International Journal of Food Science +Technology

Institute of Food Science +Technology ifst

Invited review

The local indigenous food of Sarawak as potential functional food

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(Received 2 January 2024; Accepted in revised form 11 May 2024)

Summary The local people of Sarawak commonly made unique dishes out of the local distinctive resources for its health beneficial nutrients. Yet, many potentials of the local Sarawak food ingredients are less likely to be exploited. One of the main produces of Sarawak is the starch from *Metroxylon sagu*. Our study reviewed that sago starch is not only active in health beneficial bioactivities such as antioxidative, it also possesses positive prebiotic response. Other local indigenous fruits, vegetable and spices of Sarawak as potential functional food includes Sarawak pepper; *midin*, the edible fern; *terung asam*, the sour eggplant; *dabai*, the Bornean olive; *engkalak*, the Bornean avocado; *Terap*, the local 'jackfruit'; *embangan*, the local wild mango; and the edible palm heart (EPH) from palm tree. Research on the edible fern (*midin*), edible palm hearts (*umbut*), spices such as turmeric and pepper from Sarawak has revealed a positive functionality in terms of prebiotic potential, antioxidative, antimicrobial and many more. Conclusively, the wide food varieties of Sarawak are potential functional food. Therefore, this work aimed to publicise the health beneficial functionalities of the local indigenous food which then value-added the rare local food resources, and boost the local farmer's production and economic status.

Keywords Borneo food, Malaysian Food, prebiotic, spices, wild crops.

Introduction

Functional food has been gaining attention by many people for boosting and maintaining human health and well-being. Functional food is usually available in our daily meals and it is consumed as food or part of a dish. In other words, the only key point that differentiate functional food with medication or drugs is that, functional food can only be sell as food products and remained as food or part of the food in a dish of our daily diet (Hui Yan *et al.*, 2021).

The Association of Southeast Asian Nation (ASEAN) was established by ten different countries. This includes Brunei, Burma, Cambodia, Indonesia, Laos, Philippines, Singapore, Thailand, Vietnam, Timor-Leste and Malaysia. In Malaysia, the state of Sarawak is the largest crop producer with the most land for cultivation and agricultural activities. The locals in Sarawak of Malaysia are made up by several major ethnic, not only the Malay, Chinese, Indian, there are Iban, Melanau, Bidayuh, Orang Ulu, Kayan, Lun Bawang, Kedayan and many more (Sageng *et al.*, 2020). Therefore, Sarawak of Malaysia has a multi-culture with various food delicacies. Not to forget, the locals of Sarawak who explored the natural resources of the rainforest which then leads to many unique food and dishes. In which, these indigenous food in Sarawak is, therefore, a symbol of Sarawak culture.

By having various source of fruits and vegetables, Sarawak, Malaysia has a remarkable diversity of flora. These precious resources have been an important food resources for the local Sarawakian ever since. These wild crops, therefore, has become unique dishes and even significance symbols in their culture. One of the signature food in Sarawak is the sago starch. In which, the sago starch is served in the form of sago pearls which are distributed worldwide and served as a dessert. For instances, the *Sagu Gula Melaka* (Sago pearls in coconut syrup). In Sarawak, sago starch is served not only as a dessert, but also as the main dish in the daily meals of Sarawakian. To go with these main dishes, vegetables such as the edible fern known as *midin*, the core of palm tree as edible palm hearts, the sour eggplant named *terung asam*, spices like black pepper, white pepper and many rare and wild flavouring plants were involved in their daily meals. Not to mentioned the unique local fruits, namely *Dabai*, the Sarawak 'Olive', the native *Terap* fruit that looks like

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doi:10.1111/ijfs.17246

a jackfruit, the nipa palm sugar (*gula apong*), *Engkalak*, the Sarawak 'Avocado' and *Embang*, the local wild mango. Not to forget, one of the most high priced product of Sarawak, the edible bird's nest (EBN), which is the 'caviar of the East' and Sarawak is the third largest producer throughout the world. These indigenous foods and crops are rare, yet commonly utilised by the local people due to the beliefs of its high valued nutritional functionalities (Kasron *et al*., 2020). However, studies regarding the nutritional value and health beneficial functionalities are scarce. This review thus increased the awareness of researchers towards Sarawak indigenous food resources and its health benefits as a potential functional food (Table 1). This then contribute to the broaden the market value of these indigenous food with great nutritional functionalities.

Functional food: Definition and criteria

Functional food is defined as 'natural or processed foods that contain biologically active compounds, which is defined with effective, and non-toxic amounts that provides a clinically proven and documented health benefit utilizing specific biomarkers for prevention, management or treatment of chronic diseases or its symptoms' (Hui Yan *et al*., 2021). Generally, functional food is well-known for its health beneficial effects. However, functional food is different from drugs or medicine as they both helps in human health. That is, functional foods can be consumed as in our daily diet which helps to maintain and boost our health and well-being in a positive way. Yet, medicine is only consumed in the period of illness to control the sickness symptoms. As functional food, the key criteria of being one depends on the natural properties of the ingredients itself. In which, most of the key points goes around the health benefits, functionalities and ways of consumption. The ingredients can be a functional food in its natural existing form. Otherwise, ingredients can be considered as a functional food by (i) enrichment with health beneficial nutrients or components; (ii) removal of any deleterious component and (iii) modification using technologies such as fermentation, thermal treatment, etc which enhanced the health benefits of the ingredient; and/or (iv) any combination of the mentioned. In short, these ingredients remained as food in our daily diet while bringing health benefits to human well-being from the consumption.

Indigenous food resources in Sarawak, Malaysia

As one of the members in the Association of Southeast Asian Nations (ASEAN), Malaysia too has a significant varieties of food resources. The land of Malaysia, particularly Sarawak which is the largest producer for many crops has a wide cultivation range for indigenous ethic food resources (Kasron *et al*., 2020). The consumption of these food resources by the local communities has, therefore, created several unique cuisines that significantly represent Sarawak, Malaysia. In other words, these indigenous foods are commonly consumed by the locals ever since, therefore, it has become the so called 'Sarawak Food Culture'. These cultures were then continued to be practiced traditionally for its distinctive and unique taste. Not only for the sake of the taste and flavour of the Sarawak, the locals also have several health beneficial beliefs on these unique food resources. Today, many scientific evidence has managed to verify many of these nutritional functionalities for its health benefits. These includes studies on sago starch, black and white pepper of Sarawak, the edible fern named *midin*, and many indigenous fruits such as *dabai*, *terap, embang, engkalak*, the sour eggplant and more.

The sago starch

The annual production of sago starch is around 656 000 tons with major producers from both Sarawak of Malaysia and Indonesia. Although Indonesia has the largest sago tree cultivation area, yet the national production is still low. This made Malaysia the current largest producer of sago starch, particularly Sarawak of East Malaysia with modern processing industries which led to stable production of sago starch (Trisia & Ehara, 2021). Sago starch is obtained from the pith of a sago palm tree (*Metroxylon sagu*) using wet milling process (Zailani *et al*., 2022). Whereby, the tree trunk of the sago palm tree is break into pieces, then grinded and underwent filtration before left for sedimentation to obtain the sago starch at. The fresh raw sago starch obtained is locally known *Lemantak* (Arshad *et al*., 2018). Sago starch is usually consumed in the form of sago pearls, cookies, also in the form of glue-like starch paste called *linut* in Sarawak. Thus, this made the sago starch as a thickener in many foods which enhance the food texture and help people with swallowing difficulty (Syahariza & Yong, 2017). The gluten-free and grain-free sago starch is, therefore, a unique of source of carbohydrate similar to those in grain and wheat starch (Kumari, 2019). Studies have reported that consumption of sago starch is beneficial to human health. In which, it helps to manage body weight, reduce risk for heart diseases, control blood pressure and improve circulation. This is due to the high resistant starch (RS) content of up to 69% which made the sago starch itself to be low digestible and thus, an alternative for starch with low glycaemic index and prebiotic effects (Thompson *et al*., 2023). Also, latest research by Zailani *et al*. (2023) also supported the statement of native sago starch has a glycaemic value which is beneficial towards people with issues related to obesity and diabetes.

Table 1 List of indigenous food in Sarawak, Malaysia as potential functional food

No.	Type of food	Consumption method	Functionality and health benefits
1	Sago starch	Consumed in the form • Sago pearls • Cookies • Glue-like starch paste called *linut*	• High resistant starch (RS) content • Manage body weight • Reduce risk for heart diseases • Control blood pressure • Improve circulation
2	Sarawak black & white pepper	Consumed as spices added in dishes to increase flavour of food • Powder form • In whole form	• Increase appetite • Potential prebiotic ingredient • Enhance bioavailability of food nutritional functionalities • Improve wound healing • Antihypertensive, antioxidant, antitumor, anti-inflammatory, antidiarrheal, antibacterial, antifungal, anticolon toxin
3	*Midin* (edible fern)	Consumed as vegetable dish, juice and traditional medicine • Stir-fried dish mixed with garlic, dry shrimps and shrimp paste • Salad • Juice	• Antimicrobial • Antifungal • Antioxidative • Promotes growth of probiotics
4	*Dabai* The 'local olive'	Consumed as snacks, fruits and dishes	• Cholesterol-lowering agent • Antioxidative • Antimicrobial • Potential fat alternative
5	*Gula Apong* Nipa palm sugar	Consumed as sweetener in desserts and cakes	• Antioxidative • Alternative sweetener
6	*Terap* (*Artocarpus odoratissimus*)	Consumed as raw fruit and juices	• Antioxidative • High phenolic and flavonoid content
7	*Embangan* The Sarawak wild mango	Consumed as raw fruit and juices	• Rich in source of fibre, vitamin C, carotenoid, phenolic compounds • Antioxidative compounds
8	*Engkalak* The local 'avocado'	• Soaked in hot water until soften before consumption • Eaten raw or with rice and other spices and flavouring	• Antioxidative • Antibacterial • Antifungal • Anticancer • Anti-inflammatory activities
9	*Umbut* edible palm hearts	• *Umbut* from oil palm tree, coconut palm and/or sago palm tree • Salads and stir-fry meals	• Potential prebiotic ingredient • Rich in fibre and carbohydrate
10	*Terung asam* The sour eggplant	• Served in the form of soup cooked with seafood or any meat • Cook with fish due to their ability to reduce the fishy odour and fattiness of pork	• High in Vitamin C, also calcium, fibre, phosphorus, potassium and minerals • High in phenolic compounds and flavonoids with powerful antioxidative activities
11	Edible bird's nest (EBN)	• Double-boiled with rock sugar, ginseng, red dates and other herbs • Consumed as soup, desserts or drinks	• Antioxidative • Antihypertensive • Anti-inflammatory activities • Promote cell proliferation & anti-ageing • Stimulates neurological development and memory enhancement • Antiarthritis and bone strengthening • Potential prebiotic ingredient

Modification of sago starch AS resistant starch

However, the utilisation of native sago starch in industries is limited due to its functional limitation such as swelling power, solubility, water binding capacity, glycaemic index, digestibility and resistancy. For example, to increase the RS content in sago starch for health-promoting purposes. Therefore, further modification is required to broaden the application in more industries. Similar modification technique on starch was conducted many other starches which include corn, cassava, rice, potato and lotus starch. For example, type III retrograded resistant starch from wheat, potato, corn and more which resist digestion (Klingbeil *et al.*, 2019; Arp *et al.*, 2020; Jia *et al.*, 2022). The modification of starches involves three main treatment techniques which are the physical, chemical or enzymatic treatments. (Zailani *et al.*, 2022). The combination of either two or all three types of methods was also investigated. The chemical and enzymatic treatment had displayed promising improvement in the functionality and benefit of starches such as better emulsifying properties and higher resistant starch (RS) content.

Previous study by Ahmad *et al.* (2016) modified native sago starch to produce resistant starch type III through retrogradation with the aid of an enzyme, namely pullulanase. Sago starch undergo 8 h enzymatic debranching (DSS8) has the highest RS content. Observation from this study indicated that it is possible to complete the debranching process in sago starch for a high yield production RS. In which, increase RS in sago starch is beneficial towards human health, particularly in obese and diabetic patients.

Physical modifications

Physical modifications are more preferable for its simpler and more 'natural' procedure like using heat treatment. Study by Zailani *et al.* (2023) has performed modification of sago starch using microwave heat treatment. The predicted glycaemic index (pGI) of the food formulated with 50 and 75% of modified sago starch is significantly decreased due to the increase of RS content. Thus, positively stimulated the growth rate of probiotics (i.e. *Lactobacillus casei* and *Bifidobacterium lactis*) in 24 h *in vitro* fermentation.

Chemical modifications

Study by Paramitasari *et al.* (2024) uses substitution-type modification using low dose of propylene oxide to perform hydroxypropylation on sago starch for improvement in terms of functionalities with preferable molar substitution. From the study, the modified sago starch has an enhancement in swelling power, water-holding capacity, oil-holding capacity, solubility and paste viscosity. At the same time, hydroxypropylation has also reduced the amylose content, gelatinised temperature and breakdown viscosity. Therefore, hydroxypropylated sago starch can be a suitable thickener in food industries. Study by Lele *et al.* (2018) also synthesised sago starch maleate monoesters using elongation-type modification with maleic anhydride in water and ethanol precipitation. This co-polymerisation process was then continued with cross-linking technique through UV irradiation in the presence of cerium (IV) ammonium nitrate to produce gel particles. In which, these treatments increase the thermal stability and swelling power which suits the criteria of functional biomaterials such as coagulants, chelating resins, drug delivery, wound dressing, films and etc (Zhu, 2019). Degradation-type modification of sago starch was also performed by using alcoholic-alkaline solution and acids to produce cold-water soluble starch. In which, degradation of sago starch has granules with destroyed maltese-cross linking, enlarged size, reduced pasting event and increase amylose content (Azmi *et al.*, 2017).

The Sarawak black and white Pepper

Black and white pepper of the species *Piper nigrum* L. is regarded as the king of spices with pungent aroma that enhanced food flavour, and Malaysia is the fifth largest producer of peppercorns. According to Malaysian Pepper Board, the national production of pepper is approximately 31 073 tonnes (5.9% worldwide) with 11 714 tonnes were for exportation that values at around RM 200.95 million (Johny *et al.*, 2020; Tan *et al.*, 2021). Studies reported that pepper berries of *P. nigrum* L. can be the same, yet the level of aroma may be different due to different chemical composition (particularly piperine and oleoresin) depending on the geographical factors that affects the soil fertility, rainfall, fertilisers and pesticides usage and even post-harvest handling (Mercer *et al.*, 2019). This then further decides the market prices of the pepper to not only based on size and weight, but also the geographical origin. The chemical profiling of Sarawak pepper revealed a unique presence of elemene isomer (e-elemene), andrographolide, (e)-1-(piperidin-1-yl) dodec-2-en-1-one, (2E,4E,6E)-7-(Benzo[d](I,3)dioxol5-yl)-1-piperidin-1-yl) pent-2-en-1-one, and gibbenellic acid. Also, the compounds of Sarawak pepper have a lower concentration which is less volatile when compared to those from India. Additionally, pepper also contains abundant bioactive compounds that are capable of enhancing human health. This spice contains high bioactive compounds in enhancing human health and contains up to 33% dietary fibre. Other than that, the presence of alkaloids, polyphenols and flavonoids also increases its ability to act as a prebiotic. Some

studies conducted proved that these secondary metabolites might contribute to improving intestinal health by maintaining the microbial environment in the gut through stimulation of *Lactobacilli* and *Bifidobacteria*, and inhibiting the pathogenic bacteria population in the human gut, which exerting the prebiotic-like effects (Dreger *et al*., 2014). *Piper nigrum* L. also showed promising result and its effectiveness as prebiotic ingredient as food ingredient (Nashri *et al*., 2023). Also, in livestock production, it has a positive effect towards the appetite also act as antibiotic substitute (Ashokkumar *et al*., 2021). Other than positive effects towards gastrointestinal health, *P. nigrum* L. as well revealed functional properties in improving wound healing as claimed for home remedy (Wong *et al*., 2018). Through cell migration assay, the study demonstrated significant wound healing properties in ethanolic extract of *P. nigrum* L. at 0.3 and 1.0 μg mL^{-1} concentration. It is also reviewed by Shukla *et al*. (2018) that piperine also exhibits other health-promoting activities such as antihypertensive, antiplatelets, antioxidant, antitumor, antiasthmatics, antipyretic, analgesic, anti-inflammatory, antidiarrheal, antispasmodic, anxiolytic, antidepressants, hepato-protective, immunomodulatory, antibacterial, antifungal, antithyroids, antiapoptotic, antimetastatic, antimutagenic, antispermatogenic, anticolon toxin, insecticidal and larvicidal activities etc. The study also reported that piperine is able to enhance the bioavailability of many food nutritional functionalities. It also boost the therapeutic efficiency of drugs, vaccines and many other medications (Johnson *et al*., 2011). However, investigations on Sarawak pepper were scarce and further researches were required in terms of doses control using animal models and also clinical trials.

The famous edible fern: *midin*

Ferns are found in many places throughout the world and more than 140 species has been well-known to be edible as food and medicinal plants (Dvorakova *et al*., 2024). This includes different species of edible ferns from India, Nigeria, Vanuatu, Vietnam, Iran, Bangladesh, North America, Nepal, China, Indonesia, Philippines and also Malaysia. In Malaysia, *Stenochlaena palustris* or *midin* is an indigenous edible fern found in Sarawak and also southeast Asia. This red young fern is commonly consumed among local people as a vegetable dish, juice and traditional medicine. Traditionally, *midin* is widely consumed among the local people as stir-fried dish mixed with garlic, dry shrimps and shrimp paste (Dash, 2016). When cooked, *midin* has a crunchy-succulent texture. *Midin* is also served as salad with dressing of vinegar, dried shrimps or anchovies, locally it is known as '*ulam*' in Malay language (Chai, 2016; Dash, 2016). Besides that, the studies also mentioned that *midin* is consumed as juice in the old days. In which, it is believed that juice of *midin* is used to treat fever (Ponnusamy *et al*., 2013). The unique component of *midin* is the abundant mucilage, a sticky, gluey substance within the plant which may contribute to the pharmacology properties of *midin*. Studies validated these health beneficial beliefs of *midin* such as antimicrobial, antifungal and antioxidative. Recent study also revealed that *midin* has a positive prebiotic response. In which, *in vitro* study of *midin* stimulates the growth of probiotic strains like *Lactobacillus* spp. and *Bifidobacteria* spp. (Hui Yan *et al*., 2022). It is also reported that *S. palustris* contains metabolites namely kaempferol glycosides, fatty acids and phytosterols. These phytocompounds have demonstrated functional bioactivities such as antioxidant, antiglucosidase, cytotoxic, antimicrobial, antibutyrylcholinesterase, antimetalotoxic, antipyretic and termiticidal activities (Quah *et al*., 2022). Therefore, contributed to its application and utilisation in food, cosmetic and food packaging materials. However, there is no attempt to cultivate *midin* as a farm crop as it is easily available from the wild for everyone to harvest (Chai, 2016). Therefore, the upcoming development of *midin* are focusing the cultivation, farming, commercialization and marketing of the food crop.

The local olive: *Dabai* fruit

One of the underutilised local indigenous fruits in Sarawak that come from the Burseraceae family is *dabai*, *Canarium odontophyllum*. It is commonly consumed as snacks among the locals. As the fruit has a hard skin and flesh, it is usually soaked in warm water for 10 min before consumption. Sometimes, it is cooked into dishes and consumed with rice as well. Currently, a total of approximately 75 recognised species have been found mainly in Asia, the Pacific and tropical Africa. In Malaysia, particularly Sarawak, it is reported that there is an estimation of 13 000 *dabai* trees with average production of 650 metric tonnes of *dabai* per season on October to December of the year (Jacintha, 2023). *Dabai* is highly demanded due to its natural delicious creamy and 'fatty' taste almost similar to avocado, being exotic and unique to Sarawak, and also its rich in nutritional properties such as protein (3.8%), fat (26.2%), energy (339 kcal) and carbohydrate (22.1%) (Mundi *et al*., 2022). Hence, the oil extraction of nutritive *dabai* has become one of the interests of the recent studies. The chemical characteristics of the extracted oils from both the *dabai* flesh and the kernel were discussed. The *dabai* flesh oil was found to be comparable to palm oil, particular palm olein with similar composition and quantity of saturated (43.42%), monosaturated (42.53%) and polyunsaturated acids (14.05%). Thus, making *dabai* flesh oil

an alternative for conventional oil for production of soap and shampoo. Meanwhile, the *dabai* kernel oil is similar to cocoa butter which abundant saturated fatty acids was found. Specifically, palmitic acid (40.31%) and minor quantity of myristic acid, stearic acid and arachidic acid. Later led to further investigation of the possible cholesterol-lowering agent due to its high antioxidant ability. The fruit is slightly triangular in the cross section, ovoid to ellipsoid. It is also rich in phenolic compounds and vitamin E, such as γ-tocopherol. In addition to the nutritional value of dabai fruit, it has been proven that extract from dabai is able to lower plasma cholesterol (Mokiran et al., 2014). It is also reported that *dabai* has a potential for antiacetylcholinesterase activity from the extract of the flesh and seed of dabai (Ali-Hassan et al., 2013). In which, acetylcholinesterase is responsible to breakdown of acetylcholine, which act as a neurotransmitter that prevent the loss of cholinergic neurons that causes Alzheimer's disease. Other functional values of *dabai* include antimicrobial and potential fat alternative. In which, the fat and oleoresin of *dabai* flesh, skin and seeds are applicable in food products such as ice creams, spread and sauce as a healthier choice of fat (Hamzah *et al*., 2022) (Table 2).

Gula apong (Nipa palm sugar), the must have ingredient for Sarawak ice cream

Nipa sap or locally known as *air sadap* or *air nira* is a traditional beverage consumed by people in Sarawak. While, *gula apong* is the nipa palm sugar (*Nypa fruticans*) is made by boiling to concentrate the sap of nipa palm tree. It has a golden caramel colour and unique fragrance sweet taste (Jaraee *et al*., 2023). It is commonly used as sweetener in cakes/*kuih*, desserts and beverages in Sarawak. The nipa palm sugar contains high amounts of phenolic and flavonoid compounds, vitamins and minerals (Yahaya *et al*., 2021) and hence it is well-known as a healthier alternative of white and brown sugar. Other than the unique taste and fragrance, another unique characteristic of *gula apong* is the low glycaemic index (GI) of the sugar itself without losing the unique sweetness, taste and fragrance of the nipa palm. In short, it is a healthier choice with high nutrients, antioxidative properties and great flavouring which helps in managing the occurrence of diabetic and obesity related disorders (Saengkrajang *et al*., 2021). The nipa palm sugar, therefore, brings health-promoting functionalities such as antioxidative functionalities for its content of kaempferol, quercetin, gallic acid, cinnamic acid, caffeic acid, coumaric acid, maleic acid and chlorogenic acid reported by Yahaya *et al*. (2021). Therefore, the *gula apong* has a great potential as a derivative which can be safe for all individuals including the diabetics.

The native fruit, *Terap*

In Sarawak, *Terap* or *Artocarpus odoratissimus* is famous for the unique fragrance, taste and crispy texture. In which, *Terap* has been gaining visibility in the local industries in recent years. From the harvest, it is usually harvested just the beginning of the rainy season between October to January of the year. It is usually harvested green and allowed to be ripen off which appeared to be hard and brittle (Abu Bakar & Abu Bakar, 2018). As *terap* is not well-explored and constantly produced, studies on the nutritional health benefits of *Terap* is also scarce. It is reported that *Terap* contains high carbohydrate content, Vitamin B1 and potassium is the major mineral component found in *Terap* (Ismail & Ramaiya, 2021). Recent studies on the seed and oil of *Terap* also reported with several functional properties (Ismail *et al*., 2022). In which, they are fried and consumed as snacks with fatty flavour similar to hazelnuts. In terms of appearance, taste and fragrance, the *terap* is similar to *Artocarpus heterophyllus* (jackfruit) and *Artocarpus altilis* (breadfruit). The sensory report stated that *terap* is more delicious and preferable than jackfruit and breadfruit (Abu Bakar & Abu Bakar, 2018). In which, *terap* has a sharp pungent aroma even when the fruit is unopened. It also has a starchy bitter taste when it is not fully ripened. When ripe, the flesh of this fruit is soft and easy to chew as well as it has a thick peel with soft spines like-texture.

Recent study by Ismail *et al*. (2023) revealed that *terap* contains high phenolic compounds in the inedible part than the edible part, particularly the peel. The study also reported that *terap* also has a high content of flavonoid compounds. In which, both phenolic and flavonoid compounds in plants contributes to health beneficial functionalities such as antioxidative, antibacteria, protection against UV radiation and more (Ismail *et al*., 2023). Another noticeable feature of *terap* is the abundant vitamin B1 (Thiamine) which is 39 times higher than those in breadfruit. It also contains other vitamins such as B9, B3, B2. Meanwhile, the inedible part like the seed of *terap* contains significant portion of unsaturated fatty acids at 57.10%, majorly nervonic acid (45.32%). Thus, making *terap* a potential functional food yet require further study due to scarce research was done. Also, this indigenous fruit is less likely to be explored, therefore, *terap* itself is also yet to be cultivated and farmed which made *terap* to not have any reported annual production numbers (López-Martínez *et al*., 2023). The estimation from Abu Bakar & Abu Bakar (2018) that *terap* is most probably one of the most highly esteemed fruits to be exported in the future. Currently, there is a ready local market for the small quantities supplied. The Agriculture Department also reported that the nation imported fruits of worth RM 1.8 billion and exported

Table 2 Unique characteristics of Sarawak indigenous food source

Sarawak indigenous food source	Similar food source	Unique characteristics compared to other similar source	Reference
Sago starch	Wheat starch Grain starch (Barley, Oats, Rye, Spelt etc.)	• Grain-free • Gluten-free • Starch content of sago is about 88%, which is higher than most cereal grains	Kumari (2019) and Du *et al.* (2020)
	Corn starch Potato starch	• Higher amylose and resistant starch (RS) contents • Peak viscosity and breakdown of starch were lower than corn starch • Setback was higher than potato starch • Lower gelatinization enthalpy and higher regeneration tendency • Lower shear thinning degree and thixotropy	Du *et al.* (2020)
	Tapioca starch	• Sago starch gave higher syneresis values (percentage of water separation) than tapioca starch. • Thawed at low temperature • Higher potential as an alternative thickener compared to tapioca starch as it provides higher viscosity and more elastic behaviour in rice porridge which help people with dysphagia (difficulty in swallowing)	Varavinit *et al.* (2000) and Syahariza & Yong (2017)
Sarawak pepper	• Pepper from India	Malaysia pepper: • Has a lower concentration of compounds • Less volatile • Showed longer retention time in chromatogram • Specific compounds present in Sarawak pepper: • Elemene isomer (e-elemene) • Andrographolide • (e)-1-(piperidin-1-yl) dodec-2-en-1-one • (2E,4E,6E)-7-(Benzo[d](l,3)dioxol5-yl)-1-(piperidin-1-yl) pent-2-en-1-one • Gibbenellic acid India pepper: • Specific compounds present in India Pepper: • 4(10)-Thujene • Bicyclo(3.1.0) hexan-2-ol • Alpha-copaene • Artemisinin • (2e,4e,14e)-n-isobutylicosa-2,4,14-trienamide	Mercer *et al.* (2019)
Midin, the edible fern *Stenochlaena palustris* (Burm.) Bedd.	• *Blechnum orientale* L. • *Cibotium barometz* (L.) J. Sm. • *Diplazium esculentum* (Retz.) Sw. • *Marsilea minuta* L. • *Osmunda japonica* Thunb. • *Polypodium vulgare* L.	• Kaempferol glycosides isolated from *midin* • 3-O-α-rhamnopyranoside, • 3-O-(6″-O-E-p-coumaroyl)-β-glucopyranoside, • 3-O-(3″-O-E-p-coumaroyl)-β-glucopyranoside • 3-O-(3″,6″-di-O-E-p-coumaroyl)-β-glucopyranoside • 3-O-(3″-O-E-p-coumaroyl)-(6″-O-E-feruloyl)-β-glucopyranoside • 3-O-β-glucopyranoside • 3-O-(6″-O-α-rhamnopyranosyl)-β-glucopyranoside • Kaempferol 3-O-(3″-O-E-p-coumaroyl)-(6″-O-E-feruloyl)-β-glucopyranoside at highest activity that is comparable to BHT at IC_{50} • Traditionally used to treat fever, skin diseases, ulcers and more	Yeou (2015)

Table 2 (*Continued*)

Sarawak indigenous food source	Similar food source	Unique characteristics compared to other similar source	Reference
Dabai The local olive	Olive & Olive oil	• A unique fruit whereby the fruit is served by steeping at about 60 °C for 15–20 min to soften the flesh • Known as the local olive because its physical appearance, smooth texture and rich flavour are similar to olive fruits. The skin of the fruit turns dark purple black colour when fully ripe. The flesh is bright yellow in colour with a single three-angled seed • Important food and oil resource for the native people in Sarawak • The content of total saturated fatty acid was found to be 44.4% in dabai pulp, kernel (60.8%), palm oil (47.9%) and olive (25.5%) oils. Palmitic, myristic, oleic and linoleic acids were detected in dabai pulp oil (36.1%, 5.8%, 41.5% and 11.8%) dabai kernel oil (46.4%, 9.3%, 35.1% and 2.8%), palm oil (33.8%, 9.2%, 39.7% and 10.9%) and olive oil (9.9%, 12.9%, 64.4% and 5.1%) • The physicochemical characteristics of *dabai* oils show better quality than the studied commercial oils. Whereby, the iodine value of dabai oil is similar to those in palm oil and olive oil. The saponification values of dabai pulp and kernel oils (171–181 mg KOH/g) were comparable to African black olive. Lower peroxide value was obtained for dabai pulp oil and the value was similar compared to commercial palm and olive oils	Ding and Tee (2011), Basri *et al.* (2014) and Azlan *et al.* (2020)
Gula Apong Nipa palm sugar	Coconut palm sugar (*Cocos nucifera*) Palm sugar (*Arenga pinnata*) Cane sugar	• Low glycaemic index without negatively affects its indulgent fragrance and sweetness • Contains high amounts of vitamins and minerals • Palm syrups generally contained higher nutrients and antioxidants with a lower glycaemic index than sugarcane	Saengkrajang *et al.* (2021)
Terap (*Artocarpus odoratissimus*)	• Artocarpus heterophyllus (jackfruit) • Artocarpus altilis (breadfruit)	• Unique flavour profiles that is much more delightful than Jackfruit and Breadfruit in sensory reports • Waste of *terap* contain bioactive compounds which is sustainable and potential source for functional food • Contain 39 times higher vitamin B1 than those in breadfruit • Seed of *terap* contains significant portion of unsaturated fatty acids at 57.10%, majorly nervonic acid (45.32%)	Alvarado (2023) and Ismail *et al.* (2023)
Embangan The Sarawak wild mango (*Mangifera pajang*)	Common mango *Mangifera indica*	• Superior variety which is usually characterised by sweet and less-fibrous flesh • Fifty volatile components were identified in *M. pajang*; monoterpene hydrocarbons (91.3%) and esters (7.6%) predominated with α-pinene (67.2%) and α-phellandrene (11.0%) constituting the two most abundant components • Kernal extracts were found to be inhibiting cancer cell lines	Bakar & Fry (2013)
Engkalak The local 'avocado'	Common avocado	• The fat content gives a creamy texture and buttermilk taste • The energy content is lower than common avocado (160 kcal) • High saturated fatty acid (76.94%) with lauric acid as the main component (40.73%) compared to avocado	Amit & Zinyin (2021)
Umbut Edible palm hearts from coconut tree, oil palm and sago palm tree	Peach palm heart (Brazil, Costa Rica) Acai palm heart	• Flavour resembling artichoke • Alternative source of carbohydrates and/or dietary fibre • A good source of protein, vitamin C, niacin, potassium, zinc, folate, calcium, iron, magnesium, phosphorus, copper and manganese	Lee-Ling *et al.* (2022)

Table 2 (*Continued*)

Sarawak indigenous food source	Similar food source	Unique characteristics compared to other similar source	Reference
Terung asam The sour eggplant	Common eggplant	• Appeared in round and taste sour • Ability to reduce the fishy odour and fattiness of meat and fish • High powerful antioxidative compounds	Soon & Ding (2021)
Edible bird's nest (EBN)	Non-applicable	• Contains unique sialylated-mucin glycoprotein • Contains abundant amount of sialic acid and epidermal growth factors that helps in managing brain development and cell proliferation • Thermodynamic process such as soaking as heating do not breakdown the insoluble glycoprotein. It only appeared as a swelled-sponge	Hui Yan *et al.* (2021)

at about RM615 million. If *terap* cultivation and production is to be established, this numbers will be a motivation for the local agriculture field. Study by Alvarado (2023) also reviewed that *terap* waste may be a potential source of bioactive compounds such as polyphenols, anthocyanin, carotenoids and more. Probably, utilisation of these waste may be beneficial to the economic, at the same time effective in terms of sustainability in waste management.

Embang, the wild mango of Sarawak

Embang is also commonly known as the Bornean mango, human head mango or *bambangan* (*Mangifera pajang*) (Tangah *et al.*, 2017; Jahurul *et al.*, 2018). In fact, it is an ovoid shaped wild mango in Anacardiaceae family, Sapindales order and Magnoliopsida class. It has a bright yellow flesh with sweet and sour taste. The flesh of the *embang* contains mainly carbohydrate at around 78%–81%, protein, fat, and also dietary fibre which is beneficial to human health. The pulp contains flavonoids (daidzein, genistein, hesperidin, kaempferol, naringin, luteolin and quercetin), phenolic acids (caffeic acid, chlorogenic acid and p-coumaric acid), carotenoids (α-carotene and β-carotene) and xanthophylls (cryptoxanthin and cis-cryptoxanthin). Also, extract of *embang* is reported with the identification of volatile phytochemicals such as monoterpene hydrocarbons (91.3%) and esters (7.6%) predominated with α-pinene (67.2%) and α-phellandrene (11.0%) constituting the two most abundant components. Therefore, the *embang* was found to possess pharmacological properties such as antioxidative, antibacterial, anticancer and cytoprotective activities. In which, recent reports on *embang* have disclosed that certain fractions of *embang* extracts has the ability to inhibit cancer cell proliferation, particularly from the kernal (Bakar & Fry, 2013). Meanwhile, the kernel of *embang* is high in carbohydrate and plant fats. It is rich in source of fibre, vitamin C, carotenoid, antioxidative compounds and phenolic contents. Specifically, the fat of *embang* kernal is rich in total phenolic content (TPC). In which, this then made *embang* kernal economically important for the production of functional food, pharmaceutical and nutraceutical products instead of discard as waste. In terms of market and production, it is reported that mango is the dominant tropical fruit being produced worldwide (Bakar & Fry, 2013).

Engkalak, the local 'avocado'

Among the indigenous fruits, *engkalak* has a 10% preferences and demand among the local of Sarawak, Malaysia. *Engkalak* or scientifically known as *Litsea garciae* is the local 'avocado' of Sarawak. It has a white flesh with a creamy sweet taste like buttermilk (Mahlan, 2022). The fruit is usually soaked in hot water until soften before consumption. It can be eaten raw or with rice and other spices and flavouring. It is reported the *engkalak* has an energy content less than avocado but higher than those in banana. In which, it has a higher fat content (6.8%) than its protein content (1.4%). It also has a high saturated fatty acid (76.94%) with lauric acid as the main component (40.73%); moderate amount of monounsaturated fatty acids at 16.23%, and a small amount of polyunsaturated fatty acids at 7.1%. In other words, the *engkalak* kernel contain saturated fatty acids which has a quantity similar to those in coconut and palm oil. Thus, it is a suitable and healthier alternative to replace coconut and palm oil (Amit & Zinyin, 2021). Other than that, it also contains phenolic contents, flavonoids which lead to high antioxidative properties. (Amit & Zinyin, 2021). The study also reported a positive response in terms of antibacterial, antifungal, anticancer and anti-inflammatory activities. In which, these nutritional functionalities have made *engkalak* a potential functional food beneficial for human health.

Edible palm hearts (*UMBUT*)

Edible palm hearts (EPH), known as palmito, chonta or swamp cabbage in America or umbut in Malaysia, is a type of vegetable harvested from palm tree species. Edible palm hearts (EPH) are the edible cores from palm tree stems and are also an alternative source of carbohydrates and/or dietary fibre (Lee-Ling *et al.*, 2022). Its crisp texture makes EPH an ideal addition in dishes such as salads and stir-fry meals. The EPH is firm and smooth and described as having a flavour resembling artichoke. Therefore, our previous work on the nutritional and prebiotic potential of EPH as a food ingredient disclosed that EPH contain abundant carbohydrates, insoluble fibre as well as essential macro-minerals such as potassium, magnesium, phosphorus and calcium. In which, these has supported the growth of *Lactobacillus*, the probiotic strains which made EPH a potential prebiotic ingredient. It also helps in inhibiting the growth of colonic pathogen and being selectively fermented by the colon microbiota.

Terung Asam Sarawak, the sour eggplant

The sour eggplant or *Terung Asam* Sarawak (TAS) or scientifically known as *Solanum lasiocarpum Dunal* is one of the indigenous crops in Sarawak (Soon & Ding, 2021). The TAS has an adventive nature in which TAS is able to adapt rapidly even along roadside. However, as an indigenous crop, TAS is still cultivated in small scale land such as edges of villages and in the wild (Soon & Ding, 2021). Traditionally, it is commonly served in the form of soup cooked with seafood or any meat. It is also a choice of the locals to cook with fish due to their ability to reduce the fishy odour and fattiness of pork. Traditionally, the Dayak people use TAS to treat pinworms; the Temuan tribe takes TAS for treating hypertension and spiritual ailments. Today, scientific studies has revealed that TAS is high in Vitamin C, also calcium, fibre, phosphorus, potassium and also other minerals. Other than that, the TAS fruit contains phenolic compounds and flavonoids with powerful antioxidative activities (Ab Rahman *et al.*, 2019).

The precious edible Bird's nest

Edible swiftlet's nest (ESN) is dried gelatinized saliva secreted by swiftlets during the breeding season. The ESN has been widely consumed as a food and medicine since the ancient dynasty of China, particularly in the practice of Traditional Chinese Medicine (TCM). As a food with health-promoting effects, this made ESN a potential functional food. Whereby, functional food is food that can be consumed in the daily diet which then enhanced human health through nutritional aspect, but not as the cure of a disease. Scientific evidence has proven that ESN consists of the unique glycoprotein of great value which provides high nutritional and functional properties for human health benefits. These include antiageing, antihypertension, immunity and neurological enhancement contributed by not only the unique glycoprotein but also sialic acid, epidermal growth factor (EGF) and other bioactive compounds (Hui Yan *et al.*, 2021). ESN also can be incorporated further as a complete functional food by fortification of vitamins, high fibre diets and prebiotic ingredients which contribute in promoting probiotic growth, suppressing the growth of pathogen and promote the production of beneficial organic acids in the human body.

Others

Other indigenous food in Sarawak includes the *kelulut* honey or stingless bee honey, which contains higher protein content and phenolic compounds that lead to high antioxidative activities and antibacterial capacity (Tuksitha *et al.*, 2018). Also, indigenous durians namely *Durio graveolens* and *Durio oxleyanus* with extraordinary flavour and aroma (Sujang *et al.*, 2022). There are also a few indigenous food flavouring plants that were used by the locals like *Pangium edule* (daun kepayang), *Premna serratifolia* (daun singkil), *Pycnarrhena tumefacta* (daun tubu), *Scorodocarpus borneensis* (daun kesinduk) and *Syzygium polyanthum* (daun bungkang) as flavour enhancer or modifier in their cooking (Yusli *et al.*, 2022). In which, these wild herbs are high in antioxidative activities for its phenolic, flavonoid and other biocompounds.

Conclusions

There are various of ethnic foods in Sarawak of Malaysia, in which these foods are commonly consumed by the locals in various ways. The indigenous foods and crops contain nutrients which then promote human health in many ways as a food that can be consumed daily. However, information on these wild crops and foods are scarce and required further studies by researchers. Thus, contribute in broaden the local market of Sarawak.

Acknowledgments

This work is supported by Fundamental Research Grant Scheme (FRGS/1/2019/WAB01/UPM/2/19) provided by the Malaysia Ministry of Education, and the Sarawak Research Development Council Research Catalyst Grant (RDCRG/CAT/2019/26). The authors would also like to thank the ASEAN FOOD CONFERENCE 2023 for their support and invitation in this work.

Author contributions

Tan Hui-Yan: Conceptualization (equal); formal analysis (equal); investigation (equal); methodology (equal); visualization (equal); writing – original draft (equal). **Shahrul Razid Sarbini:** Funding acquisition (equal); project administration (equal); supervision (equal); validation (equal); writing – review and editing (equal).

Ethical statement

None.

Conflict of interest statement

The authors declare no conflict of interest.

Peer review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/ijfs.17246.

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