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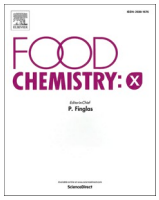

Harnessing the health benefits of purple and yellow-fleshed sweet potatoes: Phytochemical composition, stabilization methods, and industrial utilization- A review

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ABSTRACT

Purple-fleshed sweet potato (PFSP) and yellow-fleshed sweet potato (YFSP) are crops highly valued for their nutritional benefits and rich bioactive compounds. These compounds include carotenoids, flavonoids (including anthocyanins), and phenolic acids etc. which are present in both the leaves and roots of these sweet potatoes. PFSP and YFSP offer numerous health benefits, such as antioxidant, anti-inflammatory, anti-cancer, and neuroprotective properties. The antioxidant activity of these sweet potatoes holds significant potential for various industries, including food, pharmaceutical, and cosmetics. However, a challenge in utilizing PFSP and YFSP is their susceptibility to rapid oxidation and color fading during processing and storage. To address this issue and enhance the nutritional value and shelf life of food products, researchers have explored preservation methods such as co-pigmentation and encapsulation. While YFSP has not been extensively studied, this review provides a comprehensive summary of the nutritional value, phytochemical composition, health benefits, stabilization techniques for phytochemical, and industrial applications of both PFSP and YFSP in the food industry. Additionally, the comparison between PFSP and YFSP highlights their similarities and differences, shedding light on their potential uses and benefits in various food products.

1. Introduction

Purple flesh sweet potatoes (PFSP) and yellow flesh sweet potatoes (YFSP) are highly cultivated and important food crop in various countries (Wang et al., 2019). The production volumes of PFSP and Yellow YFSP vary from year to year and by region. However, some of the top producers of sweet potatoes, including PFSP and YFSP, are China, Uganda, Nigeria, Indonesia, and India. These countries have significant annual production volumes of sweet potatoes, although specific data on the production volumes of PFSP and YFSP may not be readily available (Ginting et al., 2022; Tang et al., 2015; Tong et al., 2020). PFSP and YFSP are specific varieties of sweet potatoes that have a distinct yellow or purple color to their flesh, as opposed to the more common white or orange varieties. This color variation is due to the presence or absence of certain enzymes in the sweet potato, which impact the pigmentation of the flesh (Kotíková et al., 2016). Despite their name, they are not actually potatoes and do not belong to the same botanical family. PFSP and YFSP, which belong to the *Ipomoea genus*, offer a range of nutritional benefits. They are rich in, starch, amino acids, vitamins, minerals, beta-carotene and tocopherol. They contain easily fermentable sugars like glucose, fructose, and sucrose, as well as dietary fibers, while having minimal amounts of lipids and proteins. Compared to regular potatoes, PFSP and YFSP have superior nutritional profile, providing higher energy value and vitamin C levels, with at least twice the amount found in ordinary potatoes (Zhang et al., 2016).

Various studies, including in vitro, in vivo, and clinical trials, have demonstrated the wide range of bioactivities associated with bioactive compounds, particularly anthocyanins derived from PFSP (Gutiérrez-Quequezana et al., 2020). These bioactivities include antioxidant, immunomodulatory, hepatoprotective, anti-inflammatory, antitumor/anticancer, antimicrobial, antidiabetic, antiulcer, and anti-obesity properties (Guclu et al., 2023). The presence of these bioactive component has led to the development of functional foods and nutraceuticals, promoting the consumption of sweet potatoes. While PFSP are

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known for their high anthocyanin content, YFSP contain lower levels of anthocyanins (Aziza et al., 2022; Kim et al., 2019). PFSP and YFSP anthocyanins and other bioactive compounds are considered safer than synthetic colorants, making them preferred by consumers. Bioactive componds like Anthocyanins, being water-soluble natural colorants, exhibit the ability to generate blue, red, and purple colours, positioning purple sweet potato anthocyanins as promising natural alternatives to synthetic colorants in foods (Li, Wang, et al., 2021; Li, Yu, et al., 2021). While commercial anthocyanins are readily available, the extraction of anthocyanins from PFSP offers a unique and potentially more cost-effective natural alternative. The concentrations, ease of extraction, and cost-effectiveness of post-processing from PFSP need to be evaluated in comparison to the industrial extraction methods from wine co-products, blackcurrants, and red sorghum, which contain stable anthocyanins (Piasecka et al., 2024; Xiong et al., 2022). Notably, the comparison should focus on the competitiveness of these factors with respect to established industrial practices, such as the production of natural colorants like E163 (i), (ii), and (iii) from wine co-products and blackcurrants. Considering the market demand for natural alternatives and the stable anthocyanins present in red sorghum, industries may find extracting anthocyanins from PFSP advantageous in terms of cost efficiency and meeting consumer preferences for natural colorants.

However, a significant challenge arises from their susceptibility to rapid oxidation or color fading during food processing, storage, and commercialization(Zhao et al., 2022). This is primarily due to the inherent instability of natural colorants when compared to their synthetic counterparts. Anthocyanins, in particular, possess desirable characteristics for food colouring, including, low toxicity, vibrant color, and beneficial biological properties. Nevertheless thermal instability hampers their widespread use in commercial applications(Ceci et al., 2022). As a result, PFSP and YFSP have garnered increased interest as a potential source of these compounds. Co-pigmentation and encapsulation have been studied as preservation methods for these compounds in PFSP and YFSP (da Cruz et al., 2023; Susanti et al., 2018). These approaches have proven effective in stabilizing anthocyanins and carotenoids, allowing for the production of food products with improved nutritional value and longer shelf life(Gutiérrez-Quequezana et al., 2020; Hara-Skrzypiec et al., 2018). While co-pigmentation and encapsulation are indeed commonly studied methods for preserving these compounds, there are other techniques such as extraction, drying, and fermentation that can also be used for preservation or stabilization of bioactive compounds in sweet potatoes (Huang et al., 2021; Susanti et al., 2018).

To the best of our knowledge, there have been limited or no review/research articles on YFSP and PFSP. Both YFSP and PFSP have received relatively little research attention, highlighting the need for extensive investigation in this field. While a few articles have covered PFSP, they have only addressed certain aspects, and there is a lack of comprehensive information on the physiological function, emulsification properties, and food applications of YFSP and PFSP. Therefore, the specific aims of this review paper are to provide an up-to-date overview of the composition, health benefits, and stabilization of phytochemical in YFSP and PFSP. Additionally, we aim to explore the physiological functions of YFSP and PFSP, with a focus on their potential effects on human health. Furthermore, we will examine the emulsification properties of YFSP and PFSP and their potential applications in food products.

2. Chemical composition in PFSP and YFSP

2.1. Nutritional composition

As per the guidelines provided by the Food and Drug Administration (FDA), the classification of a nutrient in a food depends on its percentage of the Daily Value (%DV). A food can be categorized can be categorized as “low source” (<5% DV), “good source” (10–19% DV), or “rich source” (>20% DV). Considering this classification and taking serving size into account, PFSP and YFSP are considered a rich source (Table 1) of dietary fibers, various minerals and vitamins (Geng et al., 2023; J. Park et al., 2021). PFSP can contain anywhere from 2 to 3 times more β-carotene than YFSP varieties (Hwang et al., 2011). In contrast, PFSP and YFSP leaves are known to be an excellent source of lutein compared to other commonly consumed vegetables such as, spinach, kale, broccoli, green peas and lettuce (Lv et al., 2022). The protein found in YFSP and PFSP leaves has been determined to be of good quality based on its amino acid composition. Lysine, in particular, was identified as either the sole or second limiting amino acid, highlighting the potential of PFSP and YFSP leaves as a valuable protein source (da Cruz et al., 2023; Zhang et al., 2016). Additionally, YFSP and PFSP leaves are considered to be comparable or even superior to spinach and other common Asian and African vegetables in terms of vitamins, minerals, and other nutrients (Ghasemzadeh et al., 2016). These findings indicate that PFSP and YFSP are low in fat, rich in minerals and proteins, and contain significant amounts of carotenoids such as β-carotene and lutein. As a result, vitamins, have the potential to be an excellent source of essential dietary nutrients for the prevention and management of malnutrition associated with vitamin A deficiency and other micronutrient deficiencies(Guclu et al., 2023; Tribst et al., 2016). However, it’s important to note that there can be variations in the nutritional composition of YFSP and PFSP, which may be influenced by factors such as geographical location, harvesting, maturity and genotype. Table 1 present a summary of the nutritional composition of sweet potato leaves and roots, encompassing proximate composition, minerals, vitamins, and essential amino acids, as documented in various sources. The proximate composition in both PFSP and YFSP includes proteins, fat, ash, carbohydrates, and fiber. The variability in nutrient content within PFSP and YFSP plants can be attributed to several factors. For example, the protein content in PFSP leaves as evaluated by Jiang et al., 2020, ranged from 16.7 to 31.1 g/100 g DW across 40 cultivars, while in 9 evaluated tubers, it varied between 1.91 and 5.83 g/100 g DW as reported by Alam et al., 2016. This variability is observed not only in proteins but also in carbohydrates, fiber, and other nutrients.

The mineral composition, vitamins (such as vitamin A, B1, B2, B3, B6, E, and C), and amino acid composition also exhibit differences among plant parts and cultivars. Some cultivars demonstrate high nutritional content while others have lower levels. For instance, research by Tang et al., 2021 highlighted variations in iron (8.82–18.44 mg/100gDW), calcium (500–1068 mg/100gDW), copper (1.25–1.93 mg/100gDW), and magnesium (200–280 mg/100gDW) content, as well as vitamin content, across different plant parts and cultivars. This variability underscores the influence of plant part and cultivar on the nutritional profile, as supported by various studies referenced in Table 1.

The variations in nutritional content among different plant parts and cultivars of PFSP and YFSP can be attributed to genetic differences, environmental factors, maturation stage, storage and processing methods, and soil nutrient content. Genetic variations impact the synthesis and accumulation of nutrients, while environmental conditions such as soil quality and climate affect nutrient uptake (Rytel et al., 2014; Sendangratri & Elya, 2019). The maturation stage of the plant, storage and processing techniques, and soil nutrient composition also play a role in determining the nutrient profile of PFSP and YFSP. A combination of these factors contributes to the variability in nutritional content observed among different plant parts and cultivars (Chen et al., 2019; L. Zhang et al., 2016).

2.2. Bioactive components

The composition of bioactive compounds in PFSP and YFSP is diverse and can be influenced by postharvest and handling methods, as noted by Gutiérrez-Quequezana et al. (2020). Numerous studies have identified over 135 compounds from various parts of PFSP and YFSP especially in PFSP plant, such as leaves, roots, and skins. These compounds include

Table 1
Nutritional composition of YFSP and PFSP.

Nutrients	Plant Part	No. of cultivars studied	Reported content	Reference
	Proximate composition (g/100 g DW)			
Protein	Leaves	40	16.7–31.1	(Jiang et al., 2020)
		2	3.7–3.8	(Zhang et al., 2023)
		1	26.2–30.8	(Santiago Suárez Taihua and Añón, 2020)
		11	16.2–30.3	(Tang et al., 2021)
		13	28.01–38.52	(Hong et al., 2020)
	Tubers	9	1.91–5.83	(Alam et al. 2016)
		1	1.82	(Queenie et al., 2019)
		1	5.61	(Tian et al.,2019)
Fat	Leaves	40	2.1–5.3	(Oladejo et al., 2017)
		2	0.3–1.0	(Ishida et al., 2000)
		1	2.9–3.6	(Santiago Suárez Taihua and Añón, 2020)
		13	2.49–4.28	(Hong et al., 2020)
	Tubers	9	0.17–0.63	(Alam et al. 2016)
		1	1.29	(Queenie et al., 2019)
		1	0.90	(Tian et al., 2016b)
Ash	Leaves	40	7.4–14.7	(Sun et al., 2014)
		2	1.5–1.9	(Ishida et al., 2000)
		1	10.39–11.30	(Santiago Suárez Taihua and Añón, 2020)
		13	13.43–16.99	(Hong et al., 2020)
	Tubers	9	1.17–1.31	(Alam et al. 2016)
		1	3.47	(Queenie et al., 2019)
		1	4.07	(Tian et al., 2016b)
Carbohydrate	Leaves	40	42.0–61.3	(Sun et al., 2014)
		2	0.9–2.0	(Ishida et al., 2000)
		13	30.13–42.19	(Hong et al., 2020)
	Tubers	9	21–25	(Alam et al. 2016)
Fiber	Leaves	40	9.2–14.3	(Sun et al., 2014)
		2	5.9–6.9	(Ishida et al., 2000)
		1	49.8–51.8	(Santiago Suárez Taihua and Añón, 2020)
		11	5.18–10.38	(Tang et al., 2021)
		13	9.26–11.4	(Hong et al., 2020)
	Tubers	9	0.30–0.54	(Alam et al. 2016)
		1	2.79	(Queenie et al., 2019)
Mineral composition(mg/100gDW)				
Magnesium	Leaves	40	220.2–910.5	(Sun et al., 2014)
		2	79–107	(Ishida et al., 2000)
		1	455–513	(Santiago Suárez Taihua and Añón, 2020)
		11	200–280	(Tang et al., 2021)
		13	438.70–761.25	(Hong et al., 2020)
	Tubers	9	21.28–25.40	(Alam, 2021)
		3	28.9–34.7	(Mohamad Zahari et al., 2016)
		NS	18.2–254	(dos Santos et al. 2019)
Iron	Leaves	40	1.92–21.77	(Sun et al., 2014)
		2	5.43–5.54	(Ishida et al., 2000)
		1	11.1–19.9	(Santiago Suárez Taihua and Añón, 2020)
		11	8.82–18.44	(Tang et al., 2021)
		13	11.93–41.02	(Hong et al., 2020)
	Tubers	9	0.91–1.40	(Alam, 2021)
		1	19.13	(Queenie et al., 2019)
		NS	0.122–0.522	(dos Santos et al. 2019)
Zinc	Leaves	40	1.20–3.23	(Sun et al., 2014)
		2	0.60–0.86	(Ishida et al., 2000)
		1	3.2–3.3	(Santiago Suárez Taihua and Añón, 2020)
		11	2.80–4.84	(Tang et al., 2021)
		13	2.53–11.33	(Hong et al., 2020)
	Tubers	9	2.85–4.25	(Alam et al. 2016)
Copper	Leaves	40	0.67–1.86	(Sun et al., 2014)
		2	0.43–0.55	(Ishida et al., 2000)
		1	1.35–1.52	(Santiago Suárez Taihua and Añón, 2020)
		11	1.25–1.93	(Tang et al., 2021)
		13	0.54–0.91	(Hong et al., 2020)
	Tubers	9	0.25–0.67	(Alam et al. 2016)
		NS	0.027–0.156	(dos Santos et al. 2019)
Calcium	Leaves	40	229.7–1958.1	(Sun et al., 2014)
		2	174–187	(Ishida et al., 2000)
		1	1318–1407	(Santiago Suárez Taihua and Añón, 2020)
		11	500–1068	(Tang et al., 2021)
		13	1002.90–1582.36	(Hong et al., 2020)
	Tubers	9	21.98–27.35	(Alam, 2021)
		3	45.3–69.1	Mohamad Zahari et al., 2016
		NS	16.8–34.2	(dos Santos et al. 2019)
Potassium	Leaves	40	479.3–4280.6	(Sun et al., 2014)
		2	357–639	(Ishida et al., 2000)

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Table 1 (*continued*)

Nutrients	Plant Part	No. of cultivars studied	Reported content	Reference
		1	1963.8–3341.7	(Santiago Suárez Taihua and Añón, 2020)
		11	4546–5966	(Tang et al., 2021)
	Tubers	9	310.04–368.35	(Alam, 2021)
		3	435–518	(Mohamad Zahari et al., 2016)
		NS	85.6–500	(dos Santos et al. 2019)
Vitamin composition (mg/100 g)				
Vitamin C	Leaves	2	62.7–81.0	(Ishida et al., 2000)
		1	21.9–104	(Santiago Suárez Taihua and Añón, 2020)
		9	146.64–349.05	(Abong et al., 2021)
		11	99–511	(Tang et al., 2021)
		13	10.78–152.95	(Hong et al., 2020)
	Tubers	9	4.85–5.73	(Alam et al. 2016)
		9	4.53–19.05	(Abong et al., 2021)
		11	35.81–83.73	(Hou et al., 2019)
		1	109.24	(Tian et al., 2019)
		4	66–87	(Grace et al., 2014)
Vitamin B1	Leaves	2	0.053–0.13	(Ishida et al., 2000)
		1	0.49–0.62	(Santiago Suárez Taihua and Añón, 2020)
		13	0.12–2.26	(Hong et al., 2020)
	Tubers	11	0.02–0.37	(Hou et al., 2019)
		2	0.038–0.046	(Barrera & Picha, 2014)
Vitamin B2	Leaves	2	0.248–0.254	(Ishida et al., 2000)
		1	4.45–6.36	(Santiago Suárez Taihua and Añón, 2020)
		13	3.7–4.69	(Hong et al., 2020)
	Tubers	11	0.19–0.34	(Hou et al., 2019)
		2	0.02–0.04	(Barrera & Picha, 2014)
Vitamin B3	Leaves	2	0.86–1.50	(Ishida et al., 2000)
		1	0.45–0.54	(Santiago Suárez Taihua and Añón, 2020)
		13	0.56–0.58	(Hong et al., 2020)
	Tubers	11	1.54–4.28	(Hou et al., 2019)
Vitamin B6	Leaves	2	0.12–0.33	(Ishida et al., 2000)
	Tubers	2	0.16–0.23	(Barrera & Picha, 2014)
Vitamin E	Leaves	2	1.39–2.81	(Ishida et al., 2000)
		1	3.24–5.80	(Santiago Suárez Taihua and Añón, 2020)
		13	4.33–8.75	(Hong et al., 2020)
	Tubers	11	0.61–2.49	(Hou et al., 2019)
β-carotene (Provit A)	Leaves	2	0.27–0.40	(Ishida et al., 2000)
		14	35.21–52.01	(Li et al., 2017)
		9	13.33–28.07	(Ooko Abong et al., 2020)
		13	47.92–119.23	(Hong et al., 2020)
		2	3.07–3.11	(Khan et al., 2016)
	Tubers	9	0.23–6.71	(Alam et al. 2016)
		4	0.1–25.3	(Grace et al., 2014)
		9	0.73–18.18	(Ooko Abong et al., 2020)
		11	0.77–42.02	Hou et al. (2019)
		2	0.73–5.93	(Khan et al., 2016)
Vitamin C	Leaves	2	62.7–81.0	(Ishida et al., 2000)
		1	21.9–104	(Santiago Suárez Taihua and Añón, 2020)
		9	146.64–349.05	(Abong et al., 2021)
		11	99–511	(Tang et al., 2021)
		13	10.78–152.95	(Hong et al., 2020)
	Tubers	9	4.85–5.73	(Alam et al. 2016)
		9	4.53–19.05	(Ooko Abong et al., 2020)
		11	35.81–83.73	(Hou et al., 2019)
Amino acid composition (mg/g DW)				
Methionine	Leaves	2	3.67–4.10	(Ishida et al., 2000)
		1	0.6–0.9	(Santiago Suárez Taihua and Añón, 2020)
		11	4.1–8.0	(Tang et al., 2021)
		13	0.7–1.5	(Hong et al., 2020)
	Tubers	NS	16.01	(Sawicka et al., 2020)
		NS	1.20–1.24	(Hou et al., 2019)
		1	16.1	(Mu et al., 2009)
		2	0.033–0.057	(Kurnianingsih et al., 2020)
Phenylalanine	Leaves	2	12.1–13.4	(Ishida et al., 2000)
		1	8.8–11.1	(Santiago Suárez Taihua and Añón, 2020)
		11	28.0–49.9	(Tang et al., 2021)
		13	9.0–10.9	(Hong et al., 2020)
	Tubers	NS	69.82	(Sawicka et al., 2020)
		NS	4.79–4.87	(Hou et al., 2019)
		1	54.3	(Mu et al., 2009)
		2	0.67–0.77	(Kurnianingsih et al., 2020)

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Table 1 (*continued*)

Nutrients	Plant Part	No. of cultivars studied	Reported content	Reference
Threonine	Leaves	2	10.4–11.4	(Ishida et al., 2000)
		1	7.0–8.9	(Santiago Suárez Taihua and Añón, 2020)
		11	24.8–43.8	(Tang et al., 2021)
		13	7.2–8.5	(Hong et al., 2020)
	Tubers	NS	62.94	(Sawicka et al., 2020)
		NS	3.71–3.77	(Hou et al., 2019)
		1	55.8	(Mu et al., 2009)
		2	0.53–0.92	(Kurnianingsih et al., 2020)
Tryptophan	Leaves	2	2.9–3.6	(Ishida et al., 2000)
		11	2.6–4.0	Tang et al., 2021)
	Tubers	NS	0.47–0.49	(Hou et al., 2019)
		1	5.85	(Mu et al., 2009)
		2	0.19–0.53	(Kurnianingsih et al., 2020)
Valine	Leaves	2	12.3–13.4	(Ishida et al., 2000)
		1	8.8–11.4	(Santiago Suárez Taihua and Añón, 2020)
		11	32.4–56.5	(Tang et al., 2021)
		13	9.2–10.6	(Hong et al., 2020)
	Tubers	NS	65.24	(Sawicka et al., 2020)
		NS	4.43–4.49	(Hou et al., 2019)
		1	62.0	(Mu et al., 2009)
		2	0.61–1.12	(Kurnianingsih et al., 2020)
Isoleucine	Leaves	2	9.60–10.62	(Ishida et al., 2000)
		1	6.7–8.8	(Santiago Suárez Taihua and Añón, 2020)
		11	25.6–44.8	(Tang et al., 2021)
		13	6.9–8.3	(Hong et al., 2020)
	Tubers	NS	51.26	(Sawicka et al., 2020)
		NS	3.27–3.35	(Hou et al., 2019)
		1	43.7	(Mu et al., 2009)
		2	0.44–0.72	(Kurnianingsih et al., 2020)
Leucine	Leaves	2	18.3–20.3	(Ishida et al., 2000)
		1	11.9–16.1	(Santiago Suárez Taihua and Añón, 2020)
		11	45.3–79.1	(Tang et al., 2021)
		13	12.9–15.5	(Hong et al., 2020)
	Tubers	NS	94.33	(Sawicka et al., 2020)
		NS	4.85–4.91	(Hou et al., 2019)
		1	57.9	(Nazir et al., 2019)
		2	0.62–1.13	(Kurnianingsih et al., 2020)

Table 1 (*continued*)

Nutrients	Plant Part	No. of cultivars studied	Reported content	Reference
Lysine	Leaves	2	11.8–12.9	(Ishida et al., 2000)
		1	10.0–13.1	(Santiago Suárez Taihua and Añón, 2020)
		11	31.6–54.7	(Tang et al., 2021)
		13	10.8–12.7	(Hong et al., 2020)
	Tubers	NS	14.12	(Sawicka et al., 2020)
		NS	3.56–3.66	(Hou et al., 2019)
		1	43.3	(Mu et al., 2009)
		2	0.44–0.71	(Kurnianingsih et al., 2020)

flavonoids, organic acids, phenolic acids and carotenoids, as well as other compounds like sesquiterpenes, alkaloids, triterpenes, and monoterpenes A comprehensive summary of these compounds can be found in Table 2.

2.2.1. *Flavonoids*

Flavonoids, which are a diverse group of phenolic compounds, are bioactive components that exhibit various biological activities. These compounds are responsible for the vibrant pigmentation in PFSP and YFSP, with a content of up to 41 mg quercetin equivalents per 100 g dry weight (Luo et al., 2021). To date, over 58 distinct flavonoids have been discovered and characterized in PFSP and YFSP, encompassing flavones, flavones, anthocyanins and flavanols (Table 2).

The characterization of anthocyanins in PFSP and YFSP has gained significant attention in recent years. In addition to anthocyanins, non-anthocyanin flavonoids have also been identified in PFSP and YFSP. Park et al. (2016) isolated 3 flavonols (quercetin, kaempferol, myricetin) and 1 flavone (Luteolin) from Sinjami roots using HPLC-PDA. Similarly, Wang et al. (2018) discovered a total of 19 non-anthocyanin flavonoids, including 5 flavanols, 12 flavones, and 2 flavon-3-ols, in Xuzishu No.3 and Jizishu No. 1 using online HPLC-ESI-MS/MS. The Primary non-anthocyanin flavonoids found in PFSP and YFSP included quercetin, luteolin, hesperetin, chrysoeriol, and kaempferol and their glycosides. These findings highlight the diverse array of non-anthocyanin flavonoids present in PFSP. In another study, Luo et al. (2021) successfully identified 10 non-anthocyanin flavonoids (rutin, hyperoxide, isoquercitrin, astragalin, quercetin, kaempferol,diosmetin, jaceosidin, chrysin, pectolinarigenin) in YFSP. Xu et al. (2018) in their study identified five anthocyanins [Peonidin 3-(6″-dicaffeoyl sophoroside)-5-glucoside-2, Peonidin 3-(6″-caffeoyl-6‴-p-coumaryl sophoroside)-5-glucoside, Peonidin 3-(6″-feruloyl-6‴-p-hydroxybenzoyl sophoroside)-5-glucoside, Peonidin 3-(6″, 6‴-diferuloyl sophoroside)-5-glucoside] including a novel anthocyanin named peonidin 3-(6″-caffeoyl-6‴-p-coumaryl sophoroside)-5-glucoside, from 60% ethanol extracts of Eshu No. 8. Kim et al. (2019) in his work evaluated the anthocyanin content in the storage roots of different cultivars of sweet potato. Among the different varieties, YFSP exhibited the highest level of anthocyanins, while the other samples contained smaller amounts. The major anthocyanins identified in the YFSP sample were peonidin 3-caffeoyl-p-hydroxybenzoyl-sophoroside-5-glucoside and peonidin 3-caffeoyl sophoroside-5-glucoside. Additionally, peonidin 3-(6″-caffeoyl-6‴-feruloyl sophoroside)-5-glucoside was identified as the second major anthocyanin. In another study, Lebot et al. (2016) successfully identified 11 anthocyanins in YFSP of which the most abundant were cyanidin-3-sophoroside-5-glucose;,peonidin-3-sophoroside-5-glucose; and peonidin-3-(6‴-p-hydroxybenzoylsophoroside)-5-glucose. In recent study, Li, Lin, et al., 2019, Li, Yu, et al. (2019) employed UPLC-QTOF-MS/MS to

Table 2
Bioactive compounds in YFSP and YFSP.

Type	Sweet potato flesh color	Compounds	Plant parts	Reference
Flavonoids				
Anthocyanins	Purple	Cyanidin-3-sophoroside-5-glucoside Peonidin-3-sophoroside-5-glucoside Cyanidin-3-(6″-p-hydroxybenzoyl sophoroside)-5-glucoside Peonidin-3-(6″-p-hydroxybenzoyl sophoroside)-5-glucoside Cyanidin-3-(6″-feruloyl sophoroside)-5-glucoside Peonidin-3-(6″-feruloyl sophoroside)-5-glucoside Cyanidin-3-(6″-caffeoyl-6‴-phydroxybenzoyl sophoroside)-5-glucoside Cyanidin-3-(6″-caffeoyl sophoroside)-5-glucoside Cyanidin-3-(6″-caffeoyl-6‴-feruloyl sophoroside)-5-glucoside Peonidin-3-(6″-caffeoyl-6‴-p-hydroxybenzoyl sophoroside)-5-glucoside Peonidin-3-(6″-caffeoyl sophoroside)-5-glucoside Peonidin-3-(6″-caffeoyl-6‴-feruloyl sophoroside)-5-glucoside	Root	(Jiang et al., 2019)
	Yellow, and purple	Cyanidin-3-sophoroside-5-glucoside, Peonidin-3-sophoroside-5-glucoside, canidin-3-(6″-p-hydroxybenzoylsophoroside)-5-glucoside, Peonidin-3-(6″-phydroxybenzoylsophoroside)-5-glucoside, Cyanidin-3-(6″-feruloylsophoroside)-5-glucoside, Cyanidin-3-(6″-caffeoylsophoroside)-5-glucoside, Cyanidin-3-(6″-caffeoyl-6‴-p-Hydroxybenzoylsophoroside)-5-glucoside, Peonidin-3-(6″-caffeoylsophoroside)-5-glucoside, Cyanidin-3-(6″-caffeoyl-6″- feruloylsophoroside)-5-glucoside,	Root	(Lebot et al., 2016)
	Yellow	Cyanidin 3-caffeoylsophoroside-5-glucoside Cyanidin 3-(6″-caffeoyl-6 -feruloylsophoroside)-5-glucoside, Peonidin 3-caffeoyl-p-hydroxybenzoyl-sophoroside-5-glucoside	Root and leaves	(Grace et al., 2014)
	Purple	Peonidin-3-(6″-p-hydroxybenzoyl-6‴-feruloyl sophoroside)-5-glucoside	Root	(Li et al., 2013)
	Purple	Peonidin-3-soph-5- glucose, cyanidin-3-p-hydroxybenzoylsoph-5- glucose, Cyanidin-3-(6‴caffeoylsoph)-5- glucose, Peonidin-derivative, Peonidin-3-p-hydroxybenzoylsoph-5- glucose, Cyanidin-3-feruloylsoph-5- glucose, Peonidin-3-feruloylsoph-5- glucose, Cyanidin-3-(6″caffeoylsoph)-5- glucose, Cyanidin-3-(6″,6‴-dicaffeoylsoph)-5- glucose, Cyanidin-3-(6″-caffeoyl-6‴-p-hydroxybenzoylsoph)-5- glucose, Peonidin-3-(6″caffeoylsoph)-5- glucose, Peonidin-3-(6″,6‴-dicaffeoylsoph)-5- glucose, Peonidin-3-(6″-caffeoyl-6‴-p-hydroxybenzoylsoph)-5- glucose, Peonidin-3-(6″-caffeoyl-6‴-feruloylsoph)-5- glucose,	Root	(Esatbeyoglu et al., 2017)
	purple	Delphinidin-3,5-diglucoside Cyanidin 3-(6″-dicaffeoyl sophoroside)-5-glucoside Cyanidin 3-(6″-caffeoyl-6‴-p-hydroxybenzoyl sophoroside)-5-glucoside	Root	(Xu et al., 2015)
	purple	Peonidin 3-(6″-dicaffeoyl sophoroside)-5-glucoside Peonidin 3-(6″-caffeoyl-6‴-p-coumaryl sophoroside)-5-glucoside Peonidin 3-(6″-coumaryl-6‴-p-hydroxybenzoyl sophoroside)-5-glucoside Peonidin 3-(6″, 6‴-diferuloyl sophoroside)-5-glucoside	Root and leaves	(Wang et al., 2017)
	Purple	Cyanidin 3-(6″-p-coumaryl sophoroside)-5-glucoside Peonidin 3-(6″-p-coumaryl sophoroside)-5-glucoside Cyanidin 3-(6″-caffeoyl-6‴-p-coumaryl sophoroside)-5-glucoside	Leaves	(Li et al. 2017)
	Yellow	Peonidin 3-(6″-dicaffeoyl sophoroside)-5-glucoside Peonidin-3-sophoroside-5-glucoside	Root	(Tong et al., 2020)
	Yellow	Peonidin 3-caffeoyl-p-hydroxybenzoyl-sophoroside-5-glucoside, peonidin 3-caffeoyl sophoroside-5-glucoside . Peonidin -(6″-caffeoyl-6‴-feruloyl sophoroside)-5-glucoside Cyanidin 3-(6″,6‴-dicaffeoyl sophoroside)-5-glucoside	Root	(Kim et al., 2015)
	Yellow and purple	Cyanidin-3-sophoroside-5-glucose; peonidin-3-sophoroside-5-glucose ,peonidin-3-(6‴-p hydroxybenzoylsophoroside)-5-glucose; Cyanidin-3-(6″-feruloylsophoroside)-5-glucose; Cyanidin-3-(6″-caffeoylsophoroside)-5-glucose; Cyanidin-3-(6″-caffeoyl-6‴-p-hydroxybenzoylsophoroside)-5-glucose; Ceonidin-3-(6″-caffeoylsophoroside)-5-glucose; Cyanidin-3-(6″-caffeoyl-6‴-feruloylsophoroside)-5-glucose; Peonidin-3-(6″-caffeoyl-6‴-p-hydroxybenzoylsophoroside)-5-glucose; Peonidin-3-(6″-caffeoyl-6‴-feruloylsophoroside)-5-glucose.	Root	(Jiang et al., 2022)
Flavonols	Purple	Quercetin Kaempferol Quercetin-3-O-galactoside Quercetin-3-O-glucoside Kaempferol-3-O-galactoside Kaempferol 3-O-glucoside Isorhamnetin O-hexoside	Root	(Park et al., 2016) (Park et al., 2016)
	Yellow	rutin, hyperoside,	Leaves	(Luo et al., 2021)

(*continued on next page*)

Table 2 (*continued*)

Type	Sweet potato flesh color	Compounds	Plant parts	Reference
		isoquercitrin, astragalin, quercetin, kaempferol, diosmetin, jaceosidin, chrysin, pectolinarigenin		
flavones	Purple	Luteolin Luteolin 7-O-glucoside 3,7-dihydroxy-3′,4′-dimethoxyflavone 3,4′,5,7-tetrahydroxy-3′-methoxyflavone Nobiletin Tangeretin Chrysin Chrysoeriol 7-O-hexoside Chrysoeriol O-malonylhexoside Chrysoeriol O-hexoside Chrysoeriol 5-O-hexoside Hesperetin O-hexoside Hesperetin 5-O-glucoside	Root	(Wang et al., 2018)
flavanes	Purple Yellow purple	Catechin Catechin Rosinidin O-hexoside	Root	(Liu et al., 2018)
Phenolic acids	Purple	5-caffeoylquinic acid 5-feruloylquinic acid 3,4-diO-caffeoylquinic acid 3,5-diO-caffeoylquinic acid 4,5-diO-caffeoylquinic acid 5-feruloylquinic acid 3,4-diO-caffeoylquinic acid 3,5-diO-caffeoylquinic acid 4,5-diO-caffeoylquinic acid		(Esatbeyoglu et al., 2017)
	Purple	5-caffeoylquinic acids, 5-feruloylquinic acid and derivative, 3,4-, 4,5-, 3,5-dicaffeoylquinic acids	Root	(Esatbeyoglu et al., 2017)
	Purple, yellow,	caffeic acid, 3,4-, 4,5-, 3,5-dicaffeoylquinic acids		(Grace et al., 2014)
	Yellow, purple	3,4-, 4,5-, 3,5-dicaffeoylquinic acids	Root	(Lebot et al., 2016)
	purple	P-hydroxybenzoic acid Vanillic acid Trans-p-coumaric Caffeic acid Chlorogenic acid	Roots	(Chen et al., 2017)
	Yellow	caffeic acid chlorogenic acid, isochlorogenic acid	Root	(Grace et al., 2014)
	Purple	Quinic acid	Roots	(Zhu et al., 2017)
	Purple	Chlorogenic acid-3-glucose 4-methylumbelliferyl phenylphosphonate O-Feruloyl quinic acid Quinacyl dihydrocoumarin 4-O-ρ-Coumaroyl quinic acid 3-O-Feruloyl quinic acid Ferulic acid O-hexoside Chlorogenic acid methyl ester Feruloyl hydroxylcoumarin Ferulic acid 3-Hydroxy-4-methoxycinnamic acid 2,5-dihydroxybenzoic acid O-hexside Syringic acid O-hexoside Protocatechuic acid Esculetin 6-O-gluconic acid 7-O-quinacyl quinic acid O-Caffeoyl protocatechuic acid 3-O-ρ-coumaroyl quinic acid Tricin O-saccharic acid ρ-Coumaric acid *trans*-Cinnamic acid 4-Methoxycinnamic acid	Root	(Qin et al., 2022)
	Purple	4-Hydroxy benzoic acid Gallic acid Salicylic acid	Root	(Kim et al., 2019)

(*continued on next page*)

Table 2 (*continued*)

Type	Sweet potato flesh color	Compounds	Plant parts	Reference
	Yellow purple	3-caffeoylquinic acid, 3,5-dicaffeoylquinic acid		(Pazos et al., 2022)
	Yellow	gallic acid		(Cho et al., 2020)
	Yellow	Rutin, gallic acid, catechin, caffeic acid, apigenin, myricetin, quercetin and kaempferol	Root	(Majid et al., 2018)
		gallic acid		(Ooko Abong et al., 2020)
	Yellow	1-Caffeoylquinic acid, Isochlorogenic acid, Esculin, Protocatechualdehyde, Chlorogen, Cryptochlorogenic acid, , 7-Hydroxycoumarin, (Isochlorogenic acid, (Ethyl caffeate	Root	(Luo et al., 2021)
		trans-N-(p-coumaroyl) tyramine, trans-N-feruloyltyramine, cis-N-feruloyltyramine, 3,4,5-triCQA, 3,4-diCQA, 3,5-diCQA, 4,5-diCQA, 4,5-feruloylcourmaoylquinic acid, caffeic acid, caffeic acid ethyl ester, 7-hydroxy-5-methoxycoumarin, quercetin-3-O-a-d-glucopyranoside, 7,30-dimethylquercetin, rhamnetin and indole-3-carboxaldehyde	Root	(Zhang et al., 2016)
Organic acids	Purple	Acetic acid Hexanoic acid Hexanoic acid, 2-ethyl- Decanoic acid Benzoic acid	Root	(Sun et al., 2016)
		Fumaric acid Lactic acid Glycolic acid Nicotinic acid Succinic acid Glyceric acid Shikimic acid Citric acid Quinic acid	Root	(Park et al., 2016)
	Yellow	Malic acid Citric acid Oxalic acid: Succinic acid Fumaric acid:	Root	(Minemba et al., 2019)
Carotenoids				
	Purple	β-carotene	Roots	(Grace et al., 2014)
	Purple	β-Cryptoxanthin		(H. J. Kim et al., 2015)
	Purple, yellow	β-caroteno All-trans-β-carotene	Root	(Grace et al., 2014)
	Purple yellow	Neoxanthin (Z)-Violaxanthin Violaxanthin (Z)-Neoxanthin Luteoxanthin Antheraxanthin Lutein Zeaxanthin (all-E) -β-carotene (9Z)-β-carotene (13Z)-β-carotene	Roots	(Kotíková et al., 2016)
	Yellow and purple	β-carotene mono-epoxides and di-epoxides, β-cryptoxanthin, lutein epoxide, lutein β-zeaxanthin isomers, violaxanthin isomers α-carotene,		(Drapal & Fraser, 2019)

(*continued on next page*)

Table 2 (*continued*)

Type	Sweet potato flesh color	Compounds	Plant parts	Reference
		zeaxanthin		
		neoxanthin		
	Yellow	β-carotene	Root	(Tang et al., 2015)
	purple	Lutein:		
		Zeaxanthin:		
		Cryptoxanthin		
	Purple	6,7-dimethoxycoumarin	Root	(He et al., 2012)
		5-hydroxymethyl-2-furfural		
		Bicyclogermacrene		(Lee et al., 2016)
		α-Copaene		
		β-Elemene		
		(−)-Isoleden		
		Isocaryophyllene		
		β-Cubebene		
		Aromadendren		
		Germacrene D		
		β-Selinene		
		(−)-β-Caryophyllene epoxide		
		Ananosmoside A		
		Caryolane-1,9 β-diol		
		Clovane-2 β,9 α -diol		
		(+)-2-Bornanone		
		Indole-3-aldehyde		
		Batatasenol		
		Boehmerol		
Others	Purple	Batatasenol	Leaves	(Giner, 2019)
		Boehmerol		
	purple	6,7-dimethoxycoumarin		(He et al., 2012)
		5-hydroxymethyl-2-furfural		
	Purple	Bicyclogermacrene		(Lee et al., 2016)
	yellow	α-Copaene		
		Bicyclogermacrene		
		α-Copaene		
		(−)-Isoledene		
		Isocaryophyllene		
		β-Cubebene		
		Germacrene D		
		β-Selinene		

analyze PFSP leaves and successfully detected eighteen anthocyanins. This study also unveiled three newly identified anthocyanins, namely cyanidin 3-(6″-p-coumaryl sophoroside)-5-glucoside, peonidin 3-(6″-p-coumaryl sophoroside)-5-glucoside, and cyanidin 3-(6″-caffeoyl-6‴-p-coumaryl sophoroside)-5-glucoside, expanding our understanding of the anthocyanin composition in PFSP leaves.

Furthermore, Su et al. (2019) in his research found out that, that the anthocyanin composition in the leaves of PFSP P40 is similar to that in the roots, indicating a consistent pattern of anthocyanin distribution within the plant. However, the content of anthocyanins in the leaves was significantly lower compared to the roots. This difference in anthocyanin content between the leaves and roots could be attributed to various factors, such as tissue-specific biosynthesis or differential accumulation. Additionally, the absence of detectable anthocyanins in the stem of PFSP P40 highlights the tissue-specific distribution of anthocyanins within the plant.

2.2.2. *Organic acids and phenolic acids*

To date, a considerable number of organic acids and phenolic acids have been successfully identified in PSP and YFSP. Specifically, about 39 phenolic acids and their derivatives, as well as about 19 organic acids, have been reported in the roots of YFSP and PSP. These findings highlight the rich diversity of these compounds present in PSP and YFSP that contribute to our understanding of the chemical composition of this plant.

The study conducted by Wang et al. (2018) involved the analysis of metabolic profiles in five different sweet potato cultivars with varying flesh colours (yellow/orange, white and purple) using Liquid Chromatography-Electrospray Ionization-Mass Spectrometry. The major phenolic acids identified in their research included vanillic acid, ρ-coumaric acid, syringic acid, sinapic acid, ferulic acid, cinnamic acid, and caffeic acid, along with their derivatives. Previous research conducted by Park et al. (2016) indicated that ρ-hydroxybenzoic, vanillic, and ferulic acids were the primary phenolic acids in PFSP, while ferulic and sinapic acids were predominantly found in YFSP. However, in Wang et al. (2018) study, they identified two isomers of 3-O-ρ-coumaroyl quinic acid,4-O-ρ-coumaroyl quinic acid, and higher levels of ferulic acids in PFSP compared to the other cultivars. They also found that quinacyl dihydrocoumarin was present in all five cultivars without any significant difference in content. Contrary to a previous report by Clifford, (2008) which stated that feruloylquinic acids were only found in the stem but not the root, Wang et al. (2018) discovered that five types of quinic acids, including two isomers of feruloylquinic acids, were identified in the root, with higher levels observed in PFSPs.

Esatbeyoglu et al. (2017) conducted research on the water extracts of PFSP and successfully isolated and identified five phenolic acids. The primary phenolic acid found was 5-caffeoylquinic acid, followed by 3,5-di-O-caffeoylquinic acid, 4,5-diO-caffeoylquinic acid, and 5-feruloylquinic acid, Similarly, in the same year, Chen et al. (2017) successfully quantified and isolated five phenolic acids from Dphii sweet potato No.1 using HPLC. These included p-hydroxybenzoic acid (11.34 mg/100 g DW), vanillic acid (1.98 mg/100 g DW), trans-p-coumaric acid (5.04 mg/100 g DW), caffeic acid (56) (2.19 mg/100 g DW), and chlorogenic acid (176.67 mg/100 g DW).Zhu et al. (2017) conducted a separate study where they used UAE and conventional solvent extraction technique along with HPLC-ESI-MS/MS to identify several phenolic acids. Chlorogenic acid, Caffeic acid,chlorogenic acid-3-glucose and quinic acid were successfully identified. In another investigation by

Wang et al. (2018) HPLC-ESI-MS/MS was employed to detect a total of twenty-two individual phenolic acids from Jizishu No. 1 and Xuzishu No.3. The detected phenolic acids included syringic acid, p-coumaric acid,caffeic acid, sinapic acid, vanillic acid, ferulic acid, cinnamic acid and their derivatives. Kim et al. (2019) analyzed Korean PFSP using HPLC and standard phenolic acids, and their study identified five known phenolic acids as well as three new phenolic acids (4-Hydroxy benzoic acid. Gallic acid and salicylic acid). In their study, Pazos et al. (2022) conducted an analysis of phenolic compounds in various colored-fleshed sweet potato genotypes. They found that 3,5-dicaffeoylquinic acid and chlorogenic acid were the predominant phenolic compounds present in all samples, including YFSP. This finding is consistent with previous studies by Grace et al. (2014) and Lebot et al. (2016) which also identified chlorogenic acid as the most abundant phenolic acid in YFSP roots.

Furthermore, the presence of organic acids in YFSP and PFSP has also been investigated. Sun et al. (2016) identified five organic acids (Acetic acid, Hexanoic acid, Decanoic acid and Benzoic acid) from the anthocyanin extracts of PFSP using headspace solid-phase microextraction coupled with HS-SPME-GC/MS. Park et al. (2016) conducted a study on the organic acid profiles of PFSP as well. Through the use of gas chromatography-time-of-flight mass spectrometry (GC-TOFMS), they identified a total of nine organic acids (fumaric acid, lactic acid, glycolic acid, nicotinic acid, succinic acid, glyceric acid, shikimic acid, citric acid, and quinic acid) as seen on Table 2. In another study, Minemba et al. (2019) investigated the organic acid profiles of YFSP by using the HPLC technique . Through their analysis, they successfully identified malic acid, citric acid, oxalic acid, succinic acid, and fumaric acid as the primary organic acids present in YFSP.

2.2.3. Carotenoids

The roots of PFSP and YFSP have been found to contain a significant number of carotenoids, making it a valuable source of these compounds. According to a study by Pazos et al. (2022) the carotenoid content in PFSP can reach up to 0.40 mg/100 g dry weight. Furthermore, researchers have identified about 13 different carotenoids in the roots of PFSP, and about 9 in YFSP further highlighting the diversity of carotenoids present in this plant.

β-Carotene has emerged as the primary type of carotenoid present in YFSP. The β-carotene content was assessed in YFSP cultivated in three different locations, as well as in the Colorado INTA-LC variety, which exhibited the highest overall concentration of carotenoids. In the San Pedro samples, it was determined that β-carotene accounted for approximately 91 to 94% of the total carotenoids found in Beauregard sweet potatoes. However, the Colorado INTA-LC variety displayed a significantly lower proportion (47%) of β-carotene in relation to its total carotenoid content (Pazos et al., 2022) . Previous research conducted by Grace et al. (2014) had already reported β-carotene percentages around 50% for YFSP. Consequently, the comparatively low percentage observed in the Colorado INTA cultivar could be attributed to the development of yellow flesh during its cultivation in Tucumán. In a study conducted by Kim et al. (2015) the carotenoid levels in various sweet potato cultivars were examined. The researchers discovered that two YFSP along with OFSP, exhibited notably high concentrations of total carotenoids and all-trans-β-carotene. This finding aligns with previous research that has consistently identified all-trans-β-carotene as the primary contributor to the provitamin A content in YFSP along with OFSP (Drapal & Fraser et al., 2019). Furthermore, in another study, Drapal et al., (2019) utilized a liquid chromatography system to evaluate the carotenoid content in three potato varieties: white, orange, and yellow sweet potatoes. Through their analysis, they successfully identified nine carotenoids in all samples, which included β-carotene monoepoxides and di-epoxides, β-cryptoxanthin, lutein epoxide, lutein, β-zeaxanthin isomers, violaxanthin isomers, α-carotene, zeaxanthin and neoxanthin.

2.2.4. Other bioactive compounds

Furthermore, PSP (name of the compound or substance) also contains various other bioactive compounds. These include, alkaloids (Indole-3-aldehyde), triterpenol (Boehmerol and Batatasenol), monoterpenes (−l-Menthone and (+)-2-Bornanone) and some sesquiterpenes (See Table 2) (Giner, 2019; Lee et al., 2016), polysaccharides such as fructans, pectin, hemicellulose and cellulose (Gou et al., 2019; C. Tang et al., 2019) has also been identified in YPSP and PFSP.

3. Biological activities

PFSP and YFSP are commonly recognized as functional foods due to their abundance of beneficial bioactive compounds (Grace et al., 2014; Wang et al., 2018). They possess a diverse range of bioactive compound, which contribute to its various biological activities. These activities include antioxidant properties, anti-inflammatory effects, immunomodulatory effects, potential anticancer activity, hypoglycemic/hypolipidemic effects, prebiotic-like activity and hepatoprotective activity. Fig. 1 shows a summary of the health benefit of both PFSP and YFSP.

3.1. Hypoglycemic and antihyperglycemic effects

High blood glucose levels, a common complication of diabetes known as hyperglycemia, have become a significant global health concern (Kinoshita et al., 2023). Dietary components derived from PFSP and YFPS have shown promise as cost-effective agents for managing diabetes. Various animal models have been used to study the development and progression of diabetes, highlighting the importance of well-designed experiments with different dosages, schedules, administration routes, and types of animal models to understand the molecular mechanisms underlying the hypoglycemic effects of PFSP and YFPS (Bai et al., 2023; Luo et al., 2021).

Anthocyanins found in the roots of PFSP have exhibited hypoglycemic effects in non-diabetic models and antihyperglycemic effects in diabetic models induced by high-saturated fat/sugar or streptozotocin (STZ) (Zhao et al., 2013). The specific molecular mechanisms behind these effects are not extensively documented. In a study by Zhao et al. (2013), male Kunming mice were fed a diet containing PFSP anthocyanins (at doses of 1 or 10 g/kg of rat body weight) for four weeks before being injected with STZ (at a dose of 100 mg/kg of rat body weight) to induce diabetes. The diabetic rats were then continued on a diet containing PFSP anthocyanins for an additional week. The hypoglycemic properties of PFSP were demonstrated by the reduction in plasma glucose levels in mice pre-treated with the anthocyanins for four weeks and in diabetic mice induced by high-saturated fat/sugar. Treatment with PFSP anthocyanins for five weeks dose-dependently inhibited the increase in plasma glucose levels, abnormal pancreatic morphology, and body weight loss in STZ-treated mice (Zhao et al., 2013).

The hot water extracts of PFSP leaves and stems have shown hypoglycemic effects in non-diabetic models and antihyperglycemic effects in diabetic models induced by STZ (Olowu et al., 2011). Oral administration of leaf and stem extracts to healthy or diabetic rats at doses of 100, 200, and 400 mg/kg of rat body weight for 14 days resulted in dose-dependent reductions in fasting blood glucose levels in both healthy and diabetic rats. The maximum hypoglycemic effects of the extracts were observed at a dose of 400 mg/kg, comparable to the effects of glibenclamide, a reference antidiabetic drug, at a dose of 1 mg/kg. The aqueous leaf and stem extracts were found to be non-cytotoxic up to a dose of 1000 mg/kg, though the precise molecular mechanisms of their effects remain unclear. The presence of various chemical compounds such as phenolic acids, anthocyanins, and polysaccharides suggests potential antidiabetic properties in these leaf and stem extracts. In a study involving male KK-Ay mice (type 2 diabetic mice), a diet containing 3% YFSP leaf extract powder for five weeks reduced hyperglycemia by stimulating the secretion of glucagon-like peptide-1 (GLP-1). Caffeoylquinic acid derivatives were identified as significant contributors to the

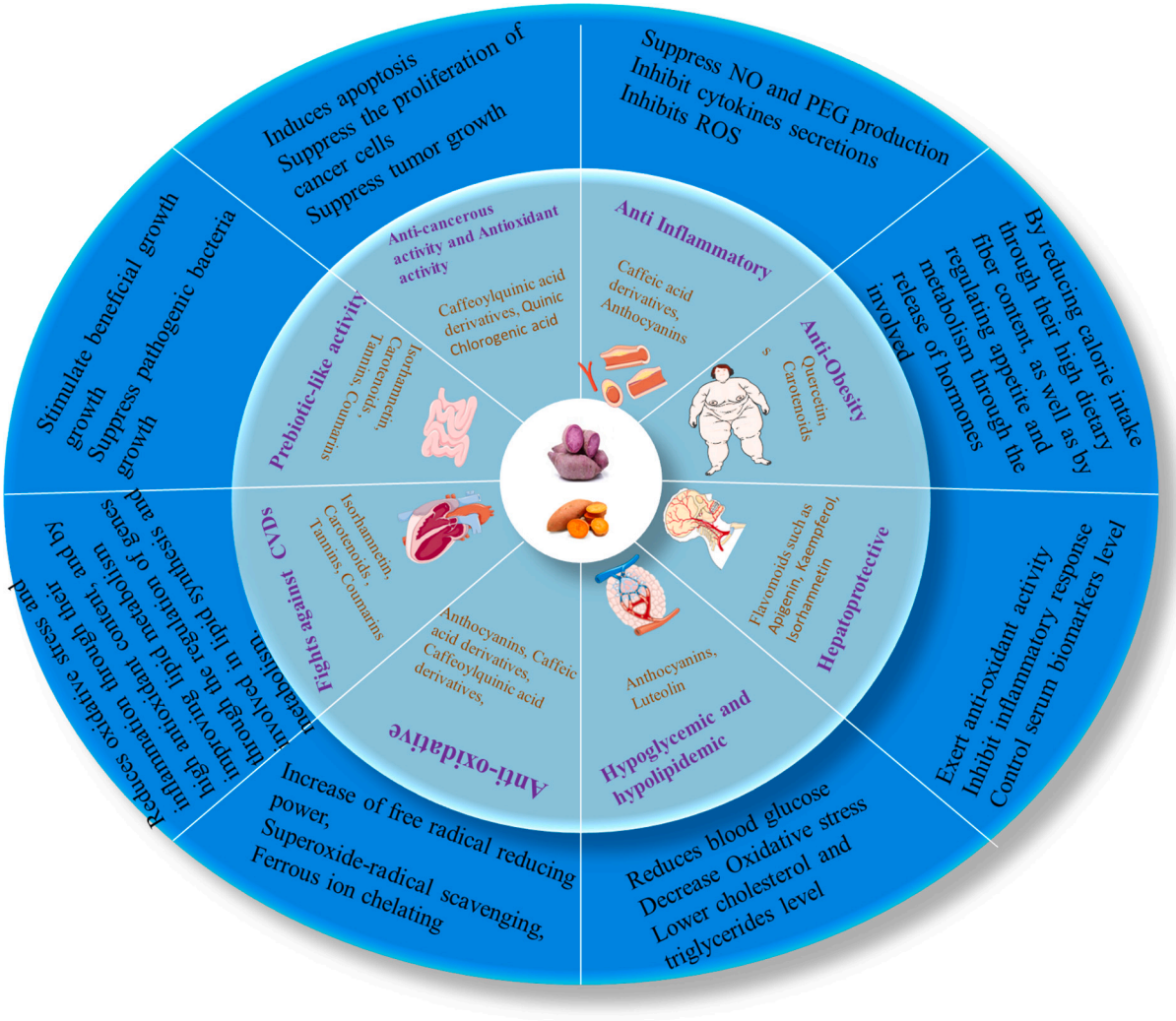

Fig. 1. Summarized health benefit of some specific bioactive compounds in PFSP and YFSP (Nguyen et al., 2021).

hypoglycaemic effects of YFSP leaves (Nagamine et al., 2014).

Multiple studies have suggested that there is a competition between anthocyanins and glucose when it comes to their transportation across various gastrointestinal barriers. This competition between the two compounds may have implications for the regulation of postprandial blood glucose levels. Recent research by Han et al. (2020) has explored this competition and its impact on blood glucose. Interestingly, a very recent study by Oliveira et al. (2019) investigated the transport mechanism of PFSP anthocyanins across a gastrointestinal cell model. The findings of the study suggested that the transport of these anthocyanins involved glucose transporters GLUT3 and GLUT1. This suggests that the transport of anthocyanins across the gastrointestinal barrier may be mediated by these glucose transporters, which could potentially play a role in the regulation of postprandial blood glucose levels. This study provides further evidence of the potential competition between anthocyanins and glucose in the gastrointestinal tract and highlights the importance of understanding the mechanisms behind the transport of these compounds.

3.2. Anti-inflammatory activity

Inflammation can be categorized into chronic or acute types, often triggered by factors such as infections, oxidative stress, tissue injury, or dysfunction. In the context of an inflammatory response, various inflammatory mediators like reactive oxygen species (ROS), prostaglandin E2 (PGE2), nitric oxide (NO), and cytokines such as tumor, interleukin-1 beta (IL-1β), necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6) play crucial roles in regulating the inflammatory process. Several studies conducted in both in vivo and in vitro have provided evidence that specific compounds obtained from PFSP and YFSP exhibit anti-inflammatory properties. These studies have provided evidence supporting the ability of PFSP and YFSP compounds to mitigate inflammation. Recently, Jiang et al. (2020) investigated the anti-inflammatory effects of two types of anthocyanin compounds derived from the root of PFSP. These compounds were categorized as protein-bound anthocyanin compounds (p-BAC-PSP) and free anthocyanin compounds with various concentrations (12.5, 25, 50, 100 and 200 μg/mL). The study focused on evaluating the effects of FAC-PSP and p-BAC-PSP on inflammatory markers in lipopolysaccharide (LPS)-induced RAW264.7 macrophages. It was found that both types of anthocyanin compounds (200 μg/mL) exhibited anti-inflammatory properties by suppressing the release of TNF-α and NO, as well as reducing the accumulation of ROS in the macrophages. These findings suggest that both protein-bound and free anthocyanin compounds from PFSP have the potential to mitigate inflammation by modulating key inflammatory markers in macrophage. More recently Sun et al. (2022) investigated the effects of polyphenols (10, 20, 40, 60, 80, 100 μg/mL) extracted from PFSP leaves on hyperuricemia mice. The study found that the polyphenols derived from PFSP leaves were effective in reducing the levels of IL-1β, IL-6 and TNF-α in the kidneys of the hyperuricemia mice. Additionally, the study

mentioned that apart from crude extracts or flavonoids, polysaccharides extracted from PFSP also exhibited anti-inflammatory effects.

In a more recent investigation, Gou et al. (2019) investigated the in vivo anti-inflammatory effects of a water-soluble polysaccharide from PFSP (0.5 mg) in mice with dextran sulfate sodium (DSS)-induced inflammation. The study found that WPSPP-1 was able to improve inflammatory lesions by increasing the levels of interleukin-10 (IL-10), superoxide dismutase and total antioxidant capacity while decreasing the levels of IL-6, IL-1β, TNF-α and malondialdehyde (MDA). Furthermore, the anti-inflammatory activity of the polysaccharide RSPP-A, which is derived from YFSP, has been scientifically established. In an experimental mouse model of acute colitis induced by DSS, RSPP-A demonstrated promising effects in reducing inflammation. It was found to decrease the secretion of IL-1β and IL-6 while simultaneously promoting the production of IL-10 in both the colon and bloodstream. Additionally, RSPP-A was observed to enhance the levels of short-chain fatty acids (SCFAs) and increase the expression of G protein-coupled receptor (GPR41) in the colon. Furthermore, the administration of RSPP-A also led to an increase in the expression of Mitogen-activated protein kinase (MEK) and extracellular signal-regulated kinase 1/2 (ERK1/2) in the colon (Feng et al., 2021).These findings suggest that the anti-inflammatory activity of RSPP-A may be attributed to the production of SCFAs and the activation of the GPR41/MEK/ERK1/2 signaling pathway.

PFSP and YFSP roots have been studied to evaluate their anti-inflammatory properties, specifically their ability to inhibit 5-Lipoxygenase (5-LOX) activity. This enzyme plays a role in the synthesis of leukotrienes, which are powerful inflammatory mediators formed through the oxidation of arachidonic acid. According to Sendangratri and Elya (2019), extracts from PFSP and YFSP roots demonstrated effective inhibition of 5-LOX activity. The IC_{50} values for the inhibition of 5-LOX were measured at 46.09 μg/mL for PFSP, and 52.12 μg/mL for YFSP.

In addition to the effects mentioned earlier, high concentrations (250 and 300 μg/mL) of alkali-soluble and water-soluble polysaccharides derived from YFSP have been identified to possess additional anti-inflammatory properties. In a study by Tang et al. (2018), it was demonstrated that alkali-soluble and water-soluble polysaccharides derived from YFSP effectively suppressed abnormal apoptosis and phagocytosis in LPS-treated RAW264.7 macrophage cell models. Moreover, they significantly reduced the excessive production of inflammatory molecules such as TNF-α, IL-6, and NO. The overexpression of IL-1 induced by LPS was notably diminished, while there was an improvement in the levels of the anti-inflammatory cytokine IL-10. Furthermore, these polysaccharides exhibited positive effects on adaptive immunity in both immunosuppressed and normal mice.

3.3. Anticancer and antitumor activity

Numerous reports have suggested that anthocyanins derived from PFSP and YFSP has the ability to inhibit the growth of cancerous cells and induce apoptosis. These effects are often attributed to the anti-inflammatory and antioxidant properties exhibited by their anthocyanins, which contribute to their anticancer potential.

For example, Guo et al. (2021) to evaluate the antileukemic effects of PFSP anthocyanins (0, 10, 20, 40, 60, 80 and 100 μg/mL). The researchers found that anthocyanins from the root of PFSP significantly suppressed the proliferation of acute lymphoblastic leukemia cells. They achieved this by inducing calcium overload and cell cycle arrest in the leukemia cells. This study was the first to explore the potential of PSP anthocyanins as an antileukemia agent. While these findings are promising, it is important to note that further research is necessary to confirm and expand upon the antineoplastic effects of PFSP anthocyanins. Animal studies and clinical trials are essential to validate the potential therapeutic benefits of PFSP anthocyanins in the treatment of cancer. These studies will provide a better understanding of the efficacy and safety of PFSP anthocyanins as potential anticancer agents.

The study conducted by Li et al. (2018) focused on exploring the therapeutic role of different doses of PSPA (100, 300, 500, 800 and 1000 μg/ml) anthocyanins in the treatment of urothelial carcinoma (cancer of the bladder). The researcher examined how PFSP anthocyanins impacted bladder cancer cell lines, specifically 5637 and T24. The results of the study demonstrated that PFSP anthocyanins had a tumor-suppressing effect on the bladder cancer cells. They achieved this by suppressing cell viability, promoting mitochondrial membrane potential collapse, inducing apoptosis, and causing cell cycle arrest. These effects collectively contribute to inhibiting the growth and proliferation of bladder cancer cells. Importantly, this was the first preclinical investigation that demonstrated the potential therapeutic effects of PFSP anthocyanins specifically in the context of bladder cancer. In a recent study conducted by, Sun et al. (2019), the antioxidant activities of phenolic profiles, cytotoxicity, and antiproliferative activities of 10 (130 μg/mL) different cultivated varieties of sweet potato in various colours were examined. Among these varieties, YFSP and PFSP were included. The findings revealed that YFSP exhibited a robust antioxidant capacity and demonstrated stronger antiproliferative effects against HepG2 cells.

Indeed, polysaccharides derived from PFSP (ranging from 100 to 500 μg/ml) have been found to possess antitumor activity, as reported by Wu et al. (2015) and Ji et al. (2021).Wu et al. (2015) investígate the anti-tumor effects of three weak alkaline polysaccharides isolated from PFSP, namely PSPP3–1, PSPP2–1 and PSPP1–1. They observed that these polysaccharides exhibited concentration-dependent antitumor effects on SW620 (human colon cancer cells) and SGC7901(human gastric carcinoma cells). PSPP1–1 exhibited the most potent antitumor activity among the three polysaccharides that were tested. Additionally, PSPP1–1 induced apoptosis in SGC7901 and SW620 cells, further supporting its potential as an antitumor agent .Ji et al. (2021) conducted a study where they isolated a newly discovered glucan from the tuber of PFSP. The researchers discovered that this glucan demonstrated inhibitory effects on colonic cancer cells, breast cancer cells (MCF-7), and HepG2 cells. Importantly, the inhibitory effects were observed to be dependent on the dosage of the glucan.

Li, Lin, et al., 2019, Li, Yu, et al. (2019) conducted a study to explore the potential anti-cancer effects of SPG-56, a glycoprotein obtained from the YFSP Zhongshu no. 1, on MCF-7. The researchers discovered that SPG-56 demonstrated dose- and time-dependent inhibition of MCF-7 cell proliferation and induced apoptosis. Furthermore, they observed that oral administration of SPG-56 at a dosage of 250 mg/kg/d suppressed breast cancer metastasis in MCF-7 and 4 T1-bearing mice. This inhibition was attributed to the modulation of expression levels of Vascular endothelial growth factor (VEGF), Matrix metalloproteinase-2 (MMP2), Matrix metalloproteinase-9 (MMP9), Claudin, Occluding and a decrease in serum tumor markers, CA125 (91.8%), CA153 (90.3%) and CEA (54.8%). In a similar vein, Tian et al. (2019) examined the anti-colorectal cancer activity of SPG-8700, a glycoprotein derived from the same YFSP cultivar Zhongshu no. 1. Their investigation revealed that SPG-8700 facilitated apoptosis in human colon cancer HCT-116 cells by affecting the expression of Bax and Bcl-2, two proteins involved in regulating cell death. Furthermore, treatment with SPG-8700 led to a 25.3% reduction in the levels of the tumor marker CA199, CA125 and CA242 by 25.3%, 36.7%, and 16.9%, respectively. Still using the same YFSP cultivar, Xu et al. (2018) investigated the effects of β-Sitosterol-d-glucoside, a phytosterol derived from Zhongshu no. 1 YFSP cultivar, on breast cancer cell lines MDA-MB-231 and MCF7 . The study revealed that β-Sitosterol-d-glucoside demonstrated cytotoxic properties against these breast cancer cell lines. It was revealed that this compound induced apoptosis and activated caspase proteases in these cancer cells. In nude mice with MCF7-induced tumors, the effectiveness of β-Sitosterol-d-glucoside was further examined. The research findings indicated that administering between 60 and 120 mg/kg doses of this phytosterol resulted in a significant inhibition of tumor growth. Additionally, the levels of tumor markers, such as CA153, CA125, and CEA, were reduced by 85.32%, 74.64%, and 64.71% respectively (Xu et al., 2018).

3.4. Obesity activity

Obesity is a significant factor in the development of various health conditions such as type 2 diabetes, high blood pressure, heart disease, stroke, arthritis, and cancer (Hwang et al., 2011). Research has shown that anthocyanins found in PFSP have anti-obesity properties. In a study involving obese ICR male mice fed a high-fat diet, a 4-week diet supplemented with PFSP anthocyanin fractions at a concentration of 200 mg/kg resulted in reduced weight gain, decreased hepatic triglyceride accumulation, and improved serum lipid profiles (Hwang et al., 2011). The anthocyanin fractions were found to activate AMPK and acetyl-coenzyme A carboxylase in the liver while down-regulating key proteins involved in lipid metabolism. This led to the inhibition of hepatic lipid accumulation through the AMPK signaling pathway.

In another study on obese C57BL/6 J male rats fed a high-fat diet, a 16-week diet supplemented with aqueous extracts of PFSP at varying doses (100, 250, and 500 mg/kg) showed dose-dependent improvements in obesity-related symptoms (Shin et al., 2013). The sweet potato extracts reduced body weight and adipose tissue mass in obese rats and decreased the occurrence of hepatic steatosis. At the molecular level, the extracts regulated genes involved in lipogenesis by suppressing the expression of key proteins such as sterol regulatory element-binding protein-1, acyl-CoA synthase, glycerol-3-phosphate acyltransferase, HMG-CoA reductase, and fatty acid synthase in liver tissue (Shin et al., 2013).

Kim et al. (2020) conducted a study to investigate the effects of carotenoid and anthocyanin extracted from YFSP and PFSP on obesity. The study encompassed in vitro experiments using 3 T3-L1 cells and in vivo experiments involving obese mice induced by a high-fat diet. The findings revealed that treating 3 T3-L1 adipocytes with carotenoid and anthocyanin extracts at a concentration of 100 μg/mL was safe and non-toxic. These extracts demonstrated significant reductions in fat accumulation, with the anthocyanin extract showing an 83.5% reduction and the carotenoid extract showing a 63.1% reduction. Additionally, the extracted anthocyanin hindered adipogenesis at intermediate stages, while the extracted carotenoid adipogenesis at all levels. Both extracts decreased triglyceride (TG) content and protein expression of PPAR during the intermediate stage of adipogenesis.

Ju et al. (2017) conducted a study to explore the potential anti-obesity effects of PFSP in obese C57BL/6 J mice that were fed a high-fat diet (HFD) for 14 weeks. The findings indicated that supplementing the diet with 30% PFSP yielded several beneficial outcomes. Firstly, the mice receiving the 30% PFSP supplementation showed reductions in body weight and fat accumulation compared to those on the high-fat diet alone. Additionally, PFSP supplementation led to improvements in the lipid profile of the mice. In the same vein, YFSP leaves have been found to possess anti-obesity potential.

3.5. Cardioprotective effect

Cardiovascular diseases are a leading cause of death worldwide, and their prevention and management are important aspects of public health. The risk factors include metabolic syndrome, elevated blood, diabetes, obesity, pressure, tobacco use, sedentary lifestyle, hyperlipidemia, an unbalanced diet (Yamani et al., 2021).One specific complication associated with CVDs is atherosclerosis, which is caused by the oxidation of low-density lipoprotein (LDL) particles (Hao et al., 2020). LDL oxidation contributes to the formation of plaque within the arteries, leading to narrowing and hardening of the blood vessels. This process can ultimately result in cardiovascular events such as heart attacks and strokes. Therefore, interventions that prevent or reduce LDL oxidation can play a crucial role in preventing CVDs and their associated complications.

The administration of YFSP root extract, which contain various compounds such as anthraquinones, tannins, saponins, reducing sugars, terpenoids, flavonoids, alkaloids, and cardiac glycosides, has been associated with certain beneficial effects. Specifically, in a study by Ubhenin (2016) it was observed that the administration of 200, 400, and 800 mg kg^{-1} YFSP extracts resulted in an effective decrease in the lactate dehydrogenase activity and level of serum creatine. Sporamin, also referred to as sweet potato trypsin inhibitors, is a prominent protein found in the roots of YFSP and PFSP. In line with this, In a study conducted by Lu et al. (2020), it was found that sporamin (10, and 15 μg) exhibited the ability to reduce LDL oxidation in vitro. LDL oxidation is a process that contributes to the development of atherosclerosis and cardiovascular diseases. Therefore, the ability of sporamin to inhibit LDL oxidation suggests a potential protective effect against cardiovascular complications.

ACE inhibitors are primarily utilized for the management of congestive heart failure and hypertension. In the context of ACE inhibition, the most potent inhibitory effect was observed in YFSP protein hydrolysates with a molecular weight ranging from 1 to 5 kDa. These hydrolysates, which underwent pepsin hydrolysis, demonstrated an approximate IC_{50} value of 0.4 mg/mL. Protein hydrolysates with a molecular weight below 1 kDa exhibited slightly weaker ACE inhibitory activity (IC50 of 1.98 mg/mL). Conversely, protein hydrolysates with molecular weights between 5 and 10 kDa, as well as those exceeding 10 kDa, displayed the lowest levels of ACE inhibitory activity (Wu & Lin, 2017).Furthermore, Nazir et al. (2019) assessed the ACE inhibition potential of YFSP protein hydrolysates prepared using different enzymes, namely, pepsin, alcalase and papain Among these hydrolysates, the YFSP protein hydrolysates with a molecular weight of <3 kDa, obtained through alcalase hydrolysis, exhibited the highest ACE inhibitory activity. The IC50 value for this particular hydrolysate was recorded as 32.24 μg/mL. Furthermore, in a study by Satriyasa (2017), rabbits fed a high-cholesterol diet and supplemented with 110 mg to 210 mg anthocyanin-containing PFSP ethanolic extract exhibited a decrease in the expression of aortic vascular cell adhesion molecule (VCAM). This finding suggests that PFSP has anti-atherogenic potential, as VCAM is involved in the development of atherosclerosis.

While there are no specific studies reporting the inhibitory effect of PFSP and YFSP leaves on lactate dehydrogenase and creatine activity, it is reasonable to expect that the phytochemical found in leave might possess this ability. However, it's important to note that further research is needed to confirm this hypothesis. In a study conducted by Cui et al. (2011) freeze-dried powders of PFSP and YFSP tips, which include the leaves and stems, were found to inhibit ACE activity. The ACE inhibitory activity of PFSP and YFSP tips may be due to the presence of chlorogenic acid derivatives (Chen et al., 2020) Angiogenesis, the process of forming new blood vessels from existing ones, plays a role in various diseases, including atherosclerosis. In vitro evaluations of PFSP leaves have shown promising results regarding angiogenesis indices. According to the study conducted by Chen et al. (2011) It was discovered that 200 g of PFSP exhibited a dose-dependent reduction in tube formation, migration, cell proliferation, and the activity of MMP-2 secreted by human umbilical vascular endothelial cells. These results indicate a potential inhibitory effect of PFSP leaves on the process of angiogenesis. However, it is important to note that while these findings provide valuable insights into the potential effects of PFSP leaves, further research is required to fully comprehend and validate the extent of their inhibitory effects on specific enzymes and angiogenesis-related processes.

4. Enhancing stability of bioactive compounds in YFSP and PFSP

The inclusion of bioactive compounds found in YFSP and PFSP, like anthocyanins, in food items encounters significant obstacles due to the inherent instability of the core flavylium cation structure. This instability makes the anthocyanins and some bioactive compounds highly susceptible to both biochemical and chemical degradation (Tan et al., 2021). The degradation of anthocyanins primarily occurs via three mechanisms: cleavage, derivatization, and polymerization(Jiang et al., 2019). Generally, the cleavage reaction of anthocyanins results in the

creation of colourless compounds, while derivatization and polymerization lead to browning and the production of colored molecules, respectively. Numerous factors influence the rate at which degradation occurs, including light, oxygen, temperature, pH, solvents, enzymes etc. (Ghareaghajlou et al., 2021). Enhancing the stability of anthocyanins and other bioactive compounds from YFSP and PFSP is a crucial approach to improve the quality of products made from this bioactive compound. Various methods have been explored thus far, including, co-pigmentation (for the stability of anthocyanins), encapsulation and the use of specific protective agents, to enhance the stability of this bioactive compounds. Encapsulation and co-pigmentation are essential techniques employed in the food industry to enhance the stability, functionality, and sensory properties of bioactive compounds. Encapsulation is utilized to protect sensitive compounds from degradation, ensure controlled release, and improve palatability in a variety of food products, while co-pigmentation enhances color stability, intensity, and antioxidant activity by forming complexes with natural pigments (Gutiérrez-Quequezana et al., 2020; C. Y. Kim et al., 2010).

In the food industry, these methods are frequently utilized to modify the color of food products, with the objective of preserving or reinstating their natural color intensity or creating new shades (Ginting et al., 2022). Consequently, notable advancements have been achieved, and various initiatives have been successfully executed. These measures can be classified into two distinct groups, based on their underlying mechanisms (Fig. 2). The initial group concentrates on improving the stability of anthocyanins directly, making them more resilient to adverse conditions. Conversely, the second group aims to protect or mitigate the external factors that can potentially harm anthocyanins, thereby ensuring their stability (Jiang et al., 2019). Presently, co-pigmentation techniques, such as intramolecular and intermolecular co-pigmentation, are extensively utilized within the first group. In the second group, encapsulation methods and the utilization of specific protective agents are commonly employed (Tan et al., 2023; Zhao et al., 2022). These strategies have demonstrated effectiveness in safeguarding anthocyanins and other bioactive compounds against destabilization, thereby preserving their quality.

4.1. Techniques used to stabilize PFSP and YFSP bioactive compounds

4.1.1. Co-pigmentation of anthocyanins

In a chemical context, co-pigmentation refers to the interactions that occur between the chromophore present in anthocyanins and a co-pigment. Co-pigmentation can be classified into two types based on the source of the co-pigment: intermolecular and intramolecular co-pigmentation. In the case of intramolecular co-pigmentation, the co-pigment is the acyl group within the anthocyanin molecule. This acyl group is covalently linked to the same sugar residue as the aglycone, which acts as the provider of the chromophore in anthocyanin (Li et al., 2022). In the context of intermolecular co-pigmentation, the term "co-pigment" refers to a separate molecule that exists independently from the anthocyanin molecule. This co-pigment can be either naturally occurring coexisting anthocyanins found in foods or a different substance introduced as needed.

When examining intermolecular co-pigmentation, there are three possible scenarios involving the interaction between the co-pigment (1) two identical anthocyanin compound integrating together, (2) two different anthocyanin compounds interacting together, and (3) interaction between an anthocyanin molecule and a non-anthocyanin

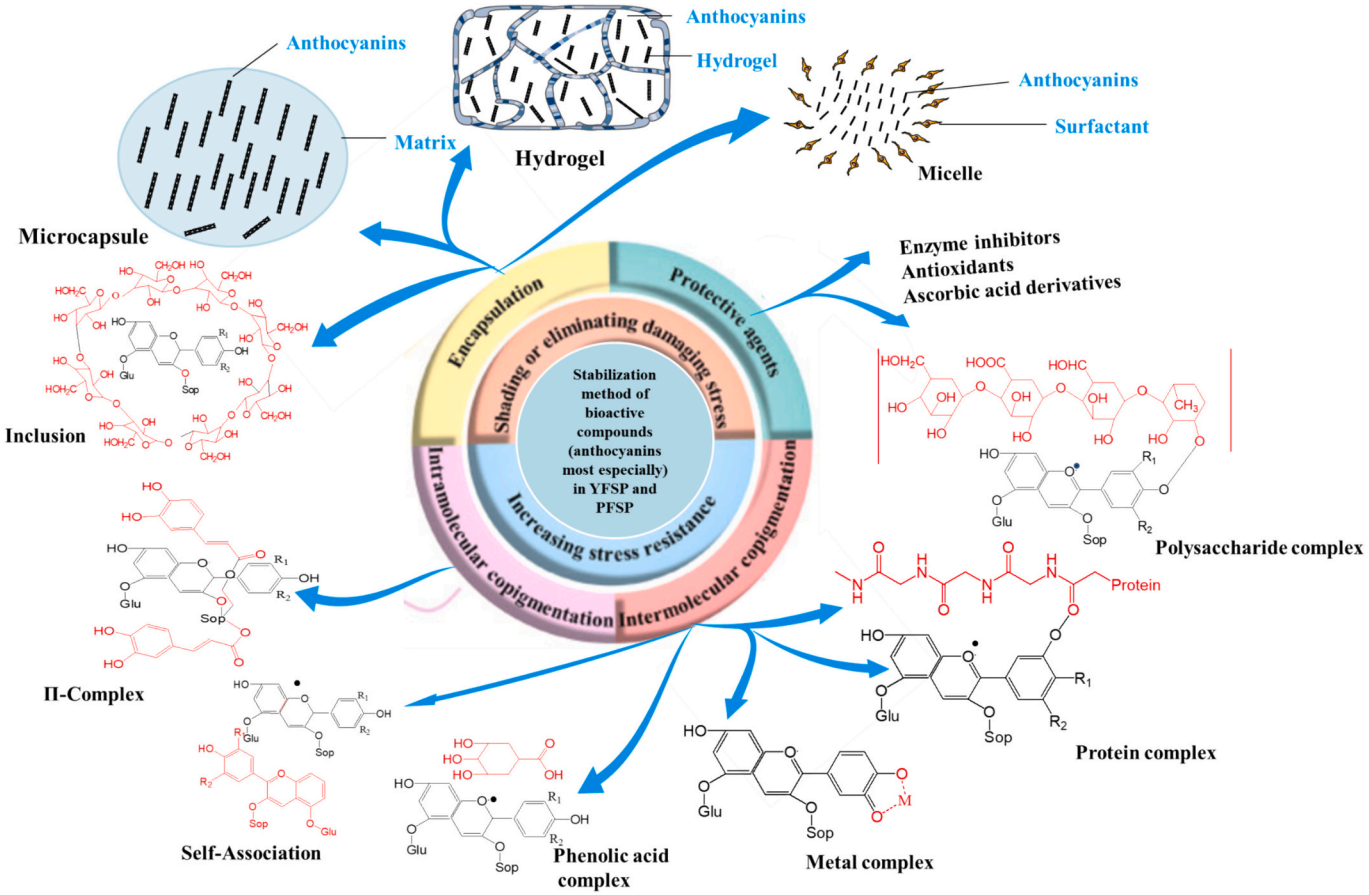

Fig. 2. A) The figure illustrates the different methods used to stabilize the anthocyanins present in PFSP and YFSP. The R1 and R2 represent different functional groups attached to the anthocyanin molecule, such as hydrogen (H), hydroxyl (OH), or methoxy (OCH3). Sop and Glu represent sophoroside and glucoside, respectively, which are sugar molecules attached to the anthocyanin. The figure also shows the involvement of metal ions (M+) in the stabilization process.

molecule. The first and second scenarios involve the self-association of anthocyanins, where vertically aligned hydrophobic interactions occur between the aromatic nuclei of stacked anthocyanin molecules in a parallel arrangement (Tan et al., 2023). Non-anthocyanin co-pigments, such as, metal ions, phenolic acids, polysaccharides and proteins are commonly used in co-pigmentation. These co-pigments interact with anthocyanin molecules through various forces, including, hydrogen bonds, ionic interactions, Vân der Waals forces, and hydrophobic forces (Khalifa et al., 2023). The consensus among experts is that the interaction with co-pigments forms a physical shield around anthocyanin molecules. This protective shield serves two purposes: firstly, it masks the functional components of anthocyanins, reducing their exposure and limiting their susceptibility to harmful reactions. Secondly, it creates a significant barrier that hinders the actions of compounds that can potentially degrade or destroy anthocyanins(Gras et al., 2018; Gutiérrez-Quequezana et al., 2020).

Unfortunately, there is a lack of available report regarding the self-association of PFSP and YFSP anthocyanins and their impact on their stabilization through co-pigmentation and also most research in this aspect has been carried out mostly on PFSP. Very little has been done on YFSP which requires more attention. Extensive studies have been conducted to explore the role of self-association in influencing the stability of anthocyanins specifically in the context of wine. In terms of co-pigmentation with non-anthocyanin compounds, the effectiveness of phenolic acids, metal ions, carbohydrates and proteins were evaluated for anthocyanins from PFSP. When comparing tannic acid and ferulic acid, both were found to induce bathochromic shifts (red-shifts) and hyperchromic effects (increase in color intensity). Tannic acid demonstrated a more pronounced hyperchromic effect compared to ferulic acid when both were applied at equivalent concentrations. Furthermore, the hyperchromic effect of tannic acid, ranging from 36.6% to 67.5%, was found to depend on the dosage, with higher concentrations leading to greater hyperchromic effects. On the other hand, the hyperchromic effect of ferulic acid reached its peak at a concentration of 0.015 mol/L, resulting in a 28.0% increase in chromatic intensity(Susanti et al., 2018). The study conducted by Qian et al. (2017) provided valuable insights into the co-pigmentation of gallic acid (GA),caffeic acid (CA) and ferulic acid (FA) with anthocyanins from PFSP both in the presence or absence of heat. In the absence of heating, the hyperchromic effect was observed to exhibit the following order: FA > CA > GA. This discrepancy was attributed to the presence of double bond in CA and FA, which introduced an additional π-electron shift not present in GA. However, the situation changed significantly when heating was applied. The set containing gallic acid displayed a higher color intensity value and a comparable mass of anthocyanin compared to the control, indicating better stability. However, both FA and CA exhibited significantly lower values in terms of color intensity and degradation half-life compared to the blank. The superior performance of GA (which resulted in higher color intensity) was attributed to its shorter distance between the chromophore and co-pigment, which facilitated more effective co-pigmentation compared to FA and CA. The inferior results obtained with CA and FA suggest that their stacking with the anthocyanins of PFSP was less compact as compared to the self-stacking of PFSP anthocyanins alone (Qian et al., 2017). The research conducted by Gras et al. (2017) demonstrated that the presence of co-pigments, such as rosmarinic and chlorogenic acid, had a positive effect on the pH stability of PFSP anthocyanins. In the absence of co-pigmentation, the equilibrium between carbinol pseudobases and flavylium cations, which occurs at a 50:50 ratio, was achieved at a pH of 3.28. However, when rosmarinic acid and chlorogenic acid were introduced as co-pigments, this equilibrium shifted to higher pH values of 3.91 and 4.32, respectively. This finding indicates that the inclusion of phenolic acids as co-pigments contributes to enhancing the pH stability of anthocyanins from PFSP. In a related study by the same author, Gras et al. (2018) found out that that phenolic acids exhibit higher co-pigmentation efficiency for non-acylated anthocyanins compared to acylated anthocyanins. The researchers suggested that this difference might be attributed to the more intricate spatial structure of acyl groups, which could pose challenges to intermolecular co-pigmentation. In contrast, nonacylated anthocyanins frequently showed greater enhancements in their visible absorption, indicating a stronger response to co-pigmentation.

Recent studies as well have shown a growing interest in the co-pigmentation of anthocyanins by food proteins. Research conducted by Fu et al. (2020) and Yin et al. (2021) highlighted the potential of food proteins, such as casein and ovalbumin, to interact with cyanidin-3-glucoside, a common anthocyanin, through van der Waals forces, hydrogen bonding and hydrophobic interactions These interactions between the anthocyanins and food proteins contribute to increased stability, particularly under heating conditions. The co-pigmentation with food proteins can enhance the thermal resistance of anthocyanins, protecting them from degradation or color fading caused by heat. Research conducted by Quan et al. (2020) demonstrated that soy protein and whey protein can serve as effective co-pigments for PFSP anthocyanins. In their study, it was found that the addition of 50 mg/L soy protein resulted in a 27.3% reduction in the thermal degradation rate of PFSP anthocyanins under conditions of 100 °C for 30 min. Similarly, the addition of 200 mg/L whey protein reduced the degradation rate by 17.4%. Furthermore, a recent study by Xu et al. (2019) showed that gellan gum was shown to alleviate the thermal degradation of PFSP anthocyanins induced by ascorbic acid. The addition of gellan gum formed a complex with the anthocyanins through dispersion interaction, hydrophobic interaction and hydrogen bonding. This complex formation led to a decrease in the degradation rate constant (K) of YFSP anthocyanins by 32.3% to 51.0%, providing protection against thermal degradation.

4.1.2. Encapsulation of anthocyanins and other bioactive compounds

Encapsulation technology is used to protect bioactive substances during storage and processing, as well as improve their stability during digestion(Li et al. 2021b). Various methods, including spray-drying, freeze-drying, nanostructured lipid matrices, coacervation, solvent evaporation and extrusion processes, have been developed to encapsulate natural bioactive compounds (Lin et al., 2023; Zhao et al., 2023). This technique is widely employed in the food and pharmaceutical industries to safeguard bioactive compounds like, polyphenols, enzymes and micronutrients from unfavourable conditions such as, light, oxygen, shear, heat and moisture (Aghlara-Fotovat et al., 2023; Li, Wang, et al., 2021; Li, Yu, et al., 2021).

To summarize, encapsulation is a method that entails confining one substance inside another, leading to the creation of particles of different sizes (Zhang et al., 2020). The material being encapsulated is referred to by different terms such as the core material,active agent, fill, internal phase or payload phase (Chen et al., 2021; Singh et al., 2020). The substance that encapsulates the material is known as the membrane, shell, coating, wall material, carrier material, exterior phase or matrix. Selecting the right wall material is a crucial aspect of encapsulation. The material should safeguard the core substance from degradation, possess adequate mechanical strength, be suitable for the food product, enable controlled release, and have thermal properties that are appropriate for the product (Milagres de Almeida et al., 2023). Encapsulation can be achieved through several types of wall materials, including carbohydrates (such as starch, maltodextrins and chitosan), cellulose derivatives (such as carboxymethyl cellulose and methyl cellulose), proteins (such as albumin, gelatin and gluten,), gums (such as sodium alginate, carrageenan and agar,), and lipids (such as oils and beeswax) (Chang et al., 2019; Lazarova-zdravkova et al., 2020; Rehan et al., 2019).The morphology of encapsulation can be characterized in several ways, including inside matrix structures, multinuclear, multi-wall, and mononuclear.

A comprehensive understanding of the interactions between anthocyanins and the wall material is crucial for interpreting the observed effects. One notable example is the use of β-cyclodextrin to incorporate

PFSP and YFSP anthocyanins, which has been found to offer protection against polymerization reactions and hydration. As a result, the storage stability of the anthocyanins is significantly enhanced. In a study by Quan et al. (2020), the degradation rate constant (K) of anthocyanins from PFSP decreased by 15.2% when encapsulated with β-cyclodextrin, resulting in improved stability over a period of 6 months at 25 °C under light conditions. Additionally, Jin et al. (2020) demonstrated that anthocyanins from YFSP could be fitted into a hydrogel composed of konjac glucomannan and xanthan gum. The loaded/fitted anthocyanins exhibited enhanced thermal stability, with a decrease in the degradation rate constant ranging from 65.1% to 85.5% at different pH values. In contrast to the encapsulation achieved using polysaccharides, the use of sodium dodecyl sulfate (SDS) micelles proved to be an effective method for capturing and enclosing PFSP anthocyanins (Liu et al., 2014). Notably, the solution containing PFSP anthocyanins encapsulated within SDS micelles exhibited transparency at a macroscopic level, which differed from the opaque appearance commonly associated with polysaccharide encapsulation. The encapsulation of PFSP anthocyanins within SDS micelles offered an additional advantage by providing the anthocyanins with an exceptional buffering capacity against color variations resulting from changes in pH. Consequently, the micelle-enclosed PFSP anthocyanins exhibited a red appearance at pH 5.0, a coloration that could not be achieved by free PFSP anthocyanins. Typically, free PFSP anthocyanins display a red color only at pH values below 2.0. The encapsulation within SDS micelles expanded the pH range at which the red color was retained, indicating an improved ability to maintain color stability and buffering capacity for the anthocyanins.

Double encapsulation has also been evaluated to safeguard bioactive compounds from sweet potato. Šeregelj et al. (2020) comparatively applied Spray drying and freeze-drying encapsulation methods as a means to enhance the of phenolics and carotenoids from YFSP, by coating them with whey protein. Spray drying was found to produce, better flow properties, smaller particle sizes and higher encapsulation efficiency of carotenoids compared to freeze-drying. During storage, the preservation of both non-encapsulated and encapsulated carotenoid and phenolics was monitored under daylight and dark conditions. The results showed that storage conditions had an impact on carotenoid retention, with higher degradation rates observed in daylight. However, phenolic compounds exhibited higher retention in all samples. The degradation kinetic parameters indicated that spray-dried encapsulated extract had a longer shelf life and was a promising method for stabilizing bioactive ingredients.

The research conducted by da Cruz et al. (2023) focuses on the use of electrospinning encapsulation as a method to protect phytochemicals from YFSP and WFSP from degradation. The researchers evaluated the thermogravimetric properties, morphology, antioxidant activity, in vitro release simulation, wettability and thermal resistance of the fibers. The encapsulated antioxidants from YFSP showed a high thermal resistance of 51.6–95.4% at 100 °C and 13.4–99.4% at 180 °C. Among the encapsulated bioactive compounds, apigenin demonstrated the most effective thermal protection. Furthermore, all the encapsulated phenolic acids from YFSP exhibited strong inhibitory action against *Staphylococcus aureus* and *Escherichia coli* as compared to the encapsulated phenolics. Thakur et al. (2017) their study successfully encapsulated β-carotene in microcapsules using casein and guar gum, resulting in improved stability and controlled release of the nutrient. The microcapsules showed promise for applications in food and food ingredients to enhance the bioavailability of β-carotene.

4.1.3. Using protective agents

It is evident that the degradation or discoloration of bioactive compound in sweet potato such as anthocyanins is closely linked to the presence of environmental stresses. To enhance the stability of anthocyanins, it is beneficial to mitigate these stresses by employing specific protective agents tailored to address the major stress factors. For instance, when formulating a food product that contains anthocyanins and aims to enrich vitamin C, various derivatives of L-ascorbic acid can be utilized as alternatives. These derivatives include 2-O-α-D-glucopyranosyl-L-ascorbic acid, (+)-5,6-O-isopropylidene-L-ascorbic acid.3-O-ethyl-L-ascorbic acid, L-ascorbic acid 2-phosphate sesquimagnesium salt hydrate, glyceryl ascorbate,and L-ascorbyl 2,6-dibutyrate. These alternative derivatives, as recommended by Gérard et al., 2019, Gérard et al. (2019), help protect anthocyanins from degradation and contribute to maintaining their stability in the presence of vitamin C. The derivatives of L-ascorbic acid mentioned earlier not only exhibited reduced bleaching effects on anthocyanins compared to ascorbic acid but also served as good sources of vitamin C. This is significant considering the role of autooxidation of ascorbic acid and the resulting radicals in anthocyanin bleaching. In the context of preventing anthocyanin bleaching, antioxidants such as sinapic acid and chlorogenic acid have been found to be effective by acting as radical quenchers. These antioxidants help counteract the impact of autooxidation and the formation of radicals, thereby preserving the color stability of anthocyanins (Gérard et al., 2019).Additionally, for degradation caused by enzyme activity, the use of inhibitors specific to polyphenol oxidase has shown promise in preventing the degradation of PFSP anthocyanins during extraction. Inhibitors such as oxalic acid, sodium borate and citric acid have been found to significantly reduce the degradation rate constant (K) of PFSP anthocyanins, with decreases ranging from 11.9% to 44.3% (de Aguiar Cipriano et al., 2015). These inhibitors act by inhibiting the enzymatic activity of polyphenol oxidase, which is responsible for anthocyanin degradation.

5. Specific effect and applications of YFSP and PFSP in the food products

PFSP and YFSP are currently cultivated extensively as a valuable resource for both food and industrial purposes. It can be used in the production of confectionery, edible films, and silk noodles, among other food products (Wang et al., 2020).

5.1. Bread

Research has indicated that incorporating yellow and purple sweet potato in bread production offers numerous advantages for both consumers' health and the agricultural industry. The inclusion of these sweet potatoes in breads results in several notable outcomes, including an increase in water activity, moisture content, orange colouring, and carotenoid levels. These changes contribute to the overall nutritional value and appeal of the breads. de Cássia Nogueira et al. (2018) focused on the use of YFSP flour in the production of sweet breads as a way to increase the industrial application of this perishable crop. The aim was to evaluate the technological quality and carotenoid content of the breads when wheat flour was replaced with 0%, 3%, 6%, and 9% YFSP flour. The findings indicated that with an increase in the concentration of YFSP flour in the breads, several changes were observed. These included a decrease in firmness and specific volume, as well as an increase in moisture, water activity, orange colouring, and carotenoid content. During storage, the most significant changes were observed after the fifth day, with a decrease in the intensity of the orange color. The β-carotene content in the breads ranged from 0.1656 to 0.4715 μg/g. this study demonstrated a new and beneficial use of YFSP in bread production, which not only enhances the health benefits for consumers but also provides opportunities for the agricultural business. In another study, Aziza et al. (2022) explored the use of local food ingredients, specifically YFSP and cornstarch, in nastar cakes and bread to reduce dependence on regular flour and enhance nutritional content. The addition of YFSP provided a unique taste to nastar cakes and bread when combined with chocolate jam.

Zhu and Sun (2019) conducted a study to assess the physicochemical and sensory properties of Chinese steamed bread (CSB) when formulated

with freeze-dried PFSP at various incorporation levels, up to 50%. The findings revealed that incorporating PFSP up to 50% resulted in increased antioxidant activities and reduced glycemic response of the CSB. The total anthocyanin/polyphenol contents of the CSB also increased with higher levels of PFSP, although some polyphenols were lost during the process. The addition of PFSP had minimal impact on the water content and water activity of CSB but led to increased hardness and decreased specific volume of the bread. In line with this Valino et al. (2020) investigated the sensory and physicochemical properties of bread made from PFSP flour, PFSP starch, and flour derived from solid waste of PFSP starch processing (SFWF). Different ratios of these ingredients were used to produce the bread, along with a control bread made from 100% wheat flour. The results showed that the ratio of flour, solid waste and starch flour had a significant impact on various characteristics of the bread, including specific volume, color, anthocyanin levels, hardness, deformation, adhesiveness, chewiness, gumminess, and sensory properties.

5.2. Biscuits and cookies

Because gluten in wheat provides dough with extensibility and rollability, it is commonly used in the production of biscuits and cookies. However, there has been increasing consumer demand for high-fiber biscuits, leading to several studies focusing on the development of sweet potato-based alternatives. In one particular study, researchers seek to increase the calcium content and improve the antioxidant activity of the cookies, as well as to evaluate their chemical and physical properties of cookies. In this study, cookies were prepared by substituting pale YFSP flour with PFSP flour and kale flour, with control cookie. The results showed that the cookies incorporated with YFSP flour with PFSP had high ash content, total dietary fiber, as well as high calcium content (Morais, Michele Utpott and Tischer, 2021).In a more recent study it was found out that Biscuits made with 5% PFSP flour and 25% PFSP fiber exhibited higher concentrations of anthocyanins and fiber content compared to biscuits made with wheat starch (Elisa et al., 2020). The composition of starch, fiber and flour in biscuits plays a crucial role in determining their physicochemical characteristics. Research has revealed that biscuits containing 30% and 40% PFSP flour exhibited elevated levels of ash, fiber, and total flavonoid content. Additionally, these biscuits received higher sensory scores across all quality attributes, indicating superior taste, texture, aroma, and overall satisfaction compared to other formulations (van Toan & Anh, 2018). Agu et al. (2020) in their study aimed to develop composite flour from YFSP and wheat flours for the production of cake, chin-chin and biscuit. Five samples were produced for each snack-type with different ratios of YFSP and wheat flours (20:80, 40:60, 60:40, 80:20, and 100:0). The sensory evaluation and proximate composition of the snacks were determined. The results showed that the cakes, chin-chin snacks and biscuits made with 20:80, 40:60, and 20:80% YFSP/wheat flour, respectively, were comparable in sensory attributes to the control sample made with 100% wheat flour. The 100:0 ratio of YFSP/wheat flour snacks had the highest energy contents (kcal/100 g). This study highlights the potential of YFSP in new product formulation for the snacks food industry.

In a recent study, Cookies that contained 20% resistant starch (RS) derived from citric acid and heat moisture combined treated starches exhibited a medium glycemic index (GI). In contrast, cookies made with 20% native starch or YFSP resistant starch from heat moisture treated starches had a high GI, comparable to the control cookies. The use of YFSP resistant starch in the cookies formulated with the citric acid and heat moisture combined treatment resulted in a more favorable glycemic response compared to using native starch or YFSP resistant starch from heat moisture treated starches alone (Van Hung et al., 2021). More recently, feeding rats with a diet containing 50% PFSP resistant starch biscuits for a period of 14 days resulted in a hypocholesterolemic effect, observed in both healthy and hypercholesterolemic rats. The study suggests that incorporating PFSP biscuits into the diet can have potential benefits for managing cholesterol levels, regardless of the initial cholesterol status of the rats (Ginting et al., 2022).

5.3. Noodles, thick-slurries and snacks

Although sweet potato starch noodles or spaghetti are gluten-free, they are considered nutritionally deficient as they lack essential proteins, minerals, vitamins, and other bioactive components. As living conditions improve, there has been an increased demand for noodles or spaghetti, leading scientists to focus on their production methods. In order to enhance the nutritional value of YFSP spaghetti, researchers have analyzed various sources of starch and compared the characteristics of fortified YFSP spaghetti with added whey protein concentration (Menon et al., 2016). Menon et al. (2016) achieved this by fortifying the noodles with whey protein concentrate (WPC) and blending YFSP starch with other starches such as banana, cassava, mung bean, and annealed cassava starch. The results showed that the highest protein retention in the cooked noodles was achieved with a 20% WPC fortification. Additionally, the noodles fortified with 40% banana starch (BS) had the lowest starch digestibility, followed by those fortified with 50% annealed cassava starch (ACS). The noodles fortified with BS and ACS also had the highest retention of resistant starch (RS), which is beneficial for digestive health. These noodles also had a medium glycemic index, indicating a moderate impact on blood sugar levels. Furthermore, the sensory evaluation of the noodles revealed high acceptability for those fortified with BS and 20% WPC.

In another study, Thai PFSP snacks made with 50% pregelatinized flour or starch exhibited several desirable qualities. These snacks had a visually appealing appearance, a light and pleasant texture, and they contained high levels of anthocyanins and antioxidants. In addition, the study suggests that PFSP flours can be utilized to create nutritionally balanced thick-slurry dishes when combined with milk powder. This implies that PFSP flour can serve as a valuable ingredient for developing dishes that provide both nutrition and a desirable texture (Phomkaivon et al., 2018). In another study, the evaluation of thick-slurry foods made with different proportions of YFSP granules and milk powder showed that an optimal ratio of 8:2 (*w*/w) of YFSP granules to milk powder resulted in favorable amino acid ratio coefficients and chemical scores. Furthermore, the protein index of the thick-slurry foods increased from 3.52 to 6.39, indicating an improvement in the protein content and quality. In terms of the ingredients used in the thick-slurry foods, saccharose (12%), sodium carboxymethyl cellulose (0.65%), and xanthan gum (0.6%) were evaluated using an orthogonal test. These findings suggest that optimizing the ratio of YFSP granules to milk powder and carefully selecting additional ingredients can enhance the protein content, nutritional value, and sensory attributes of thick-slurry foods made with YFSP(Yan et al., 2022) .Other product of PFSP and YFSP are presented in Table 3.

6. Conclusion and future recommendation

In In conclusion, the economic significance of both PFSP and YFSP roots is widely recognized, but it is important to acknowledge the untapped potential of the leaves and stems of these plants as valuable vegetable resources. While research has primarily focused on the anthocyanins found in PFSP and their color and biological properties, it is crucial to realize the diverse applications of starch and protein present in both PFSP and YFSP, extending beyond the food industry.

To promote sustainable development, it is imperative to fully explore and utilize the range of compounds found in PFSP and YFSP. Further advancements are needed to maximize their potential benefits. PFSP and YFSP offer significant health advantages, such as antioxidant, antidiabetic, anti-cancer, cardioprotective, antimicrobial, hepatoprotective, and immune-enhancing properties. To harness the potential of these bioactive compounds in managing human diseases,

Table 3
Application of YFSP and PFSP in food.

Food class	Formulated productcts	References
Snacks	Snack bar	(Tumuhimbise et al., 2019)
	Soup	(Omoba et al., 2020)
Bakery	Bread	(Nogueira et al., 2018)
		(Nzamwita et al., 2017)
		(Mbogo et al., 2021)
		(Wanjuu et al., 2018)
	Cookies and Crackers	(Adeola & Ohizua, 2018)
		(Lauková et al., 2019)
Dairy products	Fermented milk	(Ramos et al., 2017)
	Yogurt	(Tari et al., 2018)
		(Afiati et al., 2018)
		(Emmanuel et al., 2020)
Flavoring agents	Vinegar	(Wu et al., 2017)
Breverages	Juice (non-alcoholic)	(Park et al., 2019)
	Powder-based (non-alcoholic)	(Luo et al., 2020)
	Alcoholic beverage	(Weber et al., 2020)
		(Li et al., 2017)
	Shochu (alcoholic distilled spirit)	(Sato et al., 2018)
	Beer (alcoholic)	(Humia et al., 2020)
Cereal based	Porridge and fortified	(Kruger et al., 2018)
		(Kruger, 2020)
		(Lauková et al., 2019)
Pasta	Noodles	(Kadiri et al., 2020)
		(Kolarič et al., 2020)
		(Marengo et al., 2018)

appropriate evaluation methods and investigations into their underlying mechanisms within PFSP and YFSP are essential.

The reviewed studies demonstrate promising effects of compounds from PFSP and YFSP in mitigating inflammation. However, the limitations of in vitro studies, particularly the concentrations of anthocyanins applied directly to macrophages, should be considered as they may not reflect realistic circulating concentrations after oral consumption. Future research should prioritize investigating the effects of anthocyanin metabolites in realistic circulating concentrations to better understand their potential anti-inflammatory properties in vivo. Comparative studies should be conducted to determine the specificity of the observed anti-inflammatory effects attributed to the compounds from PFSP and YFSP, distinguishing them from the generic effects of pectin fractions on macrophages.

Furthermore, comprehensive toxicological studies should be conducted to ensure the safety of these bioactive constituents. Encapsulation techniques provide a promising approach to safeguard the bioactive compounds in PFSP and YFSP, enhancing their stability and bioavailability. While various delivery systems have been studied, further research is needed to explore innovative systems such as nanostructured lipid carriers, nanofibers, and liposomes. However, the scaling up of these encapsulation systems for industrial utilization poses challenges that require additional investigation. Considering the rich bioactive compounds present in both PFSP and YFSP, product development can focus on incorporating these sweet potatoes into various forms such as purees, powders, extracts, or juices. These forms can serve as versatile ingredients for a wide range of food products.

Moreover, YFSP has received relatively little research attention, highlighting the urgent need for extensive exploration in this field. Comprehensive research efforts are crucial to unlocking the untapped potential of YFSP in various aspects. By investing in further studies, we can gain a deeper understanding of the potential benefits and applications of YFSP.

CRediT authorship contribution statement

Ngouana Moffo A. Ivane: Writing – review & editing, Visualization, Methodology. **Wenxiu Wang:** Writing – original draft, Supervision, Funding acquisition. **Qianyun Ma:** Supervision, Funding acquisition. **Jie Wang:** Supervision. **Jianfeng Sun:** Writing – original draft, Funding acquisition.

Declaration of competing interest

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Data availability

Data will be made available on request.

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