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Review

Vegetables containing phytochemicals with potential anti-obesity properties: A review

David J. Williams [a,*], David Edwards [a], Ingrid Hamernig [b], Le Jian [c], Anthony P. James [d], Stuart K. Johnson [d], Linda C. Tapsell [e]

[a] Agri-Science Queensland, Department of Agriculture, Fisheries and Forestry (DAFF), PO Box 156, Archerfield BC, Queensland 4108, Australia
[b] Institute of Molecular Biosciences, The University of Queensland, St. Lucia, Queensland 4072, Australia
[c] Department of Health, 189 Royal Street, East Perth, Western Australia 6004, Australia
[d] School of Public Health, Curtin Health Innovation Research Institute, Curtin University, GPO Box U1987, Perth, Western Australia 6845, Australia
[e] Smart Foods Centre, School of Health Sciences, University of Wollongong, NSW 2522, Australia

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ABSTRACT

The incidence of obesity is rising worldwide at an alarming rate and is becoming a major public health concern with incalculable social and economic costs. Studies have exposed the relationship between the adiposity, inflammation and the development of other metabolic disorders, so dietary factors that influence some or all of these are of interest. Dietary phytochemicals appear to be able to target different stages of the adipocyte (fat cell) lifecycle. For example, several classes of polyphenols have been implicated in suppressing the growth of adipose tissue through modifying the adipocyte lifecycle. Many dietary phytochemicals also have strong anti-inflammatory activity, but the amount present in plants varies and may be affected by processing. In this review we summarise the likely mechanisms of action of plant phytochemicals. We highlight the major vegetable sources of polyphenols, including those with possible synergistic attributes, discuss the variation in polyphenol levels and their distribution in cultivars and outline the effects of food processing. The identification and characterisation of the anti-obesogenic properties of phytochemicals in vegetables, as well as an appreciation of the effect of cooking on phytochemical content provide significant new information supporting dietary guidelines that encourage vegetable consumption for the prevention and management of lifestyle related disease.

Contents

* Corresponding author. Tel.: +61 7 32766041; fax: +61 7 32166591.
E-mail address: david.williams@daff.qld.gov.au (D.J. Williams).

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1. Introduction

In 1998 obesity was defined as a "phenotypic manifestation of abnormal or excessive fat accumulation that alters health and increases mortality" (World Health Organization, 1998). The WHO report stated that obesity had reached epidemic proportions worldwide. Since then its incidence has continued to rise at an alarming rate in both developed and developing countries and is becoming a major public health concern with incalculable social costs (Popkin, 2009; Popkin, Kim, Rusev, Du, & Zizza, 2006). There is a strong association between obesity and chronic diseases such as diabetes, cardiovascular diseases, hypertension, osteoarthritis, some cancers and inflammation-based pathologies which suggests that the obese are likely to have a disproportionate use of the health care system (Marinou, Tousoulis, Antonopoulos, Stefanadi, & Stefanadis, 2010; Piper, 2011; Singla, Bardoloi, & Parkash, 2010). In order to maintain quality of life for the population and decrease the economic burden on the health system, more powerful dietary strategies to help reduce this cluster of diseases are urgently required.

While the strategy of reducing dietary fat content combined with increased physical activity has been shown to be effective in preventing obesity (Astrup, 2001; World Health Organization, 2007), numerous studies have shown that this simple message is being ignored and alternative strategies are being sought (Kruger, Galuska, Serdula, & Jones, 2004; Stern et al., 1995; Wadden, 1993). Obesity is characterised at the cellular level by an increase in the number and size of adipocytes (fat storage cells) that have differentiated from pre-adipocytes in the adipose tissue (Furuyashiki et al., 2004). This transition from undifferentiated pre-adipocytes into mature adipocytes constitutes the adipocyte lifecycle, and hence treatments that regulate both the size and number of adipocytes may provide a valuable adjunct to reduced dietary energy in combating obesity. The relationship between adiposity and inflammation is also being gradually unravelled with the recognition that adipocytes also produce inflammatory cytokines, suggesting that obesity induces an inflammatory state which may lead to further disease progression (Grundy, 2012).

With this in mind considerable interest has been aroused worldwide in the potential of dietary phytochemicals to help counteract obesity (Park & Kim, 2011; Rayalam, Della-Fera, & Baile, 2008; Santos, Rogero, & Bastos, 2010). Cell culture and animal model studies have indicated that the anti-obesity effects occur through modification of the adipocyte lifecycle. Polyphenols are a class of phytochemicals that are likely candidates as anti-obesity agents as several studies have suggested they can modulate the adipocyte lifecycle (Rayalam et al., 2008; Yun, 2010). The strongest evidence for this effect comes from: phenolic acid derivatives such as chlorogenic acid (Camire, Kubow, & Donnelly, 2009; Pan, Lai, & Ho, 2010); flavonols e.g. quercetin (Yun, 2010); and flavones such as luteolin (Rayalam et al., 2008). These classes of polyphenols (Fig. 1) are widely distributed in plants and therefore are consumed regularly as part of the human diet.

Anti-obesity mechanisms of phytochemicals appear to involve mediation of complex and interconnected cell signalling pathways, therefore the combination of multiple phytochemicals may give rise to synergistic and enhanced anti-obesity effects. Synergistic interactions with combinations of phytochemicals have previously been investigated for the treatment of some cancers (Chan, Fong, Soprano, Holmes, & Heverling, 2003; Hermlswarya & Doble, 2006; Suganuma et al., 1999). However, such synergistic interactions among dietary bioactives acting on adipocytes have received only limited attention (Adams & Cory, 1998; Yang, Della-Fera, Hausman, & Baile, 2007). So far these studies have been encouraging with results indicating an enhanced induction of apoptosis and suppression of adipogenesis by phytochemicals used in combination. Phytochemical combinations that included polyphenols such as stilbene, resveratrol, genistein and naringenin have proven the most effective (Baile et al., 2011; Nelson-Dooley, Della-Fera, Hamrick, & Baile, 2005). Results from such studies suggest that anti-obesity effects could be achieved by consuming lower levels of phytochemicals but in specific combinations.

Vegetables provide a major dietary source for phytochemicals with potential anti-obesity properties, with the types and levels varying markedly between species and even cultivar (Nuutila, Puupponen-Pimia, Aarni, & Oksman-Caldentey, 2003; Singh, Upadhyay, Prasad, Bahadur, & Rai, 2007). In addition climatic, agronomic and harvest conditions also significantly influence the levels of these phytochemicals in vegetables (Naczk & Shahidi, 2006; Tiwari & Cummins, 2011).

Post-harvest operations, including food processing have a major influence on the levels of phytochemicals in vegetables and vegetable products. Conventional (thermal), non-thermal (e.g. high pressure, ultrasound, irradiation), domestic (e.g. washing, peeling, cutting) and industrial (canning, drying) processing are widely reported to degrade phytochemicals (Rawson, Koidis, Rai, Tuohy, & Brunton, 2010; Volden, Bengtsson, & Wicklund, 2009). Heat treatment is the most common method for processing vegetables because of its inactivation of pathogenic and spoilage microorganisms and endogenous enzymes leading to improved quality and shelf-life (Rawson et al., 2011). To retain phytochemicals during the various cooking treatments on offer, the food processor must optimise all steps in order to restrict their degradation.

With this backdrop, the aims of this review are to summarise the proposed mechanisms of action of phytochemicals on obesity related pathways, highlight the vegetable sources of phytochemicals, and discuss the influence of different cultivars and distributions within the vegetable source as well as the impact of cooking on the levels of these phytochemicals.

2. Mechanisms of action of phytochemicals on adiposity

The plausible mechanisms of action of certain vegetable phytochemicals include: (a) reducing adipose tissue mass by inhibiting the proliferation of precursor cells; (b) increasing the rate of apoptosis during the adipocyte lifecycle (Rayalam et al., 2008; Yun, 2010) and (c) the inhibition of dietary triglyceride absorption via reduction in pancreatic lipase formation (Birari & Bhutani, 2007). Obesity has been associated with a chronic inflammatory status (Pan et al., 2010) and the strong anti-inflammatory activity may be one of the mechanisms of action