the 2010 apple report

Key findings from a CSIRO review of apples, their antioxidants and benefits to human health

the 2010 apple report

FOREWORD

This comprehensive report provides an overview of the evidence relating to apples and their health benefits.

Based on a CSIRO review, *The 2010 Apples Report* confirms that there is a growing body of research on the role that apples may play in human health. This ranges from a possible role in reducing allergic rhinitis to growing evidence in controlling chronic disease risk factors.

In particular, evidence for the role of apple polyphenols in lowering cholesterol has been demonstrated in double blind, placebo-controlled, human studies.

The CSIRO review also identifies the potential benefits of eating whole apples in managing appetite. Apple consumption is also associated with a lower risk of developing type 2 diabetes and asthma.

Importantly many of these benefits could be achieved through normal consumption of one to three apples a day – which is both achievable and affordable for most Australian households.

The 2010 Apples Report certainly sets an exciting agenda for future research as we continue to uncover the nutritional benefits of apples.

Associate Professor Manny Noakes
CSIRO Food and Nutritional Sciences
July 2010

INTRODUCTION

In 2010, the Australian apple industry commissioned the CSIRO to review human and animal studies relating to apples, apple antioxidants and health-related outcomes. This builds on previous reviews undertaken by the industry to establish the role apple consumption may play in human health.

The 2010 Apple Report is a summary of the CSIRO review and covers each of the disease states where CSIRO identified a potential health benefit for apples. It has been developed by Horticulture Australia Limited (HAL) and reviewed by Associate Professor Manny Noakes, CSIRO Food and Nutritional Sciences.

APPLES AND NUTRITION

Apples, as one of Australia's most popular fruits, are a good source of vitamin C, potassium, dietary fibre and phytonutrients including antioxidant compounds. Low in saturated fat, cholesterol and sodium with a GI of between 28-44, apples are low GI and so offer a sustaining source of energy.

Nutrients and units	Amount in 100g of edible portion
Water (g)	85.56
Energy (kJ)	218
Protein (g)	0.26
Total lipid, fat (g)	0.17
Carbohydrate (g)	13.81
Total dietary fibre (g)	2.4
Sugars, total (g)	10.39
Sucrose (g)	2.07
Glucose (dextrose) (g)	2.43
Fructose (g)	5.90
Starch (g)	0.05

Composition of Apples (Malus domestica), raw with skin (USDA data), summary. Refuse: 10% core and stem.

PHYTONUTRIENTS

Phytonutrients are substances in plant foods that have health benefits but unlike traditional vitamins and minerals, phytonutrients are not essential for life. For this reason they may also be known as phytochemicals and the two terms are often used interchangeably. Thousands of phytonutrients have been isolated and characterised from plant foods, including fruits and vegetables.

The major categories of dietary phytonutrients include:

- Polyphenols
- Carotenoids
- Alkaloids
- Nitrogen-containing compounds
- Organosulphur compounds

In turn, polyphenols have a significant number of sub-categories including:

- Flavonoids
- Phenolic Acids
- Stilbenes
- Coumarins
- Tannins

Apple Phytonutrients

Apples are particularly rich in flavonoids, this includes sub-classes such as the flavonols, flavones and flavanols. Phytonutrients in apples include:

- Quercetin-3-galactoside
- Quercetin-3-glucoside
- Quercetin-3-rhamnoside
- Catechin
- Epicatechin
- Procyanidin
- Cyanidin-3-galactoside
- Coumaric acid
- Chlorogenic acid
- Gallic acid
- Phloridzin

The compounds most commonly found in apple peel are procyanidins, catechin, epicatechin, chlorogenic acid, phloridzin, and the quercetin conjugates. Apple flesh contains catechin, procyanidin, epicatechin, and phloridzin, but in lower concentrations than in apple peel.

Fridge or fruit bowl?

Australia is split - 50% of us keep them in the fruit bowl and 50% in the fridge. (Newspoll, 2009)

But which is best? Keep your apples in the fridge at home to retain their antioxidants and keep them crisper for longer.

Apple Antioxidants

It is likely that the phytonutrients we know as antioxidants play a key role in the way apples exert some of their beneficial effects. It is important to note that these effects may or may not be due to antioxidant action, and so measures of antioxidant capacity – such as the in vitro measurement ORAC– may not necessarily reflect how they are actually working in the body.

Individual phytonutrients can have many important physiological effects and, as such, they are much more than just antioxidants and therefore, antioxidant testing is not the "be all and end all" of phytonutrition (Maher, 2006).

We do know that antioxidants help neutralise free radicals (highly reactive, unstable compounds) that are produced naturally within the body and found in external sources such as cigarette smoke, environmental pollutants and ultraviolet light.

If free radicals are not inactivated, their chemical reactivity can damage all types of cellular macromolecules including proteins, carbohydrates, lipids and DNA.

The human body has its own natural and complementary defences against free radical damage, but it's possible a vital second line of defence involves antioxidants from our diet.

Antioxidants and Storage

Different modes of post-harvest storage can affect antioxidant capacity and polyphenol content. Matthes and Schmitz-Eiberger (2009) tested post harvest storage at 20°C to simulate domestic conditions and cold storage at 1°C for 4.5 months.

Cold storage at 1°C increased the antioxidant capacity and polyphenol content in most of the apple cultivars but storage at 20°C led to a decrease in polyphenol content and in antioxidant capacity. Storage under controlled atmosphere led to stable or small increases of both antioxidant capacity and polyphenol content.

This underscores the importance of appropriate refrigerated storage for apples to retain antioxidants. This study also showed a positive correlation between total polyphenols and antioxidant capacity.

Peel and All

Apple peel is a good marker of the antioxidant potential of apples, (Lata, 2007). Apple peel contains from 1.5 to 9.2 times greater total antioxidant activity and from 1.2 to 3.3 times greater total phenolic content compared with flesh. A more nutritious peel may be darker, redder and bluer, while a more nutritious flesh may have a lighter colour and lower soluble solid content according to principal component analysis.

Polyphenols

What are polyphenols?

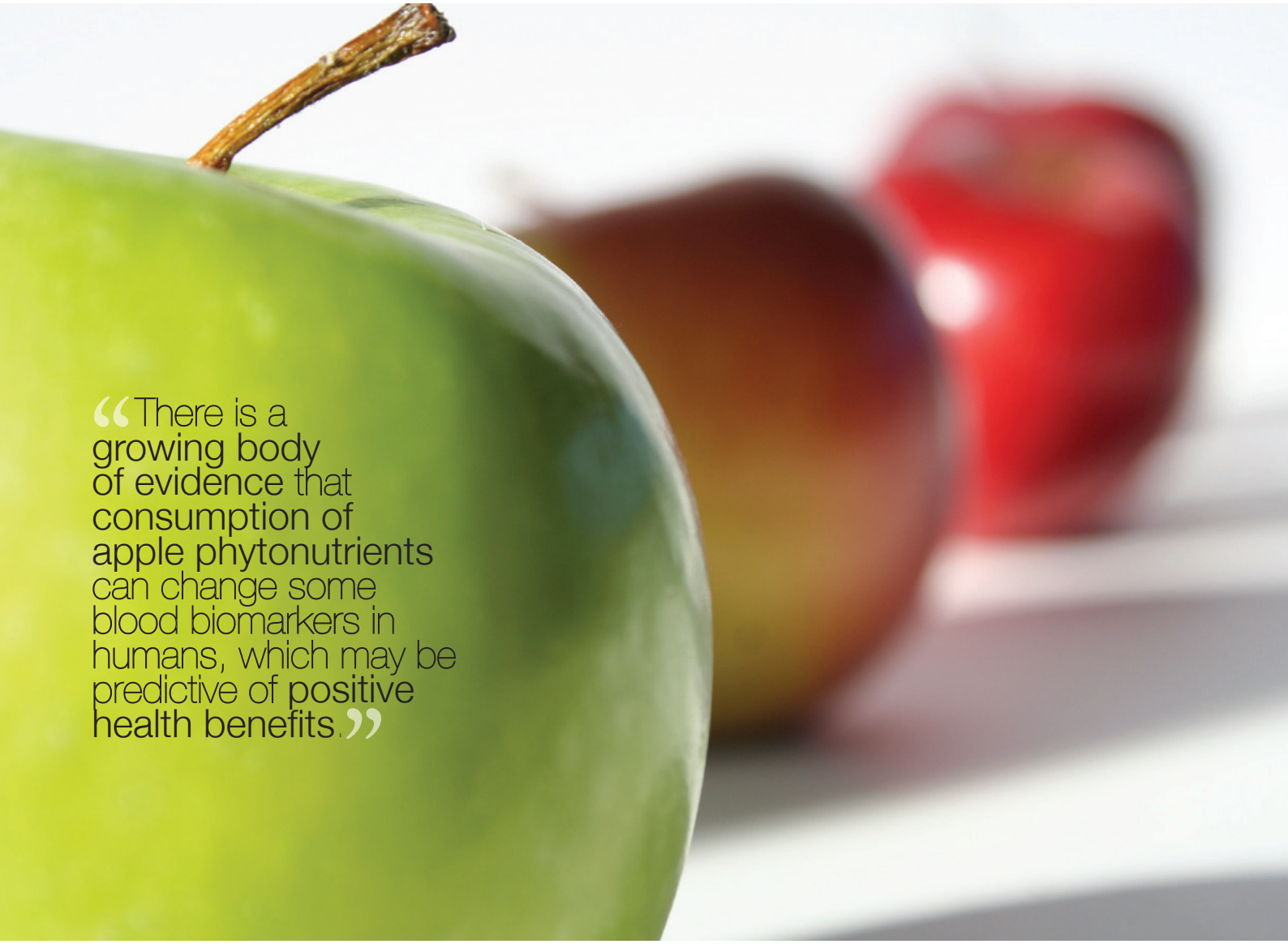
Polyphenols are a group of chemical substances found in plants. The largest and best-studied polyphenols are the flavanoids, which include several thousand compounds including the flavonols, flavones, anthocyanidins and isoflavonoids.

Numerous studies on the antioxidant properties of apples have shown contrasting results between the effects in laboratory (in vitro) analysis and in human (in vivo) studies. This is most likely due to dietary polyphenols undergoing extensive modification during metabolism so that the chemicals reaching the blood and tissues are, in general, not the same as the original dietary source used in in vivo studies.

SUMMARY

APPLES AND PHYTONUTRIENTS

- Antioxidant capacity of apples is concentrated in the peel, with higher levels of antioxidant capacity generally found in darker, redder and bluer coloured apples.
- Apples are the largest contributors of fruit phenolics in the diet as apples are the fruit consumed in the highest volume (Wolfe et al., 2008)), and apples and strawberries are the biggest suppliers of cellular antioxidant activity due to levels of consumption.
- It is important to note that measures of antioxidant capacity – such as the in vitro measurement ORAC– may not necessarily reflect how foods are actually working in the body.
- Apples are also a significant source of flavonoids in Australian adults (Somerset and Johannot, 2008).
- Appropriate cold storage of apples can maintain phytonutrient content for many months.



Bioavailability

A review of 97 bioavailablity studies has shown that bioavailability differs greatly between the various polyphenols, with the most abundant polyphenols not necessarily being those that have the best bioavailability profile in humans (Manach et al., 2004). This means the results of various laboratory measures of antioxidant capacity cannot be assumed to extrapolate directly to human health outcomes.

However, there is a growing body of evidence that consumption of apples can change some blood biomarkers in humans, which may be predictive of positive health benefits.

A review of the bioavailability and bioefficacy of polyphenols in 93 intervention studies (Williamson and Manach, 2005) suggests that for some dietary polyphenols there is enough evidence to infer possible health effects in humans based upon the presence of short-term changes in biomarkers.

For example, procyanidins (found in high concentrations in apples) have effects on the vascular system including, but not limited to, antioxidant activity in the blood.

As polyphenols are also known to have additive or synergistic effects with other polyphenols, it has been recommended that future studies should involve the whole apple rather than individual phytochemicals to better determine effects on human health (Biedrzycka and Amarowicz, 2008).

Mechanisms

Although the protective effect of dietary phenolics may in part be due to their antioxidant properties, which result in a lowering of the levels of free radicals within the body, there are alternative mechanisms, which have recently been postulated.

There is now emerging evidence that the metabolites of dietary phenolics, which appear in the circulatory system in nmol/L to low mmol/L concentrations, exert modulatory effects in cells through selective actions on different components of the intracellular signalling cascades vital for cellular functions such as growth, proliferation and apoptosis.

In addition, the intracellular concentrations required to affect cell signalling pathways are considerably lower than those required to impact on antioxidant capacity (Crozier et al 2009).

CARDIOVASCULAR HEALTH

The evidence for a role of fruit and vegetables, specifically apples, on protection from cardiovascular diseases is strengthening.

Flavonoid food composition data from three recently available US Department of Agriculture databases have been used by Mink et al., 2007 to try to improve estimates of dietary flavonoid intake and to evaluate the association between flavonoid intake and cardiovascular disease (CVD) mortality.

The study participants were 34,489 post-menopausal women in the Iowa Women's Health Study who were free of CVD and had complete food-frequency questionnaire information at baseline. The study found that dietary intakes of flavanones, anthocyanidins, and certain foods rich in flavonoids were associated with reduced risk of death due to CHD, CVD, and all causes.

In addition, an inverse association between apple consumption and incidence of ischemic heart disease mortality has been reported in a Finnish epidemiological study with 10,054 participants (Knekt et al., 2002).

Despite these promising studies it is important to note two prospective evaluations of flavonoid intakes (Sesso et al., 2003, Lin et al., 2007) have not supported an inverse association between flavonoid intake and CHD risk, suggesting that protective mechanisms may not solely relate to flavonoids.

Cholesterol

A review of nine human studies on the effects of apples on plasma cholesterol levels and cardiovascular risk has recently been published (Jensen et al., 2009). The review found that there was a cholesterol-lowering effect, in the range of 5 - 8%, after the intake of approximately three whole apples, whereas the consumption of apple juice (375 - 720 ml) had no effect on plasma cholesterol levels and may result in adverse effects on plasma triglyceride levels.

In nine experimental studies in animal models, feeding apple products resulted in decreased levels of plasma (11 - 43%) and liver (23 - 67%) cholesterol in the majority of studies and an increased excretion of bile acids (3 - 56%) and cholesterol (5 - 41%). The authors concluded that it appears likely that a reduction in plasma total and LDL cholesterol occurs after a dietary intake of apples, and that the major mechanism behind the cholesterol-lowering effect of apples involves an increased clearance of plasma cholesterol due to enhanced faecal excretion of bile acids and cholesterol.

In a 12-week randomized double-blind, placebo-controlled trial on moderately obese men and women significant reductions in total cholesterol and LDL-cholesterol levels were observed with both polyphenols extracted from apples (equivalent to three apples) and hops bract, with a greater

SUMMARY

OVERALL SUMMARY - CARDIOVASCULAR HEALTH

- The evidence for a role of fruit and vegetables - specifically apples - on protection from cardiovascular diseases is strengthening.
- There have been a range of animal and human studies investigating the potential effects of apples and their nutritional components on blood cholesterol levels, lipid metabolism, atherosclerosis, blood pressure and various forms of heart and cardiovascular disease.
- The cholesterol lowering effects of apples have been further demonstrated in double blind placebo human studies, which indicate that apple polyphenol supplements (in capsules, approximating polyphenol content in three apples) can reduce total cholesterol and LDL-cholesterol levels by 5% to 8%.

The findings from international studies recommend consumption of more than five serves of fruit and vegetables per day, with an emphasis on onions, green leafy vegetables, apples, pears, berries and other vitamin C-rich fruit and vegetables.

Heart Foundation Summary of Evidence on Antioxidants in Food, Drinks and Supplements for Cardiovascular Health. May 2010

reduction observed for apple polyphenols (Nagasako-Akazome et al., 2007). The visceral fat area and the level of adiponectin in the group administered apple polyphenols also improved in comparison with the control group. These results suggest that apple polyphenols may regulate fat metabolism in healthy subjects with relatively high body mass index. Further studies are warranted.

Mechanisms

The mechanism by which apple phytonutrients could lower plasma LDL cholesterol is thought to involve the uptake of LDL particles in the liver and subsequent increased cholesterol excretion as bile acids.

Apple phytonutrients may facilitate a decrease in intracellular fat and cholesterol synthesis, similar to the effects observed through statins, the class of cholesterol lowering drugs.

It has been suggested that apple phytonutrients - pectin and the polyphenol-rich fraction - are more effective on cholesterol metabolism when fed together than when fed separately. This implies interactions between fibre and polyphenols of apples and accounts for the biological effects of the whole fruit, which are less effective when the components are assessed separately.

SATIETY AND WEIGHT MANAGEMENT

Consumption of whole fruit has been reported to reduce ratings of satiety more than fruit juice, but little is known about the effects of different forms of fruit on subsequent energy intake. Several studies have shown that consumption of whole apple has a positive effect on satiety, compared with the same energy from juice or puree (Haber et al., 1977; Mattes and Campbell, 2009).

A recent study (Flood-Obbagy and Rolls, 2009) has tested how consuming apples in different forms (apple, apple sauce, and apple juice with and without added fibre) prior to a meal influenced satiety and energy intake at a meal. Results showed that eating whole apple reduced energy intake by 15% during the subsequent meal compared to the control group and those consuming apple sauce or juices, suggesting that that eating solid fruit at the start of a meal can reduce energy intake.

The effect of adding fruit or oats to the diet of moderately overweight women on energy consumption and body weight has been evaluated in a clinical trial in Brazil. The fruit (apples and pears) and oat cookies had the same amount of fibre and total calories (around 200 kcal), but differed in energy

density. Apples and pears were associated with weight loss, whereas body weight was unchanged in the oat group. These results suggest that the energy density of fruit, independent of the fibre amount may reduce energy consumption and body weight over time (de Oliveira et al., 2008).

SUMMARY

SATIETY AND WEIGHT MANAGEMENT

The consumption of solid fruit such as apples affects satiety more than pureed fruit or juice. Eating apples at the start of a meal can reduce energy intake and consuming apples as a snack has valuable satiety benefits which may have a possible subsequent effect on weight reduction. These effects appear to be related to the structure and energy density of apples rather than their fibre content per se.

TYPE 2 DIABETES

The incidence of type 2 diabetes has been shown in a number of large epidemiological studies to be lower in people who consume apples. A large epidemiological study of more than 38,000 women with nearly nine years of follow-up found women consuming one apple a day had a significant (28%) reduction in the risk of type 2 diabetes compared with those who consumed no apples (Song et al., 2005). A similar study involving more than 10,000 Finnish women also found an association between increased apple consumption and a reduced incidence of type 2 diabetes (Knekt et al., 2002).

Of particular interest is that the results of Song et at., and another large epidemiological study (Nettleton et al., 2006) conclude flavonoids do not have a diabetes-protective effect. This suggests that the beneficial effect observed with apple consumption may be related to a mechanism other than the action of phytonutrients such as quercetin.

Although a diabetes protective relationship is not definitive, it should also be noted that the Glycaemic Index (GI) of apples is low (28 – 44) and this could contribute to an apparent diabetes prevention effect. Furthermore as whole apples are low in energy density and may impact on appetite control, diabetes prevention mediated by potential weight control may also be a possible mechanism.

RESPIRATORY DISEASE

Allergy

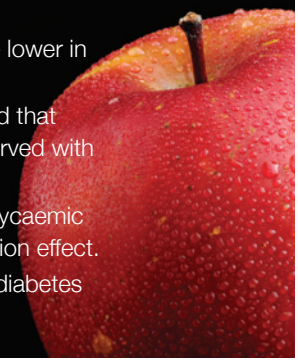
Persistent allergic rhinitis is usually treated with antihistamines and local steroids, but they often cause adverse effects such as sedation and drowsiness. Polyphenols derived from apples have shown promising results in reducing these symptoms in human clinical trials. Patients with moderate or severe persistent allergic rhinitis in whom the symptoms persisted for three years or longer were treated without apple polyphenols, with a low dose of apple polyphenols (50mg), or with a high dose of apple polyphenols (200mg), and changes in the clinical symptoms were examined. Note that one apple may contain 200mg polyphenols. Significant improvements were observed in sneezing attacks and nasal discharge in the high-dose group and in sneezing attacks in the low-dose group suggesting that apple polyphenols may be effective in alleviating symptoms of persistent allergic rhinitis (Enomoto et al., 2006).

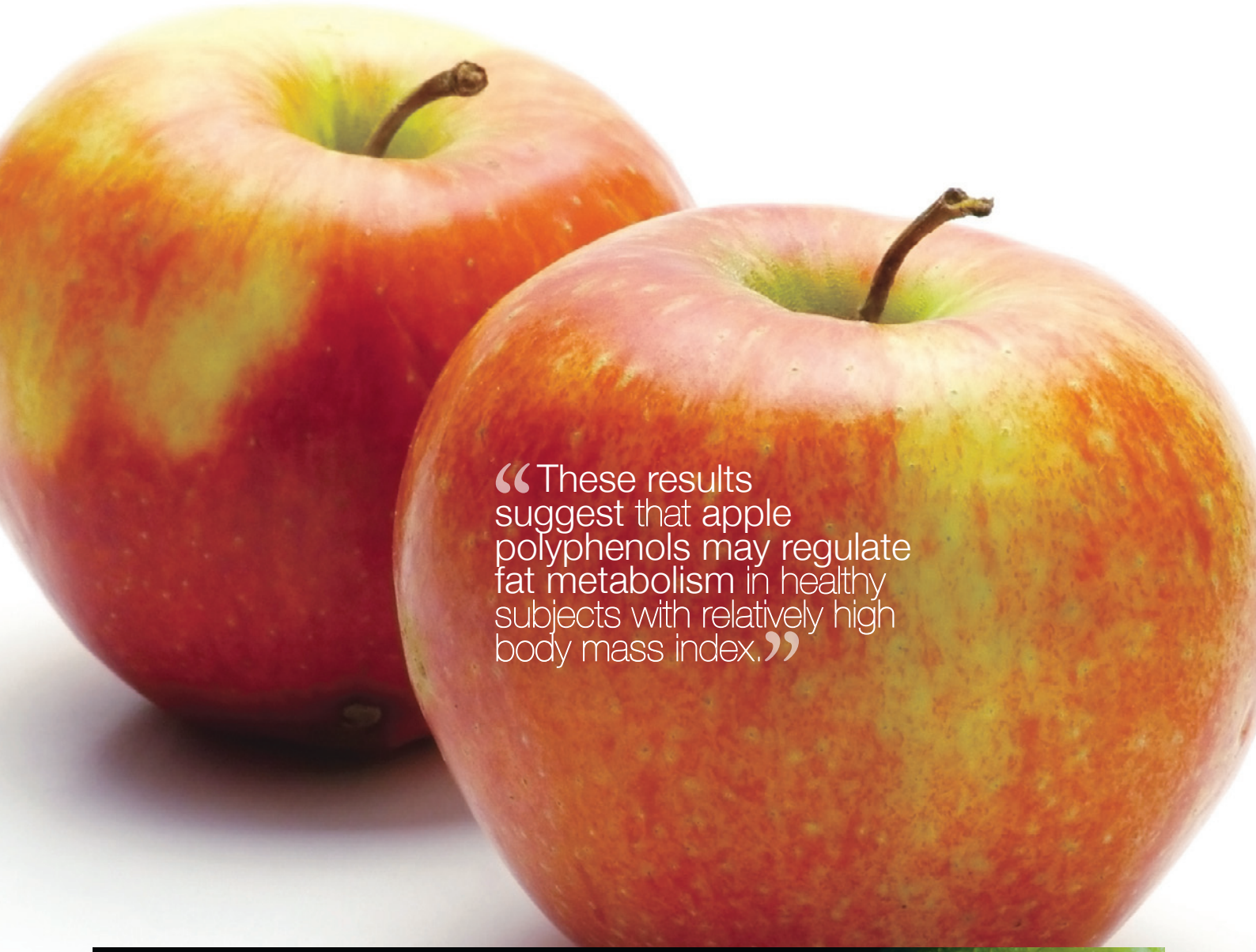
A double-blind comparative study was conducted to evaluate the treatment efficacy of apple polyphenol (500mg/day) on cedar pollinosis patients (the most common pollen allergy in Japan). The results showed that the sneezing score was significantly lower for the apple polyphenol group than with the placebo group during both the early and main periods of pollen dispersion. (Kishi et al., 2005).

SUMMARY

TYPE 2 DIABETES

- The incidence of diabetes has been shown in a number of large epidemiological studies to be lower in people who consume apples.
- Of particular interest are the results of two large epidemiological studies which both concluded that flavonoids did not have a diabetes-protective effect, suggesting that the beneficial effect observed with apple consumption may be related to the action of phytonutrients such as quercetin.
- Although a diabetes protective relationship is not definitive, it should also be noted that the Glycaemic Index (GI) of apples is low (28 – 44) and this could contribute to an apparent diabetes prevention effect.
- Furthermore, as whole apples are low in energy density and may impact on appetite control, diabetes prevention mediated by potential weight control may also be a possible mechanism.





“These results suggest that apple polyphenols may regulate fat metabolism in healthy subjects with relatively high body mass index.”

SUMMARY

ALLERGY

- Among other foods, consumption of apples has been linked to reduced incidence of atopic dermatitis (Kojima et al., 2000) and respiratory allergy.
- Apple polyphenols may help alleviate some of the symptoms of respiratory allergy such as sneezing.
- This effect has been noted with apple polyphenol amounts able to be consumed in one apple. This is an important area for further research to confirm this effect.

Asthma

Several epidemiological studies have found an association between increased apple consumption, good lung function and a reduced incidence of asthma.

Food and nutrient intakes and asthma risk has been studied in young adults (n=1601) in a community-based, cross-sectional study where subjects completed a respiratory questionnaire, a validated semi-quantitative food-frequency questionnaire, skin-prick testing, and lung function tests, including a methacholine challenge test for bronchial hyperreactivity. The results indicated that both apples and pears appear to be related to lower asthma and bronchial hyperreactivity (Woods et al., 2003).

An inverse association between apple consumption and incidence of asthma has also been reported in a Finnish epidemiological study with 10,054 participants (Knekt et al., 2002), and in a smaller study of 16-50 year old participants in 40 general practices in the UK (Shaheen et al., 2001).

An epidemiological study with 2,512 middle-aged men has also reported an association between good lung function and high intake of apples (five or more apples per week) although an association between high average apple consumption and slow decline in lung function lost significance after adjustment for confounders including body mass index, smoking history, social class, exercise, and total energy intake (Butland et al., 2000).

Maternal food consumption during pregnancy and asthma, respiratory and atopic symptoms in 5-year-old children has been evaluated. The study reported no evidence for associations between the maternal intake (assessed by food frequency questionnaire) of most foods during pregnancy, and asthma, respiratory and allergic outcomes in 5-year-old children, except for apples and fish suggesting that consumption of apples (and fish) during pregnancy may have a protective effect against the development of childhood asthma and allergic disease (Willers et al., 2007).

SUMMARY

ASTHMA

Based on food frequency questionnaire protocols, apples have been reported to be associated with lower incidence of asthma and bronchial hyperreactivity. Human clinical trials are recommended to establish causation.

EMERGING AREAS

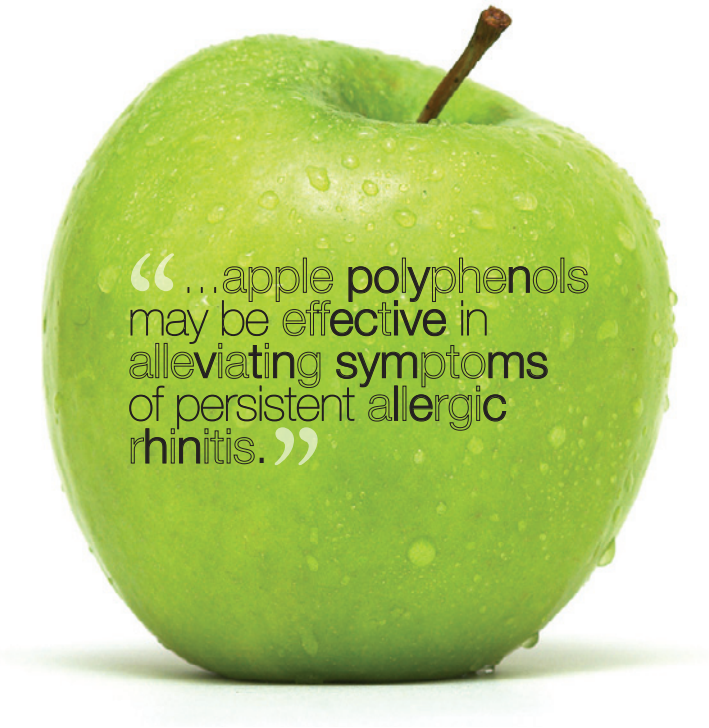
The CSIRO research review revealed emerging evidence across a range of areas including inflammatory bowel disease, certain cancers and gastrointestinal conditions.

Although diet is regarded as an important factor influencing inflammatory bowel diseases (IBD), there are no accepted dietary recommendations presently available. Several research studies looking at apple polyphenol supplementation in animal models of IBD appear promising with regard to reducing gastrointestinal inflammation. To confirm a benefit for humans, clinical trials in patients with inflammatory bowel disease are recommended. (Yoshioka et al., 2008 and Castagnini et al., 2009).

While the evidence for the role of fruit and vegetables generally in reducing cancer risk is not as strong as it once appeared, this does not rule out the potential for specific fruits and vegetables or their components. When it comes to apples, there are areas that warrant further research.

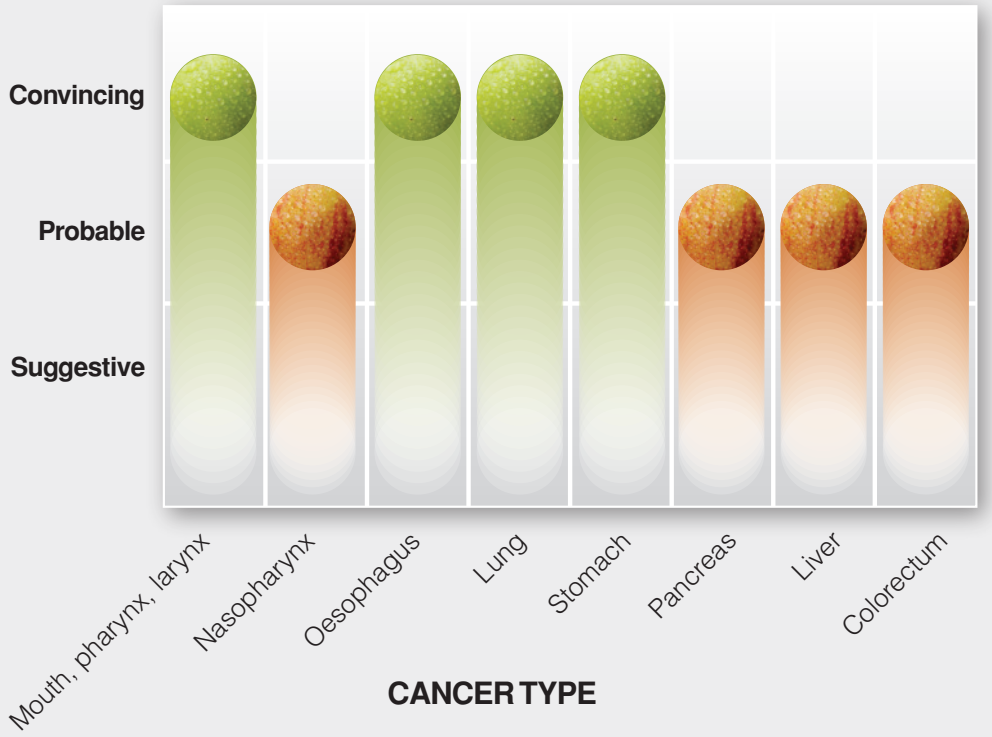
There is evidence of antigenotoxic potential of phytonutrients from both organically and conventionally grown apples (Briviba et al., 2007).

Laboratory cell-based studies have shown that apple peel extract possesses strong anti-proliferative effects against cancer cells, and apple peels should not be discarded from



STRENGTH OF THE EVIDENCE FOR FRUIT CONSUMPTION AND LOWER CANCER RISK

Source: World Cancer Research Fund.



the diet. More detailed mechanistic studies, especially in appropriate in vivo animal models, are needed to assess possible anti-proliferative and preventative effects of apple extracts against cancer.

The effect of dietary flavonoids on colorectal adenoma recurrence has been studied in The Polyp Prevention Trial (Bobe et al., 2008). High intake of flavonoids, which are at greater concentrations in beans, onions, apples, and tea, was associated with a decreased risk of advanced adenoma recurrence.

It is important to note that eating fruit such as apples and vegetables may help maintain a healthy body weight, which can reduce the risk of cancer since obesity is only second to smoking as a preventable cause.

With regard to gastrointestinal conditions, research suggests that phenols may exert direct effects within the gastrointestinal tract, because of the high concentrations present. These effects could include binding of prooxidant iron, scavenging of reactive nitrogen, chlorine, and oxygen species, and perhaps inhibition of cyclooxygenases and lipoxygenases (Halliwell et al., 2005).

Dietary derived phenolics may be degraded by the colonic microflora and absorbed via the colon in small concentrations which may exert modulatory effects in cells through intracellular signalling cascades such as in growth, proliferation and apoptosis.

METHODOLOGY

The research studies included in this review were sourced via detailed and strategic electronic searches of medical, scientific and technical literature.

Published human studies selected for retrieval were assessed for methodological validity. The levels of evidence used were those followed by the National Health and Medical Research Council for the assessment and application of scientific evidence.

The scientific review was prepared by Dr Peter Roupas and Associate Professor Manny Noakes, CSIRO Food and Nutritional Sciences, on behalf of Horticulture Australia Limited, in May 2010.

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