilers. Male broilers (n = 648), 7 days of age, were placed on floor pens on litter in an environmentally controlled room. The trial was conducted using two forms of wheat, namely, ground wheat (GW) and whole wheat (WW). The GW was fed in pelleted form, the whole wheat was fed either via MF (10 and 20% WW replacing GW during 7–21 and 22–35 days, respectively) or as FCF of WW and a protein concentrate. Each diet was fed *ad libitum* to six pens of 36 birds each. Whole-wheat inclusion, substituting up to 20% ground wheat, in a MF system, had no effects ($P > 0.05$) on body weight, feed intake and feed efficiency. Free choice feeding resulted in the lowest ($P < 0.05$) body weight and feed intake throughout the trial period, with no effect ($P > 0.05$) on feed efficiency compared to control diet. Whole-wheat feeding increased ($P < 0.05$) gizzard size, but this had no positive effects on feed efficiency. Both WW feeding systems reduced ($P < 0.05$) carcass recovery and abdominal fat. These findings suggest that whole wheat can substitute up to 20% of ground wheat in a MF system, but FCF may not be appropriate to fast-growing modern broilers.

INTRODUCTION⁵

Feeding whole grains has fascinated researchers for a long time. Lately, there has been a renewed interest in the whole grain feeding, which is driven by the need to reduce feed costs while improving animal welfare (Cumming, 1994; Covasa and Forbes, 1996). Considerable feed cost savings can be achieved by combining the whole wheat with pellet-processed feed in the broiler diet (Ferket, 2000). Feeding whole grain reduces feed cost due to reduced handling and processing. Thus, if the birds fed whole wheat have performed at least as well as those fed complete diet, then the economics will favour whole grain feeding (Forbes and Covasa, 1995).

Whole grains can be offered to poultry via three different techniques (Rose, 1996), namely, (i) Free choice feeding (FCF), where the birds reared in a flock are offered whole grain and another feed in separate feeders *ad libitum* and they have the choice to select ingredients; (ii) Mix feeding (MF), where the whole grain is added substituting part of the ground grain in a complete diet usually pelleted or adding whole grain in addition to the complete balanced diet in the same feeder at the same time; or (iii) Sequential feeding, where the whole grain is fed in sequence with other feed. The objectives of this study were to investigate the effects of feeding whole-wheat through MF or FCF on the performance, digestive tract development and carcass traits in broilers.

MATERIALS AND METHODS⁸

Day-old male broiler chicks were obtained from commercial hatchery and were reared on a littered floor in environmentally controlled room until 7 d of age. They were offered commercial broiler starter crumbles and water *ad libitum*. The temperature maintained at 31 °C at the first week and then was gradually reduced to 22 °C at 24 days of age. The birds received constant fluorescent illumination throughout the experiment. At day 7 of age, chicks were assigned on the basis of body weight to the floor pens on litter in an environmentally controlled room. A summary of treatments is shown in Table 1.

Table 1. Details of dietary treatments ¹

| | | |
|------------------------|--|--------------|
| Treatment ¹ | Diet | ² |
| GW | Ground wheat (60-69%); pelleted | |
| MF | Ground wheat (50-49%); pelleted + whole wheat (10-20%) ² | |
| FCF | Whole wheat + protein concentrate (pelleted) ³ ; choice feeding offered in two separate feeders per pen | |

¹GW, control diet based on ground wheat; MF, mixed feeding of whole wheat; FCF, free choice feeding. ³

² Whole wheat inclusions were 10 and 20% in starter and finisher diets, respectively.

³ Protein concentrate had the same ingredients as GW diet except the wheat, which was removed from the formulation. Whole wheat and the protein concentrate were offered in separate feeders

Two wheat-soy basal diets were formulated - one for the starter phase from day 7 to day 21 and the other for the finisher phase from day 22 to day 35 (Table 2). Each diet was fed *ad libitum* to six pens of 36 birds each. ⁴

Table 2. Percentage composition and calculated analysis of the basal diets ⁵

| Ingredient | Starters | Finishers | ⁶ |
|----------------------------|----------|-----------|--------------|
| Wheat | 60.00 | 69.00 | |
| Soybean meal | 31.70 | 23.14 | |
| Vegetable oil | 4.00 | 4.25 | |
| Dicalcium phosphate | 1.45 | 1.00 | |
| Limestone | 1.78 | 1.70 | |
| Lysine | 0.14 | 0.25 | |
| Methionine | 0.38 | 0.26 | |
| Salt | 0.25 | 0.20 | |
| Trace mineral premix | 0.25 | 0.15 | |
| Vitamin premix | 0.05 | 0.05 | |
| Xylanase | 0.075 | 0.075 | |
| Calculated analysis | | | |
| Metabolisable energy, | 3081 | 3194 | |
| Crude protein, % | 23.02 | 20.00 | |
| Lysine, % | 1.15 | 1.05 | |
| Total SAA, % | 0.94 | 0.76 | |
| Calcium, % | 1.02 | 0.90 | |
| Non-phytate P, % | 0.45 | 0.35 | |

The body weights and feed intake were recorded at weekly intervals throughout the trial and, feed/gain was calculated and corrected for mortality. At 35 d of age, 24 birds (4 birds/ pen) from each dietary treatment were slaughtered by cervical dislocation. Half of them were dissected and used for digestive tract measurements. The other half were used for carcass measurements (carcass weight, breast weight and weight of abdominal fat. Digestive tract and carcass data were expressed as g/kg body weight. ⁷

The data were statistically analysed using the General Linear Models procedure of SAS (1997). Differences were considered significant at $P < 0.05$ and significant differences between means were separated by the Least Significance Difference test. ⁸

RESULTS AND DISCUSSION¹

The influence of treatments on the performance of broilers is summarised in Table 3. During 7-21 days, there were no differences ($P > 0.05$) in the weight gain, feed intake and feed/gain of broilers fed the ground wheat and whole-wheat diets. During 22-35 days, the weight gain and feed intake of birds fed the whole-wheat diet was lower ($P < 0.05$) than those fed the ground wheat diet, but there were no differences ($P > 0.05$) in feed/gain. Over the whole trial period (7-35 days), however, no differences were observed between the two treatments for any of the performance parameters.

Table 3. Weight gain, feed intake and feed/gain of broilers as influenced by the method of whole wheat feeding³

| | Ground Wheat | Mixed feeding of whole Wheat | Free choice feeding of whole wheat | Pooled SEM |
|-------------------|---------------------|------------------------------|------------------------------------|------------|
| 7-21 days | | | | |
| Weight gain (g) | 681 ^a | 717 ^a | 540 ^b | 16.3 |
| Feed intake (g) | 978 ^a | 1010 ^a | 870 ^b | 17.8 |
| Feed/gain (g/g) | 1.444 ^a | 1.414 ^a | 1.610 ^b | 0.016 |
| 22-35 days | | | | |
| Weight gain (g) | 1262 ^a | 1184 ^b | 1109 ^c | 21.5 |
| Feed intake (g) | 2168 ^a | 2041 ^b | 1840 ^c | 40.8 |
| Feed/gain (g/g) | 1.790 ^a | 1.773 ^a | 1.711 ^b | 0.016 |
| 7-35 days | | | | |
| Weight gain (g) | 1943 ^a | 1900 ^a | 1649 ^b | 34.9 |
| Feed intake (g) | 3146 ^a | 3051 ^a | 2711 ^b | 55.8 |
| Feed/gain (g/g) | 1.657 ^{ab} | 1.627 ^a | 1.676 ^b | 0.012 |

^{abc} Means in the same row not sharing a common superscript differ ($P < 0.05$).⁵

Birds on the FCF treatment had the lowest ($P < 0.05$) weight gain and feed intake, and the highest ($P < 0.05$) feed/gain ($P < 0.05$) throughout the trial period. During week 1, the protein concentrate was consumed more than the whole-wheat – 69% in the first week. For this reason, the amount of protein concentrate offered was restricted during the subsequent weeks. Overall, the average consumption of protein concentrate was 56% of the total intake. Therefore, it would appear that the birds did not balance their energy consumption, resulting in the poor performance.

Our observations suggest that choice feeding may not be successful in fast-growing modern broilers. Factors that affect diet selection such as learning and previous experience, visual differences between the foods, texture and flavour of the food and palatability (Covasa and Forbes, 1996) may explain the lower whole-wheat intake in the FCF when offered *ad libitum* with the protein concentrate. Another possible reason is that the training of birds to consume whole-wheat commenced only on 7 days of age. Indeed, it has been reported by Covasa and Forbes (1996) that training should be given in the first week. It has also been supported by observation of Hess (1964) that preferences for food by birds are determined between 3 and 5 days of age. Forbes and Covasa (1995) also stated that “it is beneficial to the birds to be trained and experience choice feeding in the first week of their life as it improves their ability to select foods to meet nutrient requirements at later stages”.

In the present study, whole-wheat feeding increased ($P < 0.05$) the relative gizzard weights (Table 4). Interestingly, the FCF birds had the heaviest ($P < 0.05$) gizzards. This is consistent with

previous results (Wu and Ravindran, 2004). Health benefits of increasing gizzard weight include reduction in litter consumption, reduction in aggression, improvement in gut motility (Ferket, 2000), and improvement in digestibility of the nutrients such as starch by effective grinding in the gizzard. The increased gizzard weight may also reduce the risk of coccidiosis (Cumming, 1992).

Table 4. Relative gizzard weight (g/kg body weight) and carcass characteristics (g/kg body weight) of broilers as influenced by the method of whole wheat feeding

| | Ground Wheat | Mixed feeding of whole wheat | Free choice feeding of whole wheat | Pooled SEM |
|--------------------------|-------------------|------------------------------|------------------------------------|------------|
| Gizzard weight at day 21 | 19.6 ^a | 22.2 ^a | 33.4 ^b | 1.13 |
| Gizzard weight at day 35 | 10.9 ^a | 17.6 ^b | 20.3 ^c | 0.62 |
| Carcass recovery | 717 ^a | 699 ^b | 674 ^c | 5.64 |
| Breast meat yield | 187 ^a | 182 ^a | 166 ^b | 3.94 |
| Abdominal fat | 10.9 ^a | 8.77 ^b | 8.17 ^b | 0.68 |

^{abc} Means in the same row not sharing a common superscript differ ($P < 0.05$)

Carcass recovery was lower ($P < 0.05$) in the whole-wheat treatments (Table 4) and this may be explained by heavier gizzard weights in these treatments on day 35. No significant differences in breast meat yield were observed between the ground wheat and whole-wheat diets, but the yields from birds on FCF were significantly ($P < 0.05$) lower. Whole-wheat feeding significantly ($P < 0.05$) reduced relative abdominal fat weights compared to the ground wheat diet.

In conclusion, under the conditions of the current study, the performance of birds fed whole-wheat diets was similar to those fed the ground wheat diet. Gizzard weights were increased by whole-wheat feeding, but no advantage was noted in terms of feed efficiency. Free choice feeding of whole wheat and protein concentrate resulted in poor broiler performance. It is suggested that free choice feeding may not be appropriate to fast-growing modern broilers. Since the published reports on the effects of whole-grain feeding on broiler performance are quite contradictory, further studies are warranted to examine the causes for the variable responses.

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Grain legumes: composition and protein quality¹

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ABSTRACT⁴

A total of 68 grain legume samples, including lupins (*Lupinus albus* and *angustifolius*); n = 17), chickpeas (*Cicer arietinum*; n = 20), peas (*Pisum sativum*; n = 27) and soybeans (*Glycine max*; n = 4), were analysed for proximate contents, fibre composition, amino acid score and protein quality. The effects on organ weights (heart, liver and pancreas) were also recorded. The results showed that the protein contents of *L. angustifolius* were comparable to those of soybeans. Peas had intermediate protein levels, while chickpeas had the lowest. Both lupin species had high fibre and non-starch polysaccharide contents that were more than double those found in other legumes. All legumes were found to be deficient in methionine. The amino acid scores and the protein efficiency ratio data indicated that the protein quality of the legumes were in the following order: chickpeas > peas > lupins. Mortality was not influenced by feeding of raw forms grain legumes, suggesting that the tested cultivars did not contain significant concentrations of any anti-nutritive factors. It is concluded that the poor protein quality of the tested legumes for poultry, compared to soybean meal, is related to the deficiency of key limiting amino acids, rather than to the presence of anti-nutrients.

INTRODUCTION⁶

Meat and bone meal is an important protein component in poultry diets in New Zealand, with an annual consumption of approximately 64,000 tonnes by the feed industry. A ban on the use of meat and bone meal, however, remains a possibility in the near future. The major protein source is imported soybean meal (ca 78,000 tonnes per year), but there are concerns about increasing prices and the genetically-modified soybeans. A locally grown protein source will give the poultry feed industry more stability and add flexibility in diet formulations. Of the various possibilities, grain legumes offer the greatest potential. Usefulness of grain legumes has been extensively researched elsewhere and considerable information is available on their nutritive value. While such information could serve as a guide, it may be inadequate for accurate feed formulations under New Zealand conditions. Interactions of cultivars, soil, climate and agronomic factors could cause appreciable differences in nutrient profiles and digestibility between locally grown feedstuffs and those available elsewhere.

The utilisation of grain legumes as sources of protein for poultry is limited due to the uncertainty about their nutritional quality. The variation reported in the quality of grain legumes is related, primarily, to variable amounts of anti-nutritional factors that depress bird performance. The anti-nutritional factors commonly found in grain legumes include protease inhibitors, lectins, tannins, amylase inhibitors and non-starch polysaccharides. As a result, feeding raw legumes generally results in poor growth and feed efficiency in poultry; but each legume produces a different response. Most current cultivars have been bred for low levels of these anti-nutritional factors and can be used in diets for poultry and pigs without any need for processing. However, to the authors' knowledge, no published data is available on the nutritive value of grain legumes grown in New Zealand. Thus the aim of the evaluation reported herein was to screen the grain legume cultivars grown in New Zealand on the basis of nutrient concentrations and protein quality.

METHODOLOGY⁹

A total of 68 grain legume samples were evaluated from Year 1 harvest (2003/04). The samples included lupins (both *albus* and *angustifolius*; two cultivars each; n = 17), chickpeas (four cultivars; n = 20), Peas (nine cultivars; n = 27) and soybeans (two cultivars; n = 4). The samples were screened in three stages.

Stage 1 – Proximate and fibre composition: All samples were analysed for dry matter, crude protein, crude fat, neutral detergent fibre (NDF), acid detergent fibre (ADF) and ash. 1

Stage 2 – Mineral and amino acid concentrations: Samples were pooled within cultivars and analysed for minerals and amino acids. 2

Stage 3 – In vivo screening: *In vivo* tests (19 legume samples and a control soybean meal) were carried out using broiler chickens in a 10-day feeding trial. Weight gain and feed intake were recorded, and the protein efficiency ratio (PER) was calculated. The effects of organ weights (heart, liver and pancreas) were also recorded. The expected outcomes were to obtain preliminary data on the following: (i). the presence of anti-nutrients/ toxic factors in cultivars under test, (ii). ranking of cultivars within a grain legume, and (iii). grading of different legumes into high, medium or poor quality 3

RESULTS AND DISCUSSION 4

Proximate and fibre compositions 5

Only an overall summary of the data will be presented. The comparison of proximate and fibre compositions of the five legumes is shown in Table 2. There were marked differences between the legumes in terms of protein, fat and fibre contents. *Angustifolius* lupins had protein contents that were comparable to soybeans. Albus lupins had lower contents of protein and higher contents of fat than *Angustifolius* lupins. Both lupin species had high fibre contents (due largely to non-starch polysaccharides) that were more than double that found in other legumes. Peas had intermediate protein levels (around 25 g/ 100 g), while chickpeas had the lowest. The fat contents were high in soybeans, intermediate in lupins and chickpeas and very low in peas. 6

Amino acid profiles 7

A comparison of amino acid profile (% crude protein) of the five legumes and soybean meal is shown in Table 3. This Table enables the comparison of the ingredients on a protein basis and gives indication of deficiencies in the most limiting amino acids in poultry diets, namely lysine, methionine and threonine. It can be seen that the lysine concentrations in chickpea and pea proteins were comparable to that in soy protein, but the lysine concentration in lupin protein was lower. Compared to soybean meal, methionine concentrations in chickpeas were higher and those in peas and lupins were lower. Threonine concentrations in all five legumes were lower than that in soybean meal. 8

Table 2. Average proximate and fibre compositions (g per 100 g dry matter) of the five legumes 9

| | Lupinus albus | Lupinus angustifolius | Chickpeas | Peas | Soybeans |
|---------------|---------------|-----------------------|-----------|-------|----------|
| No of samples | 8 | 9 | 16 | 27 | 4 |
| Dry Matter | 89.12 | 88.54 | 87.81 | 87.14 | 89.33 |
| Crude protein | 36.20 | 41.31 | 21.35 | 25.73 | 40.45 |
| Crude fat | 11.25 | 5.13 | 7.85 | 1.18 | 18.16 |
| ADF | 15.79 | 19.78 | 4.97 | 6.96 | 8.67 |
| NDF | 19.73 | 24.34 | 6.37 | 9.86 | 9.77 |
| Ash | 3.76 | 4.36 | 3.42 | 3.19 | 5.62 |
| NSP | | | | | |
| - Total | 33.2 | 35.1 | 7.0 | 17.1 | 20.6 |
| - Soluble | 3.0 | 3.1 | 1.8 | 2.6 | 3.0 |
| - Insoluble | 30.2 | 32.0 | 5.2 | 14.5 | 17.6 |

Abbreviations: ADF, acid detergent fibre; NDF, neutral detergent fibre; NSP, non-starch polysaccharides. 10 11

Table 3. Comparison of amino acid profile (g per 100 g crude protein) of the five legumes and a commercial sample of soybean meal

| | Lupin, <i>albus</i> | Lupin, <i>angustifolius</i> | Chickpeas | Peas | Soy beans | Soybean meal |
|---------------------------------------|------------------------|--------------------------------|-----------|-------|--------------|--------------|
| No of samples | 2 | 2 | 5 | 13 | | 2 |
| <i>Indispensable amino acids</i> | | | | | | |
| Arginine | 10.91 | 13.76 | 8.83 | 9.20 | 7.19 | 7.99 |
| Histidine | 2.43 | 3.32 | 2.94 | 2.66 | 2.84 | 3.20 |
| Isoleucine | 3.88 | 4.27 | 4.39 | 4.03 | 4.49 | 4.91 |
| Leucine | 7.18 | 8.50 | 8.18 | 7.31 | 7.90 | 8.23 |
| Lysine | 4.71 | 5.36 | 7.10 | 7.30 | 6.44 | 6.57 |
| Methionine | 0.80 | 0.69 | 1.64 | 1.06 | 1.48 | 1.40 |
| Phenylalanine | 3.58 | 4.25 | 6.21 | 4.80 | 5.11 | 5.63 |
| Threonine | 3.73 | 3.52 | 3.88 | 3.78 | 4.22 | 4.37 |
| Valine | 3.87 | 3.99 | 4.72 | 4.75 | 4.99 | 5.22 |
| <i>Semi-indispensable amino acids</i> | | | | | | |
| Cysteine | 1.66 | 2.28 | 1.78 | 1.57 | 1.70 | 1.68 |
| Tyrosine | 4.13 | 3.55 | 2.99 | 3.19 | 3.63 | 4.23 |
| <i>Dispensable amino acids</i> | | | | | | |
| Alanine | 3.80 | 3.87 | 5.14 | 4.75 | 5.46 | 4.89 |
| Aspartic acid | 10.43 | 11.57 | 13.08 | 13.30 | 12.35 | 11.38 |
| Glycine | 3.87 | 4.35 | 4.11 | 4.33 | 4.40 | 4.83 |
| Glutamic acid | 20.12 | 25.91 | 16.54 | 17.21 | 18.59 | 18.25 |
| Proline | 3.95 | 4.33 | 4.21 | 4.21 | 5.93 | 4.76 |
| Serine | 4.81 | 4.95 | 4.81 | 4.10 | 5.14 | 5.46 |

***In vivo* evaluation**

The major findings from the *in vivo* evaluation were as follows:

1. Within each legume, some variation was seen in the protein quality (measured as weight gain and protein efficiency ratio) of the different cultivars. In general, these variations were minor and it was concluded that the cultivar effects on protein quality for broiler chickens are negligible.
2. However, there were marked differences in the protein quality of different legumes. None of the legumes were comparable to soybean meal. But chickpea was the only legume having protein quality closer to soybean meal. The quality of protein in peas and lupins were poorer. It is very likely that the observed differences between legumes is due to deficiencies in the limiting amino acids (see Table 3) and the poor performance may be overcome, to a large extent, by supplementation of amino acids.
3. Raw soybeans supported the lowest weight gain and had the lowest PER. This is probably reflective of the anti-nutritive factors in raw soybeans. The birds fed diets containing raw soybeans had high mortality and high relative weights of pancreas, the latter suggesting the presence of protease inhibitors.
4. Mortality was not increased by feeding of raw forms of chickpeas, peas or lupins, suggesting that these do not have significant concentrations of any anti-nutritive factors. There were no effects on the relative weights of any organs. The lack of effects on relative pancreatic weights of chicks fed diets containing raw legume meals indicate that the level of protease inhibitors in these legumes were low.

5. The amino acid scores and the protein efficiency ratio data indicated that the protein quality of the legumes were in the following order: soybean meal > chickpeas > peas > lupins > (raw) soybeans. ¹

6. These data suggest that the relatively poor protein quality of the legumes is due to deficiency of key limiting amino acids, rather than to the presence of anti-nutrients. This aspect will be tested in future studies involving supplementation with methionine and lysine. ²

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Primary school children from NE Thailand are not at risk to selenium deficiency¹

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ABSTRACT⁴

Selenium has important roles as an antioxidant, in thyroid hormone metabolism, redox reactions, reproduction and immune function, but information on the selenium status of Thai children is limited. Therefore, we have assessed the selenium status of 515 NE Thai children (259 males; 256 females) aged 6.00 to 12.99 yr from 10 schools in Ubon Ratchthani province. Serum selenium concentrations were analyzed by Graphite Furnace Atomic Absorption Spectrophotometry (GFAAS) and dietary selenium intakes by Hydride Generation AAS from one-day duplicate diet composites, collected from 79 (39 F; 40 M) randomly selected children. Inter-relationships between serum selenium and selenium intakes, as well as biochemical micronutrient indices (analyzed earlier) were also examined. Mean serum selenium was 1.46 µmol/L; concentrations were independent of sex, but increased significantly with age (p=0.03) among the females. This mean level was comparable to that of US children (1.48 µmol/L), but higher than that of New Zealand (NZ) (0.97 µmol/L) and United Kingdom (0.87 µmol/L) children. None of the NE Thai children had serum selenium concentrations associated with clinical selenium deficiency (i.e., < 0.1 µmol/L). Indeed for 61% (n=312), levels were indicative of maximal activity of plasma GSHPx and selenoprotein P, and for 38% (n=194) above those suggested to protect against some cancers. Mean dietary selenium intake was 46 µg/d, below that of U.S. children (92 µg/d), but slightly higher than that for NZ children in 2003. Positive correlations between serum selenium and selenium intakes (µg/day) (r=0.22; p < 0.05) and protein density (g/MJ) (r=0.21; p < 0.05) were noted. Associations also existed between serum selenium and serum zinc (r=0.22; p < 0.001), serum retinol (r=0.26; p<0.001), urinary iodine (r=-0.095; p<0.05) and haemoglobin (r=0.28; p<0.001), but the mechanisms involved are uncertain. In conclusion, there appears to be no risk of selenium deficiency among these NE Thai children.⁵

Osteoporosis: The knowledge and health beliefs of New Zealand women¹

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ABSTRACT⁴

Osteoporosis and the attendant hip and spine fractures are predicted to become key contributors to the health burden of the future. This can be partly attributed to an aging population and aspects of our modern lifestyle. Although the disease is incurable, simple lifestyle changes well before disease onset can bring about an appreciable reduction of risk. The purpose of this study was to investigate New Zealand women's knowledge of osteoporosis preventative behaviours and their health beliefs about osteoporosis. It was hypothesised that both knowledge and health beliefs would change with increasing age.⁵

Women (n=622) between the ages of 20 and 49 years responded to an email invitation to complete a web-based questionnaire to assess their knowledge about osteoporosis risk-reducing behaviours such as calcium intake and physical activity, and their health beliefs about osteoporosis. The subject group was predominantly NZ European and well-educated.⁶ There was a significant difference in the level of knowledge between the 3 different age groups (20-29, 30-39, 40-49 yrs), but overall the score was low (M=16.4, SD=4) from a possible score of 24. However, there was no difference between age groups in perceived severity of the disease, or personal susceptibility. The mean score in these sub-sets indicated a neutral attitude to personal susceptibility, and only slightly above neutral attitude to the severity of the disease.

Health promotion theories suggest that a number of conditions, including awareness of susceptibility and belief in the severity of the disease, must be met before people will change their behaviour to reduce health risk. These findings indicate that although women become more knowledgeable about osteoporosis with age, their beliefs about personal susceptibility and severity of the disease do not appear to increase.⁷

Prebiotic supplementation increases *Lactobacillus* species stability, immune cell function, and feed conversion efficiency in neonatal calves. ¹

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ABSTRACT ⁴

Prebiotics are non-digestible, short-chain oligosaccharides that promote probiotic colonisation and function in the gut. Probiotic bacteria, in turn, have been shown to affect both nutrient uptake and immune function. The commercial prebiotic supplement CalfCareTM was assessed in neonatal calves for direct effects on *Lactobacillus* and *Bifidobacterium* species diversity, and for indirect effects on nutrient uptake and immune cell function. ⁵

Milk-fed Holstein-Friesian bull calves were supplemented twice daily with the prebiotic from the age of 6 days to 27 days. Faecal samples were collected at the beginning and end of the study. Faecal DNA was amplified by PCR using genus-specific primers and assessed for species diversity by denaturing gradient gel electrophoresis. Compared to unsupplemented calves, those receiving the prebiotic experienced fewer changes in *Lactobacillus* species over the 3 week period ($P < 0.05$), suggesting that the prebiotic stabilised colonisation. No *Bifidobacteria* were detected in any faecal samples. ⁶

Calf body weights were assessed every 2 – 3 days. Calves receiving the prebiotic weighed significantly more at the end of the study. Feed conversion efficiency was 57.2% in control calves versus 71.1% in prebiotic-supplemented calves ($P < 0.05$). ⁷

Weekly blood samples were assessed for leukocyte proportions and function. Between weeks 1 and 3, the proportion of lymphocytes cells amongst the peripheral blood leukocytes increased significantly in the prebiotic-supplemented, with a concurrent, significant decrease in the proportion of neutrophils. Changes in the leukocyte populations in control calves followed a similar trend but to a lesser, non-significant degree. Neutrophil phagocytosis of bacteria significantly increased in prebiotic-supplemented calves but not control calves. There were no significant differences between the groups in incidence of rotavirus infection, scouring, or lymphocyte function. We hypothesise that the prebiotic CalfCareTM indirectly increased weight gain, feed conversion efficiency, and neutrophil function in calves by enhancing the stability and long-term colonisation of important *Lactobacillus* species in the gut. ⁸

Evaluation of free fruit provision to low decile Auckland primary school children.¹

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ABSTRACT⁴

Introduction Fruits and vegetables have health promoting properties and are healthy alternatives to energy dense, nutrient poor snacks. However, fruit and vegetable intakes in many New Zealand children are poor. This pilot study evaluated a free fruit to low decile primary schools intervention carried out in Auckland in 2004.⁵

Subjects and methods Ten pairs of South Auckland schools (matched for roll size and geographic location) were selected from the 2003 Ministry of Education database. One school within each pair was randomly selected to receive free fruit for a school term (intervention group). The dietary intakes of all children were assessed using a diet recall method on three occasions: immediately prior to the fruit provision; at the end of the fruit period; and 6 weeks after cessation of fruit provision.⁶

Results Fruit intakes were similar in the control and intervention groups at baseline, with over 40% not reporting any fruit intake. Immediately following the intervention, fruit consumption was significantly greater in the intervention group compared to controls (C=1.2 pieces/d; I=1.6 pieces/d, $P<0.001$) and the proportion of children not consuming fruit dropped to 22%. This increase in fruit consumption was not sustained at six weeks after cessation of the free fruit delivery (C=1.2; I= 0.9 pieces/d).⁷

Conclusions Provision of free fruit to low decile primary school children was an effective way of increasing their fruit intakes. However, these dietary patterns were not sustained once this short term intervention ceased. There was some evidence of substitution of free fruit for fruit that would have otherwise been brought from home. Sustained fruit interventions would conceivably have long term health benefits, but need to be supported by health promotion initiatives targeted at the whanau and community.⁸

A pilot study of breakfast consumption in Year 8 Auckland children¹

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ABSTRACT⁴

The National Children's Nutrition Survey showed that the nutritional status of older New Zealand children is appreciably worse than younger children and varies with age and ethnicity. Specifically, Pacific Island children and older children were less likely than other ethnic and age groups to have breakfast. The current study aimed to collect detailed information on breakfast habits, choices and preferences of Intermediate School children.⁵

Two multi-cultural decile 6 Intermediate Schools in Auckland were selected to participate. A dietary assessment of over two hundred subjects (12-13 years of age) was completed using a dietary recall methodology. Data were also collected on breakfast habits and preferences and anthropometric measurements made.⁶

Only 15% percent of children reported that they did not consume any food and/or beverage before leaving for school. Breakfast consumption was not significantly associated with gender, but was influenced by ethnicity. Maori and Pacific Island children were less likely to eat breakfast than children of other ethnic groups ($P < 0.001$). Of those subjects who had breakfast, 62% had cereal, 34% had bread/toast and 12% had a piece of fruit for breakfast. The majority of subjects (85%) consumed a type of beverage on its own or combined with their breakfast meal.⁷

The majority of subjects in this pilot study reported consuming a meal and/or beverage before leaving for school. The observation of different breakfast habits between ethnic groups requires further research. Adolescence is a nutritionally vulnerable period of life. Promoting and maintaining good breakfast habits in Intermediate school aged children may lead to improved breakfast consumption patterns and health as they mature into adulthood.⁸

Knowledge and attitudes towards preconception nutrition, dietary intakes and lifestyle characteristics in Auckland women of childbearing age¹

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ABSTRACT⁴

Adequate nutritional status prior to conception and during early pregnancy is important in achieving a healthy pregnancy outcome. This study examined preconception nutrition knowledge, and dietary and lifestyle habits in Auckland women of childbearing age.⁵

Women aged 18-45 years (n=115) were recruited and data collected using a detailed questionnaire, anthropometric measurements and a diet history to evaluate dietary intakes.⁶ 18 women were attempting to conceive and 97 women indicated they were not currently planning pregnancy. The reproductive history of the women identified that 53 women had previously been pregnant but only 47% of these pregnancies had been planned.

Nearly all of the women (93.7%) had heard of folic acid and 65% were aware that folic acid was required for pregnancy.⁷ Although 53.9% of the women knew that folic acid prevents birth defects, only 31.3% of women had specific knowledge that folic acid use a month before conception can prevent neural tube defects. All of the women in the study who were currently planning a pregnancy had heard of folic acid and 13 (72%) were taking a folic acid supplement ($\geq 400\mu\text{g}$).

Although 80% of the women thought that dietary habits in the preconception period could affect pregnancy outcome few women thought preconception diet could influence risk of miscarriage, preterm delivery or maternal deficiencies.⁸ 83% of women used alcohol, 13.0% had a caffeine intake $>300\text{ mg/day}$, 8% smoked and 26.0% were overweight or obese.

Women recruited to the study demonstrated a lack of awareness of the importance of preconception nutrition and were not in an optimal physical state for pregnancy.⁹ The high rate of unplanned pregnancies in New Zealand is a significant obstacle to preconception care and efforts to increase the awareness of the importance of preconception nutrition are needed.

A simple nutrient partitioning model to simulate weight changes in human adults¹

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ABSTRACT⁴

There is increasing concern about the health status of the population, particularly the increasing proportion classified as being overweight. Many factors contribute to obesity in human adults such as nutrient intake and diet composition, activity and genetic background. Traditionally, knowledge about weight changes is generated in a fragmented fashion where specific aspects of nutrition, metabolism, or genetic are investigated. A greater understanding can be obtained when all the available information and concepts are synthesised, transformed into mathematical algorithms, and integrated into a simulation model. In our simple model, the subjects are characterised by age, height and weight; nutrient intakes are defined as daily gross energy intake and the proportion of energy provided by the macronutrients. The model then takes into account the digestibility of fat, protein (CP) and carbohydrate (CH) and their respective energetic efficiencies to calculate the net energy intake. Energy and protein requirements as well as the energy cost for different physical activity level (PAL) are calculated. The daily energy balance is then converted to body weight changes. Body weight changes were first set to 0 in adjusting the activity level for a 24 year old male, 177cm tall, weighing 77.9kg and eating 1.33MJ per day, (36% energy from fat, 14% from CP and 50% from CH) using data from the NZ National Nutrition Survey 1997. Model simulations conducted over a one-year period show that increasing PAL by 5% results in a predicted 3.15kg weight loss. Manipulating the macronutrient ratio to meet the NZ dietary recommendations (30% energy from fat, 15% CP and 55% CH) generated a weight-loss of 0.270kg whereas simulating the Atkins diet (40% energy from fat and 40% from CP) predicted a 3.96kg reduction in weight over a year. Mathematical modelling can be used to predict the effect of dietary changes and can be useful in identifying the most appropriate dietary and activity recommendations.

Development and Use of a New Nutrient Database for Top-Selling New Zealand Supermarket Foods ¹

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ABSTRACT ⁴

The most commonly used dietary assessment methods are 24-hour food recalls, food records, and food frequency questionnaires. While these are largely accepted to be the best methods currently available, the search is on for more efficient and novel methods that reduce the effort required by study populations as well as researchers. One such method involves the use of an electronic data collection system to measure supermarket food purchases and their nutrient composition. ⁵

A recent pilot study (SHOP) carried out by the Clinical Trials Research Unit, University of Auckland, tested the feasibility of a randomised trial design to measure the effectiveness of interventions to promote the purchase of healthy foods from the supermarket. Data from this study was used to develop and test a database of nutrient composition data for top-selling supermarket foods. ⁶

Prior to this project, there was no single complete nutrient database available in New Zealand for researchers wishing to study the nutrient composition of brand-specific supermarket foods. Current nutrient databases include the New Zealand Food Composition Database (Food Files) and the Manufactured Foods Database (MFD) both of which are incomplete for brand-specific supermarket foods. ⁷

Only the top-selling supermarket food products in terms of sales volume were selected for inclusion in this database. Composition data for 7 key nutrients were obtained for each product. Firstly, product details were merged with the existing databases Food Files and MFD. Missing data was obtained by contacting manufacturers, searching brand websites, and visiting supermarkets to view product Nutrition Information Panels. ⁸

A new database has been created that contains nutrient data for some top-selling supermarket foods in New Zealand. As a worked example of one application, it has been used to evaluate the impact of a pilot/feasibility study of supermarket interventions on the nutrient content of supermarket purchased foods. ⁹

The SHOP nutrient database has a number of potential applications for nutrition and public health research including evaluating the impact of interventions on the nutrient content of foods purchased from supermarkets and monitoring changes in the nutrient content of supermarket foods over time. ¹⁰

Nausea and vomiting in pregnancy (NVP) is associated with reduced fat intake and altered patterns of maternal fat disposition.¹

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ABSTRACT⁴

Nausea and vomiting in pregnancy (NVP) is a common symptom of early pregnancy, occurring within 2-4 weeks of fertilisation and potentially representing a challenge to nutrient intake during a vulnerable period of fetal development. NVP is associated with favourable outcome of pregnancy, including increased birthweight and gestational age. Mechanisms by which NVP positively influences pregnancy outcome might include increased nutrient intake to alleviate symptoms, improvements in diet "quality" reduced energy expenditure and/or altered patterns of nutrient stores in response to changes in nutrient intakes.⁵

In an observational cohort study design, we recruited 52 women (with and without NVP) in Guildford, UK. Women kept a 7-day food diary and recorded symptoms and food cravings and aversions in early and late pregnancy. Weight and triceps skinfold thickness were measured. Energy and macronutrient intake fell with increased symptoms. Women reporting NVP had lower mean energy intakes, in early and late pregnancy and tended to have lower micronutrient intakes (not significant) than women without symptoms. Differences in energy intake were due to a significantly lower fat intake in women with NVP ($P=0.032$). Whilst all women studied increased their weight in pregnancy, women with NVP did not have significant increases in skinfold thickness during the final trimester, possibly indicating differences in fat deposition.⁶

These results suggest that NVP drives women to change their meal pattern and quality of their diet, particularly intake of fat. Although the lower intake of fat is associated with symptoms of NVP and food aversion in early pregnancy, these women continue to consume a diet lower in fat throughout pregnancy. This change in dietary quality may be associated with the favourable outcome of pregnancy observed in women with NVP despite their lower nutrient intake. The new finding that body fat deposition in later pregnancy differs between women with or without NVP is intriguing and requires verification in future studies.⁷

Decreased Red Meat Fat Consumption 1995-2002¹

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ABSTRACT⁴

Aim: To update red meat and meat fat supply trends, after allowing for trimming. Review of New Zealand trends in 1) Per capita meat fat supply from Food and Agriculture Organization; 2) Carcase and cuts composition reports of knife dissection and chemical analyses; 3) Butcher's records of red meat fat entering the food supply. 5) A Lincoln College study of home-cooked beef.

Between 1995 and 2002, (1) Total saturated fat availability per capita in New Zealand decreased 19% (from 65g to 53g per day), mostly due to 7g less saturated fat from red meat. (2) In addition, trimming of fat from red meat before sale (supported by virtually all butchers from 1997) decreased fat and saturated fat sold per capita: across total food supply -8%; across all meat -17%; in red meat -29%; in beef, -27%; in lamb, -30%; tallow unchanged. By 2002, fat comprised 7.4% of trimmed cuts, and 11.2% of all beef sold: cuts, mince or sausages. Fat comprised 15.3% of lamb cuts; and 15.5% with mince included. (3) Combining effects (1) and (2), saturated fat per capita decreased: -27% in total food supply; -65% in red meat excluding tallow; -48% including tallow. In 2002, 43% of fat per dressed beef carcase entered the domestic food supply. In 1995, without trimming, red meat (excluding tallow) contributed 29% of saturated fat in total food supply; in 2002, 23% before and 14% after trimming. (4) Home trimming removed 27% of fat from beef steaks.

Centralised meat processing, and Quality Mark labelling of trimmed beef and lamb since 1997, ensured meat cuts were trimmed, and reduced saturated fat in red meats by nearly one third. In 2002 mince and sausages accounted for nearly half of beef fat sold as red meat.

Dietary intake and nutritional status of Korean migrants in New Zealand¹

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ABSTRACT⁴

Migration to a new country presents lifestyle challenges that may influence future health outcomes, particularly eating patterns. Auckland is a multi-cultural city with a growing number of Asian immigrants with diverse nutritional needs. Objectives: To assess dietary intake and other health related measures in a sample of 50 middle-aged (40-55 years) Korean females resident in New Zealand for at least 5 years.⁵

The study included dietary intake assessment (24-hour dietary recalls), anthropometric measurements (including Bioelectrical Impedance Analysis), blood pressure and glucose measurements and a lifestyle questionnaire.⁶

Nutrient intakes of subjects were generally adequate. However, low intakes of calcium (595.7 mg/d) and high intakes of sodium (3748.8 mg/d) were identified.⁷ Intakes of these nutrients in this population were intermediate between native Koreans and native New Zealanders. Sodium intakes were higher than New Zealanders because of the maintenance of some traditional high sodium Korean foods in the diet e.g. *kimchi*. Intakes of calcium were lower than those of New Zealand women, but higher than native Koreans because of a significantly greater intake of dairy products. Subjects had a lower prevalence of obesity, based on BMI, according to the New Zealand classification (2%) compared to the Korean one (24%) ($P=0.005$). However, almost 50% subjects fell into the 'at risk' classification for waist-to-hip ratio, suggesting that subjects may have elevated upper body fat in relation to body size.

This study of Korean women identified areas of concern and indicated the need for further nutritional research into this population. The anthropometric findings suggest that ethnic-specific obesity indicators need to be developed to monitor disease risk in migrant populations.⁸

Iodine Status of Young Adults in Auckland¹

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ABSTRACT⁴

Iodine status has been repeatedly reported to be inadequate in New Zealand for several reasons, e.g. decreasing consumption of iodised salt, limited usage of iodised salt for processed foods, and new procedures for disinfectants in the dairy industry. The aim of the present study was therefore to evaluate the iodine status of young adults at the age of 18-30 years in the Auckland region.⁵

Participants (n = 224) were asked to collect 24-hour urine samples (n = 110) and a food frequency questionnaire (n = 107). Urinary iodine excretion (UIE) was measured by the kinetic determination based on the Sandell-Kolthoff method, after digestion with ammonium persulphate under mild heating conditions.⁶

Median UIE of the participants (23.5 ± 2.7 years) was 61 (2-261) µg/L and 84 (7-259) µg/d, after excluding values >300 µg/L corresponding to WHO criteria.⁷ The UIE of 20% of the samples was >100 µg/L and 36% of samples <50 µg/L. Significant differences were found between Asians (n = 33) and NZ-Europeans (n = 54) (p<0.05) for medians of 96 (24-237) µg/d and 82 (7-259) µg/d, respectively.

About 66% of the participants reported a regular household usage of iodised salt, in average ¼ teaspoon per serving, supplying about 69 µg iodine.⁸ The median UIE of the participants who reported to use iodised table salt or non-iodised sea or flaky salt, resp., however, were similar (82 (24-237) and 81 (7-215) µg/d). The response to the questionnaire indicated that a higher consumption of fish, milk, eggs and algae results in a higher UIE. Meat, staple food, vegetables, fruit and beverages did not influence daily iodine excretion. A mild iodine deficiency was found for young adults from Auckland based on the WHO classification of UIE. The intervention strategy with voluntary iodine fortification of table salt may no longer be of significance for iodine status in New Zealand.

Iron Nutrition in Pregnancy and Early Life¹

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ABSTRACT⁴

Iron deficiency is a relatively common problem in pregnancy in both developed and developing countries. In industrialised countries there is some debate about usefulness of routine iron supplementation in pregnancy. The aim of the Adelaide Mothers' and Babies' Iron Trial was to investigate whether routine low dose iron supplementation in pregnancy has beneficial effects for the mother and child.⁵

Randomised controlled trial of a daily iron tablet (20mg) vs placebo from 20 weeks gestation until birth. Primary outcomes included maternal iron status at the end of the pregnancy and at 6 months post partum, as well as childhood IQ at 4 years of age. Other outcomes included pregnancy outcome, maternal health and well-being and childhood behaviour at 4 years of age.⁶

Results: 431 women (215 in the control group and 216 in the iron group) were recruited from the Women's and Children's Hospital, Adelaide. The prevalence of iron deficiency anaemia (IDA) in the iron group (3%) was lower than the control group (11%). By 6 months post-partum, the frequency of IDA did not differ between the two groups but women in the iron group had less iron deficiency compared with control. There were no differences between the groups in pregnancy outcome, or any indices of maternal mood and well-being. Similarly the mean IQ and mean behavioural scores of children born to mothers in the iron and control groups did not differ. However, the percentage of children with abnormal total behavioural scores was higher in the iron group compared with the control group.

Conclusions: In our well nourished sample, there were no long term benefits of routine iron supplementation in pregnancy. The potential negative effect of supplementation on early childhood behaviour requires substantiation.⁷

Effects of storage on antioxidant status in human breast milk¹

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ABSTRACT⁴

For many mothers storing expressed breast milk provides a practical solution to continue⁵ feeding their infants with breast milk when they return to work. However, Hanna *et al* (2004) identified that the total antioxidant capacity of breast milk reduced when the milk was stored at 4°C or -4°C. In addition, Vitamin C has also been shown to degrade during storage (Buss *et al* 2001). These findings may be significant for infants due to their immature antioxidant defence system and the fact that they rely on breast milk as their sole source of antioxidants against oxidative stress in early life.

Samples of expressed breast milk are currently being collected from 10 healthy mothers.⁶ Samples will be analysed for total antioxidant status, Vitamin C, and lipid hydroperoxide at baseline and during storage conditions according to current New Zealand guidelines for storage of expressed breast milk (MOH, 2000).

Total antioxidant status will be determined using a Randox assay kit, which has been modified⁷ for use on a plate reader; Vitamin C will be measured by a fluorescent assay; lipid hydroperoxide will be measured by a ferrous oxidation of xylenol orange assay.

The results will identify whether total antioxidant status or individual antioxidants of breast⁸ milk are affected by storage at room temperature, or during refrigeration and freezing.

This study will provide preliminary evidence of storage effects on antioxidants in breast milk.⁹ Further research may be needed to modify current New Zealand guidelines for storage of expressed breast milk if significant antioxidant losses are observed in the present study.

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Aguaruna in the Peruvian Amazon Experience Healthy Diets as a Result of Traditional Food System¹

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ABSTRACT⁴

Traditional food systems generally support healthy diets for Indigenous Peoples. The Aguaruna Indigenous People live along the Rio Cenepa in the remote Peruvian Amazon and consume a cassava based diet, complemented by shift agriculture, fishing, hunting and gathering. Here we analyze the nutritional importance of the Aguaruna traditional food system (TFS). Using anthropometric measurements including, we established the nutritional status of women and young children. We recorded their dietary intakes and dietary diversity by repeat 24 hour recalls, with 3 days separation. A traditional food diversity score was calculated for each individual. Subsequently, we analyzed the relative nutrient contributions of local foods. A market survey compared the nutrient value per price of seasonal local foods with imported products. Anthropometry indicated a healthy population, although Aguaruna had short stature. Group dietary data showed adequate intakes of energy, protein, fat, iron, zinc, vitamin C and vitamin A. The Aguaruna traditional food system has many unique nutrient dense foods which are easy to obtain, including *aguaje* (Mauritian palm fruit), *suri* (a type of larva) and wild meats such as armadillo and paca. Higher traditional food diversity was associated with greater nutrient, vitamin and mineral intakes (Spearman's rho = 0.29 to 0.60). Aguaruna purchased <1% of their diet and preferred local foods, which offered better nutrient value per unit price.

In this remote setting, traditional subsistence lifestyle can provide an adequate diet and support good health. The study found that overall women and children had adequate diets. Greater traditional food diversity resulted in improved nutrient intakes. The Aguaruna study shows that traditional food systems deserve promotion and protection.

The highs and lows of dietary nutrient intakes - the 2003/04 NZ Total Diet Survey¹

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ABSTRACT⁴

Mankind's technological progress over past decades has generally seen significant improvement in both the quantity and quality of our food supply. However, there has also been concern about the potential impact on public health of both inadequate and excessive levels of nutrients in our diet.⁵

The 2003/04 New Zealand Total Diet Survey (NZTDS) was undertaken for the New Zealand Food Safety Authority by ESR. A key focus *inter alia* was to estimate selected nutrient element intakes from foods consumed by New Zealanders. The 2003/04 NZTDS involved sampling of 121 different foods, and purchase of a total of approximately 4400 samples from July 2003 to June 2004. Foods were prepared 'table ready' prior to analyses, to best reflect actual dietary intakes.⁶ Fortnightly simulated diets for eight age-sex groups within the NZ population were developed from 1997 National Nutrition Survey and 2002 Children Nutrition Survey data. The 2003/04 NZTDS confirmed that mean daily intakes of iodine in NZ have continued their steady decline of the past 20 years. Mean iodine intakes based on the simulated diets were only 40-57% of RDI for the eight NZ population groups. Dairy, other animal products and infant weaning foods were the main dietary sources. The iodine content of most foods was less than 0.05 mg/kg. Nonetheless, the NZTDS identified one brand of soy milk with 9.14 mg/kg iodine.

Even with recently fortified grain products, 25+ year females have a mean iron intake of only 51% of the RDI. Concentrations of sodium ranged from <10 to 42,000 mg/kg. Mean daily sodium intakes exceeded the upper intake limits for 7 of the 8 age-sex groups.⁷

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