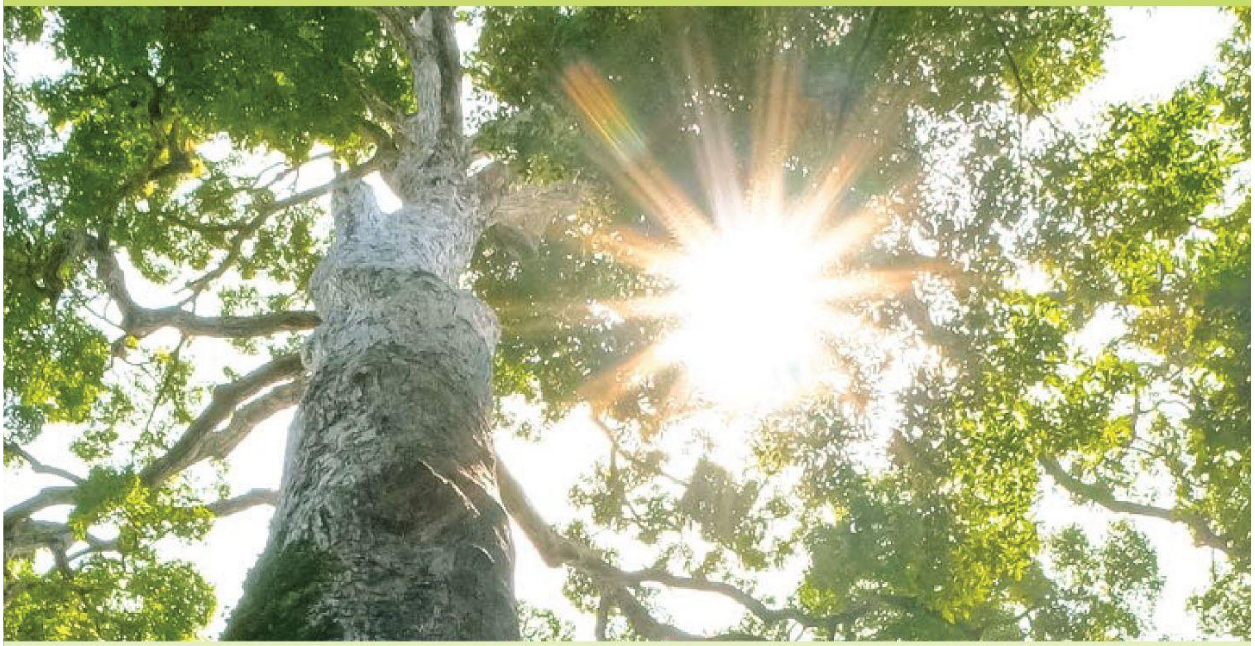

Functional Foods In Malaysia

Editors: Choon-Hui, Tan & Kalvin Meng-Jun, Chuo

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Preface

Functional food is a category of food that can enhance health status, which are not drugs, chemicals or vitamins. The global functional food ingredients market size has continuously increased through the years with a projected value to reach USD 137.1 billion by 2026 from the estimation value of USD 98.9 billion in 2021, at a compound annual growth rate of 6.8% during the forecast period. The increasing health awareness and individual preferences for healthy and convenient foods are expected to drive the growth of the functional foods market.

In the past decade, the demand for functional meals is growing in tandem with Malaysians' changing lifestyles as they begin to prioritise their physical well-being. There are many functional food products have been patented and commercialised in the Malaysian market. Some of the products are consumed as traditional or cultural foods. Consuming a well-balanced diet with functional foods on a regular basis is one of the strategies to reach optimum health fitness.

This book provides an overview of some functional foods available in Malaysia, which aims to create awareness about functional foods among consumers. The functional foods covered in the book include seaweed, pre- and probiotics, plant oils, mushrooms, herbs and spices. Nutritional benefits and functional properties of the functional foods will be addressed.

As the editor of this book and the leader of the Functional Food Research Group in UCSI University, I would like to acknowledge and extend my utmost appreciation to all authors and photographers in this book for their time and effort in the preparation of their respective chapters.

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Chapter 1

Introduction to functional foods

Crystale Siew Ying, Lim and Putu Virgina Partha, Devanthi

INTRODUCTION

Preparing for the future development of functional foods begins with an understanding of its past. Food, as a necessity of life, took a more advanced turn in the 1980s, when, after decades of economic prosperity and technological advancements, many countries began to notice the manifestation of the ageing society and the lifestyle-related diseases that accompanied aging. Although the Chinese have long held the belief that food and medicine are isogenic, the growth on aging societies around the world prompted the awareness of eating for healthy living and improved dietary practices in everyday life.

Japan, the origin of modern food science, took up the global challenge to use food science as a tool in the fight against aging and diseases. Japan made headlines in 1993 with an article in Nature entitled 'Japan explores the boundary between food and medicine' (Swinbanks & O'Brien, 1993), which introduced the term 'physiologically functional food' for the first time to the international scene.

Since then, more and more countries have jumped on the proverbial functional food bandwagon and functional food is now a popular term to label foods with health benefits. However, to ensure that functional food ultimately benefits the consumer, this chapter gives an overview of the future direction and development of functional foods from a local and global perspective.

DEFINITION & LEGISLATION OF FUNCTIONAL FOODS

Despite the advancements in functional foods, especially in Japan, functional food still faces ambiguity in terms of a single globally agreeable definition due to different opinions, regulations and local nuances.

The terminology and concept of 'functional food' was born in 1984, when the Ministry of Education, Science and Culture (MESC) of Japan began a national series of research projects, starting with the project Systematic Analysis and Development of Food Function (Arai, 1996). The second project, carried out from 1988 to 1991, was entitled

'Analysis of Body-modulating Functions of Foods', with the last project in 1992 focusing on Analysis and Molecular Design of Functional Foods (Arai 2002). In 1991, Japan then created a national policy called Foods for Specified Health Uses (FOSHU) under the Ministry of Health and Welfare, which provided legislation for functional foods with specific health claims to be legally approved, commercially produced and regulated.

In response to the introduction of 'functional food' to the world in 1993, in 1994 the United States of America (USA) established the Dietary Supplement Health and Education Act (DSHEA) system to regulate supplements with health benefits in the USA. However, although DSHEA does not specifically define 'functional food,' Japan adopted the DSHEA to introduce the New Functional Foods (NFF) system in 2015, which allows more flexibility than FOSHU, especially in the types and stringency of permissible health claims (Iwatani & Yamamoto, 2019).

More than 10 years after the USA DSHEA system establishment, in 2006 the European Parliament and Council passed Regulation (EC) No. 1924/2006 on nutrition and health claims made on foods (Laser Reuterswärd, 2007). However, both USA and the European Union do not define functional food in their legislature and Japan remains the only known country to provide a comprehensive definition and legislation for functional foods. Thus, 'functional food' in Japan is defined as "foods containing ingredient with functions for health and officially approved to claim its physiological effects on the human body" but there is debate as to whether fresh foods or foods naturally containing bioactive compounds can be categorized as functional food.

In Europe, the Nutrition and Health Claim Regulation (NHCR) regulates health benefit claims of food items, requiring scientific validation of these claims by the European Food Safety Authority (EFSA) (Lenssen et al., 2018). Validation requires that the bioactive substance in claimed food items have been characterized, a beneficial physiological effect of the consumed food item should be evident, and finally there should be proof that consuming the food item results in the described beneficial physiological effect (de Boer et al., 2016). As such, very few food items in Europe are approved for their health benefits, where any, if approved, are not legally defined as functional foods in the European Union.

In Asian countries, however, functional foods are usually referred to as health food (Tee, 2004). Malaysia also has no standard definition or regulations on functional foods, although it is generally agreed that nutraceuticals are not included in the category of "functional food" (Lau et al. 2012). Thus, in order to establish and implement functional food quality and safety in Malaysia, three entities comprising the Department of Food Quality, Malaysian National Codex Committee and the National Pharmaceutical Bureau were enlisted under the Ministry of Health (MOH) (Abu Kasim et al. 2009).

In the global economy, differences in definitions and regulations may hamper the import and export processes and ultimately consumer acceptance in respective countries. Once can imagine that import of so-called "functional food" into countries with strict legislations may not be acceptable and thus limits both the exposure of the countries' markets to global functional foods and also the export economics of the manufacturing countries. Furthermore, consumer confusion on functional foods is inevitable especially if the consumer is exposed to various products from around the world.

A lack of standardization in definition and regulation has also resulted in inaccurate market data and economics analysis. This is because as different countries define the scope and claims "functional food" differently, when reporting on product market share and consumer acceptability, data would not be comparable between countries. This may lead to uncertainties for the development for new functional foods, especially for the export market, thus exposing the food industry to financial risk and hampering innovation and development of novel functional foods (Birch & Bonwick, 2018).

Hilton (2017) reported eight key market trends driving the functional food market (Figure 1), highlighting the role of savvy consumers and use of technology. Again, these market trends are based on the many different country-specific definitions of functional food and may include a range of foods from those with strict regulation-approved clinical claims to foods that simply contain high levels of a known bioactive compound.

Thus, a standardized definition and regulatory guidelines that is agreeable by most countries is crucial to reduce exacerbation of these problems. Moving forward, labelling of functional foods and their claims must be communicated effectively to consumers, whereby enforcement of regulations must also be done diligently to ensure all information is factual. In the meantime, consumer education will be important so that the consumer can understand and select available functional foods wisely. It is interesting to observe how the database of functional foods built by an *ad hoc* team led by Arai (2002) sponsored of the Japan Ministry of Education, Science and Culture (MESC).

HOLISTIC DESIGN & DEVELOPMENT OF FUNCTIONAL FOODS

The future development of functional foods centered around a holistic design workflow that includes the nutritive and sensory aspects of foods is crucial for the advancement of their development. Functional foods should not only carry out the health claim, but also be palatable to differentiate them from drugs. Holistic research and development of functional foods that include the local nuances of a particular country or culture will also be crucial to the success of that product.

Moreover, the formulation and processing of functional food should be designed to keep the loss of bioactive components at a minimum. Food manufacturers can apply some emerging non-thermal food processing technologies such as high-pressure processing, pulsed electric field, cold plasma, ultrasonication, and microwave, to prolong and boost the bioactivity and bioavailability of food components (Alongi and Anese, 2021; Galanakis, 2021).The use of technology in the design and development of functional foods, such as nano-encapsulation of bioactive phenolic compounds into cereal (Kasote et al, 2021), has the potential to produce various beneficial functional food and functional by-products.

NOVEL CONCEPTS IN FUNCTIONAL FOODS

Probiotics and their benefits as components of functional food has been proven for decades. Lately, the emerging concepts of postbiotics and parabiotics have piqued the interest of the functional food community. Postbiotics are described as the metabolites of live probiotics which have health benefits while parabiotics are defined as the dead or inactive cells of probiotics themselves (Nataraj et al. 2020).

Postbiotics and parabiotics offer some advantages to probiotics which explains their attractiveness to the food industry. Probiotics have to be kept alive for optimal derivation of their health benefits, while some strains of probiotics contain antibiotic resistance genes that may be a concern for antibiotic resistance development in pathogenic bacteria (Aguilar-Toala et al., 2018). Postbiotics and parabiotics do not contain live cells and consist of small molecules which allow their travel around the body to act like signaling molecules. Postbiotics and parabiotics have been claimed to possess the ability to modulate gut microbiota, modulate the immune system, lower cholesterol and lower blood pressure, among others. However, these claims will have to be substantiated by human clinical trials.

In Malaysia, thus far most of the limited number of postbiotic reports have been focused on applications as a functional food for animals. The probiotic *Lactiplantibacillus plantarum* has been the focus of these studies, with its postbiotics shown to have antioxidant and antibacterial activities (Izuddin et al, 2019; Chang et al, 2021) and anticancer properties in vitro (Chuah et al, 2019).

CONCLUSION

Moving forward, the scientific community must come together to agree on food functionalism and reject attempts to reap purely economic benefits by diluting the claims.

Functional food is the epitome of “food as medicine” and “food for health” whence natural sources of health benefits to humans and animals will, in time, provide scientifically-proven alternatives to pharmaceutical drugs and generally prevent diseases and illnesses from manifestation.

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Chapter 2

Prebiotics

Lionel L. A., In

INTRODUCTION

Prebiotics, a term first described by Gibson and Roberfroid in 1995, are defined as compounds in food that influence the composition, growth and activity of beneficial gastrointestinal microorganisms, also known as the gut microbiome. They do so by acting as a fermentable substrate for specific commensal host bacteria, leading to the release of various metabolites such as short-chain fatty acids (SCFAs) in the gut intestinal tract. These metabolites directly and indirectly influence many molecular and cellular processes, which ultimately bring about various health benefits to the host.

As a rule of thumb, a food component can only be termed as a “prebiotic” if it fulfils three fundamental criteria: **(1)** Be resistant to upper gastrointestinal digestion and be able to withstand food processing conditions, **(2)** Be fermentable by the gut microbiota and **(3)** Be able to specifically stimulate the growth and activity of intestinal bacteria to benefit host health (Gibson *et al*, 2017). Since prebiotics share an inevitably synergistic relationship with gut microorganisms or probiotics, and are often used concurrently in each other’s presence, a relatively new combinatorial term called ‘synbiotics’ was coined. According to the International Scientific Association for Probiotics and Prebiotics (ISAPP), this term is most recently defined as a mixture comprising live microorganisms and substrate(s) selectively utilized by host microorganisms that confers a superior health benefit on the host (Swanson *et al*, 2020). Examples of some synbiotic-type foods commonly consumed by Malaysians include tempeh, tapai, kimchi, miso, achar, sayur acin and tempoyak.

In this chapter, we will be using an evidence-based approach to discuss the latest findings concerning the various aspects of prebiotics, ranging from the different types of prebiotics, its sources amongst Malaysian foods, its mechanism of action and its corresponding conferred health benefits.

TYPES OF PREBIOTICS

There are many types of prebiotics reported to date, with a vast majority of them being a subset of carbohydrate groups (oligosaccharide and polysaccharides) also known as dietary fibres. These carbohydrate groups can either be manufactured synthetically or be naturally available in different dietary local Malaysian food products, including asparagus, sugar beet, garlic, chicory, onion, artichoke, wheat, honey, durian, barley, tomato, rye, soy tempeh, human's and cow's milk, peas, beans, and recently in seaweeds and microalgae as well (Davani-Davari *et al*, 2019). The complicated relationship between prebiotic sources, their active molecular composition, active fermentable metabolites, correlating microbes and their corresponding health benefits are often intertwined with one another and are summarized in **Table 1** below.

Table 1: An evidence-based overview of various prebiotics, metabolites and correlating microbes toward beneficial health effects.

Prebiotic sources[†]	Active prebiotic components & metabolites	Microbial correlate (genus)	Conferred health benefit(s)	Reference(s)
Acorn	SCFA: Propionate[††]	Lactobacillus, Bacteroides, Parabacteroides, Rikenellaceae, Paraprevotella, Sutterella	• Type-2 diabetes • Colon cancer	Ahmadi et al, 2019
Sago	SCFA: Lactate[††], Propionate[†]	Streptococcus, Actinobacteria, Lactococcus	• Type-2 diabetes	Ahmadi et al, 2019
Tempeh, Legumes	SCFA: Butyrate[††]	Direct effects on host	• Graft versus host disease (GVHD) • Type-2 diabetes	Yoshifuji et al, 2020, Huang et al, 2018
Artichoke, Chicory, Garlic, Onion, Asparagus, Durian Tempoyak	Fructo-oligosaccharides (FOS)	Bifidobacterium, Faecalibacterium, Lactobacillus	• Increased satiety • Relieves constipation • Reduces oxidative stress • Improves intestinal epithelial barrier function	Hiel et al, 2019 Wu et al, 2017 Vandeputte et al, 2017 Guarino et al, 2020, Leisner et al, 2001
Tempeh, Legumes, Cabbage, Kimchi, Sayur asin,	Galacto-oligosaccharides (GOS)	Rhizopus, Bifidobacterium, Lactobacillus	• Skeletal health • Traveler's diarrhea • Anxiety disorders	Huang et al, 2018, Davani-Davari et al, 2019 Whinner and Castillo, 2018 Johnstone et al, 2021

			• Inflammatory bowel disease	van den Broek et al, 2008, Rodzi & Lee, 2021
Bamboo shoots, Honey	Xylo-oligosaccharides (XOS)	Lactobacillus, Streptococcus, Bifidobacterium	• Anti-inflammation • Anti-oxidation	Markowiak & Śliżewska, 2017 Chen et al, 2021
Sugar beet, apples, olives, citrus	Pectic-oligosaccharides (POS)	Bifidobacterium, Faecalibacterium	• Hyper-cholesterolemia • Colon cancer	Babbar et al, 2016 Míguez et al, 2016
Potatoes, Sweet potatoes, Oats, Maize	Resistant starch (RS)	Ruminococcus, Bifidobacterium	• Metabolic syndrome • Type-2 diabetes • Constipation • Colon cancer	Ze et al, 2012 Birt et al, 2013, Zheng et al, 2016
Cocoa	Flavanols	Bifidobacterium, Lactobacillus	• Hypertension • Thrombosis	Tzounis et al, 2011

† *Food sources with high amounts of said prebiotics*
†† *Product of bacterial fermentation*

Fructo-oligosaccharides (FOS)

Fructo-oligosaccharides, also known as fructans, is a category of oligosaccharides consisting of inulin and oligofructose. They are composed of linear chains of fructose units, linked by beta (2-1) bonds. The number of fructose units ranges from 2 to 60 and often terminate in a glucose unit. Since these group of prebiotics are present in relatively minute amounts in over 35,000 types of plants, they are therefore commonly artificially synthesized at an industrial scale either chemically or enzymatically for consumption in the form of prebiotic supplements. These fructans are believed to be the most used and effective in relation to many species of probiotics (Markowiak & Śliżewska, 2017). FOS have important beneficial physiological effects such as low carcinogenicity, improved mineral absorption and decreased levels of serum cholesterol, triacylglycerols and phospholipids (Sabater-Molina *et al*, 2009).

Galacto-oligosaccharides (GOS)

Galacto-oligosaccharides (GOS) are the product of lactose, sucrose and lactulose extension (Davani-Davari *et al*, 2019), and constitutes a significant part, to as much as 40% of produced oligosaccharides (Markowiak & Śliżewska, 2017). GOS molecules are typically synthesized by the enzymatic activity of β-galactosidase on lactose in a reaction known as transgalactosylation. Health benefits of consuming GOS that have been reported includes alleviation of anxiety disorders, reduction of cancer risk, control of serum lipid and cholesterol levels, and inflammatory bowel disease (IBD) (van den Broek *et al*, 2008). GOS has also been bestowed the Generally Recognized as Safe (GRAS) status by the FDA, and can be used in a several foods including infant formula milk, fermented dairy products, confectionary products and breads.

Xylo-oligosaccharides (XOS)

Xylo-oligosaccharides (XOS) are made up of xylose units linked by β-(1→4) bonds, that can reportedly be found naturally in some foods, including bamboo shoots, fruits, vegetables, milk, and honey. Basically, XOS are the degraded products of xylan prepared via chemical, physical or enzymatic degradation. The degrees of polymerization (DP) of XOS are usually 2–7 and they are also known as xylobiose, xylotriose, and so on depending on their DP. They elicit a variety of functional biological activities including anti-inflammation, antioxidative, antitumor, antimicrobial properties (Chen *et al*, 2021).

Glucose-derived oligosaccharides

This group of prebiotics are essentially resistant to the upper gastrointestinal digestion and is commonly known as resistant starch (RS). There are currently 5 types of resistant starch (Types I-V) based on its digestive rate (Englyst *et al*, 1992). Several studies in humans have shown that RS can elicit health benefits such as improved insulin sensitivity for diabetic individuals, obesity control, colon cancer and constipation relief (Birt *et al*, 2013).

Pectic oligosaccharide (POS)

Pectic-oligosaccharides (POS) is a new class of prebiotics made up of homogalacturonan (HG, α-1,4-linked galacturonic acid monomers) and rhamnogalacturonan (RG, alternate galacturonic acid and rhamnose backbone with neutral side chains). Examples of common POS include oligo-galacturonides (GalpOS), galacto-oligosaccharides (GalOS) and rhamno-galacturonan-oligosaccharides (RGOS) (Babbar *et al*, 2016). Reported health benefits of POS include its positive effects on hypercholesterolemia, metabolic syndrome and colon cancer (Míguez *et al*, 2016).

Non-carbohydrate prebiotics

Although carbohydrates are more likely to meet the criteria of prebiotics definition, there are some compounds that are not classified as carbohydrates but are recommended to be classified as prebiotics, such as cocoa-derived flavanols which has been reported to stimulate the growth of certain lactic acid bacteria such as Bifidobacterium and Lactobacillus populations (Tzounis *et al*, 2011). Other examples of non-carbohydrate prebiotics include curcumin, anthocyanin, licorice, ginger and other such phytochemical-based spices and herbs (Anand *et al*, 2021).

PREBIOTIC MECHANISM OF ACTION

In essence, prebiotics can basically influence host health through two separate mechanisms: **(1)** Direct or **(2)** Indirect. Directly, prebiotics which mostly comprise of oligosaccharides and polysaccharides, acts on our gut epithelial cells to exert anti-inflammatory effects, improves barrier function and mucosal permeability (Réquilé *et al*, 2018; Wu *et al*, 2017).

Indirectly, prebiotics acts as a highly fermentable substrate for energy production by specific bacterial taxa. This not only positively balances the composition of gut microbes, but also influences the release of a wide array of metabolites to regulate various biological pathways to boost host health. Additionally, the product of fermentation are often organic acids which decreases the gut pH. This 1-2 units of pH reduction can ultimately alter the composition of acid-sensitive bacteria populations such as Bacteroides, Firmicutes and other lactic acid bacteria (Duncan *et al*, 2009).

Since the metabolic products of prebiotic fermentation are often SCFAs, which are small enough to diffuse through gut enterocytes and enter blood circulation, a vast majority of research findings to-date has attributed the positive health effects of prebiotics via microbiome-gut-brain axis modulations. Therefore, prebiotics are able to affect not only the gastrointestinal track but also other distant site organs and systems (den Besten *et al*, 2013).

HEALTH BENEFITS OF PREBIOTICS

It is noteworthy that prebiotics do not only incur protective effects on the gastrointestinal system but also on other distant parts of the body, such as the central nervous system, immune system, skeletal system and cardiovascular system (Tzounis *et al*, 2011). Another evidently clear benefit of prebiotics is its influence on allergic diseases such as atopic dermatitis, respiratory allergies and food allergies (Brosseau *et al*, 2019). Numerous studies have also reported both direct and indirect effects of prebiotics towards the maintenance of epithelial barrier function and the modulation of gut microbiota respectively, leading to decreases in intestinal inflammation and subsequent prevalence of large bowel diseases (Brosseau *et al*, 2019).

While prebiotics have been shown to improve a number of chronic inflammatory conditions, there are a growing number of evidence describing the prebiotic effects on calcium metabolism and bone health (Whinner and Castillo, 2018). These novel dietary fibres have been shown to increase calcium absorption in the lower intestines in both preclinical animal and human models. Current prebiotic mechanisms for improved mineral absorption and skeletal health include a complex interaction between the gut-bone axis encompassing alterations in gut microbiota composition, production of short-chain fatty acids, altered intestinal pH, biomarker modification, and immune system regulation. Collectively, these physiological changes results in improved bone mineral uptake and subsequent osteoblast activity.

CONCLUSION

In conclusion, it is evidently clear that various types of prebiotics are able to both directly and indirectly benefit human health through the prevention or control of numerous diseases when incorporated in our diet. It is also important to note that an appropriate and balanced daily uptake of prebiotics is equally crucial to attain an optimum impact on our gut microbiota. With so many sources and types of prebiotics being reported to date, it is now a lot easier to selectively incorporate these ingredients into the wide variety of local Malaysian cuisine. Current studies are now focused towards optimizing more balanced combinations of prebiotics and probiotics into Malaysian symbiotic foods to achieve new synergistic effects to further improve overall health. A deep dive into the roles that various gut probiotics play are discussed in the subsequent chapter.

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Chapter 3

Probiotics

Jiun-Yan Loh

INTRODUCTION

Probiotics refer to a group of living bacteria that survives passage through the gut while improving the gut's microbial balance (Fuller, 1989; Gilliland, 1990). The term "probiotics" had been redefined by FAO/WHO as live microorganisms that promote the health of humans and animals, and must be safe and sufficient for physiological functions (FAO/WHO, 2002). Functional probiotics should contain at least 10^6 live cells or colony-forming-units (CFU/g) in any product to ensure the application efficacy of health improvement.

Some of the most important groups such as *Lactobacilli*, *bifidobacteria*, and lactic acid-producing bacteria (LAB) which are isolated from fermented dairy products and/or the fecal microbiome have traditionally been used as probiotics for human consumption (**Figure 1**). As our understanding of the human microbiome and its functions has grown, different discovery approaches have been applied to identify and characterize new potential probiotics from various origins (Veiga et al., 2020). New strains of potential probiotics such as *Akkermansia* spp., *Bacteroides* spp., *Eubacterium* spp., *Faecalibacterium* spp., and *Roseburia* spp. have been isolated from the human body e.g. the gastrointestinal tract (GIT) (Brodmann et al., 2017; O'Toole et al., 2017). These novel probiotics may offer physiological functions which are not usually found in the group of *bifidobacteria* or *lactobacilli* (Blaak et al., 2020).

Other than the GIT, the female urogenital tract, mouth cavity, nasopharyngeal tract, and skin are potential niche areas for novel species discovery (Cribby et al., 2008; George et al., 2016; Maguire and Maguire, 2017). Generally, fermented foods are an important source of LABs. Nevertheless, the unfermented food sources such as fruits, vegetables, grains/cereals, cheese, vinegar, meat/fish products, and honey, as well as environmental sources (e.g. soil, crops and marine resources) (**Figure 2**) are also the major source of LABs, and these sources might be potential for future probiotic development (Zielińska and Kolożyn-Krajewska, 2018).

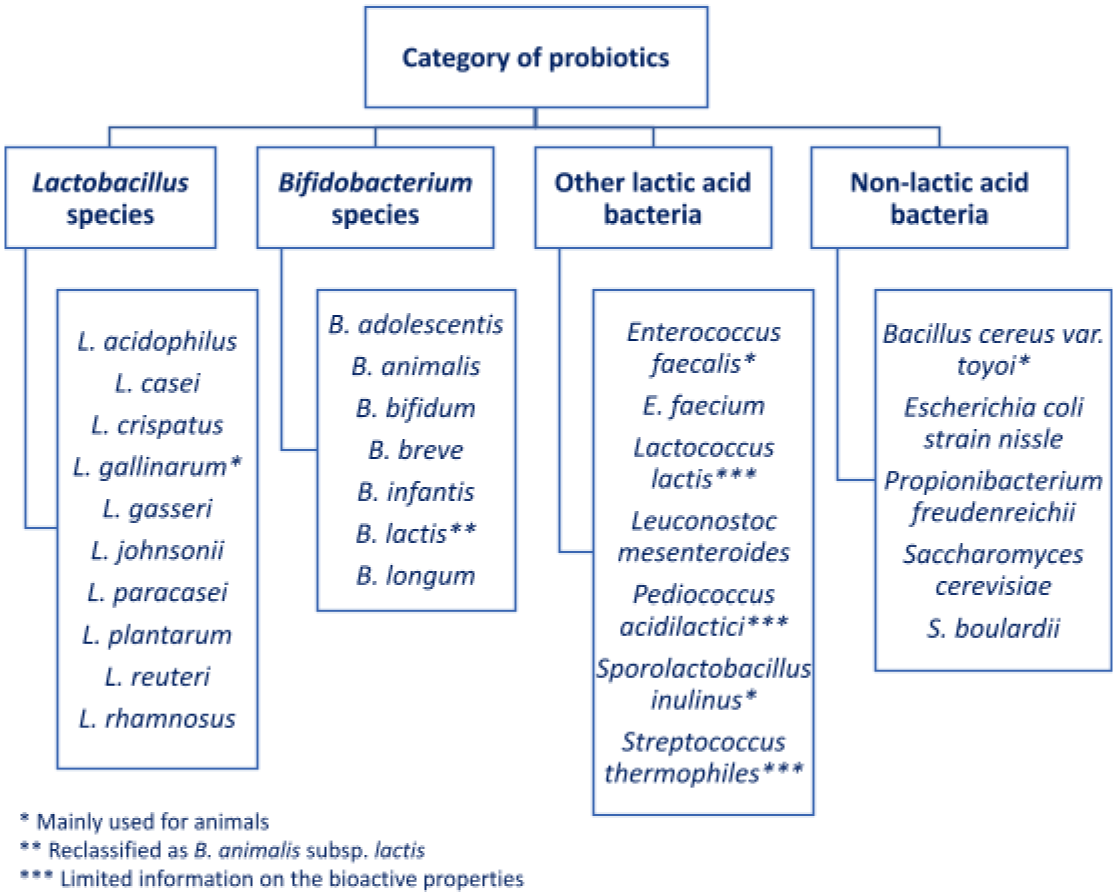

Figure 1. The category of microorganisms that considered as probiotics (Modified from Kechagia et al., 2013)

Fermented foods such as Tempeh (made from fermenting boiled and dehulled soybeans with a starter culture of *Rhizopus oligoporus*) (**Figure 3a**) and Punjabi lassi (made from yogurt, water, spices, and sometimes fruits) (**Figure 3b**) are the most common edible sources of probiotics in Asian communities. Numerous studies have shown that consumption of these probiotics has been associated with many health benefits as well as maintenance of well-balanced intestinal microbiota (Taylor et al., 2020), including the lowering of high blood pressure, serum cholesterol, risk of type 2 diabetes, and cardiovascular diseases (Marco et al., 2017; Pasolli et al., 2020; Saha et al., 2021). **Table 1** summarizes the major strains of probiotics that showed potential health benefits to humans.

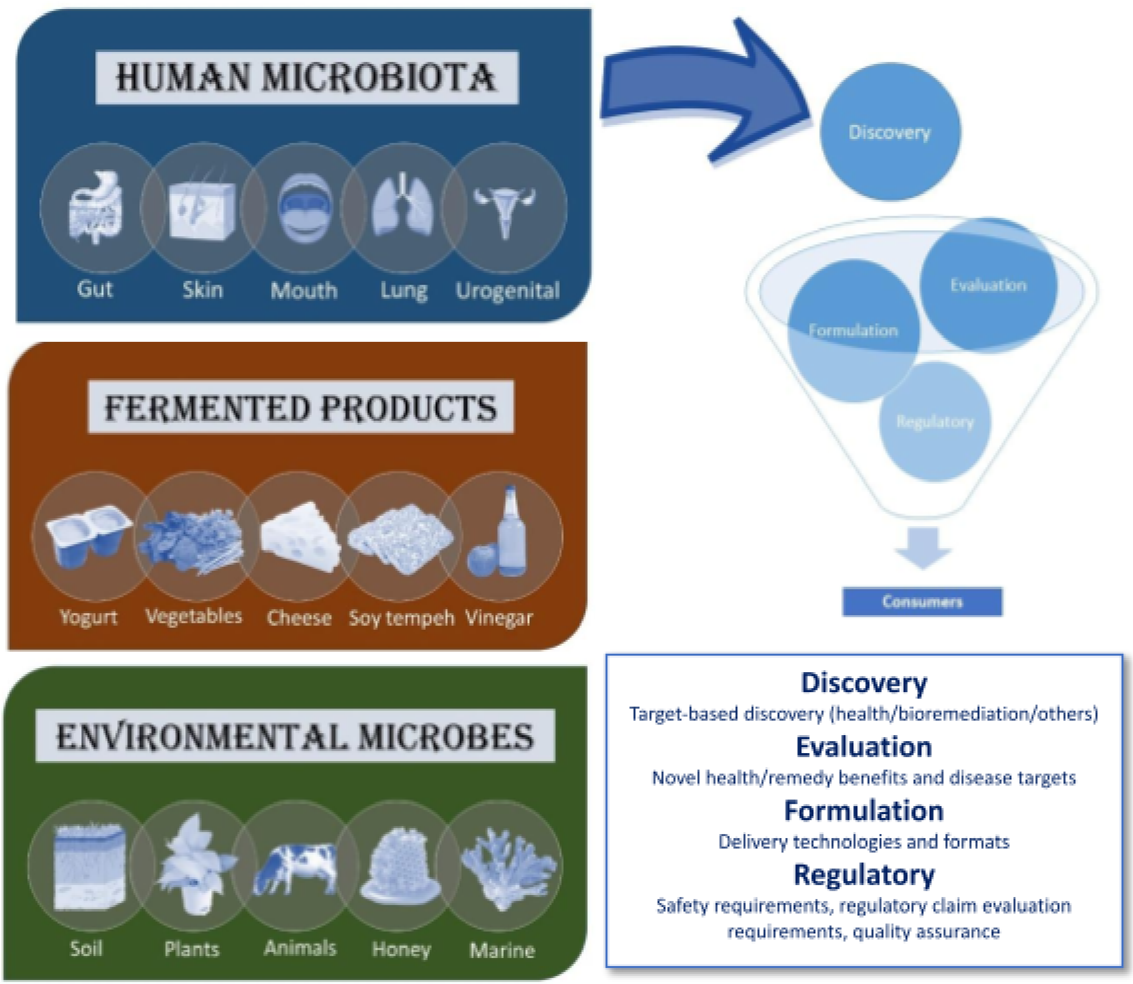

Figure 2. Development of probiotics from different sources. Potential probiotics must be: (i) sufficiently characterized and safe for the intended use; (ii) viable at an efficacious dose during delivery; (iii) supported by positive clinical trials under scientific standards or as per regulatory requirements of local/national authorities.

(a) (b)

Figure 3 (a) Tempeh is one of the common fermented foods among Malaysian (b) Punjabi lassi is not only popular for its taste, but also contained various probiotics.

MECHANISMS OF ACTION OF PROBIOTICS

The probiotic mechanisms of action can be divided into several broad categories (**Figure 4**):

- **PATHOGEN INHIBITION**

Most LABs produce antimicrobial peptides (AMPs) such as nisin, bacteriocin, and organic acids. These AMPs show promising inhibitory activities against pathogenic microorganisms. These bacteriocin-mediated killing effects include the destruction of the bacterial cell wall and inhibiting cell wall biosynthesis of spore-forming bacilli (Bermudez-Brito et al., 2012; Loh et al., 2017). Certain species of gut microbiota, such as *Bacteroides intestinalis able* to deconjugate and dehydrate bile acids whereby the secondary metabolites could inhibit *Clostridium difficile* spore germination and inhibit the growth of *C. difficile* (Ridlon et al., 2006; Jandhyala, 2015).

- **ADHESION TO THE INTESTINAL MUCOSA/COMPETITIVE EXCLUSION**

Probiotics could prevent the post-colonization of pathogens. These beneficial microbes could re-establish, maintain host-microbial homeostasis and reduce pathogenic invasion and proliferation in the host's intestinal mucosa. When probiotics occupy all functional niches in the intestinal tract, the likelihood of pathogenic invasion and colonization in that ecosystem could be reduced and thus prevent opportunistic infection (Harper et al., 2018). For example, *bifidobacteria* have been shown to colonize the gut for up to 6 weeks after oral supplementation, and it can inhibit the growth and development of enteropathogenic bacteria and alter the composition of the gut flora (de Vrese, 2007).

- ## NUTRITIONAL FUNCTIONALITY/XENOBIOTIC METABOLISMS

A range of chemical processes catalyzed by enzymes produced by the gut microflora has been described in many studies. Some LABs produce enzymes such as proteases, peptidases, polysaccharide degrading enzymes, ureases, lipases, amylases, esterases, and phenoloxidases, which have a broader range of activity than the host enzymes, and these enzymes play an important role in the digestive system of mammals (Padmavathi et al., 2018). Certain probiotic strains contribute to the synthesis of vitamins (e.g. vitamin K and vitamin B12), short-chain fatty acids (ScFAs), pyridoxine, biotin, folate, nicotinic acid, and thiamine (Vandenplas et al., 2015). These bioactive compounds are the major energy sources for enterocytes and are associated with the health status of the enteric mucosa (Ríos-Covián et al., 2016). Recent research also suggested that gut microbial metabolites can bio-convert mycotoxin to a less toxic form, α-ZOL and β-ZOL (Złoch et al., 2020). These new findings of the gut microbiota in drug and xenobiotic metabolism could offer different therapy options for various medical conditions in the future.

- ## MODULATION OF THE IMMUNE SYSTEM

Probiotics have diverse effects on the immune system through cytokine production, including interleukins (ILs), tumor necrosis factors (TNFs), interferons (IFNs), transforming growth factor (TGF), and chemokines from immune cells which are responsible to initiate adaptive responses. The inflammatory process depends on pro-inflammatory and anti-inflammatory cytokines, some probiotic species act as immunostimulants (i.e., pro-inflammatory) due to their ability to induce IL-12 and natural killer (NK) cell immunity (Aziz and Bonavida, 2016). Some species act as immunoregulatory (i.e., anti-inflammatory) in the regulatory T cell pathways and induction of IL-10 (Azad et al., 2018). These inflammatory processes increase gut barrier functions by stimulating B cells, in turn, enhance the immune responses of the host body (Azad et al., 2018).

- ## AMELIORATION OF FOOD CONTAMINANTS

Recent *in vivo* studies suggested that probiotics competitively inhibit the intestinal absorption of food contaminants and reduce the risk from the uptake of hazardous compounds during intestinal transit. For example, *Pedicococcus pentosaecus* breaks down fumonisins and lowers their availability in the host's GIT (Bisanz et al., 2014; Vandenplas et al., 2015). Some probiotics have also been shown to have biological functions in stimulating intestinal peristalsis, enhancing intestinal barrier function, and regulating the junction of the epithelium of the small intestine (Średnicka et al., 2021).

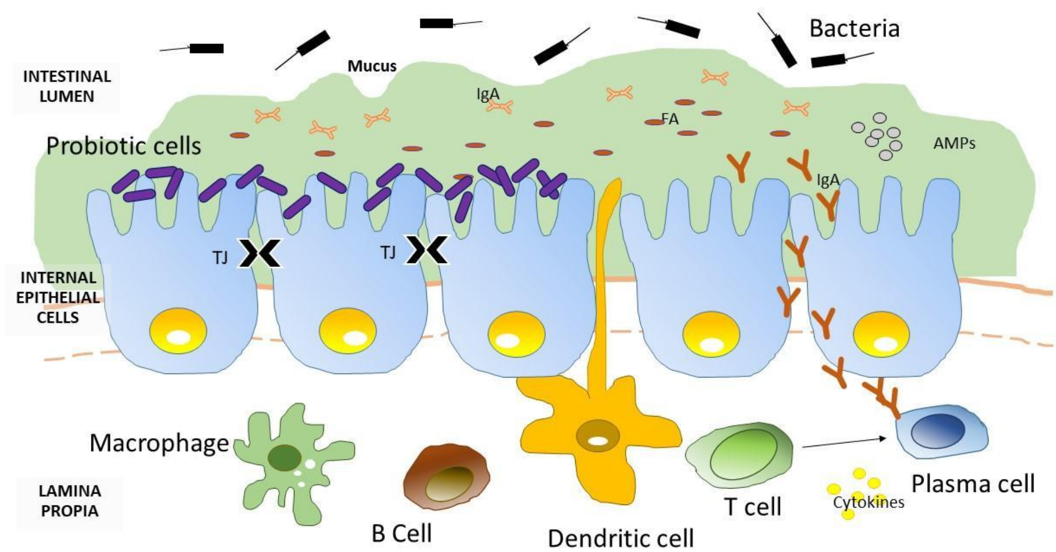

Figure 4 The probiotic mechanisms of action occur at the intestinal barrier. The mucus is a sieve-like layer overlying the intestinal epithelium. Antimicrobial peptides (AMPs) and secretory IgA molecules are secreted in the mucus layer as immune-sensing and regulatory proteins. The mucosa act as a semipermeable barrier that allows the absorption of nutrients and immune sensing, also functions to limiting the transport of potentially harmful antigens such as food antigens (FA). The tight junctions (TJ) regulate the transport of small molecules and ions. T cells, B cells, macrophages and dendritic cells in the lamina propria responsible for the adaptive and innate immune system.

Table 1 Functional properties of different probiotic strains

Probiotics	Gram	Functionality	Reference(s)
Akkermansia muciniphila	(-)	Reduces body fat, serum triglyceride, fasting glucose levels and enhances insulin sensitivity	Everard et al. (2014); Zhai et al. (2018)
Brevibacillus laterosporus	(+)	Exhibits antibacterial and antitumor activity	Hong et al. (2005); Jiang et al. (2017)

Bacteroides xylanisolvens	(-)	Increases the level of TFa-specific immunoglobulin M serum antibodies	Ulsemer et al. (2012); Ulsemer et al. (2016)
Bifidobacterium bifidum	(+)	Produces greater cytokine (IL-6) and promotes active phagocytic property	Ku et al. (2016); LeBlanc et al. (2017)
Bifidobacterium breve	(+)	Exhibits anti-infectious activity	Asahara et al. (2004)
Bifidobacterium infantis	(+)	Exhibits therapeutic effect against irritable bowel syndrome and inhibits the secretion of allergen-induced IgE	Osman et al. (2006); Yuan et al. (2017); Liu et al. (2017)
Bifidobacterium lactis	(+)	Promotes plasminogen binding activity and regulates the co-stimulatory molecules (CD80, CD86, CD40) that required for activation of T-cells	Ruiz et al. (2012); Merenstein et al. (2015)
Bifidobacterium longum	(+)	Modulates the immune system through IL-10 production	Celiberto et al. (2017)
Clostridium butyricum	(+)	Promotes neuroprotective effects against vascular dementia	Liu et al. (2015)
Enterococcus faecium	(+)	Modulates the Th2-mediated pathological response	Rho et al. (2017); Vimont et al. (2017)
Faecalibacterium prausnitzii	(-)	Exhibits anti-inflammatory effects by blocking NF-kappaB activation and IL-8 production	Sokol et al. (2008); Martín et al. (2017)
Lactobacillus acidophilus	(+)	Reduces the level of cholesterol through reverse transport in macrophages	Hong et al. (2016)
Lactobacillus brevis	(+)	Exhibits antidepressant, antihypertensive, and anti-diabetic effects	Wu et al. (2018)
Lactobacillus bulgaricus	(+)	Promotes anti-microbial peptide production	Moro-García et al. (2013)
Lactobacillus casei group (LCG)	(+)	Enhances anti-inflammatory response	Aktas et al. (2015); Hill et al. (2018)
Lactobacillus gasseri	(+)	Reduces body weight and adipose tissue mass	Kadooka et al. (2010)
Lactobacillus helveticus	(+)	Inhibits the proliferation of lymphocytes through suppression of JNK signalling pathway	Hosoya et al. (2014)

Lactobacillus plantarum	(+)	Promotes cholesterol-lowering activity	Costabile et al. (2017); Behera et al. (2018)
Lactobacillus salivarius	(+)	Reduces pathogenicity of C. albicans by inhibiting the biofilm formation	Krzysciak et al. (2017); Neville et al. (2010)
Lactococcus lactis	(+)	Uses as a vehicle to deliver therapeutics e.g. cytokines into the human body	Song et al. (2017)
Pediococcus acidilactici	(+)	Enhances antimicrobial activity against several food-spoilage and food-borne pathogens	Abbasiliasi et al. (2017)
Streptococcus thermophiles	(+)	Suppresses the Th17 response in inflamed intestines, useful in inflammatory bowel disease	Ogita et al. (2011)
Saccharomyces boulardii	Yeast	Exhibits positive responses in Clostridium difficile-associated disease, antibiotic-associated diarrhoeas, and acute infectious diarrhoeas	Czerucka et al. (2007); Buts (2009)

CONCLUSION

Numerous scientific reports confirm that probiotic organisms are playing an important role in maintaining intestinal microbiota and human health. A positive effect of probiotics in the course of various drug metabolism and anti-cancer therapies is also worth noting. Increasing studies have shown the effectiveness of using probiotic strains to detoxify pollutants such as pesticides, toxins, and heavy metals. It has been proven that gut microflora is associated with the occurrence of metabolic diseases such as diabetes, obesity, allergies, inflammatory, bowel disease, and liver cancer. An increasing number of potential probiotic strains can be characterized through the advancement of research tools. However, more comprehensive *in vivo* research should be performed to understand the probiotic-host axis to reduce the risk of xenobiotic-induced gut dysbiosis and chronic toxicity. Probiotics are not drugs, they show positive effects in enhancing human health but they could also cause serious pathological conditions such as inflammatory bowel disease (IBD), hepatic encephalopathy, etc in certain cases. Hence, rigorous regulations are needed in developing and sourcing medically beneficial probiotics.

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Chapter 4

Plant oils

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INTRODUCTION

Plant oils are typically obtained from beans, nuts, seeds, or fruits and are widely used for cooking, cosmetics, or even biofuels. The major vegetable oils that are traded in the world include palm oil, soybean oil, coconut oil, olive oil, safflower oil, canola oil, corn oil, and sunflower oil. In 2020, the global vegetable oil output was estimated at around 209.14 million metric tons. It is projected that the global edible oil market will grow from a market value of USD96.878 billion in 2019 to USD119.571 billion by the end of 2025. Each plant oil comprises different fatty acid composition, physicochemical properties, and phytonutrient content. Functional oils have various health benefits, such as reducing the risk of certain types of cancer, cardiovascular disease, a source of energy for growth and development.

The main extraction methods for plant oils are mechanical pressing or solvent extraction. Moreover, vegetable oils may lose their quality and properties by becoming rancid due to undesirable materials, exposure to sunlight and moisture (Negash et al., 2019). Rancid oils, which form toxic compounds and produce reactive oxidative products could increase the risk of having health diseases such as cancer and inflammation (Negash et al., 2019). Therefore, refining is a process to remove unwanted contents in the oil such as phospholipids, free fatty acids, sulfur compounds, and monoacylglycerols. Thus, important parameters such as free fatty acid content, moisture, specific gravity, and peroxide value are used to monitor the quality and shelf life of the oils. With the refining process, desirable characteristics and phytonutrients are also lost, which significantly reduces the health benefits of the oil.

Technological advancement in extraction and refining has been developed to retain desirable characteristics and phytonutrients to provide significant health benefits. In Malaysia, plant oils that are gaining popularity for its functional properties are red palm oil and virgin coconut oil. The extraction, physicochemical properties and nutritional benefits of these two oils are addressed in this chapter.

RED PALM OIL

- ### EXTRACTION

The processing of red palm oil (RPO) begins from fresh fruit bunches (**Figure 1**) of oil palm trees, commercially known as *Elaeis guineensis*. Fresh fruit bunches undergo various processes in small to large mills including sterilization, threshing, digestion, pressing, clarification and drying to produce crude palm oil (CPO). Next, CPO is converted to RPO (**Figure 2**) via mild refining stages involving degumming, deacidification, deodorization and distillation to remove impurities and free fatty acids (FFA) while retaining its carotenes (Tan et al., 2021). Cassiday (2017) also reported emerging ways of extracting RPO such as cold filtration, which retains most of the carotenes but contains 3% more FFA.

Figure 1: Fresh fruit bunch from palm tree (Photo credit: Adrian Choo)

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Figure 2: Red palm oil (Photo credit: Adrian Choo)

- ## PHYSICOCHEMICAL PROPERTIES

According to Tan et al. (2021), RPO has a FFA of 0.1% and iodine value of 51.5g I2/100g which is the lowest among RPO, red palm olein and crude red palm olein. This low value of FFA and iodine value reduces the susceptibility of RPO to oxidation. Moreover, RPO has a balanced fatty acid composition of 50% saturated acids, 42% of monounsaturated fatty acids and 10% of polyunsaturated acids that contribute to the stability in frying and storage of the oil (Tan et al., 2021). The main fatty acid components are palmitic acid (42%) and oleic acid (42%) (Nayana et al., 2021). RPO has a unique bright red-orange colour resulting from high amounts of retained carotenes. RPO is the highest natural resource that contains 500 ppm to 700 ppm of carotenoids (Mba et al., 2015). Within the carotenoids in RPO, -carotenes has the highest percentage of 65% followed by α-carotenes (33%) and other carotenoids such as lycopene and y-carotenes at 2% (Mba et al., 2015). The high number of carotenes can act as an antioxidant and help to prevent the oxidation of RPO. Other than carotenoids, tocopherol and tocotrienols also acts as an antioxidant in RPO to maintain the stability and quality of the oil. RPO contains 600 ppm to 1000 ppm of tocopherol and tocotrienols (Tan et al., 2021). Other minor phytonutrients such as phytosterols, squalene and ubiquinone can also be found in RPO**.**

- **NUTRITIONAL BENEFITS**

Red palm oils are mainly taken as a main source of dietary fat due to its various phytonutrients and nutritional benefits. High levels of carotenoids, tocopherols and tocotrienols contained in RPO can provide numerous health and nutritional benefits to humans. Carotenoids are fat soluble and are known as pro-vitamin A, which are converted in the human body into vitamin A. According to several studies, carotenes provide protection against certain types of cancer in certain areas such as breast, colon and stomach and prevent vitamin A deficiency (VAD) related diseases such as eye and skin diseases (Choudhary & Grover, 2019). In an animal study by Boateng (2006), the authors reported that by giving red palm oil with 7% fat for 13 weeks can reduce the amount of aberrant crypt activity. Thus, inhibiting the progress of cancer, reduces the effects of chemotherapy and improve cancer management.

According to Loganathan et al. (2015), major phytonutrients such as carotenoids and vitamin E possess certain anti-cancer effect to prevent human breast cancer cells. In developing countries, VAD is an alarming issue toward public health and consensus in searching sustainable food-based solution to address this problem. A meta-analysis of randomized controlled trials of preventing or alleviating vitamin A deficiency was done by Dong et al. (2017) suggested that RPO is highly effective in improving VAD among populations that are at risk of VAD in the form of supplements and food fortification.

Pignitter et al. (2016) studied fortified vegetable oils mainly mildly and highly oxidised palm oil and after fortification at 32 °C for 57 days, it was concluded that household storage of mildly oxidised palm oil did not have any loss of vitamin A. This concludes mildly oxidised palm oil can be recommended for vitamin A fortification. In underdeveloped populations, especially in Africa and Asia, rates of children with vision impairment, blindness, stunting and respiratory related issues due to deficiency of vitamin A are high (Loganathan et al., 2017). Various studies have shown that supplements and foods fortified with RPO are capable of improving vision, eye complications and growth development in children (Loganathan et al., 2017).

Furthermore, Ermatov et al. (2019) revealed that RPO can be used as a treatment to anemia and complex gastrointestinal diseases due to the anti-inflammatory and regenerative-improving effects of RPO. Ermatov et al. (2019), conducted 3 stages of RPO at a clinical setting, depending on the severity of the anemia for evaluation of nutritional and biological effects of RPO in patients with anemia, it was concluded RPO has a decisive remedial effect for varying severity of anemia. Additionally, tocopherols and tocotrienols of RPO are capable of inhibiting the synthesis of cholesterol in the liver

(Choudhary & Grover, 2019). Song & DeBose-Boyd, (2006) studied the daily consumption of tocotrienol-enriched palm oil within 4 weeks and found that there is a significant reduction in thromboxane, serum cholesterol and LDL cholesterol.

VIRGIN COCONUT OILS

- ### EXTRACTION

Virgin coconut oil (VCO) is derived from using wet method that uses fresh or mature coconut kernels from coconut tree (*Cocos nucifera*). The wet method is a means of extracting VCO from coconut milk by mechanical or natural without involving any chemical or heat, which helps to produce a significantly different oil in terms of physicochemical and sensory characteristics (Rohman et al., 2021). There are a few commercially used methods to extract VCO from coconut milk, this includes cold extraction, centrifugation, fermentation, aqueous enzymatic extraction, and hot extraction (Agarwal, 2017). Refined, bleaching, and deodorized method is used in some companies however this method reduces the health benefits of the oil (Ng et al., 2021).

- ### PHYSICOCHEMICAL PROPERTIES

In terms of fatty acid composition, VCO consists of 94% saturated fatty acid in which the predominant saturated fatty acid is medium chain fatty acid (62%). Medium chain fatty acid helps in resisting oxidation and polymerization compared to unsaturated fatty acids (Ng et al., 2021). Most of the medium chain fatty acids are lauric acids (C12) and myristic acids (C14) (Ng et al., 2021). VCO (**Figure 3**) has an iodine value ranging from 4.13 g I_2/100g to 4.26 g I_2/100g, free fatty acid saponification value of 0.29 to 0.46, moisture content of 258.23% to 262.72 and viscosity of 0.04 Pa.s to 0.11 Pa.s depending the type of extraction technique used (Rohman et al., 2021). Therefore, VCO that has a low moisture content can increase the shelf life and reduce the hydrolysis and oxidation that results in rancidity in oils.

Martins et al. reported that the ash content of industrial VCO is 0.005%, density of 0.897%, pH value of 3.33 and peroxide index of 0.959. Additionally, according to Mohammed et al. (2021), redness (a*) of VCO ranged between -1.245 to 0.94, yellowness (b*) ranged between 0.735 to 2.755 and brightness (L*) ranged between 98.855 to 99.725, which delivers a bright transparent yellow to VCO. Moreover, Rohman et al. (2021) reported that VCO contains phenolic compounds (250.9mg/Kg) compared to commercial coconut oil (91mg/Kg), namely, ferulic acid and p-coumaric acid at 5.09mg/Kg and 0.75mg/Kg respectively that contributes to the antioxidant properties of VCO. Other than ferulic acid and p-coumaric acid, VCO also contains caffeic acid, quercetin and catechins (Rohman et al., 2021).

Figure 3: Virgin coconut oil (Photo credit: Adrian Choo)

- ## NUTRITIONAL BENEFITS

Inflammation is a response from the immune system to fight against foreign pathogens, but the various mediators or processes of this response may cause diseases or disorders such as cancer, atherosclerosis, ischemic heart disease and Alzheimer's disease if unregulated (Holt, 2016). VCO is rich in phenolic compounds such as p-coumaric acid, caffeic acid and ferulic acid that can act as an antioxidant and can increase antioxidant enzymes levels in the body that contributes to the reduction in inflammation and lipid peroxidation (Wallace, 2019). Furthermore, phenolic compounds in VCO showed potential in reducing stress-induced damage and maintaining antioxidant balance (Marina et al., 2009). Rahim et al. (2021) studied on the neuroprotective potential of VCO against lipopolysaccharide-challenged rats which were fed with 1 to 10g/kg of VCO and were tested to a maze test. They concluded that the study demonstrated a memory enhancing and neuroprotective effects of VCO, which may benefit the cholinergic, antioxidant, anti-inflammatory and anti-amyloidogenic pathway.

VCO is rich in tocopherols and tocotrienols, which are powerful antioxidants. These phytonutrients act as a scavenger to damaging oxygen free radicals. In general, physical exercise will increase oxygen intake due to increase metabolism which causes fatigue and injuries to the muscle. Oxidative stress may occur when skeletal muscle contracts, which can lead to high reactive oxygen species (Sinaga et al., 2021). Sinaga et al. (2021) studied the potential of virgin coconut oil in reducing creatine kinase levels in non-athlete students. The study was divided into two groups; one with 15 ml dose of VCO and the other was given a placebo and was subjected to a physical routine for 3 times a week and the results showed that a significant reduction in creatine kinase levels was found in students who were given 15 ml of VCO.

Diabetes mellitus is caused by the reduction of insulin secretion or reduced insulin sensitivity. A few common factors of diabetes mellitus include diet, obesity, genetic and physical inactivity. VCO is an oil that is rich in lauric acid and capric acid. A study on the effects of lauric and capric acids reported that it significantly increases basal insulin secretion, which suggested VCO can control blood sugar levels in the body (Garfinkel et al., 1992). Narayanankutty et al. (2016) reported replacing coconut oil with VCO in rodents that were given high fructose diet. The rodents had only 17% increase in blood glucose levels as opposed to a 46% increase for rodents that were fed with coconut oil. Besides, VCO may prevent the development of insulin resistance and hyperglycaemia due to high antidiabetic and insulin sensitizing effects from caffeic acid, ferulic acid and catechins.

Cardiovascular disease is known worldwide for its high mortality rate. A systematic review studied by Ma & Lee (2016) showed that VCO can lower the risk of cardiovascular disease whereby it is caused by poor intake of polyunsaturated fatty acids. Another study by Chinwong et al. (2017) reported that VCO consumption significantly increased high-density lipoprotein cholesterol levels, which are closely associated with cardiovascular disease. Obesity, another independent risk factor for cardiovascular disease can reduce waist circumference and body mass index by consuming coconut oils. Assunção et al. (2009) reported 40 women between the age of 20 to 40 years who consume coconut oils showed a higher level of high-density lipoprotein and significant reduction in body mass index and waist circumference. **Table 1** summarizes the comparison of physicochemical properties and nutritional benefits of different plant oils.

Table 1 Comparison of physicochemical properties and nutritional benefits of different plant oils.

VEGETABLE OILS	PHYSICOCHEMICAL PROPERTIES	NUTRITIONAL BENEFITS	REFERENCE(S)
VIRGIN COCONUT OIL	Predominantly medium chain fatty acid (65.7% to 71.3%) High amounts of lauric acid (48.40% to 52.84%) Contains phenolic compounds (7.49 to 104.52 mg/ml)	Improve energy production Effective against lipid-coated viruses Reduce risk of obesity and heart disease	(Boateng et al., 2016; Ghani et al., 2018)
RED PALM OIL	Balance fatty acid composition (50% saturated & 50% unsaturated) High carotenoid value (500 ppm to 786 ppm) 600 ppm to 1000 ppm of tocopherols & tocotrienols)	Reduce deficiency of vitamin A Increase serum retinol Lower cholesterol Increase antioxidant level Reduce risk of cancer	(Tan et al., 2021)
CANOLA OIL	Predominantly monosaturated fatty acid (60% to 65%) High oleic acid (60 % to 85%) Rich in polyunsaturated fatty acid	May reduce risk of coronary heart disease	(Bailey & Shahidi, 2005)
COTTONSEED OIL	26% saturated, 52% polysaturated & 18 to 24% monounsaturated fatty acid Mainly contain linoleic acid (54.4%)	Reduce cholesterol level Anti-allergic response Anticancer activity	(Riaz et al., 2021; Zia et al., 2022)
OLIVE OIL	85% unsaturated fatty acid composition is unsaturated fats 70% are oleic acid Contains squalene and terpenoids	Reduce risk of cardiovascular disease Antitumor effects Antimicrobial function Reduce risk of colon, cancer breast and skin cancer	(Foscolou et al., 2018)
RAPESEED OIL	68.6% monounsaturated fatty acid and 17.4% polyunsaturated fatty acids Abundant of oleic acid (63.7%) and linoleic acid (17.4%)	Maintain skin integrity, cell membrane and immune system Improve blood lipid profile and osteoporosis	(Chew, 2020)
SAFFLOWER OIL	Contains 77.9 to 79.5% of linoleic acid and 9.5 to 11.3% oleic acid	Control cholesterol and high-density lipoprotein level	(Khalid et al., 2017)

	Only containing 9.7% to 10.8% of saturated fatty acids. Contains 1248 to 2976 mg/kg of sterols Tocopherol content ranging 319 to 648 mg.kg	Improving skin health, hair growth and immune system Control muscle contraction and premenstrual syndrome

CONCLUSION

Plant oils are usually aimed for cooking and functional oils like red palm oil and virgin coconut oil in Malaysia provide various health benefits. Red palm oil is extracted from *Elaeis guineensis* and it contains a balanced fatty acid composition (50% saturated & 50% unsaturated). The oil is high in carotenoids and vitamin E, which have anti-cancer properties. Red palm oil can overcome vitamin A deficiency due to the presence of different carotenoid fractions like α-, β-, and γ-carotenes. Meanwhile, virgin coconut oil is extracted from *Cocos nucifera* and the oil is high in phenolic content as well as medium chain fatty acids. Virgin coconut oil has anti-inflammatory properties and can control blood sugar levels and lower the risk of cardiovascular disease.

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Chapter 5

Fish Oil

Kar Lin Nyam

INTRODUCTION

FISH OIL

Fish oil (FO) supplements consumption is comparable to fish consumption in terms of EPA and DHA content. Fish oil capsule is one of the most popular non-vitamin, non-mineral, dietary supplements around the world (Hilleman et al. 2020). Fish oil supplements are commonly sold in triglyceride form because it is less expensive to produce (Harris et al. 2013; Shahidi and Ambigaipalan 2018).

Fish oil is known to be an important source of n-3 polyunsaturated fat such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which are well-known to be effective in the prevention of several diseases. The DHA and EPA are essential fatty acids that only can be obtained through diet. FO can be obtained by consuming fish or taking supplements. Fish that are high in n-3 fatty acids include tuna, salmon, mackerel and herring (Özogul and Özogul 2007). Fish oil is extracted from the fish tissue by wet pressing and extraction using solvents conventionally (Bonilla-Méndez *et al.* 2018). A more recent proposed extraction method would be supercritical fluid and fish silage.

FATTY ACID PROFILES

The saturated fatty acids (SFA) content in marine fish species from different regions range from 25.2-43.6%, while monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) content range from 16.7- 48.3% and 20.9- 49.9%, respectively (**Table 1**). In terms of EPA and DHA content, it ranges from 1.15- 10.8% and 3.08- 31.3%, respectively. It is observed that the fatty acid content from different types of fish varies significantly. However, the fatty acid content in fish oil supplement is normally standardized.

Table 1 Comparison of fatty acid profiles in marine fish species from different regions around the world (Zhang et al., 2020)

Number of Species	Locations	SFAs	MUFAs	PUFAs	EPA	DPA	DHA
23	**Pearl River Estuary**	**38.9 ± 4.07**	**31.1 ± 5.61**	**20.9 ± 4.61**	**5.72 ± 2.12**	**1.77 ± 1.01**	**7.44 ± 2.55**
12	East China Sea	34.5 ± 2.76	31.0 ± 4.10	28.4 ± 5.97	6.81 ± 1.46	2.48 ± 1.21	14.8 ± 3.98
6	Minnan-Taiwan fishing ground	36.8 ± 1.05	26.6 ± 2.74	36.7 ± 2.41	2.87 ± 0.48	2.54 ± 0.32	20.1 ± 2.10
8	The northwest Pacific Ocean	25.2 ± 3.73	31.9 ± 12.2	39.6 ± 10.4	10.8 ± 2.01	1.57 ± 0.71	20.1 ± 7.75
4	Brazil	25.4 ± 6.52	31.1 ± 17.1	31.5 ± 11.7	7.85 ± 1.67	1.60 ± 0.92	19.2 ± 9.73
4	Panama	39.8 ± 1.72	31.8 ± 1.86	28.3 ± 3.57	6.24 ± 0.87	1.46 ± 0.23	15.3 ± 3.17
6	Adriatic Sea	31.7 ± 3.01	16.7 ± 4.26	49.9 ± 4.69	8.53 ± 1.64	2.68 ± 2.39	31.3 ± 8.24
8	Egypt	25.6 ± 2.06	48.3 ± 6.97	26.1 ± 6.61	1.15 ± 0.90	0.92 ± 0.55	10.3 ± 5.69
11	Queensland	31.9 ± 2.15	17.6 ± 2.51	42.5 ± 2.92	4.09 ± 0.55	3.36 ± 0.58	17.7 ± 3.40
9	Polish	27.7 ± 6.54	27.4 ± 13.4	45.0 ± 17.9	8.74 ± 9.08	2.46 ± 1.88	20.1 ± 16.2
8	Turkey	30.5 ± 5.05	21.1 ± 5.80	36.1 ± 8.14	5.40 ± 1.09	NA	21.8 ± 9.18
8	Mediterranean and Black Seas	31.3 ± 3.50	20.7 ± 4.66	34.8 ± 7.05	6.95 ± 2.55	NA	21.1 ± 8.41
11	Southern Italy	43.6 ± 3.47	24.9 ± 4.74	31.5 ± 2.28	6.82 ± 0.87	NA	13.8 ± 2.42
10	India	37.1 ± 2.07	23.7 ± 1.18	32.3 ± 1.48	4.28 ± 0.56	2.74 ± 0.83	3.08 ± 0.86
6	Black Sea	31.3 ± 2.49	28.4 ± 4.60	27.0 ± 8.01	6.30 ± 2.19	NA	14.5 ± 7.47

SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids; EPA: eicosapentaenoic acid; DPA: docosapentaenoic acid; DHA: docosahexaenoic acid; NA: not analysed. Results represent mean ± SD.

HEALTH EFFECTS AND CLINICAL TRIALS

The World Health Organization recommends eating 1-2 portions of fish per week because of the health benefits from n-3 fatty acids. Consumption of fresh fish is more superior in modifying lipid profile than taking fish oil supplements (Zibaeenezhad *et al.* 2017). A study showed that individual who consumes a lot of fish regularly have a lower risk of heart disease (Chowdhury *et al.* 2012). Clinical studies have shown that consumption of fish or fish oil are able to reduce biomarkers of heart disease such as increasing HDL-C (but not reducing LDL-C), lowering triglycerides by 15-30%, reduce blood pressure and preventing hardening of plaques in arteries (Balk *et al.* 2006, Eslick *et al.* 2009, Din *et al.* 2013, Oelrich *et al.* 2013, Miller *et al.* 2014, Ras *et al.* 2014, Minihane *et al.* 2016, Wang *et al.* 2018). Although FO is suggested to have favourable effect on the risk factor and biomarkers of heart disease, there is no evidence of prevention of heart disease and stroke by consuming fish oil supplementation (Hooper *et al.* 2015).

Besides that, FO consumption is beneficial for neural development and function, including reducing the chances of psychotic disorders (Amminger *et al.* 2010). Other health benefits includes aids in weight loss, support eye health by reducing the risk of age-related macular degeneration, reduce inflammation and reduce liver fat (Jiménez-Gómez *et al.* 2010, Parker *et al.* 2012, Merle *et al.* 2014, Miller and Raison 2016). However, the results for weight loss are inconsistent because not all studies get the same effect (DeFina *et al.* 2011, Munro and Garg 2013).

Fish oil contains significant amount of omega-3 fatty acids, which are known as beneficial oil for human health (Özogul and Özogul 2007). The two omega-3 fatty acids found in fish oil are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These two types of omega-3 fatty acids found in fish oils have greater health benefits than those obtained from plant sources (Fleming and Kris-Etherton 2014). In terms of cholesterol levels, numerous studies have shown that fish oil supplementation can have triglyceride lowering effect and increase high-density lipoprotein cholesterol (HDL-c), but have an insignificant effect on the total LDL-c. (Petersen *et al.* 2002, Eslick *et al.* 2009). Some studies even found out the unfavourable impact of fish oil on LDL-c (Balk *et al.* 2006, Oelrich *et al.* 2013). Besides, the consumption of omega-3 fatty acids is also known to promote the secretion of anti-inflammatory prostaglandins and decreases leukotrienes (Bradberry and Hilleman 2013). These anti-inflammatory properties are thought to provide beneficial health effects in metabolic syndrome such as insulin resistance, hypertension, central obesity and dyslipidaemia (Barden *et al.* 2015). Nevertheless, another study in 2013 reported an increased risk of prostate cancer among men with high long-chain omega-3 polyunsaturated fatty acid (LCΩ-3PUFA) in a fish oil intervention (Brasky *et al.* 2013). Thus, more data are required to validate the dispute of fish oil's effect on lipid profile and the prevention of chronic diseases.

CONCLUSION

Fish oil consumption has many benefits to human health. Researches have shown that consumption of fish oil is able to reduce biomarkers of heart disease, beneficial for neural development and function, including reducing the chances of psychotic disorders, aids in weight loss, support eye health by reducing the risk of age-related macular degeneration, reduce inflammation and reduce liver fat. Furthermore, the optimum dosage for the intervention aimed at cardiovascular events reduction was not established, but to maintain the individual health markers, the range within 2000 to 3000 mg/d of fish oil omega-3 PUFA intake was considered sufficient though impacts might not be significant. Therefore, those who wanted to prevent cardiovascular events by fish oil omega-3 PUFA consumption for primary prevention should start the intervention as early as possible. For secondary prevention, it is suggested to take a higher dosage and balance with comprehensive lifestyle-pattern improvement.

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Chapter 6

Fruits

Ianne, Kong and Liew Phing, Pui

INTRODUCTION

Unbalanced diets, including a lack of fruits and vegetables in daily meals, have been linked to noncommunicable disease mortality, such as cardiovascular diseases (GBD 2017). It was discovered that free radicals damage constituents in body cells such as lipids, proteins, and nucleic acids, resulting in the emergence of cardiovascular diseases. In addition, recent research indicates that eating fruits on a regular basis is associated with a lower risk of developing stroke and cancer (Wang et al. 2014). The antioxidant microconstituents found in fruit parts play a significant role in this preventative effect. Polyphenol content, vitamin C, vitamin E, carotenoids, and flavonoids are the compounds that influence the antioxidant capacity of various fruits (Saura-Calixto and Goni 2006). As a result, the use of fruits as antioxidants in processed foods is gaining popularity in the food industry as an alternative to synthetic antioxidants. Malaysia is a prosperous country that grows a wide range of fruits that are popular with both locals and tourists. The fruits can be blended into juice, dried into snacks, processed into jam or eaten fresh and unprocessed after cleaning.

However, not all fruits are as well utilized and popular as the common ones such as pineapple, papaya, and others. There are fruits that are underutilized, unpopular, or unknown in the community, but contain an abundance of nutrients and a high concentration of antioxidant compounds (Khoo et al. 2016). According to Khoo et al. (2010), asam, bacang, bambangan, cerapu, durian, jambu, kuini, pulasan, cempedak, jackfruit (nangka), ceri, kedondong and salak are examples of commonly underutilized fruits in Malaysia. These fruits have a high potential for incorporation into the development of new food products, as well as leading the market trend, which could help to improve overall country revenue through proper publicity of the usage of these underutilized fruits. Over the years, intensive research has been conducted to investigate the physicochemical, functional properties, and nutritional qualities of a wide variety of underutilized fruits.

The fruits discussed in this chapter are associated with the properties and nutritional characteristics of five different underutilized tropical fruits grown and found in Malaysia, namely salak, bambangan, jackfruit, cempedak and kuini. These underutilized tropical fruits contain phytochemical compounds with promising antioxidant properties, as well as nutritional content that contributes to a wide range of functional and health benefits.

UNDERUTILIZED FRUITS (SALAK, BAMBANGAN, JACKFRUIT, CEMPEDAK and KUINI)– NUTRITIONAL INFORMATION and FUNCTIONAL APPLICATION IN FOOD PRODUCTS

The nutritional information of the underutilized fruits is shown in **Table 1**. The 'snake fruit', salak is a tropical palm from the family Arecaceae, a palm tree family. According to Čepková et al (2021), this fruit thrives under humid tropical lowland conditions with rainfall of 1,700–3,100 mm per year and a temperature range of 22–32°C. The salak fruit, according to Mazumdar et al (2019), has a high nutritional value and a low calorie count. The edible fruit portion contains a lot of carbohydrates and fibre, but not much protein or fat. The flesh of the salak fruit also contains a high concentration of minerals such as sodium, magnesium, potassium, and calcium. Besides that, salak, on the other hand, is regarded as one of the tropical fruits with the highest level of total sugars. Salak fruit also has a moderate amount of Vitamin C. Vitamin C is essential for human health and act as an antioxidant agent associated with the prevention of the occurrence of some degenerative and inflammatory diseases, such as cardiovascular diseases, inflammatory bowel disease (IBD), asthma, diabetes, and arthritis (Li et al. 2020).

Bambangan is a fruit of the family (Anacardiaceae) that is indigenious to Borneo's lowland rain forests, which include Sabah, Sarawak, Brunei, and Kalimantan (Lim 2012; Khoo et al. 2016; Abu Bakar et al. 2013). When compared to salak, the edible parts of the bambangan have a higher proximate nutrient composition. According to **Table 1**, bambangan has a higher protein, fat, and total fibre content but a lower ash content. These nutrients are linked to a variety of potentially beneficial health properties. Most importantly, Jahurul et al (2018) discovered that bambangan flesh was high in dietary fibre, which can be beneficial to human health. Besides that, the amount of beta-carotene in bambangan indicated that the flesh has the potential to be a functional food and drink, as a high intake of β-carotene has been linked to disease prevention.

On the other hand, *Artocarpus heterophyllus* Lam is the scientific name for jackfruit, which belongs to the Moraceae family (mulberry family) (Wiater et al. 2020). They are one of the most important and widely planted trees in Indian and Bangladeshi gardens. Jackfruit is high in phytochemicals, including phenolic compounds, and provides opportunities for the innovation of value-added products, such as neutraceuticals and food applications, to improve nutritional benefits (Ranasinghe et al. 2019). Most importantly, based on **Table 1**, it contains a high concentration of carotenoids, which are powerful antioxidants in the human body (Shin et al. 2020). Carotenoids found in jackfruit may help prevent cancer, inflammation, cardiovascular disease, cataracts, and age-related macular degeneration, among other chronic degenerative diseases (Bungau et al. 2019; Shin et al. 2020; Bhatt and Parker et al. 2020). Jackfruit could be classified as a functional food because of valuable compounds found in various parts of the fruit that have functional and medicinal properties.

'Cempedak' is the local name for *Artocarpus integer* in Malaysia. Sumatra, Borneo Island, Sulawesi, Maluku, and western New Guinea are the origins of this fruit. Thailand, Sumatra, Peninsular Malaysia, Indonesia, and Myanmar are among the countries where it has been widely planted (Abu Bakar et al. 2015). Cempedak is a fragrant and nutritious fruit that can be used to make functional food products. **Table 1** shows that compared to other fruits, cempedak has a relatively high amount of sucrose. Aside from that, it contains a significant amount of polyphenols nutrients, which are linked to the antioxidant activity of the fruits (Abu Bakar et al. 2013). Carotenoids, such as beta-carotene, protect against vitamin A deficiency and anaemia, as well as cancer, diabetes, heart disease, and other non-communicable diseases and degenerative processes involving oxidative stress (Umerah and Nnam 2019).

Mangifera odorata is a fruit that belongs to the Anacardiaceae family and is considered underutilized. In Malaysia, the fruit is known as kuini and is primarily grown in Peninsular Malaysia (Perak, Kelantan, Malacca, and Pahang) (Lim 2011). In comparison to other *Mangifera* species, the pulp of kuini is high in nutrients like protein, calcium, and carotenoids (Mirfat et al. 2015). **Table 1** shows that kuini has the highest amount of carotenoid when compared to other fruits, implying that kuini could be an antioxidant fruit. In comparison to the table, kuini has the most total flavonoid compounds. Few volatile components were identified in the kuini by Wong and Ong (1993), with oxygenated monoterpenes (45.4%) and esters (33.0%) constituting the main classes of kuini fruit volatiles, and a-terpineol (31.9%) being the major component. The presence of these phytochemicals in edible parts of kuini suggests a potential used as a food ingredient in the development of functional food products or beverages with health-promoting properties.

Table 1 Nutritional information of underutilized fruits

Nutritional information	Salak (Setiawan et al. 2001; Chareoansiri and Kongkachuichai 2009; Haruenkit et al. 2007)	Bambangan (Khoo et al. 2010; Ibrahim et al. 2010; Abu Bakar et al. 2009)	Jackfruit (de Faria et al. 2009; Jagtap et al. 2010 Baliga et al. 2011; Arina and Azrina 2016; Paull and Duarte 2012).	Cempedak (Abu Bakar et al. 2015; Arina and Azrina 2016; De Almeida Lopes et al. 2018; Pui et al. 2020; Paull and Duarte 2012)	Kuini (Lim 2011; Mirfat et al. 2015; Lasano et al. 2021)
Carbohydrate (g/100g)	n.d.	21.02	16.0–25.4	84–87	14.5
a) Sucrose	7.6	n.d.	6.9	18	13.41
b) Fructose	5.9	n.d.	1.7	4.5	3.89
c) Glucose	3.9	n.d.	6	6.5	1.39
Fibre (g/100g)	1.7	5.26	1.0–1.5	5.0–6.0	15.71

Protein (g/100g)	0.7	1.13	1.2–1.9	3.5–7.0	0.9
Fat (g/100g)	0.1	1.98	0.1–0.4	0.5–2.0	0.1
Ash (g/100g)	0.6	0.43	2.2	2.0–4.0	0.43
Total sugar (g/100g)	17.4	n.d.	20.6	n.d.	n.d.
Minerals (mg/kg)					
a) Sodium	231	n.d.	2.0–41.0	25	2
b) Potassium	11.339	11300	191–407	184-434	610
c) Magnesium	607	1100	27	n.d.	80
d) Calcium	220	600	20.0–37.0	40	50
e) Phosphorus	1161	n.d.	38.0–41.0	<10	n.d.
f) Iron	12	50.1	0.5–1.1	<10	2.08
Total polyphenols (mg /100 g fresh weight)	217.1	596	71.098	440	257.17
Total flavonoid (mg /100 g fresh weight)	61.2	7	120	82	202.33
Carotenoid (μg/ 100g)	140	7.97–20.04	34.1–150.3	65–80	450
β-carotene (μg/ 100g)	2997	20040	45	2.30–12.23	78.58
Vitamin A (μg/ 100g)	500	n.d.	52.5–162	14.4	315

The functional application of underutilized fruits in food products are shown in **Table 2**. It was discovered that snake fruit Kombucha can be produced from salak through fermentation (Zubaidah et al. 2018). The fermentation increased the antioxidant activity of salak Kombucha by increasing the levels of phenolics, tannins, and flavonoids. This demonstrates that snake fruits can be used to create functional food beverages and foods such as through Kombucha fermentation. Besides that, probiotic salak juice can be fermented with soygurt (richesse), which was well received by the sensory panellists in the study conducted by Chanawanno and Mongkontanawat (2020). The probiotic salak juice could preserve living probiotic cells that met FAO/WHO standards, making it a nutritious drink for health-conscious consumers. Mustafa et al (2020) was able to produce salak chips after investigating vacuum frying parameters. Salak chips fried in a vacuum frying machine are completely intact and crunchy, and this method was able to extend the shelf-life of this fruit. Salak flour was also produced and used to make baked goods. Salak flour baked goods have a high nutritional value, with 287.5-479.0 kcal of energy, 0.8-3.8 g of water, 6.0-6.7 g of protein, 0.8-31.0 g of fat, 45.0-98.8 g of carbohydrates, and 1.1-4.6 g of fibre per 100 g of these baked food products (cake, muffin, cookies, flakes) (Sumarto et al. 2018).

Due to its high dietary fibre content, bambangan was dried to produce a high fibre product that could be used as a food ingredient in a variety of food products that can help to improve the nutraceutical properties of the specific food products (Al-Sheraji et al. 2011). Furthermore, fibrous polysaccharides from bambangan fruits were isolated and incorporated into yoghurt cultures in order to produce synbiotic yoghurt (Al-Sheraji et al. 2012). The study found that yoghurt containing fibrous polysaccharides from bambangan fruits increased the viability of bifidobacteria, which can be used as a probiotic to benefit human health. Bambangan was also used to produce lactic acid bacteria as probiotic candidates for future use in the preparation of functional food products (Ng et al. 2015). The probiotic isolated from bambangan has a high tolerance for environmental stressors such as elevated temperature and higher salt concentration, indicating a promising potential as a probiotic candidate for incorporation into fruit juice or other drinks. Bambangan carbonated drink was developed and found to be acceptable by sensory panellists, indicating that the product has a high potential for commercialization as a new functional food product concept with improved physicochemical properties and nutritional composition (Benjamin et al. 2021).

Miranti (2020) developed jackfruit jelly candy by comparing drying temperature and drying time to compare the quality of product produced. By drying at 60 °C for 5 hours, the best properties of jelly candy were produced, including the amount of water content (21.64%), vitamin C (5.10mg/100g), texture (2.01), and organoleptic colour (3.58). Mushumbusi (2015), on the other hand, has successfully produced and characterized jackfruit jam with lemon juice and sugar. In comparison to commercial mango jam, jackfruit jam had a bright colour, spread well, and had a strong aroma. Furthermore, even when processed into jam, jackfruit jam contains a lot of nutrients, both macro and micro-nutrients. Tiwari et al (2016) investigated the physicochemical properties of jackfruit jams and jellies, as well as the shelf-life and occurrence of microbial contaminants under various storage conditions. The physicochemical, sensory, and microbiological parameters of the jackfruit products were found to be stable after 12 months of storage at room temperature. It implies that jackfruit can be used in the commercial production of high-quality products such as jam and jelly. Jagtap et al (2011) developed a wine from jackfruit pulp to assess the total phenolic and flavonoid content of the wine as well as its antioxidant properties. According to the results of the experiments, jackfruit wine demonstrated antioxidant activity and DNA damage protection properties, confirming health benefits when consumed and potentially becoming a valuable source of antioxidant-rich neutraceuticals.

Cempedak is a nutritious food that has been used in various studies to develop functional food products as new alternatives to eating fruits in consuming fruits. In Pui et al (2021), cempedak juice was produced using enzyme-aided-liquefaction with various enzymes. The size of the juice droplets produced was smaller (23% of reduction) which can be used as a base feed for spray-drying to produce "cempedak" fruit powder. Arif

(2016) also produced cempedak-pineapple juice, and the shelf life of the juice was compared to pineapple and pineapple-papaya juice. When stored at -5 °C, cempedak-pineapple juice has a longer shelf life (197.85 days) than pineapple (156.85 days) and pineapple-papaya juice (172.39 days).

Dahlan (2019) produced cempedak jam to compare the effect of ripening methods on the beta-carotene content of the jam. The study discovered that cempedak jam made from traditionally ripened cempedak contains more beta-carotene (0.42) than jam made from carbide ripened cempedak (0.22). In addition, the crude fibre content in the cempedak jam traditionally ripened (average value: 0.75) is also higher than cempedak jam which is ripened using carbide (average value: 0.49) (Dahlan 2020). In the study conducted by Rahayuni et al (2021), cempedak ice cream was also produced using 0.5% carrageenan and 15% sucrose. The ice cream has the appropriate chemical properties of 1.47 % at and 15.87 % protein, as well as a moderate organoleptic acceptance by the sensory panelists. Sampurno et al (2020) produced goat milk yoghurt with jackfruit and cempedak fruit pulp using a commercial LAB starter (*Lactobacillus bulgaricus* and *Streptococcus thermophilus)*. The addition of these fruit pulps with the total LAB in accordance with the Indonesian National Standard (SNI) 2981: 2009; decreased pH value, total lactic acid, increase in viscosity, total sugar, and total reducing sugar in the yoghurt.

Alyas et al (2020) used six strains of lactic acid bacteria to produce fermented kuini beverages. After fermentation, the majority of the proximate compositions of kuini were reduced. Unexpectedly, the energy content of fermented beverages was 15 kcal/100 mg. Meanwhile, vitamin B1 and C levels in the beverage increased following fermentation, indicating that kuini pulp fermentation conditions could be used to enhance the nutritional quality of underutilised fruits. Yestiana (2017) produced kuini jam with a variety of cooking times and addition of gelatin. The functional properties of the jam, on the other hand, have not been assessed. However, the jam scored 3.20 % for flavour, 2.80 % for colour, and 3.16 % for taste on the hedonic test. In the study conducted by Desnilasari and Kumalasari (2017), whey cheese was used to produce fermented kuini juice. The juice appears darker, redder, and yellower, as well as more viscous. The pH of the product increases and the protein content decreases. The number of *L.casei* in the product increases by one log. It has been reported, however, that there is a need to improve the overall product in terms of sensory appeal.

Table 2 Functional application of underutilized fruits in food products

Fruits	Food products
Salak	Kombucha Probiotic fruit juice Fruit chips Salak flour (as food ingredient in baked good) Bubble pearl
Bambangan	High fibre product (as food ingredient)

	Synbiotic yoghurt Probiotic candidate (as food ingredient) Carbonated drink
Jackfruit	Jelly candy Jam Jelly Wine
Cempedak	Juice Jam Ice cream Goat milk yoghurt
Kuini	Fermented beverage (juice) Jam

CONCLUSION

This chapter compiles the chemical, phytochemical, and food components of five underutilized tropical fruits grown and found in Malaysia, namely salak, bambangan, jackfruit, cempedak and kuini. Despite its nutritional qualities, this variety is thought to be underutilised, so it is necessary to revitalise the use of these fruits by diversifying processed products. These fruits are high in nutritional value, and research studies have revealed the presence of several phytoconstituents that are beneficial to human health, such as polyphenols, flavonoids, and vitamins, as well as the role of these compounds as antioxidant agents that can aid in disease prevention. The findings suggest that underutilised fruits may serve as a rich source of macro, micro and phytochemical nutrients to significantly impact the health of consumers. These underutilized fruits have been used as ingredients in food, and the potentials for pharmaceutical and cosmetics manufacturing may be explored in the future. This information in this chapter could serve as a fundamental idea for future research on the potential of various underutilized fruits.

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Chapter 7

Seed

Hor Kuan, Chan

INTRODUCTION

Fruit plants are vital to people's livelihoods, cultures, and religions all throughout the world. Certain fruits are utilised as offerings in religious rituals and funerals, where else some are given as presents (Milow et. al., 2014). Malaysian fruits come in a wide variety and are popular between-meal snacks. Many can be purchased in supermarkets, but for the greatest costs and quality, it is always advisable to source directly from local farms. As a result, makeshift wooden stalls along trunk roads and highways, particularly near village parts of the country, are in high demand (Wong, 2021).

Unfortunately, the majority of Malaysian fruit seeds are abandoned and thrown away. Fruit seeds are typically discarded as garbage during processing or after being consumed by humans. Fruit seeds are regarded as agro waste, with an increased emphasis placed on the fact that these materials represent potential utilisation sources for conversion into usable goods or food, hence increasing demand for natural bioactive compounds (Hernandez, et. al., 2019). Over the years, researchers have worked hard to examine the dietary and nutritional qualities of a wide range of fruit seeds (Raihana et. al., 2015).

Fruit seeds covered in this chapter are related to the food values and their health potentials of two different fruit seeds most popular and commonly found and are very sought after in Malaysia, namely durian and rambutan. These seed by-products contain phytochemical or bioactive components as well as nutritional content that has great functional and health values (Baraheng and Karilla, 2019; Hernandez et.al., 2019)

The "King fruit," durian, is a popular seasonal and commercially available fruit. It has seeds that are around 5-7 cm long and 3-4 cm wide (Baraheng and Karrila, 2019). According to Ketsa (2018), durian fruit production generates roughly 20–25 % seed waste. Rambutan fruit, originally from Malaysia, gets its name from the Malay word Rambut, which means "Hair," referring to the soft thorns that cover the fruit's skin. Is a subtropical fruit related to the lychee and the longan (Harahap et.al., 2012). The seed has a length of 2-3 cm and is light brown in colour.

DURIAN and RAMBUTAN SEEDS - NUTRITIONAL, FUNCTIONAL and HEALTH BENEFITS

Table 1 presents the scientific name, the common uses, and the geographic regions of both the durian and rambutans seeds. Comparing with durian seed, rambutan seed has industrial application apart from being eaten and it has ethnomedical values (Palanisamy et al., 2008).

Table 1 General information of Durian and Rambutan seeds

Scientific name/ common name	Durio zibethinus Murr (Durian)	Nephelium lappaceum L. (Rambutan)
Traditional/industrial uses	Roasted, cut into slices, and eaten as candies with coated sugar, or are fried in spicy coconut oil and consumed as a dish with rice (Ho et. al., 2015)	Eaten after being roasted (Julio et al 2010). Oil, fat, protein, and carbohydrate for food application as raw materials for food based on fatty products (Harahap et. al., 2012). Products manufacturing candles, soaps, and fuels (Issara et.al, 2014). The local people in Malaysia used seed powders to control blood sugar levels (Palanisamy et al., 2008)
Geographical region	South-East Asian countries (Indonesia, Malaysia, Thailand, Philippines, and Brunei Darussalam) (Kumoro et. al., 2020)	Malaysia, Indonesia, India, Thailand, Mexico or countries with humid tropic (Hernandez,et. al., 2019)

Table 2 lists the nutritional composition of the fruit seeds by weight. According to Amin and Arshad (2009), the protein content in the durian seed kernels is low but the carbohydrate content in the seed flour is high in dietary fibre and is nutritious. Therefore, it can be included into food products such as cake, cookies, soup, and tempura. In addition, the presence of starch and hydrocolloids in durian seed flour allows it to be used as a thickening agent (Raihana et.al., 2015). Although there is higher fibre content in comparison to whole meal wheat flour, the durian seed kernel is less gritty. Hence, in terms of lipid and fibre contents, the durian seed kernel shows its predominant as a healthier food choice compared to wheat flour.

Table 2 Nutritional content of seed (% w/w)

Type of fruit seed	Carbohydrate	Protein	Lipid	Fibre	Ash	Moist	Ref.
Durian	18.20	3.40	1.32	19.88	1.58	54.9	Srianta, et. al. (2012)
Rambutan	48.00	12.40	38.90	NA	2.26	9.60	Harahap, et.al. (2012)

Rambutan seed contains a high amount of carbohydrates and lipids (Table 2). Because these seeds have lots of carbohydrate, they might be used as a respectable source of energy if added to human meals and animal feeds. There is high protein quality in the defatted seed flour, despite the rambutan seed has a moderate protein content. The presence of the most essential and non-essential amino acid depiction makes up the protein attribute (Augustin and Chua, 1988). The lipid compositions of rambutan seed kernels are alike to that of cocoa and these lipids have been investigated to be an acceptable substitute for cocoa butter in the bakery and pastry goods (Issara et.al., 2014). The rambutan seed kernel is easy to store even without addition drying because it has low moisture content. The ash content of the seed indicates the total amount of minerals present within.

Table 3 shows a summary of the bioactive properties and the bioactivities of the two seeds. The enzyme -galactosidase was successfully extracted from durian seeds using a partial purification procedure. The author stated that β-galactosidase processing could help sensitive users overcome milk sensitivity (El-Tanboly, 2001). The mechanism involves lactose hydrolysis to galactose and glucose. Furthermore, the scientists determined that the enzymes extracted from durian seed can be used in the dairy industry to make cheese, yoghurt, ice cream, and other products, however the texture and appearance were reduced (El-Hofi et. al., 2011). Methanolic crude extract from seed of durian showed an inhibition to the growth against the tested hospital isolates of *E. coli* and *S. aureus* using the Kirby-Bauer disc diffusion method (Ho et.al., 2015).

Table 3 Bioactive compound and bioactivity of seed

Bioactive compound/mode	Enzyme beta-galactosidase	Inhibition against E. coli & S. aureus	Polyphenols	Flavonoids	Tannins/ Saponins	Carotenoid
Bioactivity/health activity						
Durian	Milk intolerance (Ho, et.al.,2015)	Antibacterial (Duazo et.al.,2012)	n.d.	n.d.	n.d.	n.d.
Rambutan			Antioxidant, anti-inflammatory, antiviral, antithrombogenic, and anticarcinogenic (Duda and Tarko, 2007)	Boost immunity, antiallergy, anticancer, antioxidant, anti-inflammatory, antiplatelet, antitumor, antivirus, antimicrobial, antispasmodic, diuretic, vasoprotection (Stewart et.al., 2005)	Accelerate the healing of wounds and anti-inflammation (swollen boils, hemorrhoids, frostbite, and burns) (Li, et.al.2013)	Antioxidant activity by inhibiting fat peroxide (Li, et.al.,2013)

Phytochemicals such as flavonoids, phenolics, and carotenoids have been found in rambutan seeds (Rohman, 2017). These chemicals may be the primary contributors to the antioxidant capabilities. Much research has been conducted to assess the impact of different polarity ranges of solvents employed in seed bioactives extraction. To determine the antioxidants contained in rambutan seeds, these investigations used solvents such as water, methanol, butanol, ethanol, ethyl acetate, and ether (Chunglok et.al., 2014). Because rambutan seeds have a slightly bitter taste, they are typically discarded as agricultural or industrial waste. The bitterness of rambutan seeds has been linked to the presence of alkaloids, tannins, and saponins (Akhtar et al., 2018), but the bitterness can be reduced through fermentation (Chai, et al, 2019). Bhat and Al-daihan (2014) reported the antibacterial activity of aqueous rambutan seed extract against human pathogens (*S. aureus, S. pyogenes, B. subtilis, E. coli, and P. aeruginosa*).

CONCLUSION

This chapter collects the nutritional and bioactive components of two seasonal tropical exotic fruits seeds that are most popular in Malaysia: durian and rambutan and offers their potential waste usage as raw materials or alternatives in food and health. The high annual output of these seeds has resulted in a considerable amount of leftovers. Scientific studies have revealed the presence of several bioactive compounds in rambutan that are beneficial to human health, including polyphenols, flavonoids, phenolic acids, and carotenoid-derived compounds, and the role of these compounds as antivirus, anticancer, antimicrobial, antioxidant, and anti-inflammation agents has been demonstrated through in vitro and in vivo assays studies. Furthermore, due of its useful fat, rambutan seed is a good source of food elements. Durian seed on the other hand is a good source for flour bakery because of its high content of carbohydrate and fibre. Durian seeds also exhibit compounds that have antimicrobial activity. Durian and rambutan seeds have been used as ingredients in food and food supplements, and in the future, the possibilities in pharmaceutical and cosmetics manufacture may be investigated. This brief material in this chapter may be a useful resource for future studies on the potential of various fruit seeds.

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Chapter 8

Mushroom

Yong-Hui, Tan & Kah-Hui, Wong

INTRODUCTION

Mushroom or macrofungus, is defined as fruiting body that is large to be seem by naked eye and picked by hand (Chang &Miles, 1992). Mushrooms belong to the Kingdom Fungi, division of Basidiomycetes. The common mushroom families are Agaricaceae (gilled mushroom), Albatrellaceae, Boletaceae, Cantharellaceae, Morchellaceae, Paxillaceae, Russulaceae, Strophariaceae, Suillaceae and Tricholomataceae. Mushrooms come in varieties of colours, shapes and organoleptic properties. Approximately 12.5% of the discovered mushroom are palatable (Chun et al. 2021), other are either medicinal or poisonous. Mushroom can either grow above the ground (epigeous) or below the ground (hypogeous). Mushroom can be categorised as saprobic, parasitic or mutualistic. Saprobic mushrooms are usually grown on substrate which is high in cellulose and hemicellulose like decaying wood matter, stump and leave litter. Mushrooms contain metabolites such as phenolics compound, flavonoids, tocopherol, carotenoids, terpenoid, phytosterols, dicarboxylic acid, and bioactive polysaccharide which led to its various medicinal properties like antioxidant, antimicrobial, anticancer, anti-inflammatory, anti-obesity, neurite stimulative, neuroprotective and immunomodulatory effects.

Mushrooms that are predominantly cultivated and consumed in Malaysia and Asian countries are *Pleurotus ostreatus* (abalone mushroom), *Pleurotus eryngii* (king oyster mushroom) *Pleurotus florida* (white oyster mushroom), *Pleurotus pulmonaris* (grey oyster mushroom), *Volvariella volvacea* (straw mushroom), *Hericium erinaceus* (monkey head mushroom), *Flamminula velutipes* (enoki mushroom), *Cordyceps sinesis* (caterpillar fungus), *Boletus edulis (penny bun)*, Auricularia auricula-judae (wood ear fungus), *Tremella fuciformis (white fungus), Lentinula edodes*, (Shiitake), *Calocybe indica* (milky white mushroom), *Ganoderma lucidum* (Reishi), *Trametes versicolor (Turkey tail)*, *Grifola frondasa* (Maitake), *Agaricus bisporus (button mushroom)*, *Termitomyces hemii* (Cendawan busut) and *Agaricus subrufescens* (himematsutake) (**Figure 1**).

Figure 1 The varieties of edible mushroom commonly consumed in Malaysia. From top left: eryngii mushroom, fresh shiitake, oyster mushroom, dried shiitake, chestnut mushroom, and monkey head mushroom.

NUTRITIONAL BENEFITS

Mushrooms are considered as gourmet cuisine globally and widely appreciated for centuries due to its texture, unique umami taste (Manzi et al 2001), high nutritional benefit, and therapeutic capacity. Mushrooms contain high moisture (80-90% of fresh weight), varying amounts of carbohydrates (35-70%), proteins (15-34.7%), nucleic acids (3-8%), lipids (10%, mainly oleic acid, linoleic acid and phytosterol), minerals (6-10.9%, potassium, magnesium and zinc), (Mallikarjuna et al. 2013, Rahi and Malik 2016) and vitamins such as thiamine, riboflavin, niacin, biotin, ascorbic acid, pantothenic acid, and folic acid. Mushroom is also a rich of dietary fibre and provide 25% of recommend daily dietary intake (Cheung, 2013). Mushroom often become a prime dish for vegetarian due to its protein content which is known to be comparable to meat. It contains 9 essential amino acids required by humans and great source of vitamin D which is limited in other foods. Mushroom is also known as a mini-pharmaceutical factories due to its diverse medicinal properties. The discovery and investigation of its therapeutic potential are still actively going on.

In modern day, people are more aware what goes into their stomach and wary of medicines side effects. Mushroom is always on the list when search for innovative therapeutic strategies is concerned. Demand for mushrooms has been increased by 48% from year 2008 to 2017 (FAO. Stat 2019). Besides, over the years, interest on mushroom as dietary supplement, new mushroom product based on different processing technologies, mushroom extract fortified products or mushroom based new products has been increasing. Examples of the product are freeze-dried mushroom crunchy snack, coffee with *Ganoderma* extract, soy milk with *Lignosus rhinocerotis* sclerotia powder and ect. Mushroom based dietary formulations commonly found in the market are in the form of i) aqueous or ethanolic extract of cultivated mushroom or its sclerotia; ii) dehydrated and powdered preparations of mixture of substrate, mycelium and mushroom pin head; iii) biomass of mycelium from submerged fermentation; iv) naturally harvested, dried mushroom in the form of capsules or tablets; v) spore extracts (Wasser, 2014).

NEURITE-STIMULATIVE AND NEUROPROTECTIVE EFFECTS

According to Sabaratnam et al. (2013), macrofungi studied for brain and nerve health are still scared compared to the number of edible and medicinal species identified. The vitamin B5 (pantothenic acid) present in mushroom is especially important for building up the nervous system (Rathore et al, 2017). Mushrooms is also popular for its phytosterol and bioactive compounds such as ergothioneine (amino acid) which protect cognitive health (Cheah et al., 2016) and act as a natural antioxidant against oxidative stress. In a survey by US National Health and Nutrition Examination (NHANES), 2005–2016, mushroom consumers were found to possess a lower chance of depression (Ba et al., 2021). Among the commonly studied mushrooms for health promoting are *Ganoderma lucidum* (Ling zhi), *Hericium erinaceus* (Monkey head mushroom/ Lion's Mane) and *Pleurotus gigantus* and *Sarcodon scabrosus* and *Dictyophora indusiate* (bamboo mushroom).

Ganoderma lucidum was known to regulate the central nervous system through immunomodulatory activity and its effects include as a sedative and hypnotic, neuroprotective, antinociceptive and analgesic, antiepileptic, and antidepressant (Cui & Zhang, 2019). Triterpenoid, 4,4,14α-trimethyl-5α-chol-7,9(11)-dien-3-oxo-24-oic acid and methyl ganoderic acid B from *G. lucidum* was found to possess NGF-like neuronal survival-promoting effects (Zhang et al., 2011). Besides, *G. lucidum* spores' powder prevents nerve cells damage in pentetrazol (PTZ) -induced epileptic rat via by suppressing the expression of NF-κB and facilitate the immune reactivity of IGF-1 (Zhao et al., 2007). *Seow et al. (2013*) reported that G. neo-japonicum contained NGF-like bioactive compounds that could benefit people with neurodegenerative diseases.

Hericium erinaceus aqueous extract and polysaccharide were found to exhibit nerve regeneration and functional recovery properties in mice following peroneal nerve crush/peripheral nerve injury (Wong et al., 2016). Hericenone and erinacines from the fruiting body and mycelium of *H. erinaceous* can promote the expression of nerve growth factor (NGF) synthesis in rodent cultured astrocytes (Ma et al., 2010).

Pleurotus giganteus, an edible mushroom able to stimulate neurite outgrowth in N2a cells via the phosphorylation of the mammalian target of rapamycin (mTOR), this could be attributed to uridine present in the extract (Phan et al., 2015). *Pleurotus cornucopiae var. citrinopileatus*, was found to contain more than 1% of ergothioneine which activates Ca2+ signal mediated BDNF expression in cultured cortical neurons (Fukuchi et al., 2021).

DEPRESSION TREATMENT

Evidence has mounted in recent years that culinary and medicinal mushrooms may be effective in treating depression, though it will be crucial to conduct clinical trials to verify the safest treatment options for patients.

Table 1 shows the current evidence for the potential application of 8 species of medicinal mushrooms in the management of depression.

Mushroom	Functional compound(s) or extract(s)	Findings	Reference
Agaricus bisporus	Glucogalactan polysaccharide	Protection against trimethyltin chloride-induced neuropathy (in vivo)	Hassan et al. 2015
Agaricus brasiliensis	Aqueous extract of fresh mushroom	Protection against cerebral ischemia/reperfusion injury-induced anxiety (in vivo)	Zhang et al. 2015
Cordyceps sinensis	Hot water fraction of mycelium	Protection against immobilization stress-induced dysfunctional homeostasis (in vivo)	Koh et al. 2003
	Supercritical fluid extract	Promotion of antidepressant effect and enhanced adrenergic and dopaminergic signalings (in vivo)	Nishizawa et al. 2007
	Vanadium-enriched mycelium	Amelioration of depression-like behaviour in streptozotocin-induced hyperglycaemia (in vivo)	Guo et al. 2011

Cordyceps militaris	Cordycepin (3'-deoxyadenosine)	Amelioration of depression-like behaviour in chronic unpredictable mild stress-induced behavioural deficits (in vivo)	Tianzhu et al. 2014
		Promotion of rapid antidepressant effect and enhanced AMPA signaling (in vivo)	Li et al 2016
Ganoderma lucidum	Aqueous extract of mycelium	Reduced symptoms of anxiety and depression (in vivo)	Matsuzaki et al. 2013
		Reduced symptoms of depression (in vivo) Weak protection against 6Hz stimulation-induced seizures (in vivo)	Socala et al. 2015
Grifola frondosa	Proteo-β-glucan	Promotion of antidepressant effect and enhanced dectin-1 and AMPA receptors signalling (in vivo)	Bao et al. 2016
	Feed chow incorporated with mushroom powder	Promotion of antidepressant effect and enhanced AMPA receptors signalling (in vivo)	Bao et al. 2017
Hericium erinaceus	Standardized aqueous extract	Neuroprotection against high-dose corticosterone-induced oxidative stress in PC-12 cells	Lew et al. 2020 Chong, et al. 2021
		Promotion of neurogenesis and attenuation of neuroinflammation through enhanced the BDNF-TrkB-CREB signalling pathway	
	Ethanol extract	Promotion of anxiolytic and antidepressant-like effects, and hippocampal neurogenesis (in vivo)	Ryu et al. 2018
	Amycenone (standardized powder)	Amelioration of depression-like behaviour in LPS-induced inflammation (in vivo)	Yao et al. 2015
	Erinacine A-enriched mycelium	Amelioration of depression-like behaviour in repeated restraint stress-induced behavioural deficits (in vivo)	Chiu et al. 2018
	Cookies incorporated with mushroom powder	Reduced symptoms of anxiety and depression (clinical trial)	Nagano et al 2010
	Amyloban® 3399 (standardized powder)	Amelioration of cognitive deficits in recurrent depressive disorder (clinical trial)	Inanaga 2014

	Amyloban® 3399 (standardized powder)	Reduced symptoms of anxiety and improvement in sleep quality (clinical trial)	Okamura et al. 2015
	Micotherapy Hericium (extract of mycelium and fruitbodies)	Reduced symptoms of anxiety and depression, and improvement in sleep quality (clinical trial)	Vigna et al. 2019
Lentinus edodes (Berk.) Pegler	Lentinan	Promotion of antidepressant effect and enhanced dectin-1 and AMPA receptors signalling (in vivo)	Bao et al. 2017

ANTIOXIDANT

Oxidative stress is caused by an imbalance in cell metabolism and overproduction of reactive oxygen species. Besides, oxidative stress is a pathological hallmark of many diseases. Endogenous antioxidants such as superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPX) or exogenous antioxidant from diet is known to control our body oxidative equilibrium. Mushrooms as a source of antioxidant has been widely reported. This was attributed to the phenolic compounds, vitamin C and E, carotenoids, chrysin, rutin, lectins, glycosides, polysaccharide and ergothioneine present is some mushroom (Ferreira et al., 2009, Rana et al., 2012, Kozarski et al. 2015). It is noteworthy to know that different growth substrates play an important role in mushroom antioxidant capacity (Tan et al, 2018). As in the case of *Pleurotus djamor* that's cultivated on different ratios of rice husk and saw dusk. High rice husk supplemented to the mushroom substrate bags correlated to higher protein content in mushroom fruit body, higher total phenolic content, and radical scavenging capacity (Tan et al, 2018).

IMMUNOMODULATING AND ANTITUMOR

Having a balance immune system is everyone's wish, with no hyperallergic episode nor too weak to fight any body intruders. Mushroom is known to activate our body second line of defence by inducing the release of pro-inflammatory cytokines such as tumour necrosis factor-alpha, interferon gamma and interleukin. This thereby enhanced body cell mediated and humoral responses toward pathogen (El Enshasy &Hatti-Kaul, 2013). Mushrooms that possessed immunomodulating properties are *Agaricus blazei Murrill, Cordyceps sinensis, G. lucidum, Grifola frondose, Hericium erinaceus* and *F.velutipes* (renee). The bioactive compound from mushroom that contributes to immune balancing properties are terpenes and terpenoids, lectins, fungal imunommodulatory proteins

(FIPs), polysaccharides, polysaccharopeptides and polysaccharideproteins (El Enshasy &Hatti-Kaul, 2013). Polysaccharides, lentinan isolated from L. edodes (Shiitake/ Winter mushroom) and schizophyllan extracted from Schizophyllum commune were accepted in Japan for gastric cancer and head neck cancer respectively since 1986 (Ina et al. 2013, Ngwuluka et al. 2016). A highly priced hypogeous mushroom,Truffles contain oleic acid that is known to suppress oncogene and subsequently induce cancer cell death (Carrillo et al. 2012). Anandamide, a type of fatty acid neurotransmitter that is reported to stop breast tumour-induced angiogenesis is also found in Truffle.

CONCLUSION

Mushrooms have a humongous potential as innovative health-promoting agents. However, there are still some limitations regarding their consumption due to the cases of mushroom misidentification and poisoning cases, hazard/ metal ion accumulation when gather from polluted area or mushroom contaminated with pesticide. Nevertheless, most of the available mushrooms in the market are cultivated in a very controlled, hygienic, and automated culture room. Raw materials used to cultivate mushrooms should be screened for contaminant before large production for human consumption. We should include mushroom in our dietary diet, as mushrooms contain lots of nutritional and therapeutic properties. It is also recommended to eat everything in moderation.

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Chapter 9

Spices

Eric Wei Chiang Chan

INTRODUCTION

Spices have a long history in human civilization and have been the cause for exploration, trade and war. While there is no strict definition of a spice, the general classification is that it is included in food for flavour and fragrance rather than nutrition, and that it is often applied in a dried form (Balasasirekha 2014). Some exclude the succulent part of the plant such as flowers, leaves and fruits but this is not entirely true given the inclusion of chili peppers and cardamon which are fruits.

A strict division of spices from other culinary herbs is impossible as spices are often sold alongside herbs and are used in many of the same dishes (**Figure 1**). Even the definition of being applied in the dried form is not a rule. Ginger rhizomes are sold fresh and turmeric is more often sold in the dried form, yet both are considered spices. The only common attribute is that herbs and spices are included for their flavour.

India is the world's largest producer of spice with an annual production of 2.5 million tons valued at 3 billion USD, while Indonesia is the largest producer of cloves (Balasasirekha 2014). The bioactive properties of spices such as antioxidant, antibacterial, anti-inflammation and anti-tyrosinase properties of spices are well studied and have been shown to be present event after cooking (Chan et al. 2015).

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Figure 1. Herbs sold alongside spices at a local grocery store

NUTRITIONAL BENEFITS

Spices have a wide range of bioactive properties including:

1. Antioxidant
2. Antibacterial
3. Anti-inflammation
4. Anti-tyrosinase

Antioxidant properties are the ability of compounds in spices to prevent oxidative damage to the body by free radicals (Chan et al. 2015). These can be divided into primary and secondary antioxidants. The former scavenges free radicals directly rendering them harmless, the latter prevents the generation of free radicals.

Antibacterial properties often refer to compounds that are able to prevent the growth of bacterial cells or kill the cells (Chan et al. 2015). More recently, scientist have started searching for alternatives involving quorum sensing which reduces the virulence of bacteria but not their growth. This reduces the ability of the bacteria to cause diseases but also removes much of the selective pressure which cause antibiotic resistance.

Anti-inflammation compounds can disrupt the biological process that cause inflammation. This often has a pain reducing effect but can also be used to treat more serious conditions. Some inflammatory compounds with spices such as the salicylate derivatives like aspirin can reduce cardiovascular risk (Ekinci et al. 2011).

Anti-tyrosinase compounds can prevent browning in food and also the skin if applied topically (Chan et al. 2015). Tyrosinase is an enzyme involved in the production of melanin and can also oxidize phenols in food to produce a brown pigment. Hence, in food tyrosinase is often referred to as polyphenol oxidase.

Table 1 summarizes the common bioactive properties of some common herbs.

Table 1 Bioactive properties of common spices

Spice	Antioxidant	Antibacterial	Quorum sensing	Anti-inflammation	Anti-tyrosinase	References
Clove						Chan et al. (2015); Han & Parker (2017)
Cinnamon (cassia)						Chan et al. (2015); Gunawardena et al. (2015)
Black pepper						Chan et al. (2015); Jeena et al. (2014)
Star anise						Chan et al. (2015); Patra et al. (2020)
Cumin						Chan et al. (2015); Wei et al. (2015)
Fennel						Chan et al. (2015); Farid et al (2020)
Basil						Chan et al. (2015); Takeuchi et al. (2020)
Mustard						Chan et al. (2015); Bhat et al. (2014)
Corriander						Chan et al. (2015); Yuen et al. (2020)
Fenugreek						Chan et al. (2015); Vyas et al. (2008)
Cardamom						Chan et al. (2015); Souissi et al. (2020)
Poppy						Chan et al. (2015)

EFFECTS OF HEAT AND PROCESSING

Heat and processing are often thought to destroy phytochemicals and reduce the bioactive properties of food. This is not an accurate view that is frequently perpetuated by the wellness industry promoting raw foods. The heat involved in cooking is often not enough to degrade compose phenolic compounds that are often more stable than nutritional compounds such as sugar (Chan et al. 2015).

Even ascorbic acid, Vitamin C, a well-known compound which is degraded by heat, tolerates cooking well (Chan et al. 2008). Ascorbic acid is degraded only after an extended period of heating. Furthermore, ascorbic acid only contributes a small part to the antioxidant properties of most plants, despite being a well known antioxidant.

Bioactivity loss from processing are more often caused by leaching and enzymatic oxidation (Chan et al. 2015). Heat in many cases have a protective effect on phytochemicals by inactivating tyrosinase/polyphenol oxidase that is found in most plants.

Table 2 summarizes the effects of most common forms of cooking. Forms of cooking which have a protective effect of phytochemicals usually have minimal leaching and high heat transfer (Chan et al. 2015). Maillard browning from cooking e.g. searing can cause some loses in phytochemicals. Heating can also cause the release of additional phytochemicals, enhancing bioactivity (Chan et al. 2009).

Table 2. Effect of common cooking methods on bioactive phytochemicals

Cooking method	Description	Heat transfer	Leaching	Effect on phytochemicals
Roasting	Hot air cooking at high heat for short period of time. The inside of the food usually has a much lower temperature due to poor heat transfer of air	Slow	Not present	High heat causes Maillard browning on the surface which can reduce phytochemicals. Slow heat transfer allows oxidation by enzymes.
Baking	Hot air cooking at a lower heat than roasting but for an extended period of time. The inside of the food reaches a higher temperature due to the extended heating, despite air having poor heat transfer	Slow	Not present	High heat for an extended period can cause some losses of phytochemicals. Slow heat transfer allows oxidation by enzymes.
Boiling	Cooking in water. Temperature is limited to 100 C, a fairly low temperature.	Fast	Present	Low heat but suffer large losses from leaching
Frying	Cooking in oil. Temperature increases beyond 100 C to the smoke point of the oil used.	Fast	Present in deep frying	High heat but minimal losses from leaching except in the case of deep frying.

	Cooking duration is short, limiting the heat transfer to the inside of the food.			Maillard browning can cause losses of phytochemicals on the surface
Microwaving	Cooking using microwave which heats up water molecules inside the food. Temperature is usually limited to 100 C.	Fast	Not present	Low heat and fast heat transfer inactivates oxidative enzymes. Heat can also release additional phytochemicals
Steaming	Cooking using steam. Temperature is usually limited to 100 C but newer ovens can use superheated steam that goes beyond 100 C	Fast	Not present	Low heat and fast heat transfer inactivates oxidative enzymes. Heat can also release additional phytochemicals
Smoking	Minimal heat and cooking is incomplete. Compounds generated for pyrolysis of burning wood have antibacterial properties that can make food safe to eat.	Slow	Not present	Low heat, cells on food mostly not damaged and release of oxidative enzymes would be limited.

CONCLUSION

Spices are a good source of phytochemicals and have many functional properties in addition to providing flavour to food. In most cases, spices retain their functional properties after cooking. Phytochemicals that are bioactive are also very stable to heat. In most cases, phytochemical losses are caused by enzymatic oxidation and leaching. Heat sufficient to cause degradation would cause Maillard browning and subsequently charring. Charred food can no longer be considered edible.

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Chapter 10

Functional Foods-Malaysian Herbs

Chandran, Asveene & Gunasekaran, Baskaran

INTRODUCTION

Currently, there is an increase in the interest towards functional foods in developed economics since people are looking for safer way to improve general health and living. The demands for health enhancing foods are growing because more Malaysians are exposed to various health threats (Lau et al. 2012). Hassan (2008) has reported that in the Malaysian context, functional food is a category of food that has health-enhancing properties, and which is not drug, chemical or vitamin and not prescribed by doctors or other formally qualified medical practitioners. Functional foods are not pills, and it is in the form of food and part of the normal food pattern (Lau et al. 2012). Jarukamjorn and Nemoto (2008) defined herbs as a plant or part of plant used for its characteristic flavour, aroma or remedial properties, and medicinal products made from herbs are usually consumed as dietary supplements. Herbs have tremendous importance as functional foods because it possesses antioxidant, antimicrobial, pharmaceutical and nutritional properties (Bishnoi 2016).

In Malaysia, the interest towards functional foods which are herbs-based is gathering momentum because Malaysia is known to be rich in variety of natural resources (Ahmad 2009). In Malaysia, the tropical climate facilitates the growth of various species of plants especially the herbal plants influenced mainly by Malay, Chinese, and Indian backgrounds. Besides utilizing the herbal plants as folk medicine, it can be also marketed as functional food products (Adnan and Othman 2012). Malaysian Biotechnology Corporation (2009) has reported that Malaysia is ranked 12th in the world and 4th in Asia as a diversified country. Malaysia is a tropical rainforest consists of 100 species of ferns, 185,000 fauna and medicinal crops. It is estimated to contain 1200 to 2000 herbaceous species in Peninsular Malaysia, Sabah and Sarawak. Overall, the market value of the herbal industry has reached RM10 billion in 2008 and this figure was expected to increase further to RM32 billion by 2020 (Zakaria et al. 2019).

HERBS IN MALAYSIA

- ### Jerangau

It is also known as Sweet Flag or *Acorus calamus* belonging to Araceae (Adoraceae) family (**Figure 1**). The members of the family are rhizomatous or tuberous herbs. It is a perennial herb which is commonly found on the banks of streams and in damp marshy places with creeping and extensively branched, aromatic rhizome, cylindrical, up to 2.5 cm thick, purplish-brown to light brown externally and white internally. The leave, root and stem are the parts that commonly used (Chandra and Prasad 2017).

Jerangau has the constituent namely alkaloids, flavonoids, gums, lecithin mucilage, phenols, quinine, saponins, sugars, tannins and triterpenes (Umamaheshwari and Rekha 2018). A study reported that the plant contains glucoside, alkaloid and essential oil containing calamen, clamenol, calameon, asarone and sesquiterpenes. β- asarone, α- asarone, elemicine, cisisoelemicine, cis and trans isoeugenol and their methyl ethers, camphene, P- cymene, α- selinene, bgurjunene, β- cadinene, camphor, terpinen- 4- ol, aterpineol and a calacorene, acorone, acrenone, acoragermacrone, 2- deca -4,7 dienol, shyobunones, linalool and preisocalamendiol are the chemical constituents reported from the rhizomes, leave and roots of the plant (Chandra and Prasad 2017).

Figure 1: Rhizomes of Acorus calamus

- ### Mas Cotek

The botanical name of it is *Ficus deltoidei Jack* belonging to Moraceae family (**Figure 2**). Mas Cotek is an evergreen shrub that reaches a height of 2 meters, with whitish grey bark, leaves broadly spoon-shaped to obovate, with a leaf length between 4 cm and 8 cm, coloured bright green above, and rust-red to olive-brown beneath. The most commonly used parts of the plants are leave, root and fruit (Bunawan et al. 2014).

There is a wide variety of bioactive compounds present from different phytochemical groups including alkaloids, phenols, flavonoids, saponins, sterols, terpenes, carbohydrates, and proteins. Literature showed that different plant parts of Mas Cotek contain various types of phytochemical constituents. Leaves contain primarily polyphenols, triterpenoids, saponins, and tannins but it contains small amount of alkaloids. Flavonoids, saponins, and alkaloids are found mainly in stem part, whereas fruits predominantly contain triterpenoids, alkaloids, and flavonoids. Choo et al. (2012) reported two identified bioactive components, vitexin and isovitexin (flavonoids) in the leaves and also reported that these constituents are responsible for inhibition of α-glucosidase (Ashraf et al. 2021).

Figure 2: Mas Cotek in Malaysia

- **Misai Kucing**

It is known as *Orthosiphon stamineus (O. stamineus)* and gets the name Misai Kucing from its pale purple flowers with long wispy stamens shaped like cat whiskers (**Figure 3**). It belongs to Lamiaceae family and widely used in Malaysia. The plant can grow to about 1.2m in height and the leaves can be harvested in 2-3 months after plantings. The leaves consist of most of the bioactive compounds (Abdullah, Shaari and Azimi 2012).

The leaves contain high content of potassium and also there is the existence of inositol, as well as the isolated flavones sinensetin and 3'-hydroxy-5,6,7,4'- tetramethoxyflavone. Rosmarinic acid was detected in the stems and leaves and the content of rosmarinic acid in the stems, branches and the whole plant was less than the leaves. Thus, the accumulation of rosmarinic acid primarily occurs in the leaves (Manaf Almatar, Harith Ekal and Zaidah Ahmad 2014). There are three types of phytochemicals present in various extracts of *O. stamineus* namely polymethoxylated flavonoids, phenylpropanoids and terpenoids. A study showed the presence of flavonoids, phenols, carbohydrates, steroids, tannins, glycosides, terpenes, and saponins with the absence of alkaloids, gums, and mucilage in the methanolic extract of Indian *O. stamineus* (Ameer et al. 2012). The major identified bioactive compounds including sinensetin (polymethoxylated flavones); eupatorin; caffeic acid derivatives namely rosmarinic acid; polyphenols; sterols; diterpenes; and triterpenes (Bokhari, Lau and Mohamed 2018).

Figure 3: *Orthosiphon stamineus* in Malaysia

- **Lidah Buaya**

It is also known as Aloe Vera and the botanical name of it is *Aloe barbadensis miller* belonging to Liliaceae family (**Figure 4**). It is a perennial, drought-resisting plant which can resists more than 7 years without water with thick, tapered, green lance-shaped, juicy, basal, sharp pointed and jagged and edged leaves. The leaves are covered by a thick cuticle and successive leaves have fewer whitish spots and grey-greenish in colour (Sánchez-Machado et al. 2017).

It has been reported that there are more than 75 active ingredients have been identified in the inner gel such as vitamins, minerals, enzymes, sugars, anthraquinones or phenolic compounds, lignin, saponins, sterols, amino acids, and salicylic acid (Sajjad and Subhani Sajjad 2014). The outer layer of the leaves contains derivatives of hydroxyanthra-cene, anthraquinone and glycosides aloin A and B. The bitter yellow latex in the middle of leaf consists of anthraquinones and glycosides. The innermost layer consists of many monosaccharides and polysaccharides, vitamins B1, B2, B6, and C, niacinamide and choline, several inorganic ingredients, enzymes including acid and alkaline phosphatase, amylase, lactate dehydrogenase, lipase and organic compounds such as aloin, barbaloin, and emodin (Sahu et al. 2013).

Figure 4: Aloe vera plant

- **Pegaga**

It is scientifically known as *Centella asiatica* (**Figure 5**) which grows in shady, damp and wet places. In Malaysia, leaves of Pegaga have been used for various purposes and there are two morphologically distinct accessions of Pegaga including heavily fringed and smooth leaf margins (Tan 2017). This perennial herbaceous plant belonging to the *Apiaceae* family. It has small fan-shaped green leaves with white or light purple-to-pink or white flowers and it bears small oval fruit (Bylka et al. 2013).

The triterpenoid saponins known as centelloids were the most important constituents isolated from *C. asiatica*. Saponins may account for 1% to 8% of all *C. asiatica* constituents. Centellosides are majorly ursane and oleanane-type pentacyclic triterpenoid saponins. Centella also contains other components, such as volatile oils (0.1%), flavonoids, tannins, phytosterols, amino acids and sugars (Bylka et al. 2013). The triterpenes of Centella are composed compounds such as asiatic acid, madecassic acid, asiaticosside, madecassoside, brahmoside, brahmic acid, brahminoside, thankiniside, isothankunisode, centelloside, madasiatic acid, centic acid, and cenellic acid. In addition, it also contains high total phenolic contents which contributed by the flavonoids including quercetin, kaempherol, catechin, rutin, apigenin and naringin and volatile oils such as caryophyllene, farnesol and elemene. It is also rich in vitamin C, vitamin B1, vitamin B2, niacin, carotene and vitamin A. The total ash contains chloride, sulphate, phosphate, iron, calcium, magnesium, sodium and potassium (Seevaratnam et al. 2012).

Figure 5: *Centellaasiatica* herb

- ## Tongkat Ali

It is scientifically known as *Eurycoma longifolia Jack* (**Figure 6**) belonging to the family Simaroubaceae. The local name of it is Tongkat Ali wherein 'Ali' means "walking stick" which is assigned due to the presence of long twisted roots. The plant extract particularly roots have been used traditionally in Malaysia. It is an evergreen slow growing herbal plant. The maximum height is 15-18 m and start bearing fruit after 2-3 years of cultivation. The plant grows profusely in sandy, well-drained soil in the presence of partial shade and with sufficient amount of water (Rehman, Choe and Yoo 2016).

The plant is reported to be rich in various classes of bioactive compounds namely quassinoids, canthin-6-one alkaloids, β-carboline alkaloids, triterpene tirucallane type, squalene derivatives and biphenyl neolignan, eurycolactone, laurycolactone, and eurycomalactone, and bioactive steroids. Among these phytoconstituents, quassinoids account for a major portion of the *E. longifolia* root phytochemicals (Rehman, Choe and Yoo 2016).

Figure 6: *Long Jack* herb

THE IMPORTANCE OF THE HERBS

Herbs	Usage	Reference
Jerangau	It is effective for digestive ailments including flatulence, loss of appetite, abdominal dull pain and worms. The powder of jerangau given with lukewarm salt-water, induces vomiting and relieves phlegm, while easing coughs and asthma. As for epilepsy, it works well when mix with honey. It stimulates the uterine contractions, thus used to augment the labour pains. The rhizome used to cure fever, asthma and bronchitis, and also acts as a sedative. Decoction is made as a carminative to treat cough. Chiefly employed for digestive problems namely gas, bloating, colic, and poor digestive function. Small amounts of jerangau able to reduce stomach acidity, while larger doses increase deficient acid production	(Imam et al. 2013), (Chandra and Prasad 2017)

Mas Cotek	The juice is used to treat diabetes, high blood pressure and gout. Used for migraines, skin diseases, and diarrhoea, pneumonia and heart problems. Often used after childbirth to regain energy, and repair blood flows. Aids in detoxifying the body, improving blood circulation and reducing cholesterol. Cures low libido energy	(Rosnah, Khandaker and Boyce 2015), (Ramamurthy 2014)
Misai Kucing	The leaves have been used as diuretic, and to treat rheumatism, abdominal pain, kidney and bladder inflammation, edema and gout. The leaves exhibit a range of pharmacological properties including anti-inflammatory, antioxidant, anti-bacterial and antiangiogenetic properties. Used to regulate the blood sugar, thus acts as an alternative medicine for diabetes. Inhibitor of blood platelets from sticking together and has powerful haemolytics that can reduce blood pressure. Clean toxins within the blood via detoxification process and removing metabolic waste in the body. Aids in the flushing out uric acid and blocking the production of uric acid. Act as an anti-inflammatory for arthritis and rheumatism. Able to intercept the crosstalk between neurodegeneration, neuroinflammation, and oxidative stress, and hence contributes to neuroprotection via four mechanisms namely enhancing memory, anti-inflammation, antiseizure, and antioxidative	(Himani et al. 2013), (Chung et al. 2020)

Lidah Buaya	Used to treat diabetes and angina pectoris via consumption of 100 mg of fresh inner gel each day or 1 tablespoon twice daily. A dose of 25–50 ml of 95% aloe inner gel is recommended 3 times daily for the treatment of ulcerative colitis and irritable bowel syndrome. Aids in treating constipation, gastrointestinal disorders, and for immune system deficiencies. Its juice has cooling properties, is anabolic in action which guards against fever, skin diseases, burns, ulcers and boils eruptions.	(Grundmann 2012), (Radha and Laxmipriya 2015),
Pegaga	Maintain youthful skin quality by increasing collagen and fibronectin production. Journal of Alzheimer's Disease reported that it improves cognitive functions by enhancing the activity of a pathway associated with long-term memory formation. Lowers inflammation in the system and boosts energy levels by flushing out the toxins. Maintains the delicate balance of fluids in the body. The tea acts as an antioxidant by protecting the body's cells against many chronic diseases including obesity, diabetes, heart disease and arthritis. Acts as an appetizer since the salads are eaten together with main meals. Drink as thirst quenching or cooling drink to reduce the inner heat which assists in healing and curing of aphthous ulcers.	(Ng 2019), (Bylka et al. 2013)

Tongkat Ali	Root extracts used to reduce blood pressure, fevers and fatigue. Regular intake of root extracts enhances the testosterone levels. Enhance the muscle mass and strength in those who involved in body building. Root extract restores energy and vitality, enhance blood flow, acts as herbal ingredient for women after child birth. The leaves used to cure malaria, ulcers, prevent gum diseases and as a treatment for sexually transmitted diseases like syphilis and gonorrhoea. The fruits are used in curing dysentery. It is used to cure lumbago and indigestion.	(Rehman, Choe and Yoo 2016)

CONCLUSION

Since ancient time, there is a significant linkage between food habit and disease prevention especially the herbs. The growing popularity of functional foods with natural herbs resulting in promising health benefits that are free of side effects. Therefore, all the herbs related functional foods plays a significant role in the maintenance of the quality of human life through offering an abundant source of antioxidants and medicinal constituents. Malaysia has a rich biodiversity of flora and fauna and can offer potential large sources of variety of new functional foods.

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Chapter 11

Seaweed

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INTRODUCTION

Malaysia has a long coastline surrounded by islands, which provides a variety of habitats for seaweed growth. Generally, algae are divided into three groups based on their pigmentation: Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae) (Aroyehun et al., 2020). Red seaweed is smaller than brown seaweed and is similar to green seaweed in size, ranging from centimetres to one metre in length. Additionally, red seaweed is not always red; it might be purple or brownish red, but botanists still identify it as Rhodophyceae due to other traits (Cunha & Grenha, 2016; Peng et al., 2015).

The majority of Malaysian seaweed is grown in the Semporna district of Sabah, primarily for the extraction of carrageenan, a hydrocolloid generated from red seaweed that is used in food, dairy, and pharmaceuticals (Li, Ni, Shao, & Mao, 2014). The recent rise of the seaweed industry has been aided by rising demand for processed foods in the United States and Europe (Ferdouse, Holdt, Smith, Murúa, & Yang, 2018). Indonesia, the Philippines, Malaysia, the United Republic of Tanzania, and Vietnam were the top five largest producers of seaweed carrageenan in 2016 (13.0 million t wet weight or 1.3 million t dry weight) (FAO, 2016). As seaweeds become more popular and getting more commercialise demands worldwide, the Malaysian government is focusing on growing seaweed cultivation as an alternative source of nutritious food products. Apart from being consumed as human foods, they are also used as animal feed, fertiliser, fungicides, herbicides, condiments, dietary supplements, and cosmetic compounds for the nutraceutical and pharmaceutical industries. This is expected to help raise household incomes by generating foreign exchange revenues, creating jobs, developing alternative sources of income, and establishing businesses for commercial investment opportunity (Nor, Gray, Caldwell, & Stead, 2020).

Several research showed that seaweeds are a nutritious food that contains major and micronutrients such as vitamins, minerals, fibre, and lipids that are important for humans and animals (Rodrigues et al., 2015; Seghiri, Kharbach, & Essamri, 2019; Subramaniam, Subakir, Mohamad, Chik, & Azman, 2021). Seaweeds, on the other hand, are high in natural bioactive compounds such as sulphated polysaccharides, polyunsaturated fatty acids (PUFAs), organic acids, phlorotannins, other phenolic compounds, and carotenoids, which have antioxidant, anticancer, antibacterial, antifungal, antimicrobial, antiviral, and other biologically active properties (Hafting, Critchley, Cornish, Hubley, & Archibald, 2012; Pooja, Rani, Rana, & Pal, 2020). However, due to factors such as species, maturity, habitats, wild or farmed cultivation methods, and environmental circumstances such as climate, geographical location, and sunshine exposure, the nutrients and physiochemical properties of the seaweeds are varying. For instance, brown seaweed has a low protein concentration compared to red and green seaweeds, with an average dry matter value of 3–15%, whereas red and green seaweeds have protein content ranging from 10–30% and 3–47%, respectively (Subramaniam et al., 2021).

In recent years, there are growing interest in exploration of seaweed as functional food, energy, pharmaceuticals and medicine due to their bioactive components or phytochemicals that could benefits human and animal health such as reduce the risk of metabolic syndrome, hyperglycaemia, hypercholesterolemia and hyperlipidaemia (Collins, Fitzgerald, Stanton, & Ross, 2016). Additionally, seaweeds have been consumed as traditional cuisines in many Asian countries, which has led to their development as a functional food in Western countries.

TYPES OF MALAYSIAN SEAWEEDS

- **Chlorophyta (Green Algae)**

Chlorophyll-a and chlorophyll-b give these algae their green colour (**Figure 1**). The majority of the species are aquatic and can be found in both freshwater and marine habitats. *Halimeda* species (*H. discoidea, H. opuntia, H. tuna*), erect coralline algae that contribute to reef construction by retaining calcium carbonate in their cell walls, also dominate coral reefs. Other green algae inhabiting coral areas include *Anadyomene plicata, Boodlea montagnei, Cladophoropsis* species, *Dictyosphaeria cavernosa, Valonia aegagropila, Cladophora fascicularis, Bryopsis pennata, Codium* species, *Udotea javensis, Udotea flabellum, Tydemmania expeditionis, Bornetella* species and *Neomeris* species. Other than growing in the marine habitats, some green algae are terrestrial, such as *Enteromorpha* and *Ulva* are found in shores and mudflats while *Enteromorpha intestinalis, E. chlathrata, Ulva lactuca* and *U. fasciata* are commonly found in soil, rocks and trees (Phang, Yeong, & Lim, 2019; Phang, 2006).

Figure 1. Example of green algae (photo credit to Dr. Chew Li Lee)

- **Cyanophyta (Blue-green Algae)**

Cyanophyta is a form of plankton or algae that has a dominant green colour, hence the name "blue green algae." Cyanophyta can be easily found in high-salinity seas, lakes, and freshwater rivers, as well as in extreme environmental conditions including high acidity and high temperatures. For instance, *Brachytrichia* is commonly seen on rocks and dead corals, while *Lyngbya majuscula* and *Oscillatoria* species are commonly found in mudflats and sandy-muddy areas (Phang et al., 2019; Phang, 2006).

- **Phaeophyceae (Brown Algae)**

The dominance of the xanthophyll pigment fucoxanthin, which conceals other pigments such as chlorophyll-a and chlorophyll-c, β-carotene, and other xanthophylls, gives these algae their brown colour (**Figure 2**). Most of the brown algae grow in marine environment and most of them are found in cold water. *Padina* are the most easily found species that live in mangroves, sandy areas, mudflats, coral reefs, and rocky coastlines. On the intertidal coral reefs, *Turbinaria* and the encrusting *Lobophora variegata* frequently accompany the *Padina*. On the other hand, *Sargassum* and *Dictyota* dominate in the brown algae family in terms of species number (Kumar, Ganesan, Suresh, & Bhaskar, 2008; Phang et al., 2019; Phang, 2006).

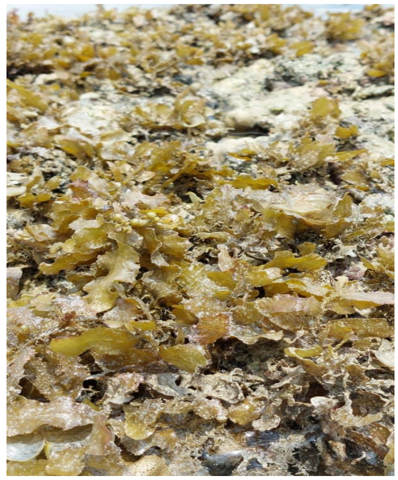

Figure 2. Example of brown algae (photo credit to Dr. Chew Li Lee)

- **Rhodophyta (Red Algae)**

The pigments phycoerythrin and phycocyanin are dominant in these algae, giving them their red colour. Carrageenan and cellulose agar make up their walls. The red algae have the greatest diversity of taxa, most of them grow in marine environment (Kumar et al., 2008). The Rhodophyta has seen a rise in the number of taxa reported, mainly because of the increased interest in commercial red seaweed species. For instance, *Gracilaria, Gelidium, Euchema, Porphyra, Acanthophora*, and *Palmaria* are the typical examples of Rhodophyta. (Phang et al., 2019).

MALAYSIAN SEAWEEDS AS FOODS

Seaweed is well-known for its nutritional benefits, as it can give minerals, vitamins, calories, and important antioxidants to humans and animals. In Malaysia, seaweeds have been reported as being used for both food and traditional medicine. Several species of *Gracilaria*, *Eucheuma* and *Caulerpa* were used for making salads while *Eucheuma* and *Kappaphycus* are grown for carrageenan extraction in Sabah, Malaysia. Some seaweeds are served as traditional medicine such as *Corallina* (*Amphiroa*) can be a vermicide to fed the kids while *Sargassum* and *Turbinaria* are used to cook in a traditional Chinese cuisine. *Acanthophora spicifera, Eucheuma spinosum, Gracilaria sp., Hypnea musciformis, Dictyopteris sp., and Sargassum spp. Halimeda opuntia, Acanthophora spicifera, Eucheuma spinosum, Gracilaria sp., Hypnea musciformis, Dictyopter* are believed to have the antibiotic functions.

Due to the getting well-known on the seaweeds benefits to health, especially an increase commercial products derived from *Kappaphycus* and *Eucheuma,* has resulted in an increased interest in urban populations seeking natural and "health-promoting" foods in recent years. For instance, *Kappaphycus alvarezii* and *Eucheuma denticulatum* are sold as "sea bird's nest" with qualities similar to valuable bird's nest (solidified saliva of swiftlets in their nests), resulting in a tenfold or greater increase in selling price.

Kappaphycus and *Eucheuma* are also used to make soaps, shampoos, desserts, jams, and noodles (Phang, Yeong, Lim, Nor, & Gan, 2010).

Apart from being consume as traditional food or medicine, seaweed has other commercial value in the food industry. For example, alginic acid derived from seaweed has thickening and stabilising properties, which is ideal for making syrups, ice creams, sauces, juices, shakes, sweets, and bakery products. In additional, there are seven different types of carrageenas found in seaweed containing the sulfated galactose unit, three of which are economically exploited. Carrageenas is a coarse thickening agent that is used to make pizzas, desserts, gels and canned foods. It is also used as a preservative or additive agent, and carrageenas additives are commonly labelled as E407. Agaropectin and agarose, which are galactopyranose polymers, make up the majority of seaweed, also commercially used as a gelling agent, primarily in canned goods, sweets, and pie fillings, label as E406 in the food industry (Nakhate & van der Meer, 2021). **Table 1** shows the common Malaysian seaweeds used as human foods.

Table 1 Malaysian seaweeds as human foods

Constituents	**Common species in Malaysia**	**Use as food**
Chlorophyta (Green Algae)	Caulerpa species Bryopsis pennata Codium species	fresh vegetable or salads
Phaeophyceae (Brown Algae)	Sargassum species Turbinaria species	Used to cook in a traditional Chinese herba soup which has the function to “cool” the body system
	Padina species Lobophora variegate Dictyota species	Alginate from brown algae has thickening agent, gelling agent, stabiliser and emulsifier properties to be used for making frozen food, ice creams, instant food drinks
Rhodophyta (Red Algae)	Eucheuma species Kappaphycus species	Edible as salads. Carrageenan extraction from the seaweeds, as a coarse thickening agent that is used to make pizzas, desserts, jams, gels and canned foods.
	Kappaphycus alvarezii Eucheuma denticulatum	Sold as "sea bird's nest" with qualities similar to valuable bird's nest
	Corallina (Amphiroa)	Vermicide to fed the kids

	Gracilaria species	Fresh vegetable or salads
	Gelidium species Porphyra species Acanthophora species Palmaria species	Agar from red algae has laxative agent, stabiliser, solidifying agent and emulsifier properties to be used for making jam, jelly, cakes, chocolates, candies, sauces etc

PHARMACOLOGICAL PROPERTIES OF MALAYSIAN SEAWEEDS

As seaweeds have long been used as food and medicine especially in Asian countries, their health benefits have also been extensively studied. Some of the health benefits such as antioxidant, antidiabetic, antihypertensive, anti-inflammatory have been documented in the literature. Among the Malaysian seaweeds, three red seaweeds (*Eucheuma cottonii, Eucheuma spinosum*, and *Halymenia durvillaei*), two green seaweeds (*Caulerpa lentillifera* and *Caulerpa racemosa*), and three brown seaweeds (*Dichotoma dichotoma, Sargassum polycystum,* and *Padina spp*.) were examined for their antioxidant properties (Mohamed, 2011). Methanolic extracts of *C. lentillifera* and *C. racemosa*, as well as *S. polycystum*, showed to have antioxidant properties. On the other hand, extracts of *Kappaphycus alvarezii, C. lentillifera,* and *S. polycystum* showed to have hypolipidemic and cardiovascular protective properties (Matanjun, Mohamed, Muhammad, & Mustapha, 2010). Crude water extracts of *Halimeda macroloba, Padina sulcata, Sargassum binderi,* and *Turbinaria conoides* showed to have inhibitory activities against α-glucosidase and DPP-4 which help in regulating blood glucose (Chin et al., 2015). *Gracilaria manilaensis* may contain potent bioactive chemicals that mirror the neuroactivity of nerve growth factor for neuronal survival, development, and differentiation, and has potential to be used as a dietary supplement for neurological diseases prevention (Pang et al., 2018).

Antioxidants contained in seaweeds have also been discovered to have anti-aging capabilities. Intake of seaweed causes a number of biochemical changes in humans, including antioxigenic activity, cell adhesion inhibition, binding toxic compounds, induction of apoptosis, and the addition of important trace minerals to the diet, all of which are important in preventing chronic diseases and slowing down the ageing process. In addition, high antioxidant activity of seaweeds may help to slow the growth of cancer cell. Seaweeds have a high antioxidant activity, which helps to slow the growth of cancer cells. Seaweed consumption lowers plasma cholesterol levels and consequently lowers the risk of cardiovascular disease (Pandey, Chauhan, & Semwal, 2020).

Seaweeds can also help those with diabetes. During an in-vivo research, oral administration of *Ulva faciata* aqueous extract significantly lowered blood glucose and glycosylated haemoglobin levels when compared to other standard medicines (Abirami

& Kowsalya, 2013). Methanolic extracts of seaweeds showed to have high antimicrobial effect against bacteria such as *Staphylococcus, Bacillus, Streptococcus, Enterobacter, E. coli,* and *Proteus* (Karthikaidevi, Manivannan, Thirumaran, Anantharaman, & Balasubaramanian, 2009). Sufated polysaccharides present in seaweed, such as carrageenans, fucoidans, and rhamnogalactans are showed to have protective effect on viral infection. These seaweed chemicals have antiviral and anti-enzyme activities, preventing viruses from infecting cells (Pandey et al., 2020).

CONCLUSION

Malaysia has extensive coastline and islands provide various habitats to cultivate a diversity of seaweeds. The research on nutritional value of Malaysian seaweeds are getting attention recently. Taking into account that seaweeds have long time been consumed by the Asian population, there are growing trend to discover more edible species of seaweeds to meet the growing demand from customers. As seaweeds are high in nutrient composition and also the antioxidant, antidiabetic, antihypertensive and anti-inflammatory properties, seaweeds are potential to be a functional food. Significant efforts are needed to investigate what it does and how it can be used in direct-consumption wellness foods. It is also important to promote public awareness of seaweeds in order to develop a larger and easily accessible alternative ingredient supply for foods with therapeutic properties. However, there are still many things to consider when producing functional food using seaweed as the main component to achieve market success. For instance, increasing the number of farms and farmers, strengthening local seaweed cooperatives and including them in decision-making, as well as technological advancements in the form of new and improved strains, more efficient seed supplies, may help to increase the production of seaweed. Anyhow, it is necessary to assess the nutrition and functional components of seaweeds, as these vary with species, genera, temporal, and regional variations. Apart from the health benefits, certain seaweed can cause allergic reactions in humans, thus choosing the right edible seaweed is essential before utilizing it as food.

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