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Defence Nutrition Workshop, April 2006, Proceedings

Human Protection and Performance Division
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ABSTRACT

As a component of the Defence Nutrition Plan, the Defence Nutrition Workshop was conducted to provide guidance to DSTO-Scottsdale on the most effective and efficient way in which S&T support could be provided to the ADF in nutrition and food science. Experts from Australia and overseas presented on the current status and likely future directions of research into a wide range of Defence-related food science and nutrition issues. These include development of rations for short-term operations, educating warfighters in better nutrition, development of a procurement process for combat ration packs, and the potential for particular forms of carbohydrate to enhance or maintain ADF health and performance.

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Executive Summary

Recent increases in the complexity and tempo of military operations, and the advent of network-centric warfare, have led to an urgent need to enhance individual survivability, mobility and sustainability to ensure the maintenance of optimal health and military performance of ADF members.

Nutritional status is of fundamental importance in sustaining health and performance. Therefore, it is essential that ADF members have access to adequate quantities of nutritious and palatable food during all phases of operations.

The increasing range of environments in which the ADF operates requires the development of rations tailored to specific missions and situations—such as lightweight rations to reduce load carriage on sustained or extended operations; rations that reduce human waste for covert operations; and rations that optimally support operations in climatic extremes.

As one element of the Defence Nutrition Plan, in April 2006 a workshop was conducted to provide expert guidance to the research program of DSTO-Scottsdale for the next 5–10 years. Australian and overseas military and civilian experts presented on current and projected future nutrition or food technology research areas that are likely to be of Defence significance. Each presenter also submitted a short paper for publication in the proceedings of the workshop; these papers constitute the body of this report.

In the body of this report, *freeze drying* is identified as the best available technology for the production of light-weight, shelf-stable and palatable rations. Recently-developed technologies and nutritional approaches that are also considered likely to have Defence value include *high pressure processing*, *high-powered ultrasound, pulsed electric field*, *micro-encapsulation*, *prebiotics, probiotics, glycaemic index* and *resistant starch* (including the development of new cereal cultivars that may lead to substantial improvements in gut health of military personnel). Resistant starch may have the potential to protect against immediate health threats such as gastrointestinal infections, and also against long-term health threats such as increased risk of disease through the use of extreme diets (e.g. those high in protein).

Current food technology research programs at DSTO-Scottsdale emphasise *micro-encapsulation* and *probiotics*. Microencapsulation is being used to protect vitamins that are not stable during processing and storage, and to similarly protect probiotics. The potential health benefits of incorporating probiotics into ration pack items are also being investigated.

Potential development areas for cooperation/collaboration between DSTO-Scottsdale and other research organisations include: consumer science aspects of combat ration pack (CRP) design, i.e. the psychological aspects of appetite and consumption in the field; access to

process engineering technology to enable a smooth transition of research outcomes to the food industry; other encapsulation technologies in addition to spray and freeze drying, fluidised bed and simple extrusion; and access to food grade pilot plant facilities.

A strong argument is made for maximising the use of 'naturally-functional' foods—those that were available during the time of the most rapid phase of human evolution, and hence could be said to constitute the 'natural diet'. Recent evidence from large-scale epidemiology suggests that a diet rich in a variety of relatively unrefined plant- and animal-based foods may be optimal for both short-term mental and physical performance and long-term health outcomes.

Futuristic concepts are suggested, including the likely use of nutrigenetics (the effects of individual genetic characteristics on nutritional requirements) and nutrigenomics (the effects of nutrients on gene expression) to impact positively on nutritional status, health, resistance to physical injury, fatigue and CBR injury. Research would use gene science and molecular biology to link human physiological response with nutrition.

Problems with ADF feeding that need to be addressed are identified, including: a requirement to enhance bone health; the need to investigate the effects on military performance of under-consumption of CRP; declining levels of iron, reduced vitamin status—particularly B group vitamins and vitamin K—and impaired immune status when rationing is by CRP; and the effects on health, performance and nutritional status attributable to modifiable behaviours such as smoking and high levels of alcohol consumption. Because a large proportion of ADF activities occur in hot climates, the effects of dehydration are identified as being of particular importance.

A health promotion program—combining nutrition and fitness education—is described. This program led to improved quality of diet, increased physical fitness, and a reduction in levels of risk factors for chronic diseases such as diabetes and heart disease.

The development of a light-weight 'First Strike Ration' (FSR) for the US Army is described. The nutritionally-enhanced and utensil-free design of the FSR provides a high-performance ration that will optimise troops' cognitive and physical performance by enhancing nutritional status and metabolic fuel availability, while minimising ration weight and volume, and reducing food wastage.

The principles and processes underlying ration pack design, development, assembly, quality assurance, and evaluation are described, including the value of using a 'performance based contract' to ensure that quality and timeliness are optimised.

National dietary trends and the recently published Nutrient Reference Values (NRV) are described. The NRV will be of great value to Defence in the development of military-specific NRV.

It is pointed out that Australia's increasingly ageing population means that Defence will face continually increasing competition from other employers for the dwindling proportion of the population who qualify to join the ADF. Nutritional and other health related strategies are needed to maximise the percentage of the population who meet Defence criteria for recruitment. Research is described on the development of preventive strategies and food products that should reduce the health burden due to chronic illnesses, and thereby contribute to the availability of sufficient fit, healthy potential recruits to meet the ADF's requirements.

Contents

1. Introduction

Over the past decade there has been a substantial increase in both the tempo of ADF operations and the range of environments in which the ADF operates. Often with little time for recovery, troops could find themselves in a hot/wet climate such as East Timor, followed by the cold and altitude of Afghanistan in winter, and then perhaps in the hot/dry conditions that prevail in Iraq in summer.

At the same time there has been an increase in the complexity of ADF activities—operations are no longer confined to daylight hours, and are increasingly 'network centric'. As a result, the maintenance of high levels of physical and cognitive performance during sustained operations is of increasing importance to mission success.

Also, the roles and responsibilities of the ADF have recently been widened—in addition to war-fighting, troops may now be involved in Peacekeeping, Peace Making, Nation Building, Humanitarian Operations or Combating Terrorism. Often two or more of these operational situations apply simultaneously.

This increasing range of operational types and greater tempo of operations implies a need for more efficient and effective logistic capabilities, together with enhanced individual survivability, mobility and sustainability to allow the maintenance of optimal health and military performance of ADF members.

Nutritional status is of fundamental importance in sustaining health and performance. Therefore, it is essential that ADF members have access to adequate quantities of nutritious and palatable food:

(i) *Before* deployment, to ensure that troops have optimal nutritional status at the start of the operation;
(ii) *During* deployment, to support the maintenance of good health and performance for the entire operation; and
(iii) *Post-deployment*, to facilitate rapid recovery.

It is also worth noting that food has a major impact on morale, an impact that can be positive or negative depending on the perceived quality (in terms of palatability) of the food provided. Morale can also be affected in more subtle ways—for example, if the supply line providing the rations is fully functional, the individual soldier can be confident that the logistic system in general is working and that he is fully supported.

The increasing range of environments in which the ADF operates requires the development of rations tailored to specific missions and situations—such as lightweight rations to reduce load carriage on sustained or extended operations, rations that reduce human waste for covert operations, and rations that optimally support operations in climatic extremes. There is a clear need for R&D in nutrition and food technology in support of the ADF.

DSTO-Scottsdale (also known as Defence Nutrition[1]) provides R&D support to the ADF in the fields of nutrition and food technology. In 2005 work commenced on developing a Defence Nutrition Strategic Plan that focuses on identification of client requirements and the development of capabilities needed to address those requirements. The first step in this process was the conduct of a 'Client Workshop', which aimed to identify the requirements for nutrition and food science S&T support of all interested ADF authorities in the short, medium and longer terms. The Client Workshop was conducted in Canberra in September 2005. It was attended by representatives of 16 stakeholders, who confirmed that Defence requires an S&T capability in nutrition and food science & technology. This workshop also identified some key areas that need further consideration, including:

(i) The potential effects on performance of the use of dietary supplements and other purported aids to health and/or performance;
(ii) Nutrition education;
(iii) The potential for DSTO-Scottsdale's R&D to add value to all three services (some attendees expressed a concern that often the sole beneficiary is the service that sponsors the task);
(iv) The impact of nutrition on –
    a. Selection,
    b. Conditioning and training requirements,
    c. Feeding on operations (e.g. possible use of intermediate moisture foods),
    d. Cognitive enhancement,
    e. Fatigue prevention, and
    f. Injury prevention,
(v) Waste management (including reduced packaging and reducing human waste production);
(vi) Novel systems for water capture in the field; and
(vii) Ration pack development.

Having confirmed the need for a Defence Nutrition capability, and identified some key nutrition-related areas that need to be addressed, the next step was determining how to maximise the value to Defence of the staffing resources and expertise available at DSTO-Scottsdale. To assist in answering this question a second workshop was conducted, the Defence Nutrition Workshop. This workshop aimed to provide expert guidance to the research program of DSTO-Scottsdale for the next 5–10 years. The topics considered to be of most relevance were:

(i) Consumer science covering such issues as consumer attitude and behaviour, the variables that affect appetite, and improving palatability;
(ii) Appetite regulation and stress, interactions between appetite and hydration in a hot environment;
(iii) Gut health and probiotics in relation to working in a hot environment;

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[1] DSTO-Scottsdale is a part of the Human Protection and Performance Division (HPPD) of the Defence Science and Technology Organisation (DSTO). These relationships are briefly explained in Appendix A.

(iv) Bioavailability of nutrients;
(v) Enhancement of performance—both cognitive and physical—through nutrition; and
(vi) Innovative food processing.

The Defence Nutrition Workshop was conducted at Bridport, Tasmania on 27/28 April 2006. Australian and overseas experts were invited to present on these and other Defence-related aspects of nutrition and food science. Attendance at the workshop is shown at Appendix B, together with the membership of the organising committee and the staff members who handled local administration. Speakers, their affiliations and the titles of their presentations are in the workshop program shown at Appendix C.

In addition to making a presentation, each speaker submitted a paper of 2–3 pages. These papers form the body of this report, which constitutes the primary output of the Defence Nutrition Workshop.

The papers are shown in the order in which they were presented.

2. Keynote Address: Designing foods for Performance – Peter Lillford

Professor Peter J. Lillford, CSIRO Food Futures Flagship Fellow

A. Some History
Food technology shapes our civilisation. Once *Homo sapiens* had learned to farm animals and plants, a few individuals could feed many others, allowing the rest to develop politics, art, music, sport and fighting with their neighbours!

The first hurdle to the expansion of both civilian and military organisations is to maintain the efficiency of their work force by providing a reliable, safe and palatable food supply. This meant the development of food preservation methods, allowing storage and movement of food supplies, and the provision of diets that avoided the proliferation of debilitating diseases. The military has been particularly innovative in this respect, and many historical examples are available:

- Seeds are naturally stable due to their dry state. This allows cereals and pulses to be transported over long distances and stored for over a year. The Roman army knew this well, and so did their enemies, who attacked their grain supplies. Similarly, preservation by drying is one of the oldest known methods of storing meats.
- However, the texture of foods normally consumed at high water content, such as meat, vegetables and fruit, is very different in the dried state. The preservation of these materials, in the wet state was developed by Nicholas Appert as a result of a competition to improve the rations of Napoleon's army.
- Neither is it just the provision of macronutrients that is important. The extremely restricted diet of the early English navy led to the identification of vitamins, and the need for vitamin C in combating scurvy.
- More recently, the overriding need for light weight field rations has led to the development of freeze drying. Without this demand from the armed forces, it is unlikely that the civilian food industry would have invested in the development of the technology.

Nowadays, the provision of better quality and more convenient preparation of meals is common to both civilian and military supply chains, and the requirement for a diversity of choice is also recognised. Frozen storage is capable of holding large volumes of high moisture materials stable for long periods, without dramatic quality loss, but is expensive in both maintaining and transporting the frozen material. For static populations, civilian and military supply chains share all the same interests in novel technologies.

B Near Future Foods
Low level irradiation can kill micro-organisms without radically changing the cellular structure of meat and vegetables or the fabricated structures of bread, sauces and soups. Very successful, ambient-stable products are available, but the association of irradiation and food is not normally acceptable to the public. This risk is very small and highly palatable rations have been developed.

Exposure to extremely high pressure also kills vegetative cells by disrupting membranes. Elimination of spores is not achieved, so this technology is not equivalent to sterilisation. However, there are many foodstuffs in which spore outgrowth represents no risk. Furthermore, the absence of heat results in less change in the composition of flavour chemicals, and an apparently "fresher" product. Other non-thermal methods of microbial kill are also under investigation, such as electroporation, intense light pulses etc. Concept products are available, but most represent niche applications where product improvements are demonstrable. However, thermal sterilisation still provides a very useful and generally applicable route to ambient stable foods. The biggest change in convenience is shown by the replacement of cans by plastic pouches, providing easier opening and less weight.

However, the military have even more testing logistical requirements than the sudden and rapid availability of large volumes of food material, ready to eat. In addition to long term ambient stability, the military must source lightweight, nutritious and acceptable food for field troops.

C. In Your Dreams?
This additional constraint requires foods designed to maintain high performance under extreme conditions in the field, with little or no support from normal food preparation equipment. Ideally, the answer would be to transport food in the dried state and simply add water at the point of eating. Freeze drying is the best available technology at present, but nature has a few more tricks which we might learn to apply in the future:

- Plants subjected to extreme and sudden drought conditions have developed survival techniques which allow protection of their entire metabolic processing capability. As yet we do not understand how this is done, but it certainly requires special cell wall structure, selection of specific membrane lipids and the storage of intracellular osmolites such as sugars and amino acids.
- This capability is not limited to plant tissue—small animals (e.g. soil nematodes) are capable of demonstrating the same survival strategy, and use apparently similar cellular regulation.

One day we may be capable of generating similar revival and rehydratable strategies by selecting genotypic and post harvest modifications of food materials.

D. Human Health and Performance.
As we learn more about the impact of diet with human physiology, we recognise the need for personalised diet matched with physical activity. The athlete has a great deal in common with the needs of troops in the field. Now, Performance Foods are being developed which provide maintenance of high energy, physical dexterity and cognitive function. The deliberate use of performance-enhancing drugs may be necessary in high intensity field operation during wartime, but increasingly we realise that minor components in food are capable of stimulating or maintaining performance with a lower chance of the development of dependency.

Finally, the impact of body water balance, during extremes of physical activity and climate are beginning to be understood, leading to design of new food and drink for athletes, combatants and even the more adventurous civilians. The effect of dehydration on performance is significant, and in a life and death situation, vital.

The potential performance of individuals under extremes of physical or mental stress is not just a function of training, but inherent in their gene make-up. It may not be so long in the future when one of the recruitment tools for elite troops is their genetic profile. After all, the expression of growth hormone and the physical height it produced was a traditional selection process for both the Guards and the UK police force!

About the speaker

Formerly Chief Scientist at Unilever Research—where he worked primarily on Food Texture and Fabrication, but also on Preservation Microbiology and Consumer Sciences—Professor Peter Lillford is now a CSIRO Food Futures Flagship Fellow, advising on Food Design and Processing. Professor Lillford is also Chairman of the Advanced Food Manufacturing LINK Program in the UK, and Professor of Public Awareness of Science at York University.

Session 1. Feeding the Warfighter in the Battlefield of the Future – a Perspective from 'Down Under'

1.1 Enhancing ADF capability through nutrition – Christine Booth

Dr Christine K. Booth, Defence Nutrition, DSTO-Scottsdale, Human Protection and Performance Division

To complement the developments in food technology, the aims of military nutrition research are to identify the optimum mix of nutrients to sustain warfighters under all operational conditions, to understand the negative nutritional effects of operational stresses—which include sleep deprivation, intense physical activity, extreme climate and negative psychological factors—and to enhance appetite despite these stresses. Importantly, the food scientist and nutritionist need to understand the limitations of the usage of combat ration packs (CRP) in the military context.

A study on nutritional status and fatigue among Army recruits highlighted that many improvements to the food services and the eating behaviours of the recruits were required[1]. The same is probably true for other ADF training units. For example, additional dietary studies have revealed that young female officers-in-training are at risk of eating insufficient calcium and iron[2,3]. Decreased nutritional status of personnel resulting from operational training exercises can contribute to health problems, including reduced immune status and increased risk of cardio-vascular disease and thereby reduced capability[4].

This paper briefly discusses three nutritional issues of concern to the ADF—under-consumption of CRP, iron status, and bone health—and highlights the knowledge gaps in our understanding of these issues.

1. Determination of dietary intake under actual deployment conditions in different environments, taking into consideration gender differences
Anecdotal information suggests that current conditions of deployment can put troops at risk of either significant weight gain or loss with, for in most cases, a consequent loss in physical fitness. However, a review of the military literature reveals that there is little data to support our knowledge of warfighters' eating and drinking patterns under actual conditions of deployment, or even under training conditions that simulate operations.

2. Maintenance of an accurate and up-to-date nutrient composition database for combat ration packs (Australian and international)
Despite having detailed specifications for the nutritional content of Australian CRP, we do not have an accurate and up-to-date nutrient composition database for our CRP. An increasing emphasis on Australian involvement in coalition-led operations means that Australian soldiers are more frequently being fed by fresh foods and CRP issued by allied nations. We have no information regarding the feeding policies or nutritional composition of freshly-cooked food or CRP being issued by coalition countries.

3. *Determining the effects of environmental, physical and psychological stresses (including sleep deprivation) encountered by the military on specific nutrient requirements, and on eating and drinking behaviour*
In hot environments, whole body losses of electrolytes and trace elements resulting from high sweat rates and gastrointestinal disturbances have not been well established[5]. There is poor understanding of the causes and effects of 'operational anorexia', a tendency to under-consume food and drinks during typical operations. Altered eating and drinking behaviours due to extremes of both cold and hot environments could have significant detrimental effects on nutritional status, physical capability and cognitive performance.

4. *Determining the role of gut health in mitigating the adverse effects of the military environment*
There has been no major study of the effects on bowel health of operational deployments, yet gut health plays an essential role in maintaining nutritional status. In particular, poor gut health can result in decreased immunity to infection and in the longer-term to increased susceptibility to cancer. Optimal gut health is essential to maintain electrolyte balance and euhydration.

5. *Determining whether the decreases in iron status observed during military training decrease physical and/or cognitive performance in military settings*
Decreased iron status has been a consistent finding in all our nutrition-related field studies[2,3,6,7]. It is unclear whether these observed decreases in iron status had any detrimental effect on military performance or outcomes. Furthermore, the possible benefits of iron supplementation in terms of military outcomes has not been studied.

6. *Identifying ADF groups at high risk of bone-related injury and implementing appropriate intervention programs*
We do not have a comprehensive injury database to enable a clear understanding of the aetiology of bone-related injuries across the ADF population. Nor do we know the prevalence or importance of individual risk factors for bone health among ADF personnel. Understanding the prevalence of risk factors such as reduced bone mineral density, cigarette smoking, alcohol consumption and poor diet could be a key to designing effective screening and prevention strategies, particularly for recruits.

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About the speaker

Dr Christine Booth is an Accredited Practicing Dietitian with a PhD in biochemistry and post-graduate teaching qualifications from the University of Queensland. Dr Booth worked in public health and medical research at the University of Queensland and Queensland University of Technology as a Kellogg Research Fellow, then as a supervising scientist of metabolic chemistry at Royal Brisbane Hospital. Her present position is Task Manager of the Nutrition Task at DSTO-Scottsdale. She is also an Associate Research Fellow at the School of Human Life Sciences at the University of Tasmania.

1.2 Educating future warfighters to feed themselves: the New Zealand perspective – Nicola Martin

CAPT Nicola Martin, Dietitian, New Zealand Defence Force

The major nutrition issue within the New Zealand Defence Force (NZDF) is that until recently nutrition has never been an issue or more importantly, a priority.

The results of a health promotion intervention study, conducted in Papakura Military Camp during 2003 highlighted the impact that nutrition education (both for the individual and as a group) can have on the health and performance of NZDF soldiers.

The aim of the study was to implement and measure the effects of a nutrition education programme conducted by a dietitian and an exercise intervention programme conducted by a sports scientist in a sample of NZDF soldiers.

From an initial 45 volunteers, 35 highly-trained soldiers (including 3 females) aged between 20 and 40 years started the 12-week intervention study following clearance by a Medical Officer. Subjects were randomly assigned into four groups (as outlined in the following table). All groups were matched for age, weight and baseline fitness. A total of 28 subjects completed all tests—the attrition rate being attributable to injuries or work commitments.

	Exercise Intervention	**No Exercise Intervention**	**Total**
Nutrition Education	10 **GROUP A**	9 **GROUP B**	19
No Nutrition Education	8 **GROUP C**	8 **GROUP D**	16
Total	18	17	35

Groups A and B received three 30-minute one-on-one consultations with a dietitian throughout the 12-week intervention. They also received a series of six one-hour seminars conducted by a dietitian over a seven-week period, which covered general healthy eating, nutrition issues in exercise, fuel nutrients (role, quantity and timing), fluids (including dehydration and alcohol), sports supplements, choosing healthy foods and cooking at home.

Training programmes in the NZDF are generally group-based and of a one-size-fits-all nature due to the large numbers often involved, and also to foster teamwork. Individuals at the extremes of fitness often obtain fewer benefits from this system.

Groups A and C received individualised training programmes, based on the results of their baseline fitness tests, which were designed to target their weaknesses. These programmes consisted of seven sessions per week, only two of which were supervised. The training was similar in intensity and volume to the routine army physical training.

The outcome measures that were assessed at baseline and at the end of the 12-week intervention included:

- General health status – blood pressure, lipids, iron status, folate, vitamin B12, height, weight, skinfolds, body mass index (BMI) and fat mass

- Dietary intake – three-day diet record

- Physical performance – required fitness level (RFL, a level 1 pass for males is ≤10mins for 2.4 km run, ≥66 curl-ups, ≥30 press-ups, ≥8 pull-ups), ladder climb, body drag, rope climb and strength testing

- Perceived impact on health and performance – retrospective survey using five-point LIKERT scale

- Laboratory based – explosive strength, acceleration and speed, joint flexibility and aerobic capacity by gas exchange, assessed in eight subjects (four each from Groups B and C).

The significant results (p value ≤0.05) due to the effects of the nutrition education programme alone (Groups A+B versus Groups C+D) were:

- Reduced intake of total fat (-33%), saturated fat (-35%), monounsaturated fat, (-36%) and polyunsaturated fat (-30%)
- Reduced sodium intake (-36%)
- Increased vitamin C intake (+116%)
- Increased sprint speed (+4.8–6.7%) and $\dot{V}O_{2max}$ (+12%)
- Improved perception of energy levels, alertness and recovery times
- High level of confidence regarding understanding of nutrition education and impact on health and performance.

The significant results (p value ≤0.05 due to the effects of the individualised training programme alone (Groups A+C versus Groups B+D) were:
- Reduced run time (-2.8%)
- Improved leg squat (+112%).

On average, only 30 of 60 prescribed unsupervised training sessions were achieved.

The nutrition education intervention provided worthwhile effects, such as improvements in lowering fat (in particular saturated fat) and sodium intakes, whilst increasing vitamin C intake (most likely from increased fruit and vegetable consumption), which all have known health benefits in the prevention of lifestyle diseases such as heart disease, stroke, type 2 diabetes and some cancers.

There were significant improvements in post-exercise nutrition in terms of carbohydrate intake and timing. This is likely to be a contributing factor to the performance improvements and increased energy and alertness seen in the nutrition education intervention groups.

The nutrition education only group (Group A) decreased their weight by 2.5% ($p=0.02$) and their BMI by 0.7 kg/m^2 ($p=0.02$).

Using New Zealand Ministry of Health data from 2003 on disease relative risk it can be concluded that in the 25–34 year age group a 0.7 kg/m^2 decrease in BMI equates to a relative risk reduction of 8% for ischaemic heart disease death and a 9%, 16% and 2% reduction of incidence for stroke, type 2 diabetes and colon cancer respectively. These risk reductions become even more pronounced over 34 years of age.

In conclusion, a health promotion intervention, involving both nutrition education and exercise programming, can improve both the health and physical performance of highly-trained soldiers.

The recommendations for Papakura Military Camp were:

- Regular dietetic clinics
- Regular nutrition education sessions
- Provide a sports drink during and after intense physical training sessions
- Provide longer mess timings to cover post-physical training times
- Initiate a prescribed, focused physical training programme for pre-deployment training longer than four weeks
- Utilise individual sports physiological assessments as appropriate.

The recommendation for NZDF was:

- Employ a registered dietitian to develop and implement nutrition policy.

About the speaker

Captain Nicola Martin is a Registered Dietitian with Bachelor of Science – Physiology, and Bachelor of Consumer and Applied Science – Human Nutrition, from the University of Otago. Captain Martin worked as a clinical dietitian at Auckland Hospital for three years before taking up a full-time position as the New Zealand Army's dietitian, and subsequently as the NZ Defence Force dietitian. She was in the Territorial Force (Reserves) for four years prior to transferring to the regular force to fill her current position.

Session 2. Feeding the Warfighter in the Battlefield of the Future – an International Perspective

2.1 Military rations for short-term, high-intensity combat operations – Chad Koenig

MAJ Chad Koenig, United States Army Research Institute of Environmental Medicine

The current operational tempo frequently subjects U.S. personnel to an increased level of physical and mental stress. Missions often involve operating without adequate sleep and recovery time in rugged terrain and environmental extremes while carrying heavy loads (35 to 65 kg). Maintaining optimal physical and mental status of warfighters is essential to the success of these military operations, but logistical and practical considerations often prevent troops from receiving the energy and nutrients needed to meet their requirements.

While short-term energy and other nutrient deficits may have only a limited influence on a warfighter's ability to accomplish the mission, an escalating impact can be expected when troops are exposed to repeated missions over the course of a year-long deployment without proper nutrition. The actual consequences of improper nutrition are wide ranging and vary depending on the source of the deficit, but could include an increased rate of injuries, greater occurrence of illness, and decrements in physical and cognitive performance. Besides providing appropriate nutrition, military rations for high-intensity missions must also be lower in weight and volume as well as and easy to eat while on-the-move, allowing troops to be unencumbered and able to sustain moderate to high-intensity physical work with limited re-supply.

The primary eat on-the-move ration provided for U.S. troops has long been the Meal, Ready-to-Eat (MRE). While this ration is still able to serve the needs of U.S. warfighters in many environments, it has become clear that it does not provide the best solution for all situations. One initiative currently under development to nutritionally optimize dietary intakes during short duration high-intensity missions is the First Strike Ration (FSR). The FSR is being developed to provide a smaller, lighter ration with eat-on-the-move properties more conducive to the way that warfighters operate during particular dismounted operations.

The nutritionally enhanced and utensil-free design of the FSR allows for a high-performance, efficient alternative to the MRE that will optimize troops' cognitive and physical performance by enhancing nutritional status and metabolic fuel availability while minimizing ration weight, volume, food wastage and source material. The FSR contains an entire day's food in one package that is lower in volume (.14 cu ft compared to .25 cu ft) and mass (1.27 kg compared to 2.49 kg) than three MREs (U.S. military doctrine calls for providing three MREs per day during standard operations). The packaging improves a warfighter's ability to eat while conducting movements or driving, thus reducing the chance of skipping meals due to operational workload.

The FSR is considered to be a restricted-energy ration, but nearly doubles the standard 1,500 kcal (6,000 kJ) required of U.S. restricted-energy rations. Additionally, because of the high consumption rates (90% versus 60–70% for the MRE) the FSR actually delivers nearly the same amount of energy as three MREs, despite the single package and much lower volume and mass. The FSR is moderate-to-high in carbohydrate, moderate-to-low in fat, and high in protein. Recommendations provided by the Committee on Military Nutrition Research of Institute of Medicine call for the next generation of the FSR to contain 450 g of carbohydrate, 100–120 g of protein (1.25–1.5 g/kg for an 80 kg warfighter), and 58–67 g of fat. The FSR does not deliver the 4,600 ± 1,000 kcal/d (18,500 ± 4,200 kJ/d) needed to match energy expenditures estimated during field testing of the FSR with Light Infantry, Rangers, and Special Forces soldiers in Afghanistan. However, if the FSR is consumed for short periods and high consumption rates are maintained, it will supply enough energy to moderate weight loss and provide adequate macronutrients and micronutrients to sustain health and performance. While increasing the fat content would increase the energy density, greater priority was given to providing additional carbohydrate to optimize physical and cognitive performance, and protein to reduce muscle protein losses, maintain immune function, and adequately provide for serum proteins.

The FSR contains several items that are new to the U.S. military operational ration system. Some of these new items are unique to the FSR, while others are offered independently of the ration. One such item is the "ERGO (Energy Rich Glucose Optimized) Drink" a powdered 12% carbohydrate beverage that contains 55–160 mg sodium, 20–55 mg potassium, and delivers 170 kcal (700 kJ). Other unique items include "Zapplesauce" (an apple sauce containing maltodextrin), and "Stay Alert", a caffeinated gum containing 100 mg of caffeine per pellet. The "ERGO Drink" and "Zapplesauce" provide a carbohydrate source that helps to augment glycogen stores and maintain physical and cognitive performance, while the "Stay Alert" gum provides a rapidly absorbed source of caffeine which has been demonstrated to help offset sleep deprivation and sustain operational capabilities for prolonged periods of time. By delivering the caffeine in the form of a gum, instead of a liquid or a pill, the caffeine in "Stay Alert" is absorbed through the vascular tissues in the mouth speeding the entry of caffeine into the circulatory system.

Comparison of MRE (Meal Ready to Eat) with current and future FSR (First Strike Rations)

	Current 3 MRE	**Current** *First Strike Ration*	**Program Objective** *First Strike Ration*
Size Weight	0.25 cu ft 5.5 lb	0.14 cu ft 2.8 lb	0.12 cu ft 2.8 lb
Nutritional Content	Energy 3,900 kcal CHO: 489 g Protein: 132 g	Energy: 2,973 kcal CHO: 360 g Protein: 110 g	Energy: 2,800 kcal CHO: 450 g Protein: 100–120 g
		Calcium: 673 mg Potassium: 2,289 mg	Calcium: 750–850 mg Potassium: 3,300–4780 mg
Delivery Ease	60% consumed	90% consumed	95% consumed

While the FSR is clearly a step in the right direction, efforts are underway to improve the next generation of FSR as well as to provide new, innovative products to help sustain physical and cognitive performance during high-intensity and high-stress combat operations. Additional strategies currently being explored by the United States Army Research Institute of Environmental Medicine in partnership with the Department of Defense Combat Feeding include evaluating the advantages of a low glycemic-index energy gel for enhancing cognitive and physical performance, exploring the advantages of additional protein supplementation during underfeeding, determining the consequences of low zinc intake on protein synthesis, bone health and immune function, exploring the impact of prebiotics, probiotics, and zinc on diarrheal illness, and evaluating the potential of utilizing tyrosine to improve reasoning, memory, and visual vigilance. Together with the FSR these initiatives are expected to result in a more agile and deployable force that will be more resilient to the performance degradation often associated with repeated high-intensity, high-stress military operations. This in turn will result in a payoff for both warfighters and the U. S. Military.

Note: Opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the US Army.

About the speaker

Major Chad Koenig is the Detachment Commander and Adjutant at the US Army Research Institute of Environmental Medicine (USARIEM) at Natick, Massachusetts. He is a dietitian by training and worked in the Military Nutrition Division of USARIEM before taking on the role of Detachment Commander. Major Koenig has worked extensively on the First Strike Ration, including conducting a combat assessment with soldiers deployed in Afghanistan.

2.2 A development and procurement experience of Singapore Armed Forces field rations – Patsy Tan

Ms Patsy Tan, Defence Science and Technology Agency, Singapore

The aim of this presentation is to share our experience with:

(i) The development of Singapore Armed Forces (SAF) field rations; and
(ii) The procurement strategy applied to the field rations supply contract to achieve the best performance from suppliers.

Introduction
Field Rations constitute the primary source of energy and nutrition for soldiers in the field. Rations must satisfy the hunger of the soldiers as well boost their morale. Hence it is important that the Field Rations are nutritious and palatable to:
- Meet the nutritional needs of soldiers so that they can exhibit optimal physical and mental performance in the field;
- Meet the palate expectation of the soldiers so that they will eat the complete pack of FR to obtain the required nutrition.

Development of the Singapore Armed Forces (SAF) Field Rations
Canned Rations - Combat Rations
The provision of Field Rations started with the establishment of the SAF in the 1970s. At that time, the FR consisted of four components—plain biscuits as the main energy and carbohydrate source, canned meat to provide protein, chocolate bar and sweets as supplementary carbohydrate source, and lemonade powder mix.

The concern on the Canned Combat Rations was as follows:
- Sourced from commercial market
- Limited to bulky canned items
- Biscuits as the main carbohydrate source
- Low receptivity
- Lack of variety (only 3 menus – Muslim, Non Muslim and Vegetarian)
- Nutritional concern
- Heavy to carry
- Inconvenient to open canned food

Due to the above concerns, a collaborative team comprising of the SAF, Defence Science & Technology Agency (DSTA) and food industry was set up to revamp the then canned combat rations.

Development Considerations
During the development stage, the collaborative team considered the following:
(a) Nutritional Content
(b) Taste and Variety
(c) Special and Halal Requirements

(d) Weight and Volume
(e) Soldiers' Feedback

1st Generation Retort Pouched Field Rations
Since 1995, we have used the retort pouch technology to develop the 1st generation retort pouch FR. We envisage that the FR should provide the servicemen with cuisine that they could find during peacetime. This will serve as a morale booster while in the field. In collaboration with the food industry, retort pouches food that consists of plain rice, savoury rice, glutinous rice, meat dishes, vegetable dishes and dessert were developed. These are retort pouched food with Asian recipes.

During the development and introduction stages, questionnaires were designed to obtain feedback from the servicemen in terms of palatability, variety, ease of handling etc. In addition, periodic shelf life testing was also conducted to check on the sensory development (i.e. appearance, taste & texture), chemical changes (e.g. rancidity, starch retrogradation, pigmentation etc.) and microbial quality of the retort pouched food. The feedback data as well as the analysis data enable us to improve on the recipes, variety and weight of the overall Field Rations Pack.

Technical Constraints
The retort pouched field ration has been well received since implementation. However, over time, soldiers' complained that plain rice retort pouch was unpopular as it tends to cake upon storage, hence giving it a very hard texture. The rice tends to gelatinise when subjected to high pressure during the retorting process and starch crystallisation occurs upon storage. Hence it is unpalatable on its own (i.e. needs to be accompanied by a meat or vegetable dish). Some ingredients such as dried shrimp powder, eggs and leafy vegetable were also not suitable for the retorting process as they cannot withstand the high heat treatment or would react with other ingredients to form a gas.

Improved Retort Pouched Food
In 1998, we introduced the 3-in-1 retort pouched food whereby each retort pouch consists of staple, meat and vegetables. In addition, we increased the variety of the retort pouched meals to include pasta and noodles. We incorporated Asian cuisine taste to the pasta. We also improved the dessert. The introduction of the 3-in-1 retort pouched food and the improved menus were very well received by the servicemen. With the 3-in-1 pouched food, we also managed to reduce the retort pouch by 1 packet (i.e. reduce from 4 packets to 3 packets) and reduced the overall weight of the field ration pack by about 20% without compromising the nutritional characteristics.

Through product shelf-life evaluation and servicemen feedback, we have so far introduced over 100 retort pouched dishes and increased the variety of the menus to 5M, 5NM and 3 Vegetarian. We realised that menu fatigue may set in if we provide the same menu selection. Hence continuous effort has been put in to introduce new recipes and dishes every six months.

Procurement Strategy - Performance Based Contract (PBC)
Since the start of the commercialisation drive in the Ministry of Defence (MINDEF) in the 1980s, MINDEF has adopted some form of PBC for the maintenance, training and supply contracts.

Definition and Nature of PBC
PBC is defined as structuring all aspects of an acquisition around the purpose of the work to be performed. PBC emphasises objective, measurable performance requirements and quality standards in developing a service contract. The contract requirements in PBC should be defined in terms of outcomes and performance standards and instead of process and procedures. The emphasis is on procuring results and not compliance. The contracts focus on stating the problem and applicable constraints, and allowing the contractors to offer solutions. There are four key elements in PBC. These are Performance Requirements, Performance Standards, Quality Assurance Plan, and Incentives. These form the basis of a performance-based contract.

Benefit of PBC
PBC methodology has been proven to attain reduction in contract price and increased satisfaction with the contractor's work. Other benefits include:
a. Improved contract performance
b. Significant cost savings
c. Improved mission attainment and
d. Promotion of innovation.

Rationale for Selecting Field Rations Supply Contract to be PBC
With the increasing demand and expectation in the food quality and variety of FR from the servicemen, PBC was adopted with the aim to drive the outcome using an incentive-based approach.

Performance Standard & Matrix
With the review of requirements, identification and quantification of cost drivers, the following four categories of performance measures were drawn up:
(a) Basic requirement
(b) Innovation
(c) Menu Development, and
(d) Consumer Feedback

Results
As PBC is an incentive-based approach, a performance bonus (PB) pool is also available as an incentive for the supplier to achieve above the required level of performance (i.e. exceed standards). Since the establishment of the PBC for the field ration supply, the supplier has been more motivated and pro-active in the development and sourcing aspect. We envisage that such a procurement strategy will benefit the SAF for the supply of field rations in the long run.

The Way Ahead

We envisage that the retort pouch technology is still useful in the development of the SAF Field Rations. The challenges ahead will be to:

(a) Explore new packaging materials, which may be lighter but useful in meeting the food safety requirements and retention of good food quality

(b) Explore new technology to increase the variety of food components in the field pack

(c) Actively source more nutrient dense and palatable food components

(d) Develop international cuisine for variety, e.g. Italian, Mediterranean, Thai, Indonesian, Japanese and so on, and

(e) Conduct research on the rice characteristics and cooking technique to improve product quality and reduce the 'caking problem' in rice dishes.

About the speaker

Ms Patsy Tan is a nutritionist with the Defence Science and Technology Agency (DSTA) in Singapore. She obtained her BSc in Nutrition and Food Science from the University of Surrey in the UK. Ms Tan's present position is with the Defence Procurement Division of DSTA, where she is involved with Food Provisioning for the Singapore Armed Forces (SAF). This includes providing feeding/catering solutions for the operational requirements of the SAF, ensuring that the nutritional needs of SAF members are met, evaluation of field ration packs, and ensuring that suppliers meet the technical and quality requirements of SAF catering contracts and field ration contracts.

Session 3. Feeding the Future Warfighter: A Special Role for Carbohydrate?

3.1 Complex carbohydrates and gut health – David Topping

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Gut health is an area of science which focuses on the promotion of the normal function of the gastrointestinal tract and the prevention of serious diseases in the long term. Much of the research is directed towards understanding the relationships between diet and large bowel function as this viscus is becoming recognised as an important contributor to the digestive process as well as a site of serious disease.

Constipation is a major problem in developed countries, while infectious diarrhoeal diseases are a significant cause of infant death in developing ones. Inflammatory bowel disease (IBD) is a manifest problem in Australia and similar countries and is emerging in countries such as India and China with greater affluence. Irritable bowel syndrome (IBS) is a non-fatal condition which causes significant discomfort to a large proportion of the population. Large bowel cancer accounts for >4,300 deaths per annum in Australia alone.

The role of diet in the management and prevention of these conditions is accepted. Complex carbohydrates have an especially significant role to play in gut health. Non-starch polysaccharides (NSP, major components of dietary fibre) are non-digestible to human small intestine enzymes and are good faecal bulking agents. High fibre foods are a proven means of controlling constipation and a landmark study in a group of residents in an aged care facility showed the value of increased fibre consumption in this context. Before the intervention, these individuals had low fibre intakes and high rates of constipation. Increased fibre intake increased stool mass, restored regularity and lowered aperient use within a few weeks. This is an important issue for the general population of advanced and developing countries (outside Australia). Fibre intakes in this country are high, but low in the US and similar countries, suggesting that there is scope to improve bowel function through increased fibre consumption. This may also be relevant to the armed forces during deployment. CSIRO has collaborated with DSTO in analysing combat ration packs and shown that most are low in NSP. This could adversely affect capability during deployment.

While the importance of dietary fibre for regularity is recognised (and justified), its role in chronic disease prevention is less clear. Indeed, the premise on which that proposed role rests is open to question. Interest in the health benefits of dietary fibre came substantially from observational studies by British medical officers working in East Africa. They noted that the native Africans consumed a diet high in unrefined cereals (principally maize corn) compared with the Europeans who ate highly refined foods. The former foods would be expected to be generally higher in fibre than refined ones and it was assumed that the African diet was a fibre-rich one. A recent comparison using modern analytical procedures has shown this not to be the case and the African diet was lower in fibre than that of the Europeans. The key difference between the diets was that the Africans ate much more starch. Moreover, the Africans' culinary practices differed from European practice with food being cooked and then eaten cold over a few days. This would be expected to lead to retrogradation, whereby the starch aggregates leading to the formation of resistant starch (RS). RS is that fraction of starch which resists small human small intestinal digestive enzymes and escapes into the large bowel. It has been confirmed that the African foods were high in RS and that this could influence bowel health favourably.

Unlike NSP (which act largely through faecal bulking), RS functions through its metabolism by the large bowel microflora. The human large bowel contains a large and taxonomically diverse bacterial population which ferments undigested dietary components and endogenous secretions. The principal products of this fermentation are short chain fatty acids (SCFA) which are produced largely from carbohydrate. The main acids are acetate, propionate and butyrate. They are absorbed and metabolised by the viscera and <10% appear in faeces. In addition, SCFA have a number of general and specific actions which promote bowel function. These general effects include suppressing the overgrowth of potentially pathogenic bacteria.

Of the major acids, butyrate has a number of specific effects which are attracting significant attention. It is a major metabolic fuel for colon epithelial cells and promotes a normal phenotype in them. Butyrate promotes colonic blood flow and stimulates the uptake of fluid and electrolytes (including Na^+, K^+ and Ca^{2+}). Studies in individuals with cholera have shown a substantial reduction in water loss and accelerated recovery with rehydration with a solution containing RS. This role of RS in water salvage has potential military applications, given the frequency of diarrhoea on deployment. CSIRO has developed a delivery vehicle for SCFA in which the acids are esterified to starch. Experimental studies have confirmed that these acylated starches deliver specific SCFA to the large bowel, and human studies are planned to determine their effectiveness in such applications. Increasing the RS content of military rations may be particularly useful as the collaborative project with DSTO showed that ration packs were low in RS (as well as NSP).

RS is a measure of the extent of small intestinal digestion. However, the rate is also important as the rapid digestion and absorption of starch floods the circulation with glucose and increases the demand for insulin to normalise blood glucose concentrations. This is important in view of the increase in diabetes in both affluent and developing countries. Glycaemic index (GI) is a measure of the rate of digestion of and absorption of carbohydrate, and CSIRO is developing a range of cereals with low GI (and high RS). These include a new barley cultivar which has undergone extensive testing in animals and humans and has been shown to raise SCFA as well as have lower GI than standard barley. This novel barley (BARLEYmax™) has been incorporated into processed foods and preliminary data suggest good consumer acceptance. A new wheat cultivar with similar properties is also at an early stage of development. These cereals may have potential applications in foods for military personnel.

About the speaker

Dr David Topping is Chief Research Scientist at CSIRO Human Nutrition. His principal research focus is dietary carbohydrates (fibre, resistant starch and oligosaccharides), probiotics, dietary fats and gut health. Dr Topping is a Fellow of the Academy of Technological Sciences and Engineering, a Fellow of the Nutrition Society Australia (NSA), and is a past President of NSA. He is interested in the relationships between diet and prevention of the chronic diseases that contribute substantially to the national health bill.

3.2 Structuring in plant-based foods: from polysaccharides and cell walls to nutritional impact – Mike Gidley

Professor Mike Gidley, Director, Centre for Nutrition and Food Sciences, University of Queensland

Introduction

The advent of agriculture around 10,000 years ago had profound consequences on the ability of the human species to thrive in the terrestrial environment as it led to the availability of plentiful food energy, and a reduction in the time investment required to procure food. However, the major change in food intake that occurred as a result of the transition from a hunter-gatherer diet to a crop- and farm animal-based diet may have had some adverse long-term consequences (Cordain *et al*, 2005).

The rapid development of industrialised food during the 20th century has resulted in a further major modification to the diets of many people. In particular, the efficiency demands of high throughput industrial processes have tended to favour foods that are fabricated from 'simple' ingredients, e.g. starch, oils, sugars and proteins that have highly predictable properties and can be specified tightly. In contrast to the tissue-based foods characteristic of the pre-agricultural era, many 'modern' foods are (a) rapidly broken down during the digestive process and (b) contain a limited range of components due to the use of refined ingredients.

The food industry has responded to consumer demands for 'healthier' foods by inventing the category of 'functional' foods, which typically contain nutrients added to otherwise unchanged industrialised food bases. Whilst this approach may be appropriate in some cases where there are identified nutrient deficiencies or measurable biomarker outcomes, it does not address the issues of molecular complexity and prolonged digestive release. In some cases, e.g. effects of fortification with vitamins A, C, E or beta carotene on gastro-intestinal cancer, no evidence for a protective effect was found despite epidemiological evidence that a diet rich in foods containing these nutrients affords some protection (Bjelakovic *et al*, 2004).

Cordain *et al* (2005) argue that the human digestive tract evolved before the advent of agriculture and is therefore best suited to a variety of animal- and plant-based foods with limited processing prior to consumption. Whilst it is too simplistic to assume that a hunter-gatherer diet is optimal for humans, it is striking that the recent evidence from large-scale epidemiology suggests that a diet rich in a variety of relatively unrefined plant- and animal-based foods (here termed *naturally-functional foods*) may be optimal for both short-term mental and physical performance and long-term health outcomes.

The failure to reproduce 'expected' (from epidemiology of whole foods) benefits via intervention with vitamins is probably due to (a) underestimation of the role of as yet unrecognised health-benefiting molecules and/or (b) the importance of the native tissue structure of plants and animals in providing the matrix from which molecules are released during digestive processing. The science is now in place to tackle these possible causes, utilising post-genomic biology of food raw materials to better define molecular composition ("metabolomics"), and exploiting modern spectroscopic and microscopic methods to define the effect of food structure on molecular release.

Molecular complexity in "naturally functional foods"

In order to provide compelling evidence for cause-and-effect relationships between food composition and health outcomes, much more knowledge is needed on the molecular mechanisms of action, not just of individual molecules in isolation but also of complex mixtures delivered from food matrices. A 'holy grail' vision would be to reduce the response to food intake of specific receptors/cells/tissues/organs in the human body into a manageable number of *in vitro* assays. This is not an impossible goal, but depends on the level of validation that can be achieved for specific *in vitro* assays, and the consequent level of predictability when results are taken forward to clinical and other trials.

This proposition has some parallels to the advances achieved over the last two decades in the *in vitro* assessment of toxicology, where there has been a concerted drive to replace animal models. There is general agreement that a satisfactory assessment of risk can now be obtained from such cellular and molecular assay systems.

Can a similar level of credibility be obtained for *in vitro* assessment of nutritional effects? One point of distinction might be the high level of interaction between cellular processes that are affected by nutritional factors. A second point could be the molecular complexity inherent in natural foods. However, the opportunities of (a) carrying out large numbers of experiments and (b) identifying multiple effects of (mixtures of) food components in cellular and molecular assay formats make the approach a highly attractive one.

Food structure effects in "naturally functional foods"

The native tissue structure of plants and animals can provide a barrier to free passage of molecules during digestion (nutrients out, enzymes in) and result in direct physical effects contributing to e.g. satiety. Recent interest in the rate and extent of carbohydrate delivery from foods has re-stimulated awareness that food structure as well as macronutrient composition is a determinant of both short-term performance and long-term health consequences of carbohydrate-rich foods.

The emphasis in current dietary advice on vegetables/pulses and whole grains as sources of carbohydrate reflects this controlled delivery of energy in large part mediated by a plant cell wall structure (Fig 1) that is sufficiently condensed to present a significant barrier to digestive amylases and which is not degraded significantly until it is subjected to microbial fermentation in the colon. Whilst the benefits of 'dietary fibre' fermentation are well known (Topping and Clifton, 2001), the consequences of delayed release of nutrients within cellular structures is not yet widely appreciated. As an example, the micrographs in Fig 2 illustrate the very limited changes that occur to cell walls of raw carrots even after extended small intestine transit times. The only significant effect is a swelling of cell walls.

Due to this structural integrity, hydrophobic nutrients (e.g. beta carotene) are not able to be released as they cannot pass across the hydrophilic cell wall. The consequences of effectively delivering a range of plant nutrients to the colon is not yet understood, but is likely to be significant for whole grains, fruits and vegetables.

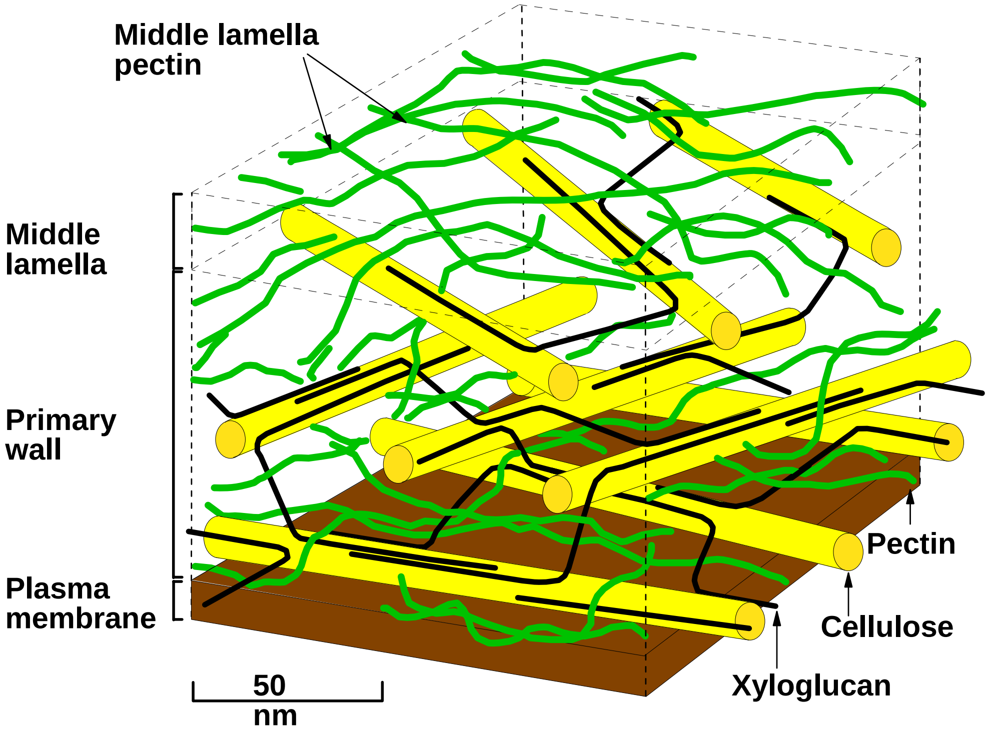

Fig 1. Schematic representation of a typical fruit or vegetable cell wall.

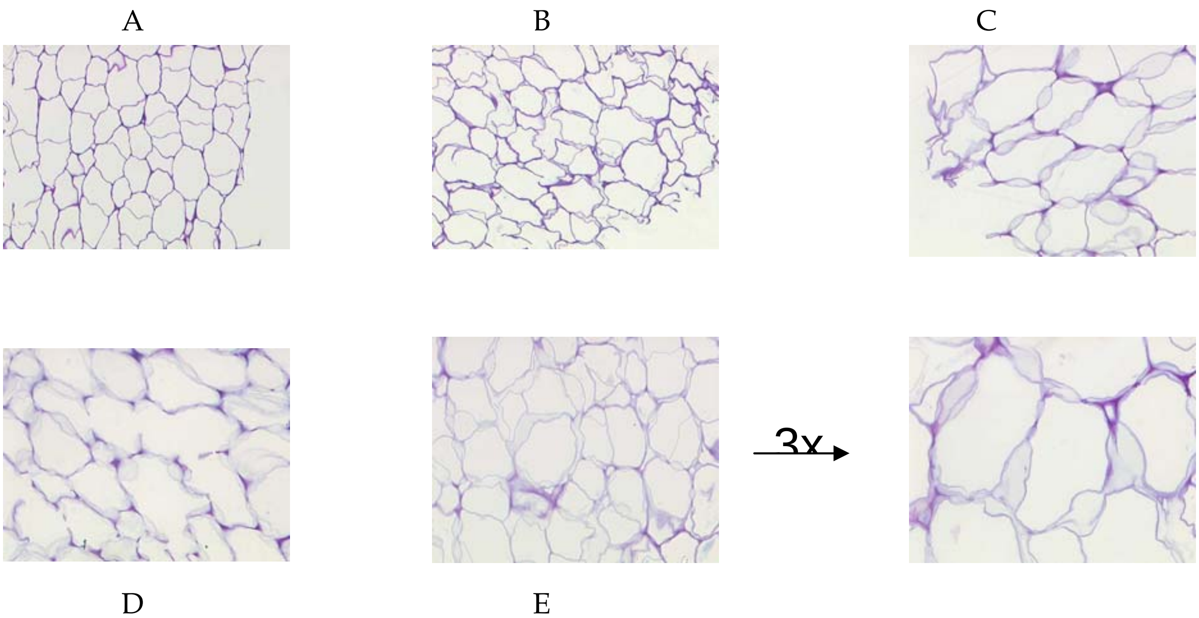

Figure 2: Raw carrot tissue structures at the end of the human small intestine after passage times of A less than 2 hours, B 2-4 hours, C 4-6 hours, D 6-8 hours, E 8-10 hours. The width of micrographs A – E is 0.5 - 1 mm. Adapted from Tydeman (2004)

Current projects at the University of Queensland are targeting both molecular complexity and food structure effects in plant-based foods with an emphasis on identifying biological, chemical and materials mechanisms that contribute to the nutritional value of naturally-functional foods. Modern methods in cell and molecular biology, molecular characterisation, spectroscopy and microscopy and a range of collaborations across scientific disciplines are being explored in order to address the knowledge gap between epidemiological evidence and causative mechanisms.

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About the speaker

Professor Gidley is Director of the Centre for Nutrition and Food Sciences at the University of Queensland, a joint initiative with the Queensland Department of Primary Industries and Fisheries. He was trained in chemistry and spent 22 years with Unilever Research in the UK before moving to Brisbane in 2003.

3.3 Colonic DNA and mucus barrier integrity: the role of dietary resistant starch –Michael Conlon

Michael Conlon[1,2], Shusuke Toden[1,4], Anthony Bird[1,2], David Topping[1,2], Guy Abell[2], Sandi McOrist[2]

Food Futures National Research Flagship[1] and Preventative Health National Research Flagship[2], CSIRO Human Nutrition, Adelaide, South Australia
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Understanding the role that dietary resistant starch (RS) or other components may play in boosting the integrity of colonic defences may assist in formulating diets that will help protect defence personnel against not only immediate health threats such as gastrointestinal infections, but also against long-term health threats such as increased risk of disease through the use of extreme diets (e.g. high protein).

Interest in dietary protein has grown considerably due to the popularity of high-protein diets for weight loss and body building, and also because recent human epidemiological and experimental studies indicate that red meat consumption is a risk factor for the development of colorectal cancer. Epidemiological evidence also suggests that dietary protein in general may represent a risk factor for colorectal cancer.

The mechanisms by which high-protein diets increase risk of bowel diseases are not entirely clear. It is known that ileal digestibility of protein is less than 100%, and protein reaching the large bowel is referred to as resistant protein (RP). RP, like its counterpart resistant starch (RS), is a fermentable substrate. Although fermentation of both RS and RP results in production of short chain fatty acids (SCFA)—especially butyrate—that are thought to be important for maintenance of bowel health, fermentation of protein may also result in the formation of toxic substances. Toxic agents produced from digestion and fermentation of dietary proteins include phenols and cresols, heterocyclic amines and nitrosamines.

We present recent experimental studies conducted in the Food Futures National Research Flagship that have demonstrated increased levels of DNA damage—a prerequisite of cancer initiation—in the colons of rats in response to high levels of dietary protein such as casein and red meat. Increasing dietary casein from 15% to 25% in the absence of added dietary RS (substituted for digestible starch; 5% wheat bran was included) resulted in a doubling of the number of DNA strand breaks in colonocytes extracted from the colon. Inclusion of red meat at 25% of the diet caused even greater damage. Inclusion of RS in the diet as high amylose maize starch at high levels (48%) abolished the protein-induced DNA damage.

However, not all sources of protein exert the same effect. Further studies demonstrated that dietary whey protein is not as damaging as casein and that soy is even more damaging than casein. However, irrespective of the source of protein, the inclusion of RS in the diet has been demonstrated to protect against, or substantially lower the level of protein-induced colonic DNA damage. High levels of dietary casein and red meat also resulted in thinning of the colonic mucus barrier, which was reversed by the inclusion of dietary RS.

The mechanism by which RS exerts its protective effects may be related to the increased levels of SCFA, especially butyrate, generated by fermentation of the starch reaching the large bowel. Butyrate is a primary energy source for the cells lining the colon and protects against aberrant cell morphology by inducing apoptosis. We recently carried out a study in which rats were fed 25% dietary protein as casein together with supplementation with 0%, 10%, 20%, 30% or 40% high amylose maize starch. The RS dose-dependently reduced protein-induced DNA damage in colonocytes with a noticeable effect when dietary levels were as little as 10%. The dose-dependent protection afforded by RS was strongly correlated with changes in SCFA levels, but most strongly with butyrate.

Studies are being carried out by us within the Preventative Health National Research Flagship to gain a better understanding of whether there is a significant variation in the levels of butyrate and other SCFA in the large bowel in humans.

In one study, faeces were collected weekly from eight healthy individuals on their normal diet for a period of 12 weeks. It was found that although there was significant variation in levels within individuals over time, baseline levels remained similar relative to those of others and appeared to show that some people could be classed as having consistently low or high faecal butyrate levels.

As SCFA production by fermentation is via the agency of bacteria, we are examining whether individuals have unique combinations of bacteria that may define their capacity to respond to substrates and generate butyrate. DNA was extracted from faeces of individuals in the human study and molecular microbiological methods such as polymerase chain reaction (PCR) to amplify 16s ribosomal DNA sequences followed by denaturing gradient gel electrophoresis (DGGE) were used to obtain a general profile of dominant bacterial groups. Individuals were shown to have combinations of bacteria that were unique and stable. Further investigations are underway to clearly correlate levels of butyrate in faeces with numbers of butyrate-producing bacteria. We have also carried out in vitro fermentations of faeces obtained from these individuals and have found that there are differences in individual capacity to generate SCFA from a range of substrates.

A subsequent study involving 46 individuals examined the effects of diets high in fibre or high in fibre plus RS on faecal SCFA levels and the gut microflora. It was found that during the four-week periods over which the RS plus fibre was consumed that SCFA levels in faeces were significantly increased compared with the normal and the fibre diets and that some individuals had consistently low or high baseline levels of SCFA, including butyrate, throughout the study, confirming our previous findings. Individuals were again found to have distinct combinations of bacteria. Sequencing of bands on DGGE gels used to separate amplified 16s rDNA products revealed that dietary RS specifically up-regulated a number of species of bacteria. Many of these are related to butyrate-producers and some do not appear to have been previously recognised as playing an important role in fermentation in humans.

In all we have presented data suggesting that high protein diets may be harmful to the health of the large bowel, but that addition to the diet of foods high in RS may protect against this damage.

We have confirmed that humans have unique combinations of bacteria in their large bowel and that, probably as a consequence, the ability to ferment RS and other substrates reaching the colon also differ.

Further studies are required to determine whether some individuals, such as those who may have a reduced capacity to generate butyrate, are at risk of disease as a result of their gut microflora profile, and also whether the risk can be managed through tailoring diets to individual needs.

About the speaker

Dr Michael Conlon is a research scientist at CSIRO Human Nutrition in Adelaide. He is currently researching the role of diet on large bowel health. Dr Conlon is a project manager in the Preventative Health Flagship, examining changes in bacteria and short-chain fatty acids in humans in response to resistant starch and fibre. His training was in biochemisty at Flinders University, where he studies the role of diet on protein metabolism and growth factors in animal growth.

Session 4. Feeding the Future Warfighter: Nutritional Trends and Health Implications

4.1 National dietary trends, Nutrient Reference Values, and their relevance to Defence Nutrition – Katrine Baghurst

Dr Katrine Baghurst, Food Standards Australia New Zealand; Chair NHMRC Nutrient Reference Values Committee

Australia has not had a National Nutrition Survey since 1995/6 but a comparison of data collected in adults in 1985 with selected data from that survey showed markedly increasing intakes of carbohydrates (in men up from 38 to 43% energy) for both starches and sugars, and decreasing intakes of fats (in men down from 36 to 33% energy) with protein intakes staying at similar levels. Intakes of cholesterol and for men, alcohol, fell markedly over this period, while dietary fibre intakes increased. Overall, energy intakes increased by about 350 kJ/day, and this was accompanied by increases in average body weight and BMI in both men and women.

Table 1. Changes in nutrient intakes in Australia in Men 25–64yrs, capital cities

National surveys	1983	1995
Energy kJ	10,824	11,195
Protein g	110	112
Carbohydrate g	260	304
% energy	38%	43%
Starch g	145	173
Sugars g	115	129
Fat g	106	100
% energy	36%	33%
Cholesterol mg	412	309
Alcohol g	24	18
Dietary fibre g	24	27

Intakes of cereal foods increased markedly from 1983 to 1995 and may, in conjunction with increased fortification, be responsible for the increases seen in intakes of B vitamins, iron, calcium and magnesium, as some of the traditional sources of these nutrients (e.g. dairy for calcium and meat for iron) did not change much or actually decreased over the period (e.g. meats for both genders and milk in women).

Vitamin C intakes for men and vitamin A intakes for women in particular, also fell markedly over the period, reflecting a major drop in fruit consumption and a lesser fall in vegetable consumption.

In assessing the importance of changes in dietary intake, nutritionists use reference nutrient intake standards. These standards have recently been reviewed jointly by

Australia and New Zealand under the auspices of the National Health and Medical Research Council (NHMRC). The new standards are called the Nutrient Reference Values, and for the first time contain recommendations for chronic disease prevention as well as prevention of deficiency states.

For each nutrient, a set of values have been established, including an Estimated Average Requirement (EAR); a Recommended Dietary Intake (RDI) – a value to cover the needs of most people within a particular age/gender group; and an Upper Level – a level of daily intake level above which adverse effects may be experienced.

Definitions form Australian and New Zealand Nutrient Reference Values

EAR Estimated Average Requirement
A daily nutrient level estimated to meet the requirements of half the healthy individuals in a particular life stage and gender group.

RDI Recommended Dietary Intake
The average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97–98 per cent) healthy individuals in a particular life stage and gender group

(RDI = EAR + 2CV)

AI Adequate Intake (used when RDI cannot be determined)
The average daily nutrient intake level based on observed or experimentally-determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate.

Nutrients for which values were set included all those from the 1991 revision plus:

Fat (for infants only)
n-6 fatty acids (linoleic)
n-3 fatty acids (α-linolenic)
LC n-3 fatty acids (omega-3 fats, DHA, DPA, EPA)
Carbohydrate (for infants only)
Dietary fibre
Water
Choline
Copper
Fluoride
Chromium
Manganese
Vitamin D
Vitamin K
Biotin
Molybdenum

The chronic disease recommendations include Acceptable Macronutrient Distribution Ranges which identify the range of intake in terms of percentage energy for fat (20–35%), protein (15–25%) and carbohydrates (45–65%) that are consistent with good health, and Suggested Dietary Targets for nutrients such as selected antioxidants, folate, dietary fibre, long-chain omega-3, generally set at the 90^{th} percentile of population intake.

Dietary modelling confirmed that the EARs can be achieved at energy intakes as low as 5,000 kJ by consumption of diets of varying composition, but which generally contain plenty of wholegrain cereals, fruits and vegetables as well as lean red meat or alternatives and low fat dairy products. However, care needs to be taken to ensure adequate intake of essential fatty acids and vitamin E by inclusion of small amounts of nuts, seeds, vegetable oils, and fish oils or fatty fish.

The analysis also emphasised the increased dietary flexibility that is possible with increasing daily activity such as occurs in occupational settings, e.g. the armed forces.

For some nutrients that are borderline in the diet or the food supply, such as folate, iodine and LC n-3 fats, food fortification may be necessary to ensure adequate population intakes in the long term.

About the speaker

Dr Baghurst has worked in nutrition research for more than 30 years, most of that time being with CSIRO, from which she retired in 2004. Her undergraduate training was at St Andrews University, Scotland, followed by a PhD at the Australian National University. Dr Baghurst was then a staff member at London University for three years. Her research interests include the psychosocial factors influencing food choice; methodologies for assessing dietary intake, and nutritional epidemiology. She has been a member of the NHMRC's Health Advisory Committee for the past six years and has co-chaired the revision of the Australian Dietary Guidelines for Adults and the Dietary Guidelines for Children and Adolescents, and chaired the revision of the Australian and New Zealand Nutrient Reference Values. Dr Baghurst is on the Technical Advisory Committee for the planned National Survey of Diet and Physical Activity in Children. She was appointed to the Board of Food Standards Australia and New Zealand in 2005.

4.2 Food and its potential role in the prevention of chronic disease – Lynne Cobiac

Dr Lynne Cobiac, Business Manager and Research Leader, P-Health, CSIRO National Flagships Research Program

As with many nations, Australia's population is aging such that the median age has more than doubled over the last century. The current population of Australia is estimated to be 20.642 million, with an overall total population increase of one person every 2 minutes and 12 seconds! The population in 2051 is expected to be 22.4 to 33.4 million, depending on a range of factors (such as fertility, migration, and future mortality rates).

Our population is also aging—the baby boomer cohort is getting older, and with better conditions we are achieving an enviable life expectancy for those born today. In the 1880s life expectancy was 47 years for men and 51 years for women; now it is 78 years and 83 years for men and women respectively. By 2051 it is estimated that these figures will increase to 85 and 95 years. At around 2020 it is anticipated that there will be more elderly people than children. By 2051 approximately 1 in 4 Australians (around 4 million) will be aged 65 years and over – a big shift from the beginning of this century when around 4% of the population was 65 years or more. Consequently, we have experienced an increase in the median age from 22.4 years in the early 1900s to the current 37 years, and likely to reach an estimated 44–47 years by 2050.

Given these demographic changes, it is not inconceivable that the military will also face an aging workforce. Competition, productivity and innovation all contribute to a vibrant workforce and economy, but the issue is how to achieve this with the current population shifts. With the aging population, it is predicted that the participation rate in the workforce will reduce from 63.5% in 2003 to approximately 56% by 2044-45. Australia needs to ensure there is increased participation in the society or the workforce, that we have more healthy years with minimal disability, and enhanced independence and autonomy. As the occurrence of chronic diseases with resultant morbidity and disability tends to increase with advancing age, it will be critical to develop preventative strategies to reduce morbidity. Whilst much can be done in a public health approach to promulgate the uptake of health promoting behaviours in society, there is still much scientific knowledge to be gained through research to further understand how to prevent or delay chronic diseases that are significant economic and health burdens in Australia. Such diseases include colorectal cancer, neurodegenerative diseases such as Alzheimer's disease, cardiovascular and inflammatory diseases, and obesity.

Australia now has 20–25% of children (around 1.5 million!) and 60% of adult males and 42% of adult women or as many as 9 million Australians aged over 18 years who are either overweight or obese. The overall economic costs of obesity are estimated to be as much as $1.3 billion pa. Being overweight or obese increases the risk of a range of chronic diseases such as cardiovascular disease (CVD) and diabetes. Foods, overall eating patterns and nutrient intakes are key factors, along with activity patterns, socioeconomic environments, genetic predisposition and individual behaviours, that need to be considered in tackling the obesity problem.

CVD already contributes a major disease burden to Australia, costing $5.5 billion pa, accounting for 36% of all deaths in Australia, and is one of the leading causes of disability. The prevalence of CVD is likely to increase due to the obesity situation but also increases with age. The role of nutrition in primary and secondary prevention of CVD has been established over the years, e.g. reduction in risk with increased consumption of polyunsaturated fats, including n-3 fatty acids.

Alzheimer's disease (AD) is the major contributor to the burden of disease in older ages and costs of care are high, estimated at $5.6 billion in 2002. Delaying the onset of AD by as little as five months to five years has been estimated to reduce the number of new cases by 5–50%[7]. There is emerging evidence for neuroprotective factors or nutrient in foods (e.g. antioxidants, folate) but there is very little definitive evidence as yet. Foods that can delay cognitive decline and maintain high cognitive performance need to be further researched.

Australia and New Zealand have one of the highest incidence rates of colorectal cancer in the world. Diet and other environmental factors appear to have a significant potential to reduce the risk of contracting colorectal cancer. Possible protective food-related strategies include increasing the consumption of fruits and vegetables, resistant starch and perhaps dietary fibre. The role that the gut microflora plays is still to be determined.

Thus, protective or health-promoting foods are important preventative strategies for many diseases, along with the development and societal uptake of methods to detect diseases earlier and more efficiently, determining approaches to encourage consumers to adopt more risk-reducing behaviours, and facilitating the improved management of health data to achieve a positive effect on clinical outcomes for patients.

To really understand how foods may be protective, we need a more thorough understanding of how our gastrointestinal system metabolises nutrients and other food components and how the gut acts as our bodies' first line of defence against dietary and many other environmental insults. Scientific knowledge on the role of diet in preventing diseases is being advanced significantly at the molecular level through the study of the impact of nutrients and other food components on gene expression (nutrigenomics), gut microflora and other dietary interactions. This raises the possibility of developing tailored protective foods based on an individual's genetic background. It also provides a potential mechanism to explain how diet can influence our health outcomes in adulthood during critical times prior to birth, during key development stages, and even over generations.

Working with a range of partners, CSIRO has assembled large multidisciplinary teams to develop preventative strategies and food products. Much of this work is being carried out in the National Research Flagships Program through the Preventative Health and Food Futures Flagships. The Preventative Health Flagship, with University of South Australia, is about to commence a National Children's Nutrition and Physical Activity Survey, funded by the Department of Health and Ageing, the Australian Food and Grocery Council and the Department of Agriculture, Fisheries and Forestry. This is the first national survey since 1995 and will provide us with a snapshot of current eating, nutrient intake, and physical activity patterns, along with measure of the weight status of children aged 2–16 years. This will help to inform future research directions and provide an evidence base for future policy decisions to help tackle chronic diseases that may be preventable by early interventions such as increasing the consumption of protective foods.

About the speaker

Dr Lynne Cobiac is a Research Leader for Protective Foods and the Business Manager for the Preventative Health National Research Flagship in CSIRO. Dr Cobiac originally trained as a dietitian/nutritionist at Flinders University before completing a PhD and Advanced MBA at the University of Adelaide. She has conducted research in diverse areas, ranging from Consumer Science (with Dr Katrine Baghurst) to nutritional biochemisty and gut health with Dr David Topping and others.

Session 5. Feeding the Future Warfighter: Novel Food Technologies

5.1 Functional foods through innovative technologies: sustainment on the battlefield – Theresa Hay

Theresa K C Hay, Tracey McLaughlin, Lan Bui, Paul Capela and Ross Coad.
Defence Nutrition, DSTO-Scottsdale, Human Protection and Performance Division.

The intention of this paper is to initiate discussion about how DSTO can best interact with the food industry and research institutes to meet their Defence clients' current and future needs.

When designing combat ration packs (CRP), and the individual foods used in the packs, DSTO-Scottsdale must keep our unique consumer in mind. The battlefield consumer is generally male, 18–26 years of age, physically active, time poor, operates under a variety of stresses, and is at risk of injury, illness and disease.

At present, the Australian Defence Organisation (ADO) procures three types of CRP: Combat Ration One Man (CR1M), Patrol Ration One Man (PR1M), and the Combat Ration Five Man (CR5M) for feeding small groups. As the ADO cannot accurately predict how many CRP will be needed in any given year, there is a considerable stockpile maintained. The need for a stockpile adds to the difficulty in designing foods for the CRP, as a two year shelf-life is required of each product – quite a challenge for the Defence food technologist. In addition to the nutritional and sensory attributes of CRP foods, packaging technologies, and restrictions on the mass and volume of the packs must also be considered.

The research program at DSTO-Scottsdale addresses our military client's requests. A wide ranging list of client request codes (CRC) is prioritised by the client. DSTO than allocates funding to support the high priority research areas. Currently, DSTO-Scottsdale's work priorities in the food science and technology program are to:

- design a light-weight ration pack for high intensity short duration operations
- investigate the technique of microencapsulation to allow the development of stable functional components for use in CRP
- provide S&T support and advice on issues related to food science & technology to the Defence Catering Policy Cell (DCPC).

Support to DCPC consists of evaluating the shelf-life of new and current CRP items by accelerated shelf-life testing and sensory evaluation, liaising with the food industry to improve existing CRP items and to develop new items, and giving advice on other technical issues such as packaging.

Microencapsulation is a technique used to provide food ingredients that are protected, stable, and which can be released over a predetermined period, i.e. undergo 'controlled release'. The process involves formation of a wall or shell around the core or active material, keeping the core material inside the shell, so that it does not escape. The shell also prevents the ingress of undesirable elements that may harm the core, such as light, oxygen and other reactive food components. Microencapsulation offers Defence a means to protect sensitive food components, and reduce the extent of nutritional losses during storage and while in use in harsh environments. It could also be used to encapsulate interesting new functional food components, selected to impart beneficial health effects, such as a boost in immune function. Superior vitamin fortification systems could also be investigated using microencapsulation.

Many different microencapsulation techniques are under investigation (see Table 1). The specific technique chosen depends on the active and shell being used, and the end use (food matrix) of the encapsulated ingredient. Early DSTO investigations in encapsulation were done in collaboration with the University of Queensland. More recently, in conjunction with Victoria University DSTO has investigated a simple extrusion technique to encapsulate probiotic bacteria for use in a freeze-dried yoghurt (Capela et al. 2004; Capela et al. 2006). In collaborative work with RMIT, DSTO is investigating a spray-drying technique to encapsulate vitamins such as ascorbic acid (Wijaya et al. 2006a; Wijaya et al. 2006b). In addition, Scottsdale has recently invested in a small fluidised-bed pilot plant to progress DSTO's microencapsulation research.

Table 1. Microencapsulation techniques: physical, chemical and physiochemical*

Physical Techniques	*Chemical Techniques*	*Physiochemical Techniques*
Spray drying#	Molecular inclusion	Coacervation
Spray chilling	Interfacial polymerisation	Organic phase separation
Spray cooling		Liposome entrapment
Fluidised bed coating#		
Freeze drying#		
Extrusion#		
Multiorifice centrifugal extrusion		
Cocrystallisation		

**(adapted from Shahidi and Han (1993)*
 # DSTO-Scottsdale is investigating this technique

A light-weight CRP for high intensity short duration operations is being designed in conjunction with Third Battalion Royal Australian Regiment Parachute (3RAR Para). Four focus groups were conducted with 3RAR Para, during 05/06, to discuss their unique operational scenarios, product concepts for field environments, and acceptability and serviceability of specific food types. Products considered include beef jerky, sports gels, long-life peanuts, a variety of protein and energy bars, freeze-dried fruit and yoghurt (developed at Scottsdale), and tuna and salmon in flexible packaging. A 72-hr prototype pack is being developed by DSTO-Scottsdale for evaluation with 3RAR Para while on field exercise in 06/07. To meet the needs of 3RAR Para, the pack will comprise largely eat-on-the-move components, with one meal per day that requires preparation.

Potential development areas for DSTO-Scottsdale in the food science and technology program include building research partnerships to investigate:

- consumer science aspects of CRP design – the psychological aspects of appetite and consumption in the field
- access to process engineering technology to enable a smooth transition of our research outcomes to the food industry
- other encapsulation technologies in addition to spray and freeze drying, fluidised bed, and simple extrusion
- access to food grade pilot plant facilities.

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About the speaker

Dr Theresa Hay obtained her Bachelor of Applied Science and Masters degrees from Victoria University, and completed her PhD through the University of Queensland while working at Food Science Australia (FS), Cannon Hill (Brisbane). Her PhD research was on meat flavour and dietary interactions. Before her move to Brisbane, Dr Hay was based at FSA – Werribee, where she conducted research on fats and oils. Dr Hay now manages a task in food science & technology at DSTO-Scottsdale, where she has been based for four years.

5.2 Better, fresher and safer foods through novel food processing technologies – Lloyd Simons

Dr Cornelis (Kees) Versteeg, Director Innovative Foods Centre, Food Science Australia, Werribee, Vic.
Mr Lloyd Simons, Manager of Business Opportunities, Innovative Foods Centre, Food Science Australia, Werribee, Vic.

(Presentation prepared by Kees Versteeg, presented by Lloyd Simons)

Emerging or Novel Food Processing Technologies are collective terms for a whole range of physical non thermal or non direct thermal microbial inactivation technologies. The primary objective of these technologies is to provide *better quality* (taste, texture, nutrition) food products which are safe, compared to more traditional preservation technologies such as heating, freezing, drying or added chemicals, whilst having an adequate shelf-life.

High pressure processing, high-powered ultrasound and pulsed electric field are three of the key emerging processing technologies under investigation at the Innovative Food Centre. Close examination of these technologies has shown that at least some heat is generated during their application. When this heat production is significant, benefits from the technology may flow from synergistic effects of temperature on microbial inactivation, and/or rapid heating, and sometimes rapid cooling. The absence of (or considerably reduced) thermal load results in improved sensory quality products, often close to fresh products (e.g. fruits).

High Pressure Processing (HPP)

When applied at low or ambient temperature, HPP is very effective in inactivation of microbial cells, including *Salmonella*, Coliforms and *Listeria* spp. However, HPP alone does not inactive bacterial spores. Therefore it is most suitable for acid (lower than pH 4.5) products and otherwise already preserved products (e.g. fermented or cured meats). Foods may be treated after packaging in flexible containers, thus reducing the risk of post-process contamination. Because pressure transmission is instantaneous, regardless of size of solids or container, process times are short, typically less than five minutes at 600 MPa (87,000 PSI). High pressure pasteurisation is acknowledged to achieve better sensory and nutritional retention than heat pasteurisation. Commercial adoption of HPP has been escalating, from virtually a zero base in 1995, to about 80 installations in 50 companies worldwide. These companies produced about $500 million worth of more 20 types of products in 2005.

High pressure does not fully inactivate enzymes; therefore to prevent enzymatic oxidation high barrier packaging and refrigeration or other hurdles are normally used for distribution. Shelf-life ranges from four weeks for guacamole to up to about three months for fruit products and pre-cooked meats. Often the shelf-life is limited by enzymatic reactions, slowly reducing the sensory qualities.

High Pressure Sterilisation combines mild initial preheating, with high pressure. For each 100 MPa increase in pressure, adiabatic heating of about 3°C occurs at ambient temperature and about 4.5°C at 90°C. The temperature rise is instantaneous with the pressure rise and the temperature drops back immediately to its starting temperature on pressure release. In contrast to normal heat penetration, the centre of the pack typically reaches the same temperature as the outside, and holds it better. Benefits arise from short controlled heating and rapid cooling cycles, minimising thermal product damage. For solid products or large packs, this is particularly difficult to achieve with any other technology. Potential synergy with temperature and pressure, may bring further benefits, reducing the total thermal sterilisation requirement. This process is suitable for ambient shelf stable products. It is not commercial yet but development and validation work is in progress and filing for regulatory approval in the USA is expected soon.

Overall, HPP offers opportunities for a whole range of high quality near-fresh products now, with sufficient refrigerated shelf-life for long distance distribution, and in the near future will also provide a range of new high-quality shelf-stable products.

High-Powered Ultrasound

Ultrasound processing involves the propagation of sound waves between 20 kHz and 1 MHz into product via a vibrating sonotrode or plate. The sound waves result in the formation of a cloud of micro-bubbles which oscillate at the sound wave frequency. The implosion of unstable micro-bubbles results in localised pressure, temperature and micro-streaming. Under stable micro-bubble conditions the oscillating bubbles can be used as sono-chemical reactors for additive-free modification of food components.

The recent development of robust and efficient industrial-scale continuous ultrasound processing systems has enabled development of a range of food processing applications. The range of applications from low to high power includes stimulation of biological systems (enzymes, fermentations), agglomeration, dispersion, encapsulation, extraction, enzyme inactivation, microbiological inactivation and nano-milling of polymers.

Microbiological and enzyme inactivation kinetics can be enhanced by implementation of ultrasound as a processing adjunct. Studies suggest that cavitation bubbles appear to micro-jet into the cell wall surface causing rupture. The high shear under intensive conditions is thought to promote conformational changes of enzymes causing improved inactivation. Ultrasound technology is well established for enhancing mass transfer, hence there is considerable potential for extraction enhancement by releasing and flushing inter-cellular components and improving penetration of the solvent. Ultrasound can be used to enhance heat transfer to potentially reduce the required pasteurisation or sterilisation treatment times. New airborne ultrasound systems have demonstrated the ability for additive-free defoaming and enhancement of drying kinetics at lower temperatures, providing the opportunity for a new approach to achieve premium quality dried products.

The ultrasound applications described above require different systems and application-specific processing conditions to deliver cost-effective solutions.

Pulsed Electric Field

Pulsed electric field (PEF) is an emerging non-thermal process for the inactivation of micro-organisms in liquid foods and preserving their fresh flavour, colour, texture and other functional attributes. The technology is particularly useful for the processing of liquid foods where traditional heat treatments have adverse effects on the biological and sensory attributes of the products. Small molecules (such as vitamins, salts, sugars) and large molecules (such as proteins and polysaccharides) are generally not affected by PEF.

The principle of PEF for the inactivation of micro-organisms involves the use of high voltage (30,000–50,000 volt/cm) electric field pulses to produce bacterial cell electroporation and membrane disruption that leads to cell leakage and inactivation. As the electric pulses used for the PEF treatment are of extremely short duration (often in the range of 1–4 microseconds), the resulting temperature increase is minimal, often in the range of 2–5°C, thus leading to minimal effect on flavour and other sensory characteristics.

It has been demonstrated in the literature in various test systems that a wide range of micro-organisms can be inactivated by PEF, including *E. coli* O157:H7, *Salmonella* spp and *Listeria monocytogenes*. However, the effectiveness of microbial inactivation is to a large extent dependent on the particular PEF equipment, the treatment chamber design, the target micro-organisms, the substrate/food environment and treatment conditions.

About the speaker

Lloyd Simons is the Food Processing Team Leader at Food Science Australia – Werribee. The team is part of the Innovative Food Centre, which investigates emerging food processing technologies. Mr Simons has a BSc (Hons). Masters in Toxicology, and MBA in Technology Management.

About the author

Dr Cornelius (Kees) Versteeg studied Food Technology and Engineering at Wageningen Agricultural University in the Netherlands, where he obtained his PhD in Food Biochemisty in 1979. In 1983 he joined the (then) Gilbert Chandler Institute of Dairy Technology in Werribee, which soon became the 'Food Research Institute'. When Food Science Australia (FSA) was formed in 1997, Dr Versteeg managed the Food Engineering Group and then the Food and Packaging Group. In 2002 he was appointed the first director of the Innovative Foods Centre at FSA – Werribee. The mission of the Innovative Food Centre is to achieve fresher, safer food or more functional food products and more efficient processes through the use of emerging food processing technologies.

Appendix A: DSTO-Scottsdale – Relationship to DSTO, Vision, Mission, and Summary of R&D

The mission of the Defence Science and Technology Organisation (DSTO) is to be:

> Australian Government's lead agency charged with applying science and technology to protect and defend Australia and its national interests. It delivers expert, impartial advice and innovative solutions for Defence and other elements of national security.

To achieve its mission, DSTO:

- Provides scientific and technical support to current Defence operations
- Investigates future technologies for Defence and national security applications
- Ensures Australia is a smart buyer and user of Defence equipment
- Develops new Defence and national security capabilities
- Enhances existing capabilities by increasing performance and safety, and reducing the cost of ownership of Defence assets
- Works collaboratively with other government agencies to strengthen national security
- Assists industry to better support Defence's capability needs

One of 13 divisions of DSTO, the Human Protection and Performance Division (HPPD) is required to:

> Apply innovative science for protection and performance of personnel in CBR and other physically challenging environments for Australian national security.

Two Major S&T Capabilities within HPPD support this—MSTC 1. *Chemical, Biological,Radiological and Nuclear Defence* and MSTC 2. *Individual Protection, Nutrition and Performance.*

DSTO-Scottsdale (also known as Defence Nutrition) provides the Nutrition & Dietetics and Food Science & Technology sub-technology components for MSTC 2. DSTO-Scottsdale, which celebrated 50 years of R&D in support of the ADF in 2004, exists to:

> Research, develop and produce specialised food and feeding systems, and advise on human health and nutrition in support of Australian national security.

With an FTE (full-time equivalent) staff of 9.4 scientists and two full-time production staff, DSTO-Scottsdale makes a small but significant contribution to Australia's Defence preparedness.

At the time of the Defence Nutrition Workshop (April, 2006) DSTO-Scottsdale had responsibility for three R&D tasks:

(i) Task Title: *Enhancing Capability through Nutrition*

Summary Task Work Program :

The major goal is to design nutritional strategies to sustain or enhance military performance. Specific aims are to: Improve training outcomes; determine the prevalence of risk factors for bone-related injury in order to design targeted intervention programs for reduction of injury risk; reduce thermal injury risk; improve the nutritional profile of combat rations in order to enhance bowel health, iron status and immune function; sustain immune function and good nutritional status during deployed operations, and improve post-deployment recovery.

(ii) Task Title: *Innovative Technologies for Dynamic Rationing*

Summary Task Work Program:

Innovative technologies for dynamic rationing provides advice and conducts research to support Defence Catering's development & design, procurement and management of combat ration packs and related issues.

(iii) Task Title: *Improved Nutrition and Fitness for Navy*

Summary Task Work Program:

An assessment will be made with regard to Navy s nutritional standards and the impact of work routines and fitness on RAN human performance. Initial methodologies and research will centre on the Hydrographic ship. The results of this work will then be transposed to the surface combatant and submarine platforms. Additional data may be sought from the surface combatant and submarine platforms. Recommendations to improve the RAN s human performance at sea will be made to include assistance to Navy to promote and help increase the wellbeing of personnel at sea.

Appendix B: List of Attendees, Organising Committee and Administration Staff

DSTO (Other than Human Protection and Performance Division, HPPD)

Brigadier (Retired) Steve Quinn, Chief Land Operations Division (LOD), DSTO-Edinburgh stephen.quinn@dsto.defence.gov.au

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Invited Speakers (Non-DSTO)

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Organising Committee

Chris Forbes-Ewan coordinated the organisation of this workshop, supported by Gülay Mann, Theresa Hay, Christine Booth, Ross Coad, David Topping and Michelle Cooke.

Administration

Administrative arrangements were handled by Michelle Cooke, Jenni Wilson and Madeline Jetson.

Appendix C: Program of Defence Nutrition Workshop

Day 1 (Thursday 27 April 2006)

0830 **Registration**

08:45 Opening Address and Overview of Human Protection and Performance Division – Dr Simon Oldfield, Chief Human Protection and Performance Division (HPPD), DSTO-Melbourne

09:15 Overview of DSTO-Scottsdale's Defence Nutrition Capability – Dr Gülay Mann, Head Defence Nutrition, DSTO-Scottsdale

09:30 Keynote Presentation: Designing foods for performance – Professor Peter Lillford, University of York (UK) and Flagship Fellow, Food Future Flagship, CSIRO

10:15 Developing issues in preventive health and performance sustainability in relation to military nutrition – GPCAPT James Ross, Defence Health Services Division

10:45 Morning Tea

11:15 – 12:30 **Session 1. Feeding the Warfighter in the Battlefield of the Future – a Perspective from 'Down Under'**

11:15 Enhancing ADF capability through nutrition – Dr Christine Booth, Nutrition Task Manager, DSTO-Scottsdale

11:45 Educating future warfighters to feed themselves: the New Zealand perspective – CAPT Nicola Martin, Dietitian, New Zealand Defence Force

12:15 Panel Discussion

12:30 Lunch

13:30 – 14:45 **Session 2. Feeding the Warfighter in the Battlefield of the Future – an International Perspective**

13:30 Military rations for short-term, high-intensity combat operations – MAJ Chad Koenig, United States Army Research Institute of Environmental Medicine

14:00 A development and procurement experience of Singapore Armed Forces field rations – Ms Patsy Tan, Defence Science and Technology Agency, Singapore

14:30 Panel Discussion

14:45 Afternoon Tea

15:15 – 1700 **Session 3. Feeding the Future Warfighter: A Special Role for Carbohydrate?**

15:15 Complex carbohydrates and gut health – Dr David Topping, Chief Research Scientist, CSIRO Health Sciences and Nutrition

15:45 Structuring in plant-based foods: from polysaccharides and cell walls to nutritional impact – Professor Mike Gidley, Director, Centre for Nutrition and Food Sciences, University of Queensland

16:15 Colonic DNA and mucus barrier integrity: the role of dietary resistant starch – Dr Michael Conlon, Research Scientist, CSIRO Health Sciences and Nutrition

16:45 Panel Discussion

17:00 **Finish of scientific program for day 1**

18:00 Wine tasting and Workshop Dinner (*dinner from ~19:00*)

Day 2 (Friday 28 April 2006)

08:20 Proceed to Conference Room (first session needs to start promptly at 08:30)

08:30 – 09:45 **Session 4. Feeding the Future Warfighter: Nutritional Trends and Health Implications**

08:30 National dietary trends, Nutrient Reference Values, and their relevance to Defence Nutrition – Dr Katrine Baghurst, Food Standards Australia New Zealand, and Chair of the National Health and Medical Research Council Nutrient Reference Values Working Party

09:00 Food and its potential role in the prevention of chronic disease – Dr Lynne Cobiac, Business Manager and Research Leader, P-Health, CSIRO National Flagships Research Program

09:30 Panel Discussion

09:45 Morning Tea

10:15 – 12:00 **Session 5. Feeding the Future Warfighter: Novel Food Technologies**

10:15 Functional foods through innovative technologies: sustainment on the battlefield – Dr Theresa Hay, Food Science and Technology Task Manager, DSTO-Scottsdale

10:45 Better, fresher and safer foods through novel food processing technologies – Dr Kees Versteeg, Director Innovative Foods Centre, Food Science Australia

11:15 Panel Discussion

11.30 Closing Address – Brig (Retired) Steve Quinn, Chief Land Operations Division (LOD), DSTO-Edinburgh

12.00 Lunch

13:00 Transport departs for Scottsdale

13:30 Tour of DSTO-Scottsdale

14:30 Transport departs for Launceston Airport

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19. ABSTRACT

As a component of the Defence Nutrition Plan, the Defence Nutrition Workshop was conducted to provide guidance to DSTO-Scottsdale on the most effective and efficient way in which S&T support could be provided to the ADF in nutrition and food science. Experts from Australia and overseas presented on the current status and likely future directions of research into a wide range of Defence-related food science and nutrition issues. These include development of rations for short-term operations, educating warfighters in better nutrition, development of a procurement process for combat ration packs, and the potential for particular forms of carbohydrate to enhance or maintain ADF health and performance.

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