DIETARY PHYTOCHEMICAL INDEX AND ITS ASSOCIATION TO BODY MASS INDEX AND HAEMOGLOBIN CONCENTRATION IN UPM FEMALE UNDERGRADUATES

KHOO ZHE CHIEN

Dissertation Submitted to the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, in Partial Fulfilment of the Requirements for the Master in Nutritional Sciences

September 2024

FPSK (m) 2024 1

ACKNOWLEDGEMENTS

First and foremost, I would like to convey my profound appreciation and gratitude to my supervisor, Dr. Salma Faeza Binti Ahmad Fuzi, for all of her assistance, patience, and dedication during the thesis writing process. Her support has been invaluable in helping me navigate this master journey.

Besides my supervisor, I am also deeply thankful to Dr. Norhafizah Binti Ab Manan, for her advice on data analysis and interpretation, which has significantly enhanced the clarity of my thesis.

I extend my special thanks to the examiners, Professor Dr. Norhasmah Binti Sulaiman, Associate Professor Dr. Hazizi Bin Abu Saad, Professor Madya Dr. Gan Wan Ying, Dr. Lee Siew Siew for their valuable comments, ideas and suggestions during the proposal presentation and viva voce. Their inputs have been beneficial for me to improve this thesis.

Biggest thanks to my supervisor's undergraduate students (researchers of the primary study), Nur Insyirah Binti Mohd Fuad and Nur Addini Binti Mat Saufi for sharing all the baseline data, allowing and supporting me in using their research data for my present study. I choose this moment to acknowledge their contribution gratefully.

Last but not least, gratitude is delivered to my family members that had directly or indirectly helped me throughout this project by providing me with their love, moral support, emotional understanding with unending inspiration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AMPK	Adenosine monophosphate-activated protein kinase
BMI	Body mass index
BSGs	Brewer's Spent Grains
CI	Confidence intervals
FRAP	Ferric reducing antioxidant power
HAMP	Hepcidin antimicrobial peptide
Hb	Haemoglobin
HPLC	High-performance liquid chromatography
IDA	Iron deficiency anaemia
IPH	Institute for Public Health
LDL	Low-density lipoprotein
MANS	Malaysian Adult Nutrition Survey
NHMS	National Health and Morbidity Survey
OR	Odds ratio
PI	Phytochemical index
PPARγ	Peroxisome proliferator activated receptor gamma gene
SQ-FFQ	Semi-quantitative food frequency questionnaire
TLR4/NF-κB	Toll like receptor 4/Nuclear factor kappa B
UPM	Universiti Putra Malaysia
WHO	World Health Organisation
WMD	Weighted mean difference

ABSTRACT

DIETARY PHYTOCHEMICAL INDEX AND ITS ASSOCIATION TO BODY MASS INDEX AND HAEMOGLOBIN CONCENTRATION IN UPM FEMALE UNDERGRADUATES

Khoo Zhe Chien, Salma Faeza Ahmad Fuzi

Introduction: The prevalence of obesity and anaemia among female population has emerged as a public health concern in Malaysia. Phytochemicals, the naturally occurring compounds in plant-based foods, demonstrated potential health benefits, including anti-obesity and anti-anaemic properties. Despite its potential benefits, few studies have explored this area, particularly with the use of the phytochemical index (PI) as a novel measurement tool in assessing dietary phytochemical intake, offering a new perspective on dietary assessment. Therefore, this study was designed to determine the associations between dietary PI with body mass index (BMI) and haemoglobin (Hb) concentration among female undergraduate students in Universiti Putra Malaysia (UPM). **Methods:** Information on the sociodemographic characteristics, anthropometric measurements and Hb concentration were collected in the primary study. This secondary data analysis study was focused on estimating the dietary PI based on 1-day 24-hour dietary recall data collected in the primary study, and assessing the associations with BMI and Hb concentration using Spearman's rank correlation. Logistic regression was used to determine the odds ratio (OR) of overweight/obese and anaemia across dietary PI quartiles. **Findings:** A total of 181 respondents with mean ± SD age of 21.14 ± 1.30 years old participated in this study. Among the participating respondents, the majority were Malay (75.7%), from the Faculty of Engineering (37.0%), and did not consume any of the phytochemical-rich foods (39.2%). Nearly 22.7% of the respondents were overweight/obese, with anaemia prevalence of 51.4%. Although bivariate analyses showed no significant correlations between dietary PI with BMI (r = -0.056, p = 0.455) and Hb (r = 0.074, p = 0.322), logistic regression showed that respondents in the third quartile of dietary PI (Q3) had significantly higher odds of being overweight/obese and anaemic compared to those in the highest quartile of dietary PI (Q4) (overweight/obese, OR: 3.250, CI: 1.048 – 10.074, $p < 0.05$; anaemia, OR: 2.500, CI: 1.064 – 5.874, $p < 0.05$). **Conclusion:** The

findings suggest that a higher dietary PI may be linked to a lower risk of obesity and anaemia in this population. These insights could inform future more targeted dietary interventions emphasising on phytochemical intake, for better management and prevention of obesity and anaemia, with the potential for developing local PI cut-offs.

ABSTRAK

INDEKS FITOKIMIA PEMAKANAN DAN PERKAITANNYA DENGAN INDEKS JISIM BADAN DAN KEPEKATAN HEMOGLOBIN DI PRASISWAZAH PEREMPUAN UPM

Khoo Zhe Chien, Salma Faeza Ahmad Fuzi

Pengenalan: Prevalens obesiti dan anemia dalam kalangan populasi perempuan telah muncul sebagai kebimbangan kesihatan awam di Malaysia. Fitokimia, sebatian semulajadi dalam makanan berasaskan tumbuhan, menunjukkan potensi manfaat kesihatan, termasuk sifat anti-obesiti dan anti-anemia. Walaupun potensi manfaatnya, beberapa kajian telah meneroka bidang ini, terutamanya dengan penggunaan indeks fitokimia (PI) sebagai alat pengukuran baru dalam menilai pengambilan fitokimia pemakanan, menawarkan perspektif baru tentang penilaian pemakanan. Oleh itu, kajian ini direka bentuk untuk menentukan perkaitan antara PI pemakanan dengan indeks jisim badan (BMI) dan kepekatan hemoglobin (Hb) dalam kalangan pelajar prasiswazah perempuan di Universiti Putra Malaysia (UPM). **Kaedah:** Maklumat tentang ciri sosiodemografi, pengukuran antropometri dan kepekatan Hb telah dikumpulkan dalam kajian utama. Kajian analisis data sekunder ini tertumpu pada menganggarkan PI pemakanan berdasarkan data daripada kaedah ingatan semula diet 1-hari 24-jam yang dikumpul dalam kajian utama, dan menilai perkaitannya dengan BMI dan kepekatan Hb menggunakan korelasi pangkat Spearman. Regresi logistik digunakan untuk menentukan nisbah kemungkinan (OR) lebihan berat badan/obes dan anemia merentasi kuartil PI pemakanan. **Keputusan:** Seramai 181 orang responden dengan min ± SD berumur 21.14 ± 1.30 tahun telah menyertai kajian ini. Antara responden yang mengambil bahagian, majoriti adalah Melayu (75.7%), dari Fakulti Kejuruteraan (37.0%), dan tidak mengambil mana-mana makanan yang kaya dengan fitokimia (39.2%). Sebanyak 22.7% daripada responden mempunyai berat badan berlebihan/obes, dengan prevalens anemia berjumlah 51.4%. Walaupun analisis bivariat tidak menunjukkan korelasi yang signifikan antara PI pemakanan dengan BMI (r = -0.056, p = 0.455) dan Hb (r = 0.074, p = 0.322), regresi logistik menunjukkan bahawa responden dalam kuartil tiga (Q3) PI pemakanan mempunyai kemungkinan yang lebih tinggi untuk mengalami lebihan berat badan/obes dan anemia berbanding

dengan kuartil tertinggi (Q4) PI pemakanan (lebihan berat badan/obes, OR: 3.250, CI: 1.048 – 10.074, $p < 0.05$; anemia, OR: 2.500, CI: 1.064 – 5.874, $p < 0.05$). **Kesimpulan:** Dapatan kajian menunjukkan bahawa PI pemakanan yang lebih tinggi mungkin dikaitkan dengan risiko obesiti dan anemia yang lebih rendah dalam populasi ini. Wawasan ini boleh memaklumkan intervensi diet yang lebih berkenaan pada masa hadapan yang menekankan pengambilan fitokimia, untuk pengurusan dan pencegahan obesiti dan anemia yang lebih baik, dengan potensi untuk membangunkan titik potong PI tempatan.

CHAPTER 1

INTRODUCTION

1.1 Background

Phytochemicals are naturally occurring compounds found in plants, including phenolic compounds, organosulfur compounds, isoprenoids and dietary fibres (Carnauba et al., 2017). Despite not being essential nutrients, the significant roles of phytochemicals on health include cancer preventive, cholesterol-lowering subsequently decreasing the risk of coronary heart disease, antidiabetic, anti-inflammatory and antioxidant properties were well acknowledged (Laka et al., 2022; Lamba & Garg, 2022). In the human diet, the most significant sources of phytochemicals are fruits and vegetables, either consumed raw or processed (Oz & Kafkas, 2017). Other dietary sources of phytochemicals include whole grains, nuts, legumes, tea, herbs and coffee (Monjotin et al., 2022; Park, 2023). Approximately 200,000 phytochemicals have been identified to date, with a proportion of 20,000 of those were fruits, vegetables, and grains (Patra, 2012).

Several methods have been used to investigate the effects of phytochemicals on health outcomes and to assess the phytochemical intake, with common methods involving the extraction of phytochemical content from foods and plant products. Luthria et al. (2015) reviewed various phytochemical extraction techniques from wheat samples, including the use of conventional solvents like acetone for phenolic compounds (Meneses et al., 2013), ultrasound-assisted extraction for lipid-soluble phenolic compounds such as alkylresorcinols (Geerkens et al., 2015), accelerated solvent extraction for phytosterols (Dunford et al., 2009), and hot acetone under reflux for plant sterols and steryl ferulates (Nurmi et al., 2012). On the other hand, when assessing human phytochemical intake, methods include measuring the phytochemical metabolites in the human samples. Polyphenol intake was assessed by measuring total polyphenol excretion in urine (Medina-Remón et al., 2015), carotenoids like lutein and

zeaxanthin in blood samples (Karppi et al., 2012), and phyto phenol metabolites or phenolic compounds quantified through analysis of faecal, blood and urine samples (Neacsu et al., 2017; Vitaglione et al., 2015).

Since quantification of phytochemicals from food sources or in human samples requires a significant investment of time and is impractical for large-scale population studies due to the high costs involved, McCarty (2004) proposed that dietary phytochemicals can be estimated by using dietary phytochemical index (PI) (Carvalhaes et al., 2023). Dietary PI is defined as the proportion of dietary calories coming from foods that are normally rich in phytochemicals, to reflect the phytochemicals content of a diet (McCarty, 2004). This index, which measures the energy intake from foods high in phytochemicals as a simple ratio to total energy intake, can be a useful and simple evaluation to promote the consumption of phytochemical rich sources during the nutrition intervention program (Eslami et al., 2020; Vincent et al., 2010). According to McCarty (2004), the best PI score has the theoretical potential to reach its peak at 100, achievable through a vegan diet, while other dietary patterns, like the typical American diet, often score considerably lower, frequently below 20.

Globally, adulthood obesity and overweight affected 39% and 13% of the world's population, respectively, with 1.9 billion adults suffering from being overweight and over 600 million of them being obese in 2016 (World Health Organization (WHO), 2021). According to the National Health and Morbidity Survey (NHMS), a growing trend of obesity prevalence in Malaysia was observed, increasing from 14% in 2006, 15.1% in 2011, 17.7% in 2015, and 19.7% in 2019 (Institute for Public Health (IPH), 2011; IPH, 2015; IPH, 2020). The main causes of obesity are environmental, genetic, and lifestyle factors, with eating behaviours being one of the significant factors contributing to obesity (Safaei et al., 2021; Wei et al., 2022). A review by Zhang et al. (2015) to summarise the recent progress on health benefits of phytochemicals recommended that plant foods should be taken into account as consumption of phytochemicals has been inversely linked to obesity and numerous chronic illnesses including cardiovascular diseases, diabetes and hypertension. Kumar et al. (2022) also suggested that the proposed mechanism underlying how

phytochemicals reduce the risk of obesity involves their impact on energy expenditure, lipase activity inhibition, and downregulating the differentiation of adipocytes. For example, quercetin, rutin and catechins induced white adipocytes browning to increase energy consumption (Zhang et al., 2019), polyphenols inhibit pancreatic lipase to reduce the fat absorption (Lunagariya et al., 2014), while kaempferol and rutin showed anti-adipogenic effect by inhibiting the cell cycle progression and reducing the expression of key adipogenic transcription factors (Khalilpourfarshbafi et al., 2019).

Not only have phytochemicals been shown to play a role in reducing obesity, but the findings by Cotoraci et al. (2021) also suggested their potential in indirectly addressing anaemia associated with chronic inflammation targeted in the elderly population, or directly induce the resolution of anaemia through antioxidant activity. Anaemia is a haematological condition caused by low blood levels of haemoglobin (Hb), typically below 13.5 g/dL for adult males and 12.5 g/dL for adult females, which reduces the ability to carry oxygen to the body cells (Cotoraci et al., 2021). According to WHO (2023), the main population groups affected by anaemia were mainly young children under the age of five and females, especially pregnant women and menstruating adolescent girls. It was estimated that nearly 40% which equates to 269 million children under the age of five, 37% of pregnant women and 30% of non-pregnant women were affected by anaemia. Poor diet, infections, chronic diseases, blood loss during menstruation and family history are several possible factors that can lead to anaemia (WHO, 2023). From a dietary perspective, the adequate intake of fruits and vegetables on a daily basis may serve to diminish the probability of developing anaemia, as suggested by Ghose and Yaya (2018). This beneficial effect may be attributed to carotenoids, a group of phytochemicals present in vegetables, which serves as precursors to vitamin A and contribute to the increase of iron absorption (Ilmiyati et al., 2021), by modulating the production of ferroportin genes that involved in iron intestinal absorption, either *in vivo* or *in vitro*, supported their positive effect in anaemia (Citelli et al., 2012). Besides, the antioxidant properties of phytochemicals like flavonoids may also serve to protect red blood cells from oxidative stress, thereby raising the Hb concentration, as suggested by Mazhar et al. (2017).

1.2 Problem Statement

University students were reported to have poor eating habits of meal skipping and low consumption of phytochemical sources. Bede et al. (2020) who assessed the dietary habits and nutritional status among medical students in Cameroon, Africa reported that approximately half of the university students were found to consume only two meals per day (49.8%). The same study also revealed that the intake of phytochemical-rich foods among university students was poor, with only 4.3% students consuming fruits, vegetables (22.1%) and legumes (8.4%) daily (Bede et al., 2020). Subramanian et al. (2019) assessed the whole grains consumption among Malaysian university students and found that the daily whole grains consumption was 13%, which was relatively low. In Lee et al. (2023) study, Malaysia university students showed a lower adherence to the dietary recommendations for phytochemical food groups, with 26.5% students met the daily recommendations of legumes and less than a quarter of students met the daily fruits (9.1%) and vegetables (4.5%) recommendations, but most of the students were able to meet the recommendations for non-phytochemical food groups, such as meat, poultry and eggs (84.8%). As dietary PI specifically reflects the intake of fruits, vegetables, legumes, and whole grains, low consumption of these foods typically results in a lower PI score (Vasmehjani et al., 2021)

These poor dietary patterns are particularly concerning given the high prevalence of obesity and anaemia among university students. Studies indicated the proportion of obese Malaysian university students ranged from 9.0% (Ahmad et al., 2023) to 17.6% (Radzi et al., 2019), while anaemia affected approximately 33.4% (Jawed et al., 2017) to 64.0% (Hassand, 2015) of female university students. In terms of gender differences, the prevalence of both obesity and anaemia is notably higher in females compared to males. According to the NHMS 2019 data for Malaysia, obesity rates were 24.7% in females and 15.3% in males, while anaemia affected approximately 30.4% of females and 12.6% of males (IPH, 2020). The high occurrence of these conditions among university students, particularly females, emphasises the need for effective dietary strategies such as increasing the intake of phytochemical-

rich foods that could improve the PI score to mitigate the risk factors associated with these diseases.

Several studies have consistently demonstrated inverse associations between dietary PI and body mass index (BMI), suggesting that a higher dietary PI was associated with a lower risk of being overweight and obesity. A study carried out by Vincent et al. (2010) in the United States found that individuals with higher dietary PI had significantly lower BMI, with obese adult group exhibiting a lower dietary PI compared to those of the normal weight group. Similar findings were reported in the studies involving children and adults from different regions, including Iran and Korea, where higher dietary PI was linked to a reduced likelihood of overweight, obesity, and abdominal obesity (Eslami et al., 2020; Im et al., 2020). Another study carried out by Orgeron et al. (2019) in the United States also found that dietary PI in normal weight adults was significantly greater than those who were obese and severely obese, whilst a strong inverse correlation was also found in the similar study between dietary PI and BMI. While these studies consistently showed inverse associations between dietary PI and BMI, the studies were carried out mostly focused on children and adult populations, with limited exploration in certain subgroups, such as university students, who are also at risk of obesity.

Not only has BMI been shown to link with dietary PI, but there is also emerging evidence suggesting that phytochemical intake could influence other health outcomes, such as anaemia. In a study conducted by Sabbah (2020) among female university students in Dubai (n = 251), it was found that factors such as high total body fat, physically inactive and poor dietary choices, including a high preference for junk foods, were related to an increased risk of anaemia among this demographic. As dietary factors appear to be a significant contributing factor to anaemia, recommendations often centre on promoting dietary diversity through increased consumption of fruits and vegetables, with the aim of addressing this ongoing problem (Beck et al., 2014). For this reason, Ghose and Yaya (2018) conducted a study on fruits and vegetables consumption to investigate whether or not the amount consumed was linked to anaemia among 15 to 49 years old non-pregnant women in Africa, and the findings

indicated that women with inadequate fruits and vegetables consumption had a higher risk of developing anaemia (Ghose & Yaya, 2018). A systematic review by Mutwiri et al. (2020) on nine studies involving children and women at reproductive age showed that improvements in Hb, serum ferritin and transferrin biomarkers were linked to the intake of improved legumes, and the prevalence of inflammation was reduced from baseline by 80%, suggesting that incorporating legumes into the diet could be an effective strategy to enhance Hb concentration and reduce the risk of anaemia by providing essential nutrients and reducing inflammation. Olii et al. (2022) analysed the effect of green beans and soybeans juice on Hb concentration among adolescent girls in Indonesia, where it was reported that both green beans and soybeans juice consumption led to significant increase in Hb concentration. Another study carried out in Indonesia demonstrated that Hb concentration of pregnant women was increased with green beans consumption, suggesting that the phytochemical content in green beans can potentially contribute to enhanced haematopoiesis and ultimately to a reduced occurrence of anaemia (Puspita et al., 2021). While individual food intakes have been extensively studied in relation to Hb concentration, research on dietary phytochemical indices remains limited.

Overall, most of the studies investigating the potential link between phytochemicals intake and obesity and anaemia were conducted in children, adults, pregnant women and non-pregnant women populations (Eslami et al., 2020; Ghose & Yaya, 2018; Im et al., 2020; Mutwiri et al., 2020; Olii et al., 2022; Orgeron et al., 2019; Puspita et al., 2021; Vincent et al., 2010). There is a lack of research on university students, who are more prone to obesity and anaemia due to unhealthy dietary habits, and no studies have yet examined their phytochemical intake using dietary phytochemical indices, particularly in Malaysia. Therefore, this study was aimed to determine the association between dietary PI and two variables of concern among university students – BMI and Hb concentration—specifically among female undergraduate students at Universiti Putra Malaysia (UPM).

The research questions for this study were:

- What is the dietary PI, derived from phytochemical intakes, among female undergraduate students in UPM?
- What is the BMI of female undergraduate students in UPM?
- What is the Hb concentration of female undergraduate students in UPM?
- Are there any association between dietary PI with (a) BMI and (b) Hb concentration among female undergraduate students in UPM?

1.3 Significance of the Study

This study is important because high prevalence of obesity and anaemia are the developing public health concerns in Malaysia. This study will help to find out the magnitude and distribution of phytochemical intake based on dietary PI, and prevalence of obesity and anaemia among female undergraduate students in Malaysia. Besides, this study also helps to examine whether BMI and Hb concentration are associated with high phytochemical intake. If significant associations are observed, this study will contribute to the body of information and provide insight on the importance of improving phytochemical intake with respect to reducing the risk of obesity and anaemia. Subsequently, it can act as a guide for nutritionists and healthcare professionals to plan an appropriate nutritional program in future. Meanwhile, it can also provide the necessary information for the policy-makers to formulate appropriate health policies in order to minimise the prevalence of obesity and anaemia in Malaysia.

1.4 Research Objectives

1.4.1 General Objective

To determine the associations between dietary PI with BMI and Hb concentration among female undergraduate students in UPM.

1.4.2 Specific Objectives

- To describe the sociodemographic characteristics of female undergraduate students in UPM.
- To determine the dietary PI of female undergraduate students in UPM.
- To determine the BMI of female undergraduate students in UPM.
- To determine the Hb concentration of female undergraduate students in UPM.
- To determine the association between dietary PI with (a) BMI and (b) Hb concentration among female undergraduate students in UPM.

1.5 Research Hypothesis

- Null hypothesis (H_0): There is no significant association between dietary PI and BMI among female undergraduate students in UPM.
  Alternative hypothesis (H_1): There is a significant association between dietary PI and BMI among female undergraduate students in UPM.
- Null hypothesis (H_0): There is no significant association between dietary PI and Hb concentration among female undergraduate students in UPM.
  Alternative hypothesis (H_1): There is a significant association between dietary PI and Hb concentration among female undergraduate students in UPM.

1.6 Research Framework

Figure 1.1 illustrates the research framework employed in the present study. This framework comprises a single independent variable and two dependent variables. The first part of the research framework concerns the association between dietary PI and BMI. The second part of the research framework concerns the association between dietary PI and Hb concentration.

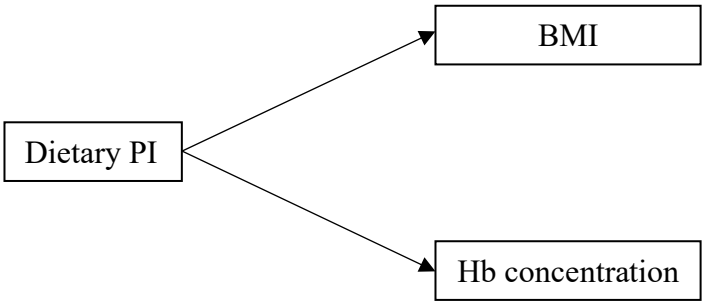

Figure 1.1: Research framework

REFERENCES

Abshirini, M., Mahaki, B., Bagheri, F., Siassi, F., Koohdani, F., & Sotoudeh, G. (2018). Higher intake of phytochemical-rich foods is inversely related to prediabetes: A case-control study. *International Journal of Preventive Medicine*, *9*(1), 64. https://doi.org/10.4103/ijpvm.IJPVM_145_18

Abubakar, A., & Haque, M. (2020). Preparation of medicinal plants: Basic extraction and fractionation procedures for experimental purposes. *Journal of Pharmacy And Bioallied Sciences*, *12*(1), 1. https://doi.org/10.4103/jpbs.JPBS_175_19

Aghababaei, F., & Hadidi, M. (2023). Recent advances in potential health benefits of quercetin. *Pharmaceuticals*, *16*(7), 1020. https://doi.org/10.3390/ph16071020

Aguilera, Y., & Benítez, V. (2021). Phytochemicals: Dietary sources, innovative extraction, and health benefits. *Foods*, *11*(1), 72. https://doi.org/10.3390/foods11010072

Aguirre, L., Fernández-Quintela, A., Arias, N., & Portillo, M. (2014). Resveratrol: Anti-obesity mechanisms of action. *Molecules*, *19*(11), 18632–18655. https://doi.org/10.3390/molecules191118632

Ahmad, S. N. F. F., Salehuddin, N. S., Sharoni, S. K. A., Fauzi, R., Buhari, S. S., & Md. Nor, N. (2023). Weight management behaviors among students in a public university. *Malaysian Journal of Nursing*, *14*(03), 67–75. https://doi.org/10.31674/mjn.2023.v14i03.008

Andrade, C. (2020). Sample size and its importance in research. *Indian Journal of Psychological Medicine*, *42*(1), 102–103. https://doi.org/10.4103/IJPSYM.IJPSYM_504_19

Ashok, C., & Karunanidhi, S. (2016). Prevalence of overweight and obesity among young female college students in Chennai city. *Journal of Obesity and Metabolic Research*, *3*(1), 23–23.

Bakrim, S., Benkhaira, N., Bourais, I., Benali, T., Lee, L.-H., El Omari, N., Sheikh, R. A., Goh, K. W., Ming, L. C., & Bouyahya, A. (2022). Health benefits and pharmacological properties of stigmasterol. *Antioxidants*, *11*(10), 1912. https://doi.org/10.3390/antiox11101912

Ballard, C. R., & Maróstica, M. R. (2019). Health benefits of flavonoids. In *Bioactive Compounds* (pp. 185–201). Elsevier. https://doi.org/10.1016/B978-0-12-814774-0.00010-4

Barreca, D., Trombetta, D., Smeriglio, A., Mandalari, G., Romeo, O., Felice, M. R., Gattuso, G., & Nabavi, S. M. (2021). Food flavonols: Nutraceuticals with complex health benefits and functionalities. *Trends in Food Science & Technology*, *117*, 194–204. https://doi.org/10.1016/j.tifs.2021.03.030

Beck, K., Conlon, C., Kruger, R., & Coad, J. (2014). Dietary determinants of and possible solutions to iron deficiency for young women living in industrialized

countries: A review. *Nutrients*, *6*(9), 3747–3776. https://doi.org/10.3390/nu6093747

Bede, F., Cumber, S. N., Nkfusai, C. N., Venyuy, M. A., Ijang, Y. P., Wepngong, E. N., & Nguti Kien, A. T. (2020). Dietary habits and nutritional status of medical school students: The case of three state universities in Cameroon. *The Pan African Medical Journal*, *35*, 15. https://doi.org/10.11604/pamj.2020.35.15.18818

Cabral, C. E., & Klein, M. R. S. T. (2017). Phytosterols in the treatment of hypercholesterolemia and prevention of cardiovascular diseases. *Arquivos Brasileiros de Cardiologia*. https://doi.org/10.5935/abc.20170158

Carnauba, R. A., Chaves, D. F. S., Baptistella, A. B., Paschoal, V., Naves, A., & Buehler, A. M. (2017). Association between high consumption of phytochemical-rich foods and anthropometric measures: A systematic review. *International Journal of Food Sciences and Nutrition*, *68*(2), 158–166. https://doi.org/10.1080/09637486.2016.1229761

Carpéné, C., Les, F., Casedas, G., Peiro, C., Fontaine, J., Chaplin, A., Mercader, J., & López, V. (2019). Resveratrol anti-obesity effects: Rapid inhibition of adipocyte glucose utilization. *Antioxidants*, *8*(3), 74. https://doi.org/10.3390/antiox8030074

Carvalhaes, V. Z., Meireles, G. C. X., Catarino, R. M., & Bueno, R. (2023). Association between the phytochemical index and risk factors for cardiovascular disease in adults. *International Journal of Cardiovascular Sciences*, *36*, e20220055. https://doi.org/10.36660/ijcs.20220055

Castañeda, R. B. Q., Turpo-Chaparro, J., Torres, J. H., Saintila, J., & Ruiz Mamani, P. G. (2021). Overweight and obesity, body fat, waist circumference, and anemia in Peruvian university students: A cross-sectional study. *Journal of Nutrition and Metabolism*, *2021*, 1–9. https://doi.org/10.1155/2021/5049037

Chagas, M. D. S. S., Behrens, M. D., Moragas-Tellis, C. J., Penedo, G. X. M., Silva, A. R., & Gonçalves-de-Albuquerque, C. F. (2022). Flavonols and flavones as potential anti-inflammatory, antioxidant, and antibacterial compounds. *Oxidative Medicine and Cellular Longevity*, *2022*, 1–21. https://doi.org/10.1155/2022/9966750

Chanput, W., Krueyos, N., & Ritthiruangdej, P. (2016). Anti-oxidative assays as markers for anti-inflammatory activity of flavonoids. *International Immunopharmacology*, *40*, 170–175. https://doi.org/10.1016/j.intimp.2016.08.038

Chen, C., Mokhtar, R. A. M., Sani, M. S. A., & Noor, N. Q. I. M. (2022). The effect of maturity and extraction solvents on bioactive compounds and antioxidant activity of mulberry (Morus alba) fruits and leaves. *Molecules*, *27*(8), 2406. https://doi.org/10.3390/molecules27082406

Citelli, M., Bittencourt, L. L., Da Silva, S. V., Pierucci, A. P. T., & Pedrosa, C. (2012). Vitamin A modulates the expression of genes involved in iron bioavailability.

Biological Trace Element Research, *149*(1), 64–70. https://doi.org/10.1007/s12011-012-9397-6

Coronel, J., Pinos, I., & Amengual, J. (2019). β-carotene in obesity research: Technical considerations and current status of the field. *Nutrients*, *11*(4), 842. https://doi.org/10.3390/nu11040842

Cory, H., Passarelli, S., Szeto, J., Tamez, M., & Mattei, J. (2018). The role of polyphenols in human health and food systems: A mini-review. *Frontiers in Nutrition*, *5*, 87. https://doi.org/10.3389/fnut.2018.00087

Costa, C., Tsatsakis, A., Mamoulakis, C., Teodoro, M., Briguglio, G., Caruso, E., Tsoukalas, D., Margina, D., Dardiotis, E., Kouretas, D., & Fenga, C. (2017). Current evidence on the effect of dietary polyphenols intake on chronic diseases. *Food and Chemical Toxicology*, *110*, 286–299. https://doi.org/10.1016/j.fct.2017.10.023

Cotoraci, C., Ciceu, A., Sasu, A., & Hermenean, A. (2021). Natural antioxidants in anemia treatment. *International Journal of Molecular Sciences*, *22*(4), 1883. https://doi.org/10.3390/ijms22041883

Craddock, J. C., Neale, E. P., Peoples, G. E., & Probst, Y. C. (2019). Vegetarian-based dietary patterns and their relation with inflammatory and immune biomarkers: A systematic review and meta-analysis. *Advances in Nutrition*, *10*(3), 433–451. https://doi.org/10.1093/advances/nmy103

Cunha, M. D. S. B. D., Campos Hankins, N. A., & Arruda, S. F. (2019). Effect of vitamin A supplementation on iron status in humans: A systematic review and meta-analysis. *Critical Reviews in Food Science and Nutrition*, *59*(11), 1767–1781. https://doi.org/10.1080/10408398.2018.1427552

Darooghegi Mofrad, M., Siassi, F., Guilani, B., Bellissimo, N., & Azadbakht, L. (2019). Association of dietary phytochemical index and mental health in women: A cross-sectional study. *British Journal of Nutrition*, *121*(09), 1049–1056. https://doi.org/10.1017/S0007114519000229

Dezateux, C., Williams, J., Walton, S., & Wells, J. (2016). *Life study standard operating procedures: Adult anthropometry*. Life Course Epidemiology and Biostatistics/ UCL Institute of Child Health. https://doi.org/10.14324/000.wp.1485682

Dunford, N. T., Irmak, S., & Jonnala, R. (2009). Effect of the solvent type and temperature on phytosterol contents and compositions of wheat straw, bran, and germ extracts. *Journal of Agricultural and Food Chemistry*, *57*(22), 10608–10611. https://doi.org/10.1021/jf9022383

Eslami, O., Khoshgoo, M., & Shidfar, F. (2020). Dietary phytochemical index and overweight/obesity in children: A cross-sectional study. *BMC Research Notes*, *13*(1), 132. https://doi.org/10.1186/s13104-020-04979-6

Farshori, N. N., Al-Oqail, M. M., Al-Sheddi, E. S., Al-Massarani, S. M., Alam, P., Siddiqui, M. A., Ahmad, J., & Al-Khedhairy, A. A. (2022). HPTLC estimation

and anticancer potential of Aloe perryi petroleum ether extract (APPeE): A mechanistic study on human breast cancer cells (MDA-MB-231). *Journal of King Saud University - Science*, *34*(4), 101968. https://doi.org/10.1016/j.jksus.2022.101968

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Firouzabadi, F. D., Jayedi, A., Asgari, E., Farazi, M., Noruzi, Z., Djafarian, K., & Shab-Bidar, S. (2021). The association of dietary phytochemical index with metabolic syndrome in adults. *Clinical Nutrition Research*, *10*(2), 161. https://doi.org/10.7762/cnr.2021.10.2.161

Gandola, A. E., Dainelli, L., Zimmermann, D., Dahlui, M., & Detzel, P. (2019). Milk powder fortified with potassium and phytosterols to decrease the risk of cardiovascular events among the adult population in Malaysia: A cost-effectiveness analysis. *Nutrients*, *11*(6), 1235. https://doi.org/10.3390/nu11061235

Geerkens, C. H., Matejka, A. E., Carle, R., & Schweiggert, R. M. (2015). Development and validation of an HPLC method for the determination of alk(en)ylresorcinols using rapid ultrasound-assisted extraction of mango peels and rye grains. *Food Chemistry*, *169*, 261–269. https://doi.org/10.1016/j.foodchem.2014.08.001

Ghoreishy, S. M., Aminianfar, A., Benisi-Kohansal, S., Azadbakht, L., & Esmaillzadeh, A. (2021). Association between dietary phytochemical index and breast cancer: A case–control study. *Breast Cancer*, *28*(6), 1283–1291. https://doi.org/10.1007/s12282-021-01265-6

Ghose, B., & Yaya, S. (2018). Fruit and vegetable consumption and anemia among adult non-pregnant women: Ghana demographic and health survey. *PeerJ*, *6*, e4414. https://doi.org/10.7717/peerj.4414

Ghosh, P., Dasgupta, A., Paul, B., Roy, S., Biswas, A., & Yadav, A. (2020). A cross-sectional study on prevalence and determinants of anemia among women of reproductive age in a rural community of West Bengal. *Journal of Family Medicine and Primary Care*, *9*(11), 5547. https://doi.org/10.4103/jfmpc.jfmpc_1209_20

Gomes, J. V. P., Rigolon, T. C. B., Souza, M. S. D. S., Alvarez-Leite, J. I., Lucia, C. M. D., Martino, H. S. D., & Rosa, C. D. O. B. (2019). Antiobesity effects of anthocyanins on mitochondrial biogenesis, inflammation, and oxidative stress: A systematic review. *Nutrition*, *66*, 192–202. https://doi.org/10.1016/j.nut.2019.05.005

Grosso, G., Stepaniak, U., Micek, A., Stefler, D., Bobak, M., & Pająk, A. (2017). Dietary polyphenols are inversely associated with metabolic syndrome in

Polish adults of the HAPIEE study. *European Journal of Nutrition*, *56*(4), 1409–1420. https://doi.org/10.1007/s00394-016-1187-z

Gupta, R. K., Gangoliya, S. S., & Singh, N. K. (2015). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. *Journal of Food Science and Technology*, *52*(2), 676–684. https://doi.org/10.1007/s13197-013-0978-y

Gylling, H., & Simonen, P. (2015). Phytosterols, phytostanols, and lipoprotein metabolism. *Nutrients*, *7*(9), 7965–7977. https://doi.org/10.3390/nu7095374

Ham, D., & Joung, H. (2020). Understanding the associations between dietary antioxidants and obesity. *Journal of Obesity & Metabolic Syndrome*, *29*(3), 163–165. https://doi.org/10.7570/jomes20070

Han, Y.-J., Baek, J.-H., Jung, S.-K., Yang, J., Shin, N.-R., & Park, M.-Y. (2023). Association between the dietary phytochemical index and lower prevalence of obesity in Korean preschoolers. *Nutrients*, *15*(11), 2439. https://doi.org/10.3390/nu15112439

Hassand, N. A. (2015). The prevalence of iron deficiency anemia in a Saudi University female students. *Journal of Microscopy and Ultrastructure*, *3*(1), 25. https://doi.org/10.1016/j.jmau.2014.11.003

Hostetler, G. L., Ralston, R. A., & Schwartz, S. J. (2017). Flavones: Food sources, bioavailability, metabolism, and bioactivity. *Advances in Nutrition*, *8*(3), 423–435. https://doi.org/10.3945/an.116.012948

Hulley, S. B., Cummings, S. R., Browner, W. S., Grady, D. G., & Newman, T. B. (2013). *Designing clinical research: An epidemiologic approach*. Lippincott Williams & Wilkins, Inc.

Ilmiyati, L., Indarto, D., & Wasita, B. (2021). Daily consumption of fruits and vegetables has different correlations with haemoglobin levels in young women at Karanganyar Regency. *Proceedings of the International Conference on Health and Medical Sciences (AHMS 2020)*. International Conference on Health and Medical Sciences (AHMS 2020), Yogyakarta, Indonesia. https://doi.org/10.2991/ahsr.k.210127.026

Im, J., Kim, M., & Park, K. (2020). Association between the phytochemical index and lower prevalence of obesity/abdominal obesity in Korean adults. *Nutrients*, *12*(8), Article 8. https://doi.org/10.3390/nu12082312

Imran, M., Ghorat, F., Ul-Haq, I., Ur-Rehman, H., Aslam, F., Heydari, M., Shariati, M. A., Okuskhanova, E., Yessimbekov, Z., Thiruvengadam, M., Hashempur, M. H., & Rebezov, M. (2020). Lycopene as a natural antioxidant used to prevent human health disorders. *Antioxidants*, *9*(8), 706. https://doi.org/10.3390/antiox9080706

Institute for Public Health (IPH). (2011). *National Health and Morbidity Survey 2011 (NHMS 2011). Vol. II: Non-Communicable Diseases*. Institute for Public Health, Ministry of Health, Malaysia.

Institute for Public Health (IPH). (2015). *National Health and Morbidity Survey 2015 (NHMS 2015). Vol. II: Non-Communicable Diseases, Risk Factors & Other Health Problems*. Institute for Public Health, Ministry of Health, Malaysia.

Institute for Public Health (IPH). (2020). *National Health and Morbidity Survey 2019 (NHMS 2019). Vol. I: NCDs—Non-Communicable Diseases: Risk Factors and other Health Problems*. Institute for Public Health, Ministry of Health, Malaysia.

Islam, T., Koboziev, I., Albracht-Schulte, K., Mistretta, B., Scoggin, S., Yosofvand, M., Moussa, H., Zabet-Moghaddam, M., Ramalingam, L., Gunaratne, P. H., & Moustaid-Moussa, N. (2021). Curcumin reduces adipose tissue inflammation and alters gut microbiota in diet-induced obese male mice. *Molecular Nutrition & Food Research*, *65*(22), 2100274. https://doi.org/10.1002/mnfr.202100274

Jawed, S., Tariq, S., Tariq, S., & Kamal, A. (2017). Frequency of nutritional anemia among female medical students of Faisalabad. *Pakistan Journal of Medical Sciences*, *33*(2). https://doi.org/10.12669/pjms.332.11854

Jiang, H., Pu, Y., Li, Z.-H., Liu, W., Deng, Y., Liang, R., Zhang, X.-M., & Zuo, H.-D. (2022). Adiponectin, may be a potential protective factor for obesity-related osteoarthritis. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *Volume 15*, 1305–1319. https://doi.org/10.2147/DMSO.S359330

Karppi, J., Laukkanen, J. A., & Kurl, S. (2012). Plasma lutein and zeaxanthin and the risk of age-related nuclear cataract among the elderly Finnish population. *British Journal of Nutrition*, *108*(1), 148–154. https://doi.org/10.1017/S0007114511005332

Kasprzak-Drozd, K., Oniszczuk, T., Gancarz, M., Kondracka, A., Rusinek, R., & Oniszczuk, A. (2022). Curcumin and weight loss: Does it work? *International Journal of Molecular Sciences*, *23*(2), 639. https://doi.org/10.3390/ijms23020639

Khairil-Shazmin, K., R., S. H., A., A., Yusof, H. M., & Wan Abdul Manan, W. M. (2021). Evaluation of somatotype, dietary intake and blood pressure among female students in Universiti Malaysia Terengganu (UMT), Malaysia. *Food Research*, *5*(2), 144–154. https://doi.org/10.26656/fr.2017.5(2).449

Khalilpourfarshbafi, M., Gholami, K., Murugan, D. D., Abdul Sattar, M. Z., & Abdullah, N. A. (2019). Differential effects of dietary flavonoids on adipogenesis. *European Journal of Nutrition*, *58*(1), 5–25. https://doi.org/10.1007/s00394-018-1663-8

Khandagale, S., Vaidya, R., Battalwar, R., Madan, J., & Udipi, S. (2018). Assessment of the dietary nutrient pattern and phytochemical index in diet of adolescents and young adults in Mumbai city. *Journal of Human Kinetics*, *4(1)*, 1905–1909.

Kim, C., & Park, K. (2022). Association between phytochemical index and inflammation in Korean adults. *Antioxidants*, *11*(2), 348. https://doi.org/10.3390/antiox11020348

Kim, D. E., Cho, S. H., Park, H. M., & Chang, Y. K. (2016). Relationship between bone mineral density and dietary intake of β-carotene, vitamin C, zinc and vegetables in postmenopausal Korean women: A cross-sectional study. *Journal of International Medical Research*, *44*(5), 1103–1114. https://doi.org/10.1177/0300060516662402

Kim, M., & Park, K. (2020). Association between phytochemical index and metabolic syndrome. *Nutrition Research and Practice*, *14*(3), 252. https://doi.org/10.4162/nrp.2020.14.3.252

Kumar, A., P, N., Kumar, M., Jose, A., Tomer, V., Oz, E., Proestos, C., Zeng, M., Elobeid, T., K, S., & Oz, F. (2023). Major phytochemicals: Recent advances in health benefits and extraction method. *Molecules*, *28*(2), 887. https://doi.org/10.3390/molecules28020887

Kumar, M., Suhag, R., Hasan, M., Dhumal, S., Radha, Pandiselvam, R., Senapathy, M., Sampathrajan, V., Punia, S., Sayed, A. A. S., Singh, S., & Kennedy, J. F. (2023). Black soybean (*Glycine max* (L.) Merr.): Paving the way toward new nutraceutical. *Critical Reviews in Food Science and Nutrition*, *63*(23), 6208–6234. https://doi.org/10.1080/10408398.2022.2029825

Kumar, V., Singh, D. D., Lakhawat, S. S., Yasmeen, N., Pandey, A., & Singla, R. K. (2022). Biogenic phytochemicals modulating obesity: From molecular mechanism to preventive and therapeutic approaches. *Evidence-Based Complementary and Alternative Medicine*, *2022*, 1–20. https://doi.org/10.1155/2022/6852276

Laka, K., Makgoo, L., & Mbita, Z. (2022). Cholesterol-lowering phytochemicals: Targeting the mevalonate pathway for anticancer interventions. *Frontiers in Genetics*, *13*, 841639. https://doi.org/10.3389/fgene.2022.841639

Lamba, A., & Garg, V. (2022). Assessment of nutritional status and academic performance of adolescents in relation to their phytochemical intake. *International Journal of Home Science*, *8*(1), 21–25. https://doi.org/10.22271/23957476.2022.v8.i1a.1223

Langford, E. (2006). Quartiles in elementary statistics. *Journal of Statistics Education*, *14*(3). https://doi.org/10.1080/10691898.2006.11910589

Lee, C. L., Abd Jamil, J., Chang, J. T., Yap, K. X., Yap, H. Y., & Khoo, W. J. (2023). Eating self-regulatory skill, diet quantity, and diet quality of Malaysian healthcare university students: A cross-sectional study. *Malaysian Journal of Nutrition*, *29*(1). https://doi.org/10.31246/mjn-2022-0025

Li, N., Liu, X., Zhang, J., Lang, Y.-Z., Lu, L., Mi, J., Cao, Y.-L., Yan, Y.-M., & Ran, L.-W. (2022). Preventive effects of anthocyanins from Lyciumruthenicum Murray in high-fat diet-induced obese mice are related to the regulation of intestinal microbiota and inhibition of pancreatic lipase activity. *Molecules*, *27*(7), 2141. https://doi.org/10.3390/molecules27072141

Li, X., Xin, Y., Mo, Y., Marozik, P., He, T., & Guo, H. (2022). The bioavailability and biological activities of phytosterols as modulators of cholesterol metabolism. *Molecules*, *27*(2), 523. https://doi.org/10.3390/molecules27020523

Listiarini, U. D., Sari, I. D., Chaniago, A. D., & Nadeak, E. (2021). The relationship of menstrual pattern with the incidence of anemia in adolescent girls at SMA PAB 5 Klumpang, Deli Serdang in 2021. *International Journal of Cultural and Social Science*, *2*(2), Article 2.

Liwa, A. C., Barton, E. N., Cole, W. C., & Nwokocha, C. R. (2017). Bioactive plant molecules, sources and mechanism of action in the treatment of cardiovascular disease. In *Pharmacognosy* (pp. 315–336). Elsevier. https://doi.org/10.1016/B978-0-12-802104-0.00015-9

Losso, J. N., Finley, J. W., Karki, N., Liu, A. G., Prudente, A., Tipton, R., Yu, Y., & Greenway, F. L. (2018). Pilot study of the tart cherry juice for the treatment of insomnia and investigation of mechanisms. *American Journal of Therapeutics*, *25*(2), e194–e201. https://doi.org/10.1097/MJT.0000000000000584

Lunagariya, N. A., Patel, N. K., Jagtap, S. C., & Bhutani, K. K. (2014). Inhibitors of pancreatic lipase: State of the art and clinical perspectives. *EXCLI Journal*, *13*, 897–921.

Luthria, D. L., Lu, Y., & John, K. M. M. (2015). Bioactive phytochemicals in wheat: Extraction, analysis, processing, and functional properties. *Journal of Functional Foods*, *18*, 910–925. https://doi.org/10.1016/j.jff.2015.01.001

Ma, H., Deng, W., Chen, H., & Ding, X. (2024). Association between dietary inflammatory index and anemia in US adults. *Frontiers in Nutrition*, *10*, 1310345. https://doi.org/10.3389/fnut.2023.1310345

Mans, D. R. A. (2023). Significance of carotenoids in traditional medicines in the Republic of Suriname (South America). In *Physiology* (Vol. 0). IntechOpen. https://doi.org/10.5772/intechopen.113013

Manthou, E., Georgakouli, K., Deli, C. K., Sotiropoulos, A., Fatouros, I. G., Kouretas, D., Haroutounian, S., Matthaiou, C., Koutedakis, Y., & Jamurtas, A. Z. (2017). Effect of pomegranate juice consumption on biochemical parameters and complete blood count. *Experimental and Therapeutic Medicine*, *14*(2), 1756–1762. https://doi.org/10.3892/etm.2017.4690

Maurya, P. K., Kumar, P., Nagotu, S., Chand, S., & Chandra, P. (2016). Multi-target detection of oxidative stress biomarkers in quercetin and myricetin treated human red blood cells. *RSC Advances*, *6*(58), 53195–53202. https://doi.org/10.1039/C6RA05121A

Mazhar, M., Faizi, S., Gul, A., Kabir, N., & Simjee, S. U. (2017). Effects of naturally occurring flavonoids on ferroportin expression in the spleen in iron deficiency anemia in vivo. *RSC Advances*, *7*(38), 23238–23245. https://doi.org/10.1039/C7RA02138K

Mazhar, M., Kabir, N., & Simjee, S. U. (2018). Quercetin modulates iron homeostasis and iNOS expression of splenic macrophages in a rat model of iron deficiency anemia. *Chinese Journal of Natural Medicines*, *16*(8), 580–589. https://doi.org/10.1016/S1875-5364(18)30095-5

McCarty, M. F. (2004). Proposal for a dietary "phytochemical index." *Medical Hypotheses*, *63*(5), 813–817. https://doi.org/10.1016/j.mehy.2002.11.004

Medina-Remón, A., Tresserra-Rimbau, A., Pons, A., Tur, J. A., Martorell, M., Ros, E., Buil-Cosiales, P., Sacanella, E., Covas, M. I., Corella, D., Salas-Salvadó, J., Gómez-Gracia, E., Ruiz-Gutiérrez, V., Ortega-Calvo, M., García-Valdueza, M., Arós, F., Saez, G. T., Serra-Majem, L., Pinto, X., … Lamuela-Raventos, R. M. (2015). Effects of total dietary polyphenols on plasma nitric oxide and blood pressure in a high cardiovascular risk cohort. The PREDIMED randomized trial. *Nutrition, Metabolism and Cardiovascular Diseases*, *25*(1), 60–67. https://doi.org/10.1016/j.numecd.2014.09.001

Meneses, N. G. T., Martins, S., Teixeira, J. A., & Mussatto, S. I. (2013). Influence of extraction solvents on the recovery of antioxidant phenolic compounds from brewer's spent grains. *Separation and Purification Technology*, *108*, 152–158. https://doi.org/10.1016/j.seppur.2013.02.015

Mirmiran, P., Bahadoran, Z., Golzarand, M., Shiva, N., & Azizi, F. (2012). Association between dietary phytochemical index and 3-year changes in weight, waist circumference and body adiposity index in adults: Tehran Lipid and Glucose study. *Nutrition & Metabolism*, *9*(1), 108. https://doi.org/10.1186/1743-7075-9-108

Mohammadi, A., Sahebkar, A., Iranshahi, M., Amini, M., Khojasteh, R., Ghayour-Mobarhan, M., & Ferns, G. A. (2013). Effects of supplementation with curcuminoids on dyslipidemia in obese patients: A randomized crossover trial. *Phytotherapy Research*, *27*(3), 374–379. https://doi.org/10.1002/ptr.4715

Monjotin, N., Amiot, M. J., Fleurentin, J., Morel, J. M., & Raynal, S. (2022). Clinical evidence of the benefits of phytonutrients in human healthcare. *Nutrients*, *14*(9), 1712. https://doi.org/10.3390/nu14091712

Morgan, L. V., Petry, F., Scatolin, M., De Oliveira, P. V., Alves, B. O., Zilli, G. A. L., Volfe, C. R. B., Oltramari, A. R., De Oliveira, D., Scapinello, J., & Müller, L. G. (2021). Investigation of the anti-inflammatory effects of stigmasterol in mice: Insight into its mechanism of action. *Behavioural Pharmacology*, *32*(8), 640–651. https://doi.org/10.1097/FBP.0000000000000658

Mu, M., An, P., Wu, Q., Shen, X., Shao, D., Wang, H., Zhang, Y., Zhang, S., Yao, H., Min, J., & Wang, F. (2016). The dietary flavonoid myricetin regulates iron homeostasis by suppressing hepcidin expression. *The Journal of Nutritional Biochemistry*, *30*, 53–61. https://doi.org/10.1016/j.jnutbio.2015.10.015

Mu, M., Wu, A., An, P., Du, X., Wu, Q., Shen, X., & Wang, F. (2014). Black soyabean seed coat extract regulates iron metabolism by inhibiting the expression of

hepcidin. *British Journal of Nutrition*, *111*(7), 1181–1189. https://doi.org/10.1017/S0007114513004005

Mutwiri, L. N., Kyallo, F., Kiage, B., Van der Schueren, B., & Matthys, C. (2020). Can improved legume varieties optimize iron status in low- and middle-income countries? A systematic review. *Advances in Nutrition*, *11*(5), 1315–1324. https://doi.org/10.1093/advances/nmaa038

Nagarajan, J., Ramanan, R. N., Raghunandan, M. E., Galanakis, C. M., & Krishnamurthy, N. P. (2017). Carotenoids. In *Nutraceutical and Functional Food Components* (pp. 259–296). Elsevier. https://doi.org/10.1016/B978-0-12-805257-0.00008-9

Neacsu, M., McMonagle, J., Fletcher, R. J., Hulshof, T., Duncan, S. H., Scobbie, L., Duncan, G. J., Cantlay, L., Horgan, G., De Roos, B., Duthie, G. G., & Russell, W. R. (2017). Availability and dose response of phytophenols from a wheat bran rich cereal product in healthy human volunteers. *Molecular Nutrition & Food Research*, *61*(3), 1600202. https://doi.org/10.1002/mnfr.201600202

Noor, H. S. M., Bakar, M. F. A., Bakar, F. I. A., Ismail, N. A., Sanusi, S. B., & Mohamed, M. (2019). Phytochemical content and antioxidant activity of selected wild ulam/vegetables consumed by indigenous Jakun community in Taman Negara Johor Endau Rompin (TNJER), Malaysia. *Food Research*, *4*(1), 28–33. https://doi.org/10.26656/fr.2017.4(1).179

Nurmi, T., Lampi, A.-M., Nyström, L., Hemery, Y., Rouau, X., & Piironen, V. (2012). Distribution and composition of phytosterols and steryl ferulates in wheat grain and bran fractions. *Journal of Cereal Science*, *56*(2), 379–388. https://doi.org/10.1016/j.jcs.2012.04.010

Olii, N., Herinawati, H., Sari, L. A., Susilawati, E., Gustina, G., Arifin, H., & Poddar, S. (2022). *The effects of green beans and soybean juice on haemoglobin (Hb) among female adolescents aged 12-14 years*.

Orgeron, R., Pope, J., Green, V., & Erickson, D. (2019). Phytonutrient intake and body composition: Considering colors. *Functional Foods in Health and Disease*, *9*(2), 108. https://doi.org/10.31989/ffhd.v9i2.583

Ostadmohammadi, V., Milajerdi, A., Ayati, E., Kolahdooz, F., & Asemi, Z. (2019). Effects of quercetin supplementation on glycemic control among patients with metabolic syndrome and related disorders: A systematic review and meta-analysis of randomized controlled trials. *Phytotherapy Research*, *33*(5), 1330–1340. https://doi.org/10.1002/ptr.6334

Oz, A. T., & Kafkas, E. (2017). Phytochemicals in fruits and vegetables. In V. Waisundara & N. Shiomi (Eds.), *Superfood and Functional Food—An Overview of Their Processing and Utilization*. InTech. https://doi.org/10.5772/66987

Palmer, B. F., & Clegg, D. J. (2017). Non-shivering thermogenesis as a mechanism to facilitate sustainable weight loss. *Obesity Reviews*, *18*(8), 819–831. https://doi.org/10.1111/obr.12563

Panche, A. N., Diwan, A. D., & Chandra, S. R. (2016). Flavonoids: An overview. *Journal of Nutritional Science*, *5*, e47. https://doi.org/10.1017/jns.2016.41

Park, K. (2023). The role of dietary phytochemicals: Evidence from epidemiological studies. *Nutrients*, *15*(6), 1371. https://doi.org/10.3390/nu15061371

Park, S., Choi, M., & Lee, M. (2021). Effects of anthocyanin supplementation on reduction of obesity criteria: A systematic review and meta-analysis of randomized controlled trials. *Nutrients*, *13*(6), 2121. https://doi.org/10.3390/nu13062121

Patra, A. K. (Ed.). (2012). *Dietary phytochemicals and microbes*. Springer Netherlands. https://doi.org/10.1007/978-94-007-3926-0

Pei, Y., Otieno, D., Gu, I., Lee, S.-O., Parks, J. S., Schimmel, K., & Kang, H. W. (2021). Effect of quercetin on nonshivering thermogenesis of brown adipose tissue in high-fat diet-induced obese mice. *The Journal of Nutritional Biochemistry*, *88*, 108532. https://doi.org/10.1016/j.jnutbio.2020.108532

Piskin, E., Cianciosi, D., Gulec, S., Tomas, M., & Capanoglu, E. (2022). Iron absorption: Factors, limitations, and improvement methods. *ACS Omega*, *7*(24), 20441–20456. https://doi.org/10.1021/acsomega.2c01833

Priyadarshani, A. M. B. (2017). A review on factors influencing bioaccessibility and bioefficacy of carotenoids. *Critical Reviews in Food Science and Nutrition*, *57*(8), 1710–1717. https://doi.org/10.1080/10408398.2015.1023431

Puspita, N. L. M., Laili, F., Kusumawati, L. S., Sa'adah, & Astutik, Y. (2021). The effect of green bean side effect on changes in hemoglobin levels in pregnant women with anemia. *Journal of Global Research in Public Health*, *6*(1), 48–51. https://doi.org/10.30994/jgrph.v6i1.313

Qauhiz, N. M. A. (2010). Obesity among Saudi female university students: Dietary habits and health behaviors. *The Journal of the Egyptian Public Health Association*, *85*(1–2), 45–59.

Qorbani, M., Angoorani, P., & Ejtahed, H.-S. (2022). Dietary phytochemical index as a biomarker in nutritional studies: Features and applications. In V. B. Patel & V. R. Preedy (Eds.), *Biomarkers in Nutrition* (pp. 307–328). Springer International Publishing. https://doi.org/10.1007/978-3-031-07389-2_18

Radzi, C. W. M., Jenatabadi, H. S., Alanzi, A., Mokhtar, M., Mamat, M., & Abdullah, N. (2019). Analysis of obesity among Malaysian university students: A combination study with the application of bayesian structural equation modelling and pearson correlation. *International Journal of Environmental Research and Public Health*, *16*(3), 492. https://doi.org/10.3390/ijerph16030492

Rahman, Md. A., Rahman, Md. S., Aziz Rahman, M., Szymlek-Gay, E. A., Uddin, R., & Islam, S. M. S. (2021). Prevalence of and factors associated with anaemia in women of reproductive age in Bangladesh, Maldives and Nepal: Evidence

from nationally-representative survey data. *PLOS ONE*, *16*(1), e0245335. https://doi.org/10.1371/journal.pone.0245335

Reichert, C. O., Marafon, F., Levy, D., Maselli, L. M. F., Bagatini, M. D., Blatt, S. L., Bydlowski, S. P., & Spada, C. (2018). Influence of hepcidin in the development of anemia. In J. Khan (Ed.), *Current Topics in Anemia*. InTech. https://doi.org/10.5772/intechopen.71476

Rex, J. R. S., Msa, M. N., & Selvakumar, P. M. (2018). Phytochemicals as a potential source for anti-microbial, anti-oxidant and wound healing—A review. *MOJ Bioorganic & Organic Chemistry*, *2*(2). https://doi.org/10.15406/mojboc.2018.02.0058

Rifat, H., Patcharanee, P., & Mondha, K. (2021). Parental factors determining the obesity prevention behaviour among Thai female adolescents: A cross-sectional study. *Acta Scientific Medical Sciences*, *5*(9), 42–49.

Román, G. C., Jackson, R. E., Gadhia, R., Román, A. N., & Reis, J. (2019). Mediterranean diet: The role of long-chain ω-3 fatty acids in fish; polyphenols in fruits, vegetables, cereals, coffee, tea, cacao and wine; probiotics and vitamins in prevention of stroke, age-related cognitive decline, and Alzheimer disease. *Revue Neurologique*, *175*(10), 724–741. https://doi.org/10.1016/j.neurol.2019.08.005

Sabbah, H. A. (2020). Prevalence of overweight/obesity, anaemia and their associations among female university students in Dubai, United Arab Emirates: A cross-sectional study. *Journal of Nutritional Science*, *9*, e26. https://doi.org/10.1017/jns.2020.23

Safaei, M., Sundararajan, E. A., Driss, M., Boulila, W., & Shapi'i, A. (2021). A systematic literature review on obesity: Understanding the causes & consequences of obesity and reviewing various machine learning approaches used to predict obesity. *Computers in Biology and Medicine*, *136*, 104754. https://doi.org/10.1016/j.compbiomed.2021.104754

Sampath, S. J. P., Kotikalapudi, N., & Venkatesan, V. (2021). A novel therapeutic combination of mesenchymal stem cells and stigmasterol to attenuate osteoarthritis in rodent model system—A proof of concept study. *Stem Cell Investigation*, *8*, 5–5. https://doi.org/10.21037/sci-2020-048

Shyam, S., Khor, G.-L., Ambak, R., Mahadir, B., Hasnan, M., Ambu, S., Chu, W.-L., & Aris, T. (2020). Association between dietary patterns and overweight risk among Malaysian adults: Evidence from nationally representative surveys. *Public Health Nutrition*, *23*(2), 319–328. https://doi.org/10.1017/S1368980019001861

Siddiqui, S. A., Azmy Harahap, I., Suthar, P., Wu, Y. S., Ghosh, N., & Castro-Muñoz, R. (2023). A comprehensive review of phytonutrients as a dietary therapy for obesity. *Foods*, *12*(19), 3610. https://doi.org/10.3390/foods12193610

Singh, M., Thrimawithana, T., Shukla, R., & Adhikari, B. (2020). Managing obesity through natural polyphenols: A review. *Future Foods*, *1–2*, 100002. https://doi.org/10.1016/j.fufo.2020.100002

Somsak, N., Peerawit, P., & Chusri, T. (2015). Hypoglycemic activity in diabetic rats of stigmasterol and sitosterol-3-O--D-glucopyranoside isolated from Pseuderanthemum palatiferum (Nees) Radlk. Leaf extract. *Journal of Medicinal Plants Research*, *9*(20), 629–635. https://doi.org/10.5897/JMPR2014.5722

Subramanian, S., Patil, S., Ponnusamy, S., Hasamnis, A., Loh, K., & Santosh, N. (2019). Whole-grain consumption and its determinants in Malaysian medical students: A cross-sectional study. *Indian Journal of Public Health*, *63*(3), 220. https://doi.org/10.4103/ijph.IJPH_278_18

Taheri, Y., Suleria, H. A. R., Martins, N., Sytar, O., Beyatli, A., Yeskaliyeva, B., Seitimova, G., Salehi, B., Semwal, P., Painuli, S., Kumar, A., Azzini, E., Martorell, M., Setzer, W. N., Maroyi, A., & Sharifi-Rad, J. (2020). Myricetin bioactive effects: Moving from preclinical evidence to potential clinical applications. *BMC Complementary Medicine and Therapies*, *20*(1), 241. https://doi.org/10.1186/s12906-020-03033-z

Talsma, E. F., Brouwer, I. D., Verhoef, H., Mbera, G. N., Mwangi, A. M., Demir, A. Y., Maziya-Dixon, B., Boy, E., Zimmermann, M. B., & Melse-Boonstra, A. (2016). Biofortified yellow cassava and vitamin A status of Kenyan children: A randomized controlled trial. *The American Journal of Clinical Nutrition*, *103*(1), 258–267. https://doi.org/10.3945/ajcn.114.100164

Tapera, R., Merapelo, M. T., Tumoyagae, T., Maswabi, T. M., Erick, P., Letsholo, B., & Mbongwe, B. (2017). The prevalence and factors associated with overweight and obesity among University of Botswana students. *Cogent Medicine*, *4*(1), 1357249. https://doi.org/10.1080/2331205X.2017.1357249

Tee, E. S., Mohd, I. N., Mohd, N. A., & Khatijah, I. (1997). *Nutrition composition of Malaysian foods* (Fourth Edition). Malaysia: Ministry of Health.

Tiwari, U., & Cummins, E. (2013). Factors influencing levels of phytochemicals in selected fruit and vegetables during pre- and post-harvest food processing operations. *Food Research International*, *50*(2), 497–506. https://doi.org/10.1016/j.foodres.2011.09.007

Urbatzka, R., Freitas, S., Palmeira, A., Almeida, T., Moreira, J., Azevedo, C., Afonso, C., Correia-da-Silva, M., Sousa, E., Pinto, M., & Vasconcelos, V. (2018). Lipid reducing activity and toxicity profiles of a library of polyphenol derivatives. *European Journal of Medicinal Chemistry*, *151*, 272–284. https://doi.org/10.1016/j.ejmech.2018.03.036

Vasmehjani, A. A., Darabi, Z., Nadjarzadeh, A., Mirzaei, M., & Hosseinzadeh, M. (2021). The relation between dietary phytochemical index and metabolic syndrome and its components in a large sample of Iranian adults: A population-

based study. *BMC Public Health*, *21*(1), 1587. https://doi.org/10.1186/s12889-021-11590-2

Vincent, H. K., Bourguignon, C. M., & Taylor, A. G. (2010). Relationship of the dietary phytochemical index to weight gain, oxidative stress and inflammation in overweight young adults. *Journal of Human Nutrition and Dietetics: The Official Journal of the British Dietetic Association*, *23*(1), 20–29. https://doi.org/10.1111/j.1365-277X.2009.00987.x

Vitaglione, P., Mennella, I., Ferracane, R., Rivellese, A. A., Giacco, R., Ercolini, D., Gibbons, S. M., La Storia, A., Gilbert, J. A., Jonnalagadda, S., Thielecke, F., Gallo, M. A., Scalfi, L., & Fogliano, V. (2015). Whole-grain wheat consumption reduces inflammation in a randomized controlled trial on overweight and obese subjects with unhealthy dietary and lifestyle behaviors: Role of polyphenols bound to cereal dietary fiber. *The American Journal of Clinical Nutrition*, *101*(2), 251–261. https://doi.org/10.3945/ajcn.114.088120

Wang, L., Li, B., Pan, M.-X., Mo, X.-F., Chen, Y.-M., & Zhang, C.-X. (2014). Specific carotenoid intake is inversely associated with the risk of breast cancer among Chinese women. *British Journal of Nutrition*, *111*(9), 1686–1695. https://doi.org/10.1017/S000711451300411X

Wang, S., Liang, X., Yang, Q., Fu, X., Zhu, M., Rodgers, B. D., Jiang, Q., Dodson, M. V., & Du, M. (2017). Resveratrol enhances brown adipocyte formation and function by activating AMP-activated protein kinase (AMPK) α1 in mice fed high-fat diet. *Molecular Nutrition & Food Research*, *61*(4), 1600746. https://doi.org/10.1002/mnfr.201600746

Wang, S., Moustaid-Moussa, N., Chen, L., Mo, H., Shastri, A., Su, R., Bapat, P., Kwun, I., & Shen, C.-L. (2014). Novel insights of dietary polyphenols and obesity. *The Journal of Nutritional Biochemistry*, *25*(1), 1–18. https://doi.org/10.1016/j.jnutbio.2013.09.001

Wei, C., Liu, L., Liu, R., Dai, W., Cui, W., & Li, D. (2022). Association between the phytochemical index and overweight/obesity: A meta-analysis. *Nutrients*, *14*(7), Article 7. https://doi.org/10.3390/nu14071429

Weidlinger, S., Winterberger, K., Pape, J., Weidlinger, M., Janka, H., Von Wolff, M., & Stute, P. (2023). Impact of estrogens on resting energy expenditure: A systematic review. *Obesity Reviews*, *24*(10), e13605. https://doi.org/10.1111/obr.13605

World Health Organization (WHO). (2010). *A healthy lifestyle—WHO recommendations*. https://www.who.int/europe/news-room/fact-sheets/item/a-healthy-lifestyle---who-recommendations

World Health Organization (WHO). (2021). *Obesity and overweight*. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

World Health Organization (WHO). (2023). *Anaemia*. https://www.who.int/news-room/fact-sheets/detail/anaemia

World Health Organization (WHO). (n.d). *Proportion of women reproductive age with anemia (%)*. https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3436

Wu, T., Jiang, Z., Yin, J., Long, H., & Zheng, X. (2016). Anti-obesity effects of artificial planting blueberry (*Vaccinium ashei*) anthocyanin in high-fat diet-treated mice. *International Journal of Food Sciences and Nutrition*, *67*(3), 257–264. https://doi.org/10.3109/09637486.2016.1146235

Yee, M. M. F., Chin, K.-Y., Ima-Nirwana, S., & Wong, S. K. (2021). Vitamin A and bone health: A review on current evidence. *Molecules*, *26*(6), 1757. https://doi.org/10.3390/molecules26061757

Yoo, S., Kim, K., Nam, H., & Lee, D. (2018). Discovering health benefits of phytochemicals with integrated analysis of the molecular network, chemical properties and ethnopharmacological evidence. *Nutrients*, *10*(8), 1042. https://doi.org/10.3390/nu10081042

Zhang, S., Cui, Y., Gao, X., Wei, C., Wang, Q., Yang, B., Sun, W., Luo, Y., Jiang, Q., & Huang, Y. (2023). Resveratrol inhibits the formation and accumulation of lipid droplets through AdipoQ signal pathway and lipid metabolism lncRNAs. *The Journal of Nutritional Biochemistry*, *117*, 109351. https://doi.org/10.1016/j.jnutbio.2023.109351

Zhang, X., Li, X., Fang, H., Guo, F., Li, F., Chen, A., & Huang, S. (2019). Flavonoids as inducers of white adipose tissue browning and thermogenesis: Signalling pathways and molecular triggers. *Nutrition & Metabolism*, *16*(1), 47. https://doi.org/10.1186/s12986-019-0370-7

Zhang, Y.-J., Gan, R.-Y., Li, S., Zhou, Y., Li, A.-N., Xu, D.-P., & Li, H.-B. (2015). Antioxidant phytochemicals for the prevention and treatment of chronic diseases. *Molecules*, *20*(12), 21138–21156. https://doi.org/10.3390/molecules201219753