UNIVERSITI PUTRA MALAYSIA

LOCAL PALM HEARTS (UMBUT) AS POTENTIAL PREBIOTIC INGREDIENTS USING IN VITRO COLON MODEL EXPERIMENTATION

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FSPP 2021 4

LOCAL PALM HEARTS (*UMBUT*) AS POTENTIAL PREBIOTIC INGREDIENTS USING *IN VITRO* COLON MODEL EXPERIMENTATION

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

February 2021

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

LOCAL PALM HEARTS (*UMBUT*) AS POTENTIAL PREBIOTIC INGREDIENTS USING *IN VITRO* COLON MODEL EXPERIMENTATION

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Chair : Prof. Shahrul Razid Sarbini, PhD
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Over the few past decades, rapid growth of palm trees has brought a significant impact on economic development in Malaysia. However, many parts of local palms are underutilized as scarce data available on the nutrient profiles of palm trees in Malaysia. In this study, edible core from the palm trees cultivated in Sarawak, Malaysia, notably the oil palm (*Elaeis guineensis*), sago palm (*Metroxylon sagu*) and coconut (*Cocos nucifera*) were investigated for their nutritive constituents and prebiotic potential. Inulin, which is a well-established prebiotic, was used as positive control. The raw and cooked palm hearts were prepared for a sequential gastrointestinal system model to study their stability in the simulated saliva, gastric and intestinal conditions. Meanwhile, the pH-controlled batch culture system was used to delineate the fermentation properties on the colonic microbiota. Samples were obtained at 0, 6^{th}, 12^{th} and 24^{th} hour for bacterial enumeration by fluorescent *in situ* hybridisation (FISH) and short-chain fatty acid (SCFA) analyses. Among the tested samples, sago palm hearts showed significant highest carbohydrates content (66.81 %) and significant highest potassium content (66 %). All the samples which are partially resistant to the gastrointestinal enzymatic reactions induced similar selective effects towards beneficial bacteria populations as inulin did at the end of fermentation. The highest significant decrease ($p \leq 0.05$) in *Clostridium histolyticum* group populations was observed in the response of raw sago palm hearts at the 24^{th} hour. In general, all the tested substrates produced significantly higher total SCFAs ($p \leq 0.05$) than inulin at the 24^{th} hour with the highest production by sago palm heart which was used as raw (286.18 mM) and cooked (284.83 mM). Overall, these findings suggested that raw local palm heart species induced a selective effect towards human gut microbiota and stimulated production of SCFA, indicating potential prebiotic ingredients.

Keywords: Prebiotics; Palm heart; Gut microbiota; Colon model; *In vitro* fermentation

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

UMBUT TEMPATAN SEBAGAI RAMUAN BERPOTENSI PREBIOTIK MENGGUNAKAN EXPERIMANTASI *IN VITRO* MODEL USUS BESAR

Oleh

CHAI LEE LING

Februari 2021

Pengerusi : Prof. Shahrul Razid Sarbini, PhD
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Sejak beberapa dekad yang lalu, penanaman pokok sawit telah membawa impak yang besar terhadap pembangunan ekonomi di Malaysia. Walau bagaimanapun, banyak bahagian sawit tempatan menjadi sisa pembuangan hasil tanaman disebabkan kekurangan maklumat tentang profil nutrien pokok sawit di Malaysia. Dalam kajian ini, umbut daripada kelapa sawit (Elaeis guineensis), pokok sagu (Metroxylon sagu) dan kelapa (Cocos nucifera) ditanam di Sarawak, Malaysia disiasat untuk kandungan nutrien dan potensi prebiotiknya. Inulin, bahan prebiotik yang terkenal, digunakan sebagai kawalan positif dalam kajian ini. Sampel mentah dan dimasak disediakan untuk sistem penghadaman sistem gastrousus bagi mengkaji kestabilan jantung sawit dalam simulasi air liur, gastrik dan usus. Sementara itu, model usus besar dengan kawalan pH digunakan untuk meniru proses penapaian pada mikrobiota dalam gastrousus manusia. Penghasilan bakteria daripada sampel yang diperolehi pada 0, 6, 12 dan 24 jam penapaian dinilai melalui analisis hibridisasi in situ pendarfluor (FISH) dan analisis asid lemak rantaian pendek (SCFA). Antara sampel yang diuji, umbut sagu menunjukkan kandungan karbohidrat tertinggi yang signifikan (66.81%) dan kandungan kalium tertinggi yang signifikan (66%). Semua sampel yang boleh tahan terhadap reaksi enzimatik gastrointestinal menimbulkan kesan selektif yang serupa terhadap populasi bakteria bermanfaat seperti yang dilakukan oleh inulin pada akhir penapaian. Penurunan signifikan tertinggi ($p \leq 0.05$) dalam populasi kumpulan Clostridium histolyticum diperhatikan dalam tindak balas umbut sagu sawit mentah pada 24 jam. Secara umum, semua substrat yang diuji menghasilkan jumlah SCFA yang lebih tinggi ($p \leq 0.05$) berbanding inulin pada jam ke-24 dengan pengeluaran tertinggi oleh jantung sawit sagu yang digunakan sebagai mentah (286.18 mM) dan dimasak (284.83 mM). Secara keseluruhan, penemuan ini menunjukkan bahawa spesies umbut sawit mentah tempatan memberikan kesan selektif terhadap mikrobiota usus manusia dan merangsang pengeluaran SCFA, yang menunjukkan ramuan prebiotik yang berpotensi.

Kata kunci: Prebiotik; Umbut; Model usus besar; Sistem penapaian *in vitro*

ACKNOWLEDGEMENTS

First of all, I would like to thank my parents, Chai Nam Moh @ Nam Fah and Sim Miaw Fung as well as my sisters, Chai Lee Ying and Chai Lee Xing for their endless support and encouragement in assuring my success in every step of my educational career. Sincere appreciation to Prof. Dr. Shahrul Razid Sarbini as my project supervisor for his guidance, encouragement, and constant support in this master project. Especially, I am thankful for his unfailing patience and critical outlook during the writing of this thesis and manuscripts for publication. My deep gratitude is also expressed to Dr. Lim Seng Joe and Dr. Noorasmah Saupi as co-supervisors for their assistance and advice throughout the research activity.

I would also like to express my deepest appreciation to the research teammates, Mrs Kathleen Michelle Mikal, Mr. Mohamad Hanif bin Rawi, Miss Tan Hui Yan, Miss Mayrilyn Solo and Miss Nur Bazilah Binti Burhan for their enthusiastic assistance and support in using the various laboratory and *in vitro* colon model equipment. Besides, I would like to thank our laboratory assistants, Miss Georgina Sylvia Ak Niwin and Miss Sawiyah Tori for their assistance throughout my research.

Last but not the least, special thanks to all my friends especially Hamad Mohamad Salah Hamad Ahallil and Ali Maru for their kindness and moral support during my study. My thanks also go to those who supported me in any way during my research.

I certify that a Thesis Examination Committee has met on 18 February 2022 to conduct the final examination of Chai Lee Ling on her thesis entitled "Local Palm Hearts (*Umbut*) as Potential Prebiotic Ingredients using *In Vitro* Colon Model Experimentation" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

DF	Dietary fibre
FISH	Fluorescence in situ Hybridization
GIT	Gastrointestinal Tract
HPLC	High Performance Liquid Chromatography
PHS	Phenol Sulphuric Acid
NSC	Non-digestible carbohydrate
NSP	Non-Starch Polysaccharides
SCFAs	Short Chain Fatty Acids
SSF	Simulated Salivary Fluid
SGF	Simulated Gastric Fluid
SIF	Simulated Intestinal Fluid
TFA	Trifluoroacetic acid

CHAPTER 1

INTRODUCTION

1.1 Study background

In alignment with Hippocrates' aphorisms "Let food be thy medicine and medicine be thy food", the concern on the administration of nutritive diet has resulted in the growing interest in finding alternative sources for functional food, such as prebiotics. Prebiotic is a non-digestible food ingredient that beneficial to the host by selectively stimulating the growth and activity of one or restricted numbers of colonic bacteria and thereby enhancing the host health (Gibson *et al.*, 2017a; Roberfroid *et al.*, 2010). Recent years, there is some interest in the alteration of the composition of the gut flora towards a potentially more remedial community through colonic anaerobic fermentation. In fact, the consumption of prebiotic has been shown to affect host health and well-being through various metabolic and physiological activities such as improvement of nutrient absorption, synthesis of bioactive compounds, improvement of intestinal barrier function, resistance to gut infections and modulation of the immune system (Sekirov *et al*., 2010). Realising on these health benefits of prebiotics, the global prebiotics market is projected to augment demand over the forecast period. According to a report by Grand View Research, Inc in 2016, the global prebiotic market is expected to reach a revenue of USD 7.11 billion by 2024.

Nowadays, the discovery of 'prebiotic plants' over the world is important in agriculture as well as medicine sectors which might offer better economic and social benefits. The very rich biodiversity of tropical rainforest in Malaysia, especially Sarawak offers an excellent source of indigenous vegetables and fruits. Realising the diverse pharmacology properties of locally available vegetables and fruits, most of the edible parts of plants can be utilised as health-promoting ingredients. One of the most well-known prebiotic ingredients naturally occurring in plants is inulin belonging to the group dietary fibres (Roberfroid, 2005). It was first discovered by German scientist Valentin Rose in 1804, from the *Inula helenium*, which is known as elecampane in the sunflower family *Asteraceae* (Boeckner *et al.*, 2001). Hence, the potential contribution of commercialised local plants can be a great interest to researchers for establishment of new direction towards alternative source of prebiotics from local crops.

In Malaysia, the palm industry has become the major commodities as a raw material in agribusiness and major contributor to Malaysia's export incomes. Palm trees are not only cultivated for their fruits, but other parts that may contain various nutritional properties (Sundram *et al.*, 2003). Due to the growing global demand on palm-based products, the cultivation areas of commodity palm species are increasing tremendously. As one of the promising plants are from palm trees, the inner core or known as palm hearts may contain specific

carbohydrates with prebiotic characteristics. In most of the palm cultivation areas, the palm tree stems are often underutilised and simply thrown away. With a sweet, subtle taste reminiscent of artichoke and an appearance resembling white asparagus, hearts of palm are a delicacy which may offer substantial nutritional benefits.

In this case, this study can provide information on the nutritional benefits of local palm hearts in Sarawak. Subsequently, the stability of palm hearts in the simulated saliva, gastric and intestinal conditions, as well as the effect of palm hearts towards the major colonic bacterial population and metabolites production through in vitro fermentation can further justify the study on the nutritive constituents from palm hearts as potential prebiotic. Therefore, this study is designed to explore more information and benefit of palm hearts towards human gut health to discover new direction towards an alternative source of functional foods from local crops.

1.2 Significance of study

The discovery of prebiotic-containing plants over the world is important in agriculture as well as medicine sectors to establish new direction towards the propagation of alternative prebiotic source which might offer better economic and social benefits. Therefore, the potential contribution of the heart of palm especially in terms of its nutritional values might be a great interest to researchers for investigation on prebiotics potential in various edible parts of palm species. However, research data on the phytochemistry and unique nutritive constituents of the edible cores from the palm tree stems are still scarce. Until now, only nutritional analysis on apong (*Nipa fruticans*) and nibong (*Oncosperma tigillaria*) palm hearts (Hoe *et al.*, 1999) has been published. In order to consider on the prebiotic potential of local palm hearts, the extracts must be tested on resistance to gastrointestinal acidity, the ability of fermentation by the gut microbiota producing metabolites such as short chain fatty acid (SCFAs) as well as able to selectively stimulate activity and growth of one or restricted number of gut bacteria that contribute to host health and well-being (Roberfroid et al., 2010; Roberfroid, 2007a). Hence, this study is designed to explore more information and benefit of hearts of selected palm species towards human gut health through probiotics improvement.

1.3 Objectives

The objectives of this study are:

i. To determine the proximate compositions and mineral contents of selected local palm hearts;
ii. To access the stability of various types of palm hearts in simulated gastrointestinal digestion;
iii. To evaluate the effect on the incorporation of palm hearts towards the major colonic bacterial population and metabolites production through fluorescent *in situ* hybridisation (FISH) and HPLC-UV analysis of fermentation metabolites production.

REFERENCES

Åberg, S., Mann, J., Neumann, S., Ross, A.B., Reynolds, A.N., 2020. Whole-grain processing and glycemic control in type 2 diabetes: A randomized crossover trial. Diabetes Care 43, 1717–1723.

Agrawal, N., Minj, D.K., Rani, K., 2015. Estimation of total carbohydrate present in dry fruits. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 1, 24–27.

Akmar, P.F., Kennedy, J.F., 2001. The potential of oil and sago palm trunk wastes as carbohydrate resources. Wood Science and Technology 35, 467–473.

Al-Sheraji, S.H., Ismail, A., Manap, M.Y., Mustafa, S., Yusof, R.M., Hassan, F.A., 2013. Prebiotics as functional foods: A review. Journal of Functional Foods 5, 1542–1553. https://doi.org/10.1016/j.jff.2013.08.009

Armenta, S., Moreno-Mendieta, S., Sánchez-Cuapio, Z., Sánchez, S., Rodríguez-Sanoja, R., 2017. Advances in molecular engineering of carbohydrate-binding modules. Proteins: Structure, Function, and Bioinformatics 85, 1602–1617.

Ashaolu, T.J., Ashaolu, J.O., Adeyeye, S.A., 2021. Fermentation of prebiotics by human colonic microbiota in vitro and short-chain fatty acids production: a critical review. Journal of Applied Microbiology 130, 677–687.

Asmussen, C.B., Dransfield, J., Deickmann, V., Barfod, A.S., Pintaud, J.-C., Baker, W.J., 2006. A new subfamily classification of the palm family (Arecaceae): evidence from plastid DNA phylogeny. Botanical Journal of the linnean Society 151, 15–38.

Bäckhed, F., Ley, R.E., Sonnenburg, J.L., Peterson, D.A., Gordon, J.I., 2005. Host-bacterial mutualism in the human intestine. science 307, 1915–1920.

Bajury, D., Nashri, S., King, P., Sarbini, S., 2017. Evaluation of potential prebiotics: a review. Food Reviews International 34. https://doi.org/10.1080/87559129.2017.1373287

Basu, P.P., Dinani, A., Rayapudi, K., Pacana, T., Shah, N.J., Hampole, H., Krishnaswamy, N.V., Mohan, V., 2010. Rifaximin therapy for metronidazole-unresponsive Clostridium difficile infection: a prospective pilot trial. Therapeutic advances in gastroenterology 3, 221–225.

Baur, D.A., Saunders, M.J., 2020. Carbohydrate supplementation: a critical review of recent innovations. European Journal of Applied Physiology 1–44.

Belenguer, A., Duncan, S.H., Calder, A.G., Holtrop, G., Louis, P., Lobley, G.E., Flint, H.J., 2006. Two routes of metabolic cross-feeding between Bifidobacterium adolescentis and butyrate-producing anaerobes from the human gut. Applied and environmental microbiology 72, 3593–3599.

Bellei, G., Haslberger, A., 2013. Dietary fibre and prebiotics. Journal of Experimental Medicine 14, 12–15.

Ben, X.-M., Li, J., Feng, Z.-T., Shi, S.-Y., Lu, Y.-D., Chen, R., Zhou, X.-Y., 2008. Low level of galacto-oligosaccharide in infant formula stimulates growth of intestinal Bifidobacteria and Lactobacilli. World journal of gastroenterology: WJG 14, 6564.

Berbesque, J.C., Marlowe, F.W., Shaw, P., Thompson, P., 2014. Hunter–gatherers have less famine than agriculturalists. Biology Letters 10, 20130853.

Bhat, R., Sridhar, K.R., 2008. Nutritional quality evaluation of electron beam-irradiated lotus (Nelumbo nucifera) seeds. Food Chemistry 107, 174–184.

Bihan, D., Rydzak, T., Wyss, M., Pittman, K., McCoy, K.D., Lewis, I.A., 2019. Method for absolute quantification of short chain fatty acids via reverse phase chromatography mass spectrometry.

Bindels, L., Delzenne, N., Cani, P., Walter, J., 2015. Opinion: Towards a more comprehensive concept for prebiotics. Nature reviews. Gastroenterology & hepatology 12. https://doi.org/10.1038/nrgastro.2015.47

Bingham, S.A., Day, N.E., Luben, R., Ferrari, P., Slimani, N., Norat, T., Clavel-Chapelon, F., Kesse, E., Nieters, A., Boeing, H., 2003. Dietary fibre in food and protection against colorectal cancer in the European Prospective Investigation into Cancer and Nutrition (EPIC): an observational study. The lancet 361, 1496–1501.

Birmani, M.W., Nawab, A., Ghani, M., Li, G., Xiao, M., An, L., 2019. A Review: role of inulin in animal nutrition. J. Food. Technol. Res 6, 18–27.

Blanco, A., Blanco, G., 2017. Chapter 12 - Digestion - Absorption, in: Blanco, A., Blanco, G. (Eds.), Medical Biochemistry. Academic Press, pp. 251–273. https://doi.org/10.1016/B978-0-12-803550-4.00012-4

Blaser, M.J., 2006. Who are we? Indigenous microbes and the ecology of human diseases. EMBO reports 7, 956–960.

Blaut, M., 2018. Composition and Function of the Gut Microbiome, in: The Gut Microbiome in Health and Disease. pp. 5–30. https://doi.org/10.1007/978-3-319-90545-7_2

Blaut, M., 2002. Relationship of prebiotics and food to intestinal microflora. European Journal of Nutrition 41, i11–i16.

Bloemen, J.G., Venema, K., van de Poll, M.C., Damink, S.W.O., Buurman, W.A., Dejong, C.H., 2009. Short chain fatty acids exchange across the gut and liver in humans measured at surgery. Clinical nutrition 28, 657–661.

Boeckner, L.S., Schnepf, M.I., Tungland, B.C., 2001. Inulin: a review of nutritional and health implications.

Borriello, S.P., Aktories, K., 2010. Clostridium perfringens, Clostridium difficile, and other Clostridium species. Topley & Wilson's Microbiology and Microbial Infections.

Bosscher, D., Van Loo, J., Franck, A., 2006. Inulin and oligofructose as prebiotics in the prevention of intestinal infections and diseases. Nutrition Research Reviews 19, 216–226.

Boyd, S.D., Liu, Y., Wang, C., Martin, V., Dunn-Walters, D.K., 2013. Human lymphocyte repertoires in ageing. Current opinion in immunology 25, 511–515.

Braga, R.M., Dourado, M.N., Araújo, W.L., 2016. Microbial interactions: ecology in a molecular perspective. brazilian journal of microbiology 47, 86–98.

Brestoff, J.R., Artis, D., 2013. Commensal bacteria at the interface of host metabolism and the immune system. Nature immunology 14, 676–684.

Brooks, C., Gausman, V., Kokoy-Mondragon, C., Munot, K., Amin, S.P., Desai, A., Kipp, C., Poneros, J., Sethi, A., Gress, F.G., 2018. Role of fluorescent in situ hybridization, cholangioscopic biopsies, and EUS-FNA in the evaluation of biliary strictures. Digestive diseases and sciences 63, 636–644.

Brou, R.M., Ekissi, G.S.E., Faulet, B.M., Fagbohoun, B.J., Kouamé, P.L., 2018. Impacts of Boiling Times on Physicochemical and Nutritive Composition from Heart of Oil Palm Tree (Elaeis guineensis Jacq.) Consumed as Vegetable in Côte d'Ivoire. Advances in Research 1–16.

Buttriss, J.L., Stokes, C.S., 2008. Dietary fibre and health: an overview. Nutrition Bulletin 33, 186–200.

Cashman, K., 2003. Prebiotics and calcium bioavailability. Current issues in intestinal microbiology 4, 21–32.

Causey, J.L., Feirtag, J.M., Gallaher, D.D., Tungland, B.C., Slavin, J.L., 2000. Effects of dietary inulin on serum lipids, blood glucose and the gastrointestinal environment in hypercholesterolemic men. Nutrition Research 20, 191–201.

Chase, M.W., 2004a. Monocot relationships: an overview. American Journal of Botany 91, 1645–1655.

Chase, M.W., 2004b. Monocot relationships: an overview. American Journal of Botany 91, 1645–1655.

Chehardoli, G., Norouzian, P., Firozian, F., 2020. Inulin-Grafted Stearate (In-g-St) as the Effective Self-Assembling Polymeric Micelle: Synthesis and Evaluation for the Delivery of Betamethasone. Journal of Nanomaterials 2020.

Chen, X., Sun, Y., Hu, L., Liu, S., Yu, H., Li, R., Wang, X., Li, P., 2018. In vitro prebiotic effects of seaweed polysaccharides. Journal of Oceanology and Limnology 36, 926–932.

Chen, Y., Chang, S.K., Zhang, Y., Hsu, C.-Y., Nannapaneni, R., 2020. Gut microbiota and short chain fatty acid composition as affected by legume type and processing methods as assessed by simulated in vitro digestion assays. Food chemistry 312, 126040.

Cheng, H.-H., Lai, M.-H., 2000. Fermentation of resistant rice starch produces propionate reducing serum and hepatic cholesterol in rats. The Journal of nutrition 130, 1991–1995.

Chervaux, C., Ehrlich, S.D., Maguin, E., 2000. Physiological study of Lactobacillus delbrueckii subsp. bulgaricus strains in a novel chemically defined medium. Applied and Environmental Microbiology 66, 5306–5311.

Christenhusz, M.J., Byng, J.W., 2016. The number of known plants species in the world and its annual increase. Phytotaxa 261, 201–217.

Clemente, J.C., Ursell, L.K., Parfrey, L.W., Knight, R., 2012. The impact of the gut microbiota on human health: an integrative view. Cell 148, 1258–1270.

Collado, M., Gil, J., Efeyan, A., Guerra, C., Schuhmacher, A.J., Barradas, M., Benguría, A., Zaballos, A., Flores, J.M., Barbacid, M., 2005. Senescence in premalignant tumours. Nature 436, 642–642.

Conlon, M.A., Bird, A.R., 2014. The impact of diet and lifestyle on gut microbiota and human health. Nutrients 7, 17–44. https://doi.org/10.3390/nu7010017

Cox, L.M., Yamanishi, S., Sohn, J., Alekseyenko, A.V., Leung, J.M., Cho, I., Kim, S.G., Li, H., Gao, Z., Mahana, D., 2014. Altering the intestinal microbiota during a critical developmental window has lasting metabolic consequences. Cell 158, 705–721.

Cui, S.W., 2005. Food carbohydrates: chemistry, physical properties, and applications. CRC press.

Cummings, J.H., 1981. Short chain fatty acids in the human colon. Gut 22, 763.

Cuvas-Limón, R.B., Julio, M.S., Carlos, C.E.J., Mario, C.H., Mussatto, S.I., Ruth, B.-C., 2016. Aloe vera and probiotics: a new alternative to symbiotic functional foods. Annual Research & Review in Biology 9, 1.

Damodaran, D., Shetty, K.V., Mohan, B.R., 2013. Effect of chelaters on bioaccumulation of Cd (II), Cu (II), Cr (VI), Pb (II) and Zn (II) in Galerina vittiformis from soil. International Biodeterioration & Biodegradation 85, 182–188.

Dan, M.C., Cardenette, G.H., Sardá, F.A., Giuntini, E.B., Bello-Pérez, L.A., Carpinelli, Â.R., Lajolo, F.M., Menezes, E.W., 2015. Colonic fermentation of unavailable carbohydrates from unripe banana and its influence over glycemic control. Plant foods for human nutrition 70, 297–303.

Daniel, H., 2020. Diet and the gut microbiome: from hype to hypothesis. British Journal of Nutrition 124, 521–530.

De Castro, M.L., Priego-Capote, F., 2010. Soxhlet extraction: Past and present panacea. Journal of Chromatography A 1217, 2383–2389.

de Paulo Farias, D., Neri-Numa, I.A., de Araújo, F.F., Pastore, G.M., 2020. A critical review of some fruit trees from the Myrtaceae family as promising sources for food applications with functional claims. Food chemistry 306, 125630.

de Souza, A.C., Prevedello, J.A., 2021. Climate change and biological invasion as additional threats to an imperiled palm. Perspectives in Ecology and Conservation.

Delgado, G.T.C., Tamashiro, W.M. da S.C., 2018. Role of prebiotics in regulation of microbiota and prevention of obesity. Food Research International 113, 183–188.

Delzenne, N.M., 2003. Oligosaccharides: state of the art. Proceedings of the nutrition Society 62, 177–182.

Delzenne, N.M., Daubioul, C., Neyrinck, A., Lasa, M., Taper, H., 2002. Inulin and oligofructose modulate lipid metabolism in animals: review of biochemical events and future prospects. British Journal of Nutrition 87, S255–S259.

Dikeman, C.L., Fahey Jr, G.C., 2006. Viscosity as related to dietary fiber: a review. Critical reviews in food science and nutrition 46, 649–663.

Donoghue, M.J., 2005. Key innovations, convergence, and success: macroevolutionary lessons from plant phylogeny. Paleobiology 31, 77–93.

Donohoe, D.R., Garge, N., Zhang, X., Sun, W., O'Connell, T.M., Bunger, M.K., Bultman, S.J., 2011. The microbiome and butyrate regulate energy metabolism and autophagy in the mammalian colon. Cell metabolism 13, 517–526.

Dwivedi, S., Sahrawat, K., Puppala, N., Ortiz, R., 2014a. Plant prebiotics and human health: Biotechnology to breed prebiotic-rich nutritious food crops. Electronic Journal of Biotechnology 17, 238–245.

Dwivedi, S., Sahrawat, K., Puppala, N., Ortiz, R., 2014b. Plant prebiotics and human health: Biotechnology to breed prebiotic-rich nutritious food crops. Electronic Journal of Biotechnology 17, 238–245.

EFSA Panel on Dietetic Products, N. and A. (NDA), 2011. Scientific Opinion on the substantiation of health claims related to the sugar replacers xylitol, sorbitol, mannitol, maltitol, lactitol, isomalt, erythritol, D-tagatose, isomaltulose, sucralose and polydextrose and maintenance of tooth mineralisation by decreasing tooth demineralisation (ID 463, 464, 563, 618, 647, 1182, 1591, 2907, 2921, 4300), and reduction of post-prandial glycaemic responses (ID 617, 619, 669, 1590, 1762, 2903, 2908, 2920) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. EFSA Journal 9, 2076. https://doi.org/10.2903/j.efsa.2011.2076

Eid, N., Osmanova, H., Natchez, C., Walton, G., Costabile, A., Gibson, G., Rowland, I., Spencer, J.P., 2015. Impact of palm date consumption on microbiota growth and large intestinal health: a randomised, controlled, cross-over, human intervention study. British Journal of Nutrition 114, 1226–1236.

Elia, M., Cummings, J.H., 2007. Physiological aspects of energy metabolism and gastrointestinal effects of carbohydrates. European Journal of Clinical Nutrition 61, S40.

Elli, M., Zink, R., Rytz, A., Reniero, R., Morelli, L., 2000. Iron requirement of Lactobacillus spp. in completely chemically defined growth media. Journal of applied microbiology 88, 695–703.

Englyst, K.N., Liu, S., Englyst, H.N., 2007. Nutritional characterization and measurement of dietary carbohydrates. European journal of clinical nutrition 61, S19–S39.

Faust, K., Sathirapongsasuti, J.F., Izard, J., Segata, N., Gevers, D., Raes, J., Huttenhower, C., 2012. Microbial co-occurrence relationships in the human microbiome. PLoS comput biol 8, e1002606.

Fernandez, M.A., Marette, A., 2017. Potential Health Benefits of Combining Yogurt and Fruits Based on Their Probiotic and Prebiotic Properties. Adv Nutr 8, 155S-164S. https://doi.org/10.3945/an.115.011114

Ferreira-Lazarte, A., Moreno, F.J., Villamiel, M., 2020. Bringing the digestibility of prebiotics into focus: update of carbohydrate digestion models. Critical Reviews in Food Science and Nutrition 1–12.

Flint, H.J., Scott, K.P., Louis, P., Duncan, S.H., 2012. The role of the gut microbiota in nutrition and health. Nature reviews Gastroenterology & hepatology 9, 577.

Floch, M.H., Hong-Curtiss, J., 2002. Probiotics and functional foods in gastrointestinal disorders. Current treatment options in gastroenterology 5, 311–321.

Fonteles, T.V., Rodrigues, S., 2018. Prebiotic in fruit juice: processing challenges, advances, and perspectives. Current Opinion in Food Science 22, 55–61.

Franks, A.H., Harmsen, H.J., Raangs, G.C., Jansen, G.J., Schut, F., Welling, G.W., 1998. Variations of bacterial populations in human feces measured by fluorescent in situ hybridization with group-specific 16S rRNA-targeted oligonucleotide probes. Applied and environmental microbiology 64, 3336–3345.

Fried, B., Sherma, J., 2017. Thin-Layer Chromatography in Food Analysis, in: Practical Thin-Layer Chromatography. CRC Press, pp. 169–192.

Fu, X., Liu, Z., Zhu, C., Mou, H., Kong, Q., 2019. Nondigestible carbohydrates, butyrate, and butyrate-producing bacteria. Critical reviews in food science and nutrition 59, S130–S152.

Gänzle, M., Follador, R., 2012. Metabolism of oligosaccharides and starch in lactobacilli: a review. Frontiers in microbiology 3, 340.

Gerschenson, L.N., Rojas, A.M., Fissore, E.N., 2017. Chapter 3 - Carbohydrates, in: Galanakis, C.M. (Ed.), Nutraceutical and Functional Food Components. Academic Press, pp. 39–101. https://doi.org/10.1016/B978-0-12-805257-0.00003-X

Gibson, G.R., Hutkins, R., Sanders, M.E., Prescott, S.L., Reimer, R.A., Salminen, S.J., Scott, K., Stanton, C., Swanson, K.S., Cani, P.D., 2017a. The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. Nat Rev Gastroenterol Hepatol 14, 491–502.

Gibson, G.R., Hutkins, R., Sanders, M.E., Prescott, S.L., Reimer, R.A., Salminen, S.J., Scott, K., Stanton, C., Swanson, K.S., Cani, P.D., 2017b. Expert

consensus document: The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. Nature reviews Gastroenterology & hepatology 14, 491.

Gibson, G.R., Probert, H.M., Van Loo, J., Rastall, R.A., Roberfroid, M.B., 2004. Dietary modulation of the human colonic microbiota: updating the concept of prebiotics. Nutrition research reviews 17, 259–275.

Giorgi, D., Farina, A., Grosso, V., Gennaro, A., Ceoloni, C., Lucretti, S., 2013. FISHIS: fluorescence in situ hybridization in suspension and chromosome flow sorting made easy. PLoS One 8, e57994.

Gozé, P., Rhazi, L., Pauss, A., Aussenac, T., 2016. Starch characterization after ozone treatment of wheat grains. Journal of Cereal Science 70, 207–213.

Greenblum, S., Turnbaugh, P.J., Borenstein, E., 2012. Metagenomic systems biology of the human gut microbiome reveals topological shifts associated with obesity and inflammatory bowel disease. Proc Natl Acad Sci USA 109, 594. https://doi.org/10.1073/pnas.1116053109

Guarino, M.P.L., Altomare, A., Emerenziani, S., Di Rosa, C., Ribolsi, M., Balestrieri, P., Iovino, P., Rocchi, G., Cicala, M., 2020. Mechanisms of action of prebiotics and their effects on gastro-intestinal disorders in adults. Nutrients 12, 1037.

Gul, S., Safdar, M., 2009. Proximate composition and mineral analysis of cinnamon. Pakistan Journal of Nutrition 8, 1456–1460.

Gyawali, R., Nwamaioha, N., Fiagbor, R., Zimmerman, T., Newman, R.H., Ibrahim, S.A., 2019. The role of prebiotics in disease prevention and health promotion, in: Dietary Interventions in Gastrointestinal Diseases. Elsevier, pp. 151–167.

Han, K.-H., Enomoto, M., Pelpolage, S., Nagata, R., Fukuma, N., Fukushima, M., 2020. In vitro fermentation potential of the residue of Korean red ginseng root in a mixed culture of swine faecal bacteria. Food & Function 11, 6202–6214.

Hardy, K., Brand-Miller, J., Brown, K.D., Thomas, M.G., Copeland, L., 2015. The importance of dietary carbohydrate in human evolution. The Quarterly review of biology 90, 251–268.

Harmsen, H.J., Elfferich, P., Schut, F., Welling, G.W., 1999. A 16S rRNA-targeted probe for detection of lactobacilli and enterococci in faecal samples by fluorescent in situ hybridization. Microbial Ecology in Health and Disease 11, 3–12.

Henao-Mejia, J., Elinav, E., Jin, C., Hao, L., Mehal, W.Z., Strowig, T., Thaiss, C.A., Kau, A.L., Eisenbarth, S.C., Jurczak, M.J., 2012. Inflammasome-mediated dysbiosis regulates progression of NAFLD and obesity. Nature 482, 179–185.

Henningsson, Å., Björck, I., Nyman, M., 2001a. Short-chain fatty acid formation at fermentation of indigestible carbohydrates. Näringsforskning 45, 165–168.

Henningsson, Å., Björck, I., Nyman, M., 2001b. Short-chain fatty acid formation at fermentation of indigestible carbohydrates. Näringsforskning 45, 165–168.

Hijova, E., Chmelarova, A., 2007. Short chain fatty acids and colonic health. Bratislavské lekárske listy 108, 354.

Hill, C., Guarner, F., Reid, G., Gibson, G.R., Merenstein, D.J., Pot, B., Morelli, L., Canani, R.B., Flint, H.J., Salminen, S., 2014. Expert consensus document: The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. Nature reviews Gastroenterology & hepatology 11, 506.

Hoe, V.B., Siong, K.H., Hoe, V.B., 1999. The nutritional value of indigenous fruits and vegetables in Sarawak. Asia Pacific Journal of Clinical Nutrition 8.

Hoffmann Sarda, F., Giuntini, E., Nazare, J.-A., KÖNIG, D., BAHIA, L., Lajolo, F., Menezes, E., 2018. Effectiveness of carbohydrates as a functional ingredient in glycemic control. Food Science and Technology 38. https://doi.org/10.1590/fst.42517

Hogg, S., 2013. Essential microbiology. John Wiley & Sons.

Holscher, Hannah D., 2017. Dietary fiber and prebiotics and the gastrointestinal microbiota. null 8, 172–184. https://doi.org/10.1080/19490976.2017.1290756

Holscher, Hannah D, 2017. Dietary fiber and prebiotics and the gastrointestinal microbiota. Gut microbes 8, 172–184.

Horn, J.W., Fisher, J.B., Tomlinson, P.B., Lewis, C.E., Laubengayer, K., 2009. Evolution of lamina anatomy in the palm family (Arecaceae). American Journal of Botany 96, 1462–1486.

Horwitz, W., Latimer, G., 2005. AOAC-Association of official analytical chemists. Official Methods of Analysis of AOAC International 18th ed, Gaithersburg, Maryland, USA 45, 75–76.

Hsiao, E.Y., McBride, S.W., Hsien, S., Sharon, G., Hyde, E.R., McCue, T., Codelli, J.A., Chow, J., Reisman, S.E., Petrosino, J.F., 2013a.

Microbiota modulate behavioral and physiological abnormalities associated with neurodevelopmental disorders. Cell 155, 1451–1463.

Hsiao, E.Y., McBride, S.W., Hsien, S., Sharon, G., Hyde, E.R., McCue, T., Codelli, J.A., Chow, J., Reisman, S.E., Petrosino, J.F., 2013b. Microbiota modulate behavioral and physiological abnormalities associated with neurodevelopmental disorders. Cell 155, 1451–1463.

Huber, D., von Voithenberg, L.V., Kaigala, G., 2018. Fluorescence in situ hybridization (FISH): history, limitations and what to expect from micro-scale FISH? Micro and Nano Engineering 1, 15–24.

Huttenhower, C., Gevers, D., Knight, R., Abubucker, S., Badger, J.H., Chinwalla, A.T., Creasy, H.H., Earl, A.M., FitzGerald, M.G., Fulton, R.S., 2012. Structure, function and diversity of the healthy human microbiome. nature 486, 207.

Jacobs, L., 2017. Probiotics, Prebiotics, and Synbiotics: What Are They and How Do They Affect Obesity? Journal of Pediatric Surgical Nursing 6, 53–55.

Jakas, A., Perc, M., Sućˊ, J., Rodriguez, M.C., Cudic, M., Cudic, P., 2016. Synthesis of anthrose lipidic derivative as mimic of B. anthracis BclA glycoprotein for use in ELISA-like binding assays. Journal of Carbohydrate Chemistry 35, 69–85.

Jiang, F., Du, C., Jiang, W., Wang, L., Du, S., 2020. The preparation, formation, fermentability, and applications of resistant starch. International journal of biological macromolecules 150, 1155–1161.

Johnson, C.R., Combs Jr, G.F., Thavarajah, P., 2013. Lentil (Lens culinaris L.): A prebiotic-rich whole food legume. Food Research International 51, 107–113.

Jong, F.-S., 1995. Research for the development of sago palm (Metroxylon sagu Rottb.) cultivation in Sarawak, Malaysia. Jong.

Kailasapathy, K., Chin, J., 2000. Survival and therapeutic potential of probiotic organisms with reference to Lactobacillus acidophilus and Bifidobacterium spp. Immunology and cell biology 78, 80–88.

Kamada, N., Seo, S.-U., Chen, G.Y., Núñez, G., 2013. Role of the gut microbiota in immunity and inflammatory disease. Nature Reviews Immunology 13, 321–335.

Kau, A.L., Ahern, P.P., Griffin, N.W., Goodman, A.L., Gordon, J.I., 2011. Human nutrition, the gut microbiome and the immune system. Nature 474, 327–336.

Kellow, N.J., Savige, G.S., 2013. Dietary advanced glycation end-product restriction for the attenuation of insulin resistance, oxidative stress and endothelial dysfunction: a systematic review. European journal of clinical nutrition 67, 239–248.

Khan, I., Yasir, M., I Azhar, E., Kumosani, T., K Barbour, E., Bibi, F., A Kamal, M., 2014. Implication of gut microbiota in human health. CNS & Neurological Disorders-Drug Targets (Formerly Current Drug Targets-CNS & Neurological Disorders) 13, 1325–1333.

Khangwal, I., Shukla, P., 2019. Prospecting prebiotics, innovative evaluation methods, and their health applications: a review. 3 Biotech 9, 187. https://doi.org/10.1007/s13205-019-1716-6

Killmann, W., Fink, D., 1996. COCONUT PALM STEM PROCESSING: TECHNICAL HANDBOOK.

Knudsen, K.E.B., 1997. Carbohydrate and lignin contents of plant materials used in animal feeding. Animal feed science and technology 67, 319–338.

Koeth, R.A., Wang, Z., Levison, B.S., Buffa, J.A., Org, E., Sheehy, B.T., Britt, E.B., Fu, X., Wu, Y., Li, L., 2013. Intestinal microbiota metabolism of L-carnitine, a nutrient in red meat, promotes atherosclerosis. Nature medicine 19, 576.

Koh, A., De Vadder, F., Kovatcheva-Datchary, P., Bäckhed, F., 2016. From dietary fiber to host physiology: short-chain fatty acids as key bacterial metabolites. Cell 165, 1332–1345.

Kolida, S., Tuohy, K., Gibson, G.R., 2002. Prebiotic effects of inulin and oligofructose. British Journal of Nutrition 87, S193–S197.

Kostic, A.D., Gevers, D., Pedamallu, C.S., Michaud, M., Duke, F., Earl, A.M., Ojesina, A.I., Jung, J., Bass, A.J., Tabernero, J., 2012. Genomic analysis identifies association of Fusobacterium with colorectal carcinoma. Genome research 22, 292–298.

Kullen, M.J., Klaenhammer, T.R., 2000. Genetic modification of intestinal lactobacilli and bifidobacteria. Current issues in molecular biology 2, 41–50.

Lal, M.K., Kumar, A., Raigond, P., Dutt, S., Changan, S.S., Chourasia, K.N., Tiwari, R.K., Kumar, D., Sharma, S., Chakrabarti, S.K., 2021. Impact of Starch Storage Condition on Glycemic Index and Resistant Starch of Cooked Potato (Solanum tuberosum) Tubers. Starch-Stärke 73, 1900281.

Lamothe, L.M., Lê, K.-A., Samra, R.A., Roger, O., Green, H., Macé, K., 2019. The scientific basis for healthful carbohydrate profile. Critical reviews in food science and nutrition 59, 1058–1070.

Langendijk, P.S., Schut, F., Jansen, G.J., Raangs, G.C., Kamphuis, G.R., Wilkinson, M.H., Welling, G.W., 1995. Quantitative fluorescence in situ hybridization of Bifidobacterium spp. with genus-specific 16S rRNA-targeted probes and its application in fecal samples. Applied and environmental microbiology 61, 3069–3075.

Le Bastard, Q., Chapelet, G., Javaudin, F., Lepelletier, D., Batard, E., Montassier, E., 2020. The effects of inulin on gut microbial composition: a systematic review of evidence from human studies. European Journal of Clinical Microbiology & Infectious Diseases 39, 403–413.

le Roux, C.W., Welbourn, R., Werling, M., Osborne, A., Kokkinos, A., Laurenius, A., Lönroth, H., Fändriks, L., Ghatei, M.A., Bloom, S.R., 2007. Gut hormones as mediators of appetite and weight loss after Roux-en-Y gastric bypass. Annals of surgery 246, 780–785.

Lehmann, U., Robin, F., 2007. Slowly digestible starch–its structure and health implications: a review. Trends in Food Science & Technology 18, 346–355.

Leong, S.Y., Duque, S.M., Abduh, S.B.M., Oey, I., 2019. 6 - Carbohydrates, in: Barba, F.J., Saraiva, J.M.A., Cravotto, G., Lorenzo, J.M. (Eds.), Innovative Thermal and Non-Thermal Processing, Bioaccessibility and Bioavailability of Nutrients and Bioactive Compounds. Woodhead Publishing, pp. 171–206. https://doi.org/10.1016/B978-0-12-814174-8.00006-8

Leterme, P., Buldgen, A., Estrada, F., Londoño, A.M., 2006. Mineral content of tropical fruits and unconventional foods of the Andes and the rain forest of Colombia. Food Chemistry 95, 644–652.

Ley, R.E., 2010. Obesity and the human microbiome. Current Opinion in Gastroenterology 26.

Ley, Ruth E, Peterson, D.A., Gordon, J.I., 2006. Ecological and evolutionary forces shaping microbial diversity in the human intestine. Cell 124, 837–848.

Ley, Ruth E., Turnbaugh, P.J., Klein, S., Gordon, J.I., 2006. Microbial ecology: human gut microbes associated with obesity. nature 444, 1022.

Licht, T.R., Ebersbach, T., Frøkiær, H., 2012. Prebiotics for prevention of gut infections. Trends in food science & technology 23, 70–82.

Liu, P., Wang, Y., Yang, G., Zhang, Q., Meng, L., Xin, Y., Jiang, X., 2021. The role of short-chain fatty acids in intestinal barrier function, inflammation, oxidative stress, and colonic carcinogenesis. Pharmacological Research 105420.

Livesey, G., Taylor, R., Livesey, H., Liu, S., 2013. Is there a dose-response relation of dietary glycemic load to risk of type 2 diabetes? Meta-analysis of prospective cohort studies. The American journal of clinical nutrition 97, 584–596.

Longstreth, G.F., Thompson, W.G., Chey, W.D., Houghton, L.A., Mearin, F., Spiller, R.C., 2006. Functional bowel disorders. Gastroenterology 130, 1480–1491.

Louis, P., Flint, H.J., 2009. Diversity, metabolism and microbial ecology of butyrate-producing bacteria from the human large intestine. FEMS microbiology letters 294, 1–8.

Ludwig, D.S., Hu, F.B., Tappy, L., Brand-Miller, J., 2018a. Dietary carbohydrates: role of quality and quantity in chronic disease. BMJ 361, k2340. https://doi.org/10.1136/bmj.k2340

Ludwig, D.S., Hu, F.B., Tappy, L., Brand-Miller, J., 2018b. Dietary carbohydrates: role of quality and quantity in chronic disease. Bmj 361.

Ma, N., Tian, Y., Wu, Y., Ma, X., 2017. Contributions of the interaction between dietary protein and gut microbiota to intestinal health. Current Protein and Peptide Science 18, 795–808.

Macfarlane, S., Macfarlane, G.T., 2003a. Regulation of short-chain fatty acid production. Proceedings of the Nutrition Society 62, 67–72.

Macfarlane, S., Macfarlane, G.T., 2003b. Regulation of short-chain fatty acid production. Proceedings of the Nutrition Society 62, 67–72.

Magallanes-Cruz, P.A., Flores-Silva, P.C., Bello-Perez, L.A., 2017. Starch structure influences its digestibility: a review. Journal of food science 82, 2016–2023.

Makki, K., Deehan, E.C., Walter, J., Bäckhed, F., 2018. The impact of dietary fiber on gut microbiota in host health and disease. Cell host & microbe 23, 705–715.

Manz, W., Amann, R., Ludwig, W., Vancanneyt, M., Schleifer, K.-H., 1996. Application of a suite of 16S rRNA-specific oligonucleotide probes designed to investigate bacteria of the phylum cytophaga-flavobacter-bacteroides in the natural environment. Microbiology 142, 1097–1106.

Marchesi, J.R., Adams, D.H., Fava, F., Hermes, G.D.A., Hirschfield, G.M., Hold, G., Quraishi, M.N., Kinross, J., Smidt, H., Tuohy, K.M., Thomas, L.V., Zoetendal, E.G., Hart, A., 2016. The gut microbiota and host health: a new clinical frontier. Gut 65, 330. https://doi.org/10.1136/gutjnl-2015-309990

Marcobal, A., Sonnenburg, J.L., 2012. Human milk oligosaccharide consumption by intestinal microbiota. Clinical Microbiology and Infection 18, 12–15.

Marcus, J.B., 2019. Chapter 2 - Nutritional and Physical Concerns in Aging, in: Marcus, J.B. (Ed.), Aging, Nutrition and Taste. Academic Press, pp. 25–63. https://doi.org/10.1016/B978-0-12-813527-3.00002-8

Martinez-Gili, L., McDonald, J. a K., Liu, Z., Kao, D., Allegretti, J.R., Monaghan, T.M., Barker, G.F., Miguéns Blanco, J., Williams, H.R., Holmes, E., 2020. Understanding the mechanisms of efficacy of fecal microbiota transplant in treating recurrent Clostridioides difficile infection and beyond: the contribution of gut microbial-derived metabolites. Gut microbes 12, 1810531.

Martin-Gallausiaux, C., Marinelli, L., Blottière, H.M., Larraufie, P., Lapaque, N., 2021. SCFA: mechanisms and functional importance in the gut. Proceedings of the Nutrition Society 80, 37–49.

Matsumoto, M., Benno, Y., 2006. Anti-inflammatory metabolite production in the gut from the consumption of probiotic yogurt containing Bifidobacterium animalis subsp. lactis LKM512. Bioscience, biotechnology, and biochemistry 70, 1287–1292.

Mattila-Sandholm, T., Myllärinen, P., Crittenden, R., Mogensen, G., Fondén, R., Saarela, M., 2002. Technological challenges for future probiotic foods. International Dairy Journal 12, 173–182.

Meyers, C.L.F., Meyers, D.J., 2008. Thin-layer chromatography. Current protocols in nucleic acid chemistry 34, A. 3D. 1-A. 3D. 13.

Miao, M., Jiang, B., Cui, S.W., Zhang, T., Jin, Z., 2015. Slowly digestible starch—A review. Critical reviews in food science and nutrition 55, 1642–1657.

Michel-Cuello, C., Ortiz-Cerda, I., Moreno-Vilet, L., Grajales-Lagunes, A., Moscosa-Santillán, M., Bonnin, J., González-Chávez, M.M., Ruiz-Cabrera, M., 2012. Study of enzymatic hydrolysis of fructans from Agave salmiana characterization and kinetic assessment. The Scientific World Journal 2012.

Minekus, M., Alminger, M., Alvito, P., Ballance, S., Bohn, T., Bourlieu, C., Carriere, F., Boutrou, R., Corredig, M., Dupont, D., 2014. A standardised static in vitro digestion method suitable for food–an international consensus. Food & function 5, 1113–1124.

Mohanty, D., Misra, S., Mohapatra, S., Sahu, P.S., 2018. Prebiotics and synbiotics: Recent concepts in nutrition. Food Bioscience 26, 152–160. https://doi.org/10.1016/j.fbio.2018.10.008

Mönckeberg, F., Corsini, G., 2011. Microbiota intestinal, metabolismo y balance calórico. Revista chilena de nutrición 38, 477–481.

Moter, A., Göbel, U.B., 2000. Fluorescence in situ hybridization (FISH) for direct visualization of microorganisms. Elsevier.

Movahed, A., Mohammadi, M.M., Akbarzadeh, S., Nabipour, I., Ramezanian, N., Hajian, N., 2011. The heart of date palm: its nutritional and functional constituents. ISMJ 14, 100–105.

Nemeth, C., Andersson, A.A., Andersson, R., Mangelsen, E., Sun, C., Aman, P., 2014. Relationship of grain fructan content to degree of polymerisation in different barleys. Food and Nutrition Sciences 2014.

Nicholson, J.K., Holmes, E., Kinross, J., Burcelin, R., Gibson, G., Jia, W., Pettersson, S., 2012. Host-Gut Microbiota Metabolic Interactions. Science 336, 1262. https://doi.org/10.1126/science.1223813

Nishida, A., Inoue, R., Inatomi, O., Bamba, S., Naito, Y., Andoh, A., 2018. Gut microbiota in the pathogenesis of inflammatory bowel disease. Clinical journal of gastroenterology 11, 1–10.

Nollet, L.M., Toldrá, F., 2012. Food analysis by HPLC. CRC press.

Nomura, A.M., Hankin, J.H., Henderson, B.E., Wilkens, L.R., Murphy, S.P., Pike, M.C., Le Marchand, L., Stram, D.O., Monroe, K.R., Kolonel, L.N., 2007. Dietary fiber and colorectal cancer risk: the multiethnic cohort study. Cancer causes & control 18, 753–764.

O'Connor, C., 2008. Fluorescence in situ hybridization (FISH). Nature Education 1, 171.

Olano-Martin, E., Mountzouris, K.C., Gibson, G.R., Rastall, R.A., 2000. In vitro fermentability of dextran, oligodextran and maltodextrin by human gut bacteria. British Journal of Nutrition 83, 247–255.

Ou, J., Carbonero, F., Zoetendal, E.G., DeLany, J.P., Wang, M., Newton, K., Gaskins, H.R., O'Keefe, S.J., 2013. Diet, microbiota, and microbial metabolites in colon cancer risk in rural Africans and African Americans. The American journal of clinical nutrition 98, 111–120.

Palmer, C., Bik, E.M., DiGiulio, D.B., Relman, D.A., Brown, P.O., 2007. Development of the human infant intestinal microbiota. PLoS biology 5, e177.

Panesar, P.S., Kumari, S., Panesar, R., 2013. Biotechnological approaches for the production of prebiotics and their potential applications. null 33, 345–364. https://doi.org/10.3109/07388551.2012.709482

Park, Y., Brinton, L.A., Subar, A.F., Hollenbeck, A., Schatzkin, A., 2009. Dietary fiber intake and risk of breast cancer in postmenopausal women: the National Institutes of Health–AARP Diet and Health Study. The American journal of clinical nutrition 90, 664–671.

Payne, A.N., Chassard, C., Lacroix, C., 2012. Gut microbial adaptation to dietary consumption of fructose, artificial sweeteners and sugar alcohols: implications for host–microbe interactions contributing to obesity. Obesity reviews 13, 799–809.

Petkova, N., Mihaylova, D., 2016. Flower heads of Onopordum tauricum Willd. and Carduus acanthoides L–source of prebiotics and antioxidants. Emirates Journal of Food and Agriculture 732–736.

Pineiro, M., Asp, N.-G., Reid, G., Macfarlane, S., Morelli, L., Brunser, O., Tuohy, K., 2008. FAO Technical meeting on prebiotics. Journal of clinical gastroenterology 42 Suppl 3 Pt 2, S156-9. https://doi.org/10.1097/mcg.0b013e31817f184e

Pokusaeva, K., Fitzgerald, G.F., van Sinderen, D., 2011. Carbohydrate metabolism in Bifidobacteria. Genes & nutrition 6, 285–306.

Pratt, C.W., Cornely, K., 2004. Essential biochemistry. Wiley Hoboken, NJ.

Pryde, S.E., Duncan, S.H., Hold, G.L., Stewart, C.S., Flint, H.J., 2002. The microbiology of butyrate formation in the human colon. FEMS microbiology letters 217, 133–139.

Quigley, E.M., 2019. Prebiotics and probiotics in digestive health. Clinical Gastroenterology and Hepatology 17, 333–344.

Reid, G., Sanders, M.E., Gaskins, H.R., Gibson, G.R., Mercenier, A., Rastall, R., Roberfroid, M., Rowland, I., Cherbut, C., Klaenhammer, T.R., 2003. New scientific paradigms for probiotics and prebiotics. Journal of clinical gastroenterology 37, 105–118.

Reiffová, K., Nemcová, R., 2006a. Thin-layer chromatography analysis of fructooligosaccharides in biological samples. Journal of Chromatography A 1110, 214–221.

Reiffová, K., Nemcová, R., 2006b. Thin-layer chromatography analysis of fructooligosaccharides in biological samples. Journal of Chromatography A 1110, 214–221.

Ríos-Covián, D., Ruas-Madiedo, P., Margolles, A., Gueimonde, M., De Los Reyes-gavilán, C.G., Salazar, N., 2016. Intestinal short chain fatty acids and their link with diet and human health. Frontiers in microbiology 7, 185.

Roberfroid, M., 2002. Functional food concept and its application to prebiotics. Digestive and Liver Disease 34, S105–S110.

Roberfroid, M., Gibson, G.R., Hoyles, L., McCartney, A.L., Rastall, R., Rowland, I., Wolvers, D., Watzl, B., Szajewska, H., Stahl, B., 2010. Prebiotic effects: metabolic and health benefits. British Journal of Nutrition 104, S1–S63.

Roberfroid, M.B., 2007a. Inulin-type fructans: functional food ingredients. The Journal of nutrition 137, 2493S-2502S.

Roberfroid, M.B., 2007b. Inulin-type fructans: functional food ingredients. The Journal of nutrition 137, 2493S-2502S.

Roberfroid, M.B., 2005. Introducing inulin-type fructans. British Journal of Nutrition 93, S13–S25.

Roberfroid, M.B., 2000. Prebiotics and probiotics: are they functional foods? The American journal of clinical nutrition 71, 1682S-1687S.

Rooks, M.G., Garrett, W.S., 2016. Gut microbiota, metabolites and host immunity. Nature reviews immunology 16, 341–352.

Rovalino-Córdova, A.M., Fogliano, V., Capuano, E., 2018. A closer look to cell structural barriers affecting starch digestibility in beans. Carbohydrate polymers 181, 994–1002.

Rowland, I., Gibson, G., Heinken, A., Scott, K., Swann, J., Thiele, I., Tuohy, K., 2018. Gut microbiota functions: metabolism of nutrients and other food components. Eur J Nutr 57, 1–24. https://doi.org/10.1007/s00394-017-1445-8

Rycroft, C.E., Jones, M.R., Gibson, G.R., Rastall, R.A., 2001. A comparative in vitro evaluation of the fermentation properties of prebiotic oligosaccharides. Journal of Applied Microbiology 91, 878–887. https://doi.org/10.1046/j.1365-2672.2001.01446.x

Saarela, M., Lähteenmäki, L., Crittenden, R., Salminen, S., Mattila-Sandholm, T., 2002. Gut bacteria and health foods—the European perspective. International journal of food microbiology 78, 99–117.

Sadasivam, S., Manickam, A., 2005. Phenol-sulphuric acid method for total carbohydrate. Biochemical methods.

Salami, M., 2021. Interplay of good bacteria and central nervous system: Cognitive aspects and mechanistic considerations. Frontiers in Neuroscience 15, 25.

Samuel, B.S., Shaito, A., Motoike, T., Rey, F.E., Backhed, F., Manchester, J.K., Hammer, R.E., Williams, S.C., Crowley, J., Yanagisawa, M., 2008. Effects of the gut microbiota on host adiposity are modulated by the short-chain fatty-acid binding G protein-coupled receptor, Gpr41. Proceedings of the National Academy of Sciences 105, 16767–16772.

Sarbini, S.R., Kolida, S., Gibson, G.R., Rastall, R.A., 2013a. In vitro fermentation of commercial α-gluco-oligosaccharide by faecal microbiota from lean and obese human subjects. British Journal of Nutrition 109, 1980–1989.

Sarbini, S.R., Kolida, S., Gibson, G.R., Rastall, R.A., 2013b. In vitro fermentation of commercial α-gluco-oligosaccharide by faecal microbiota from lean and obese human subjects. British Journal of Nutrition 109, 1980–1989. https://doi.org/10.1017/S0007114512004205

Sarbini, S.R., Rastall, R.A., 2011. Prebiotics: metabolism, structure, and function. Funct Food Rev 3, 93–106.

Sarkar, S., 2013. Probiotics as functional foods: gut colonization and safety concerns. Nutrition & Food Science 43, 496–504.

Schatzkin, A., Park, Y., Leitzmann, M.F., Hollenbeck, A.R., Cross, A.J., 2008. Prospective study of dietary fiber, whole grain foods, and small intestinal cancer. Gastroenterology 135, 1163–1167.

Scholz-Ahrens, K.E., Schaafsma, G., van den Heuvel, E.G., Schrezenmeir, J., 2001. Effects of prebiotics on mineral metabolism. The American journal of clinical nutrition 73, 459s–464s.

Schumann, C., 2002. Medical, nutritional and technological properties of lactulose. An update. European Journal of Nutrition 41, i17–i25.

Sekirov, I., Russell, S.L., Antunes, L.C.M., Finlay, B.B., 2010. Gut microbiota in health and disease. Physiological reviews 90, 859–904.

SENGUN, İ.Y., BINGOL, M.G., 2018. Plants as Prebiotic Sources. International Journal of Environmental Research and Technology 1, 11–14.

Sheard, N.F., Clark, N.G., Brand-Miller, J.C., Franz, M.J., Pi-Sunyer, F.X., Mayer-Davis, E., Kulkarni, K., Geil, P., 2004. Dietary carbohydrate (amount and type) in the prevention and management of diabetes: a statement by the American Diabetes Association. Diabetes care 27, 2266–2271.

Sherma, J., 2000. Thin-layer chromatography in food and agricultural analysis. Journal of chromatography A 880, 129–147.

Shigwedha, N., Jia, L., 2013a. Bifidobacterium in human GI tract: screening, isolation, survival and growth kinetics in simulated gastrointestinal

conditions, in: Lactic Acid Bacteria-R & D for Food, Health and Livestock Purposes. InTech.

Shigwedha, N., Jia, L., 2013b. Bifidobacterium in human GI tract: screening, isolation, survival and growth kinetics in simulated gastrointestinal conditions. Lactic acid bacteria—R & D for food, health and livestock purposes. InTech, Croatia 281–308.

Shimizu, M.M., Melo, G.A., dos Santos, A.B., Bottcher, A., Cesarino, I., Araújo, P., Moura, J.C.M.S., Mazzafera, P., 2011. Enzyme characterisation, isolation and cDNA cloning of polyphenol oxidase in the hearts of palm of three commercially important species. Plant Physiology and Biochemistry 49, 970–977.

Slavin, J., 2013. Fiber and prebiotics: mechanisms and health benefits. Nutrients 5, 1417–1435.

Slavin, J.L., Lloyd, B., 2012. Health benefits of fruits and vegetables. Advances in nutrition 3, 506–516.

Stefaniak, M., Niestrój, A., Klupsch, J., Śliwiok, J., Pyka, A., 2005. Use of RP-TLC to determine the log P values of isomers of organic compounds. Chromatographia 62, 87–89.

Sundram, K., Sambanthamurthi, R., Tan, Y.-A., 2003. Palm fruit chemistry and nutrition. Asia Pacific journal of clinical nutrition 12.

Tabora, P.C., Balick, M.J., Bovi, M.L.A., Guerra, M.P., 1993. Hearts of palm (Bactris, Euterpe and others). Williams, JT (Edited). Underutilized crops: Pulses and Vegetables, Published by Chapman & Hall, London.

Taherzadeh, M.J., Karimi, K., 2008. Pretreatment of lignocellulosic wastes to improve ethanol and biogas production: a review. International journal of molecular sciences 9, 1621–1651.

Tahir, M., Lindeboom, N., Båga, M., Vandenberg, A., Chibbar, R., 2011. Composition and correlation between major seed constituents in selected lentil (Lens culinaris. Medik) genotypes. Canadian Journal of Plant Science 91, 825–835.

Tannock, G.W., 2002. Probiotics and prebiotics: where are we going? Horizon Scientific Press.

Tarini, J., Wolever, T.M., 2010. The fermentable fibre inulin increases postprandial serum short-chain fatty acids and reduces free-fatty acids and ghrelin in healthy subjects. Applied physiology, nutrition, and metabolism 35, 9–16.

Tharanathan, R., Mahadevamma, S., 2003. Grain legumes—a boon to human nutrition. Trends in Food Science & Technology 14, 507–518.

Tie, A.P., Karim, A.A., Manan, D.M.A., 2008. Physicochemical properties of starch in sago palms (Metroxylon sagu) at different growth stages. Starch-Stärke 60, 408–416.

Todesco, T., Zamboni, M., Armellini, F., Bissoli, L., Turcato, E., Bosello, O., 2020. SHORT CHAIN FATTY ACID PRODUCTION AND POSSIBLE METABOLIC CONSEQUENCES IN HUMANS. Handbook of Lipids in Human Nutrition 23, 65.

Topping, D.L., Clifton, P.M., 2001. Short-chain fatty acids and human colonic function: roles of resistant starch and nonstarch polysaccharides. Physiological reviews.

Trabzuni, D.M., Ahmed, S.E.B., Abu-Tarboush, H.M., 2014. Chemical composition, minerals and antioxidants of the heart of Date Palm from three Saudi cultivars. Food and Nutrition Sciences 5, 1379.

Tripathi, M.K., Giri, S.K., 2014. Probiotic functional foods: Survival of probiotics during processing and storage. Journal of functional foods 9, 225–241.

Tuohy, K.M., Probert, H.M., Smejkal, C.W., Gibson, G.R., 2003. Using probiotics and prebiotics to improve gut health. Drug discovery today 8, 692–700.

Ullah, Inayat, Gul, S., Rehman, H.U., Ahmad, N., Ullah, Ikram, Aziz-ud-Din, S.M.J., Ali, J., Ahmad, A., Akbar, M.U., 2017. Analysis of nutrients and minerals of some wild edible plants. International Journal of Fauna and Biological Studies 4, 35–39.

Van der Meulen, R., Makras, L., Verbrugghe, K., Adriany, T., De Vuyst, L., 2006. In vitro kinetic analysis of oligofructose consumption by Bacteroides and Bifidobacterium spp. indicates different degradation mechanisms. Applied and environmental microbiology 72, 1006–1012.

Van Loo, J., 2006. Inulin-type fructans as prebiotics. Prebiotics: Development & Application 57–100.

Varzakas, T., Kandylis, P., Dimitrellou, D., Salamoura, C., Zakynthinos, G., Proestos, C., 2018. 6 - Innovative and fortified food: Probiotics, prebiotics, GMOs, and superfood, in: Ali, Md.E., Nizar, N.N.A. (Eds.), Preparation and Processing of Religious and Cultural Foods. Woodhead Publishing, pp. 67–129. https://doi.org/10.1016/B978-0-08-101892-7.00006-7

Venema, K., Van den Abbeele, P., 2013. Experimental models of the gut microbiome. Best Practice & Research Clinical Gastroenterology 27, 115–126.

Vieira, P.A.F., Gontijo, D.C., Vieira, B.C., Fontes, E.A., de Assunção, L.S., Leite, J.P.V., Oliveira, M.G. de A., Kasuya, M.C.M., 2013. Antioxidant activities, total phenolics and metal contents in Pleurotus ostreatus mushrooms enriched with iron, zinc or lithium. LWT-Food Science and Technology 54, 421–425.

Vital, A., Lepreux, S., Vital, C., 2014. Peripheral neuropathy and parkinsonism: a large clinical and pathogenic spectrum. Journal of the Peripheral Nervous System 19, 333–342.

Vogt, J.A., Wolever, T.M., 2003. Fecal acetate is inversely related to acetate absorption from the human rectum and distal colon. The Journal of nutrition 133, 3145–3148.

Walker, A.W., Duncan, S.H., Leitch, E.C.M., Child, M.W., Flint, H.J., 2005. pH and peptide supply can radically alter bacterial populations and short-chain fatty acid ratios within microbial communities from the human colon. Applied and environmental microbiology 71, 3692–3700.

Walker, A.W., Ince, J., Duncan, S.H., Webster, L.M., Holtrop, G., Ze, X., Brown, D., Stares, M.D., Scott, P., Bergerat, A., Louis, P., McIntosh, F., Johnstone, A.M., Lobley, G.E., Parkhill, J., Flint, H.J., 2011. Dominant and diet-responsive groups of bacteria within the human colonic microbiota. The ISME Journal 5, 220–230. https://doi.org/10.1038/ismej.2010.118

Wall, P.E., 2007. Thin-layer chromatography: a modern practical approach. Royal Society of Chemistry.

Walter, J., Ley, R., 2011. The human gut microbiome: ecology and recent evolutionary changes. Annual review of microbiology 65, 411–429.

Wang, H.-Y., Wang, C., Guo, L.-X., Zheng, Y.-F., Hu, W.-H., Dong, T.T.X., Wang, T.-J., Tsim, K.W.K., 2019. Simultaneous determination of short-chain fatty acids in human feces by HPLC with ultraviolet detection following chemical derivatization and solid-phase extraction segmental elution. Journal of Separation Science 42, 2500–2509. https://doi.org/10.1002/jssc.201900249

Wang, M., Wichienchot, S., He, X., Fu, X., Huang, Q., Zhang, B., 2019. In vitro colonic fermentation of dietary fibers: Fermentation rate, short-chain fatty acid production and changes in microbiota. Trends in food science & technology 88, 1–9.

Wichienchot, S., Thammarutwasik, P., Jongjareonrak, A., Chansuwan, W., Hmadhlu, P., Hongpattarakere, T., Itharat, A., Ooraikul, B., 2011. Extraction and analysis of prebiotics from selected plants from southern Thailand. Songklanakarin Journal of Science & Technology 33.

Williams, B.A., Mikkelsen, D., Le Paih, L., Gidley, M.J., 2011. In vitro fermentation kinetics and end-products of cereal arabinoxylans and (1, 3; 1, 4)-β-glucans by porcine faeces. Journal of cereal science 53, 53–58.

Wong, J.M., De Souza, R., Kendall, C.W., Emam, A., Jenkins, D.J., 2006a. Colonic health: fermentation and short chain fatty acids. Journal of clinical gastroenterology 40, 235–243.

Wong, J.M., De Souza, R., Kendall, C.W., Emam, A., Jenkins, D.J., 2006b. Colonic health: fermentation and short chain fatty acids. Journal of clinical gastroenterology 40, 235–243.

Wong, J.M., Jenkins, D.J., 2007. Carbohydrate digestibility and metabolic effects. The Journal of nutrition 137, 2539S-2546S.

Wu, N., Yang, X., Zhang, R., Li, J., Xiao, X., Hu, Y., Chen, Y., Yang, F., Lu, N., Wang, Z., 2013. Dysbiosis signature of fecal microbiota in colorectal cancer patients. Microbial ecology 66, 462–470.

Wu, X., Ma, C., Han, L., Nawaz, M., Gao, F., Zhang, X., Yu, P., Li, L., Zhou, A., Wang, J., 2010. Molecular characterisation of the faecal microbiota in patients with type II diabetes. Current microbiology 61, 69–78.

Xuan, C., Shamonki, J.M., Chung, A., DiNome, M.L., Chung, M., Sieling, P.A., Lee, D.J., 2014. Microbial dysbiosis is associated with human breast cancer. PloS one 9.

Yoo, H.-D., Kim, D., Paek, S.-H., 2012. Plant cell wall polysaccharides as potential resources for the development of novel prebiotics. Biomolecules & therapeutics 20, 371.

Yuan, Q., Lin, S., Fu, Y., Nie, X.-R., Liu, W., Su, Y., Han, Q.-H., Zhao, L., Zhang, Q., Lin, D.-R., 2019. Effects of extraction methods on the physicochemical characteristics and biological activities of polysaccharides from okra (Abelmoschus esculentus). International journal of biological macromolecules 127, 178–186.

Zhang, X., Tan, Y., Ling, Y., Lu, G., Liu, F., Yi, Z., Jia, X., Wu, M., Shi, B., Xu, S., 2020. Viral and host factors related to the clinical outcome of COVID-19. Nature 1–7.

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