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Chemical compositions, phytochemicals, and biological activity of dried edible wild fruits

Jintana Sangsopha[1], Anuchita Moongngarm[2,*], Suchada Pornchaiyaphum,[2] Ariya Bandorn[2], Rattiyakorn Khaejonlarp[2] and Bossarin Pluemjia[2]

[1]Department of Applied Food and Nutrition, Faculty of Science and Technology, Phetchaburi Rajabhat University;
[2]Department of Food Technology and Nutrition, Faculty of Technology, Mahasarakham University
Corresponding author email: anuchita.m@msu.ac.th

Edible wild fruits have recently attracted increased attention due to their nutritional compositions, phytochemicals, and biological properties that benefit to human health. In this study, eleven wild fruits were investigated after the drying process using tray drying. Carbohydrates are the major component of dried wild fruits ranging from 37.17% to 75.96%. The highest protein content was found in *Polyalthia debilis* (15.28%) whereas *Ficus carica* L. was high in fiber (33.26%). The highest total phenolic compounds were found in *Irvingia malayana* Oliv. (121.57 mg GAE/g), with highest TFC found in *Terminalia chebula* Retz. *Phyllanthus emblica* L., showed highest DPPH, ABTS and FRAP values. The most potent anticancer properties against MCF-7 and HepG2 cancer cells were shown by *Terminalia chebula* and *Diospyros mollis*, respectively. Highest α-amylase and α-glucosidase inhibitions were observed in the *Canarium subulatum*. Results suggested that dried edible wild fruits are a feasible source of nutrients, phytochemicals, with strong antioxidant and biological activities. These findings can be promoted and increased the utilization of wild fruits as a sustainable food source or food ingredient with applications in food formulations.

Keywords: Anticancer, antidiabetic, antioxidant, chemical compositions, indigenous wild fruit.

INTRODUCTION

Indigenous wild fruits are an important food source in many countries. Different climatic zones in Asian countries allow a broad spectrum of fruit biodiversity with unique compositions and diverse health benefits. Wild fruits contain macronutrients such as carbohydrates, fiber, vitamins, and minerals (Mahapatra *et al*., 2012; Judprasong *et al*., 2013), antioxidants, vitamin C, vitamin E, carotenoids and phenolic compounds as basic components of healthy food (Judprasong *et al*., 2013; Islary *et al*., 2017). However, a plethora of plant materials remains to be studied for nutritional composition.

Recently, the biological properties of phytochemicals such as phenolic contents, flavonoids, carotenoids, phytosterols, vitamin C and vitamin E in indigenous fruits have attracted attention for their antioxidant, anticancer and antidiabetic properties (Tshikalange *et al*., 2017; Sirichai *et al*., 2022). These phytochemicals act against reactive oxygen species by donating an electron to an unpaired molecule to neutralize free radicals. Phytochemicals can reduce the danger of cancer, cardiometabolic and endocrine syndromes (de Carvalho and Conte-Junior, 2021), prevent DNA damage and ameliorate the impacts of many disorders such as Alzheimer's and diabetes (Li *et al*., 2016; Nanasombat *et al*., 2019; Temviriyanukul *et al*., 2021). The natural bioactive substances in the fruit are involved in the prohibition enzymes including α-amylase and α-glucosidase, which are healing targets for diabetes, resulting in lower blood glucose levels (Sun *et al*., 2020). The production and use of native fruits are limited. They are mainly eaten fresh and most consumers are unaware of their health benefits. The lack of wild fruit processing technology and preservation is epitomized by inefficient marketing routes. Recently, the consumption of processed fruit with long shelf-life has increased. Among convenient fruit-based products, dried fruits are accepted by consumers as a helpful, highly nutritious snack that contains substantial amounts of fiber. Wild fruits are normally produced annually and require preservation for year-round commercial accessibility. Drying is one of the most suitable preservation methods.It has been applied to preserve food and reduce the losses of several agricultural produce. The reduction of the moisture content can prolong the shelf life of food and increase its commercial yailability. Drying can also the costs of packaging, handlingand transportation. Previous

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studies mainly reported on the chemical compositions and phytochemicals in fresh fruits, with no information available on the nutritional and phytochemical benefits of dried edible wild fruits. Rybicka *et al*. (2021) reported the nutritional value of 12 commercially available dried fruits. They found dried fruits to be nutritious and have potential applications in wider various food formulations. Investigation of the nutritional compositions, phytochemicals and biological activity of dried wild fruits will promote and increase their utilization as a sustainable food source, thereby improving nutrition security for populations in some countries. Therefore, here, eleven dried edible wild fruits were investigated for their nutritional compositions, phytochemicals, antioxidants and anticancer and antidiabetic activities to determine their medical and health-promoting properties for future applications in functional food formulations.

MATERIALS AND METHODS

***Materials*:** Eleven edible wild fruits (EWF) were collected from the Mixed Deciduous Forest in Mahasarakham Province, Northeast Thailand between 2019 and 2020 including *Antidesma ghaesembilla* Gaertn (Thai name: Mak-mao), *Canarium subulatum* Guillaumin (Mak-liam), *Dialium cochinchinense* Pierre (Mak-keng), *Diospyros mollis* Griff (Ma-kluea), *Ficus carica* L. (Ma-duea), *Flacourtia indica* (Burm. f.) Merr (Ta-kob-pa), *Irvingia malayana* Oliv. Ex A. W. Benn (Kra-bok), *Phyllanthus emblica* L. (Ma-kam-pom), *Polyalthia debilis* (Pierre) Finet & Gagnep (Kon-krok), *Spondias pinnata* (L.f.) Kurz (Ma-kok) and *Terminalia chebula* Retz (Sa-mor).

***Preparation of dried wild fruits*:** Wild fruit samples (approximately 2 kg per replicate, 3 replicates per species) were cleaned using tap water. The edible fraction was collected and dried at 60±2 °C using a tray dryer (NPD Technology Co., Ltd., Thailand) until the moisture content reached 12%. The dried fruit samples were kept in aluminum foil zip lock bags and stored in a refrigerator (5±1°C) until analysis. For analysis, the dried samples were finely ground using a grinding machine (Auto Grinder Machine, 3200W, China).

***Extraction of samples*:** Dried edible wild fruits (1 g) were extracted using 20 mL of 80% methanol and shaken using an ultrasonic bath (30 min) (Sonorex RK 100, Bandelin electronic GmbH & Co., Berlin) before shaking at 150 rpm overnight at room temperature (30 ± 2 °C). The extracts were filtered twicw through No.4 Whatman paper and kept in a refrigerator (5 ± 1 °C) for bioactive compound and antioxidant activity analyses. For the anticancer study, the crude extracts were dried by a rotary evaporator (Buchi R-114, Switzerland). The extracts were then dispersed in Dulbecco's Modified Eagle's Medium (DMEM) (Thermo Fisher Scientific, Inc., Waltham, MA, USA) at a concentration of 500 µg mL^{-1} and used to determine the cytotoxicity of human breast adenocarcinoma and human hepatocellular carcinoma cancer cell lines (Rehman *et al*., 2017).

***Chemical composition analysis*:** Chemical compositions of the dried wild fruits were analyzed following AOAC (2000). Moisture content was determined using a hot air oven (105 ± 2°C) overnight. The Kjeldahl method was used for crude protein estimation, whereas Soxhlet extraction was performed for crude fat content. Ash was obtained after complete oxidation of the organic content using a muffle furnace (550± 2°C). The crude fiber was digested using a fiber extraction **(**VELP Scientifica, Italy**)** before drying and ashing. Total carbohydrate content was calculated by the percentages remaining from the other compositions.

***Determination of total phenolic content (TPC)*:** TPC was determined following the method of Iqbal *et al*. (2005). The extract (20 µL) was pipetted in 20 µL of Folin-Ciocalteu reagent and 80 µL of 7.5% $NaHCO_3$, mixed well and left for 30 min before measuring the absorbance at 750 nm using a microplate reader spectrophotometer (SPECTROstar Nano, Germany). Results were expressed as mg gallic acid equivalent (GAE) g^{-1} dry weight (DW).

***Determination of total flavonoid content (TFC)*:** TFC was evaluated according to Tian *et al*. (2016). The extracts (20 µL) were reacted with 60 µL of DI water, 10 µL of 5% NaNO3, 10 µL of 10% AlCl3.6H2O and 100 µL of 1 M NaOH, and then kept for 30 min before measuring the absorbance at 510 nm" after (2016) Results were presented as mg rutin (RE) g^{-1} DW.

***DPPH radical scavenging activity (DPPH)*:** DPPH radical scavenging assay was evaluated following Moongngarm *et al*. (2022). The extracts (20 µL) were pipetted in 180 µL of 0.2 mM 1,1-diphenyl-2-picrylhydrazyl (DPPH) scavenging in methanol. After mixing and leaving for 30 min, the mixture was recorded for absorbance at 517 nm and results were reported as mg Trolox (TE) g^{-1} and mg vitamin C (VC) g^{-1}.

***2,2'-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) assay*:** The ABTS assay was conducted according to Re *et al*. (1999). The extracts (20 µL) were reacted with 180 µL of ABTS radical cation reagent for 6 min and then determined for absorbance at 734 nm. Results were presented as mg TE g^{-1} and mg VC g^{-1}.

***Ferric reducing antioxidant power (FRAP)*:** The FRAP assay was achieved following Wei *et al*. (2011). The extracts (20 µL) and 180 µL of FRAP reagent were mixed and reacted for 30 min before measuring the absorbance at 593 nm. FRAP values were expressed as mg TE g^{-1} DW and mg ferrous sulfate ($FeSO_4$) g^{-1} DW.

***Cancer cell culture*:** MCF-7 ATCC® HTB-22™ (human breast adenocarcinoma) and HepG2 ATCC® HB-8065™ (human hepatocellular carcinoma) cancer cell lines were purchased from the American Type Culture Collection (ATCC, Manassas, VA, USA). Cancer cells were cultured in Dulbecco's Modified Eagle's Medium (DMEM) accompanied

with 10% of fetal bovine serum, 100 units mL^{-1} of penicillin and 100 µg mL^{-1} of streptomycin under incubation at 37 °C and 5% CO_2. The DMEM was renewed every 2 – 3 days until the confluency of cell lines accomplished 80%. Phosphate-buffered saline (PBS) at pH 7.2 was used for cleaning the cell lines before they were trypsinized with 0.25% Trypsin-EDTA.

***Cytotoxicity assay*:** Cytotoxicity was evaluated using MTT 3-(4, 5-dimethylthiazolyl-2)-2, 5-diphenyltetrazolium bromide) (MTT assay) (Buranrat *et al*., 2017a,b). MCF-7 and HepG2 cells at density 5×10^3 cells/well were incubated at 37 ºC under 5% CO_2 for 24 h. An extract of edible wild fruit (EWF) at a concentration of 500 µg mL^{-1} was pipetted into each well and incubated for 24 h, 48 h and 72 h, respectively. MTT solution (5 mg mL^{-1}) was then added and incubated under the similar conditions for 4 h. The MTT was then replaced with 200 µL of dimethyl sulfoxide (DMSO) and the absorbance was measured at 600 nm using a microplate reader. Cytotoxicity ≤ 50% represented non-cytotoxic whereas cytotoxicity > 50% represented cytotoxic. To observe the morphology, the cancer cells were viewed using an inverted microscope (NIB-100, Xenon, China).

***α-Amylase inhibition assay*:** Inhibition of α-glucosidase activity followed the method of Kazeem *et al*. (2013) with some modifications. Briefly, 20 µL of extract and 20 µL of 100 mM phosphate buffer (pH 6.9) were added. Then, 20 µL of α-amylase (porcine pancreas, Sigma-Aldrich, USA) (30 units mL^{-1}) and 50 µL of 1% starch solution were added and incubated at 37 °C for 30 min. The reaction was stopped by adding 12 µL of dinitrosalicylic acid (DNS) reagent and the mixture was then boiled for 5 min. The absorbance was measured at 540 nm with a microplate reader and results were expressed as α-amylase inhibition (%).

***α-Glucosidase inhibition assay*:** Inhibition of α-glucosidase enzyme activity was performed according to Zhang *et al*. (2016). Briefly, 20 µL of the extract was mixed with 20 µL of 100 mM phosphate buffer (pH 6.9) and then 50 µL of α-glucosidase (from *Aspergillus niger*, Sigma-Aldrich, USA) (5 units mL^{-1}) was added and the mixture was incubated at 37 °C for 15 min. Then, 50 µL of 5 mM *p*NPG (p-Nitrophenyl-α-D-glucopyranoside) solution was added and the mixture was incubated at 37 °C for 15 min. The absorbance was recorded at 405 nm using a microplate reader and results were reported as α-glucosidase inhibition (%).

***Statistical analysis*:** All experiments were completed in triplicate, with results expressed as means and standard deviations. A completely randomized design and one-way ANOVA with Duncan's Multiple Range Test were used for data analysis by SPSS software.

RESULTS

***Chemical compositions*:** proximate compositions of the dried wild fruits revealed significant differences ($p<0.05$), as presented in Table 1. Moisture contents of all dried wild fruit samples were less than 12%, ranging 6.31% in *Polyalthia debilis* (Pierre) to 11.73% in *Irvingia malayana* Oliv. Protein, fat, fiber, ash, carbohydrate and reducing sugar contents significantly differed between the dried wild fruits. Crude protein content ranged from 4.32% – 15.28% while crude fat ranged from 0.22% – 3.24%. *Polyalthia debilis* (Pierre) had the highest protein and fat contents, with lowest protein found in *Flacourtia indica (Burm. f.)* Merr. and lowest crude fat found in *Irvingia malayana* Oliv. Ash content ranged from 2.42% – 7.14%, fiber ranged from 3.53% – 33.26%, total carbohydrate varied from 37.17% – 75.96% and reducing sugar ranged from 4.96% – 10.69%. *Ficus carica* L. had the highest ash, fiber and reducing sugar, whereas highest total carbohydrate was found in *Phyllanthus emblica* L.

***Phytochemicals*:** TPC and TFC indicated differences ($p<0.05$) among the wild fruit species, as shown in Table 2. TPC values ranged from 17.30 – 121.57 mg GAE g^{-1}, highest in *Irvingia malayana* Oliv. and lowest in *Ficus carica* L. TFC values ranged from 0.39 – 8.73 mg RE g^{-1}, with highest content in *Terminalia chebula* Retz. and lowest in *Ficus carica* L.

***Antioxidant capacity*:** Antioxidant activities of dried wild fruits from DPPH, ABTS and FRAP assays are shown in

Table 1. Nutritional compositions of the eleven dried edible wild fruits.

Scientific name	Composition (%)						
	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate	Reducing sugar
Antidesma ghaesembilla Gaertn.	6.51±0.04^{h}	7.79±0.34^{d}	2.40±0.09^{c}	5.65±0.04^{d}	28.69±0.36^{b}	48.96±0.61^{i}	7.44±0.32^{d}
Canarium subulatum Guillaumin	7.49±0.06^{f}	6.00±0.39^{e}	2.56±0.01^{b}	6.99±0.07^{b}	9.80±0.15^{e}	67.15±0.12^{f}	5.56±0.44^{f}
Dialium cochinchinense Pierre.	10.12±0.08^{c}	14.85±0.07^{a}	2.58±0.02^{b}	2.76±0.04^{i}	4.74±0.28^{h}	64.95±0.07^{g}	4.96±0.10^{g}
Diospyros mollis Griff.	8.91±0.06^{d}	10.00±0.29^{c}	0.96±0.02^{f}	2.87±0.04^{h}	8.41±0.39^{f}	68.85±0.19^{e}	9.52±0.17^{b}
Ficus carica L.	6.59±0.08^{h}	14.29±0.51^{b}	1.55±0.05^{d}	7.14±0.10^{a}	33.26±0.41^{a}	37.17±0.12^{j}	10.69±0.24^{a}
Flacourtia indica (Burm. f.) Merr.	10.74±0.04^{b}	4.32±0.28^{g}	1.23±0.01^{e}	3.48±0.00^{g}	6.91±0.25^{g}	73.33±0.07^{c}	4.96±0.12^{g}
Irvingia malayana Oliv.	11.73±0.05^{a}	4.91±0.25^{f}	0.22±0.09^{i}	4.89±0.10^{e}	3.53±0.02^{i}	74.71±0.00^{b}	10.55±0.76^{a}
Phyllanthus emblica L.	6.92±0.08^{g}	5.17±0.03^{f}	0.62±0.06^{g}	2.42±0.03^{j}	8.90±0.16^{f}	75.96±0.13^{a}	5.39±0.39^{f}
Polyalthia debilis (Pierre)	6.31±0.01^{i}	15.28±0.63^{a}	3.24±0.13^{a}	6.89±0.03^{c}	17.96±0.90^{c}	50.32±1.65^{h}	7.75±0.39^{d}
Spondias pinnata (L.f.) Kurz	7.01±0.00^{g}	5.15±0.00^{f}	1.00±0.03^{f}	4.22±0.02^{f}	11.23±0.26^{d}	71.39±0.27^{d}	8.18±2.69^{c}
Terminalia chebula Retz.	8.52±0.29^{e}	7.49±0.06^{d}	0.44±0.01^{h}	2.88±0.03^{h}	8.81±0.25^{f}	71.87±0.46^{d}	6.60±3.06^{e}

Different letters in each column represent significant differences ($p < 0.05$).

Table 2. Phytochemicals and antioxidant activity of the eleven dried edible wild fruits.

Scientific name	TPC	TFC	DPPH		ABTS		FRAP
	(mg GAE g^{-1})	(mg RE g^{-1})	(mg TE g^{-1})	(mg VC g^{-1})	(mg TE g^{-1})	(mg VC g^{-1})	(mg TE g^{-1})	(mg $FeSO_4$ g^{-1})
Antidesma ghaesembilla G.	45.07±0.25^{fg}	3.83±0.08^{g}	12.66±0.15^{f}	17.93±0.16^{f}	9.40±0.43^{g}	9.66±0.24^{f}	9.90±0.61^{f}	14.42±0.70^{e}
Canarium subulatum G.	68.99±3.59^{d}	6.45±0.14^{d}	30.60±1.25^{d}	37.84±1.38^{d}	22.15±0.82^{d}	30.64±0.90^{bc}	51.28±3.28^{c}	74.61±4.73^{b}
Dialium cochinchinense P.	43.49±1.88^{g}	1.32±0.07^{h}	31.12±0.90^{d}	38.43±0.99^{d}	23.56±1.06^{c}	24.51±0.71^{d}	4.41±0.21^{h}	6.25±0.21^{f}
Diospyros mollis Griff.	49.63±1.79^{ef}	3.76±0.06^{g}	11.53±0.29^{f}	16.68±0.32^{f}	9.18±0.11^{g}	9.53±0.79^{f}	8.63±0.35^{fg}	12.39±2.50^{e}
Ficus carica L.	17.30±0.48^{i}	0.39±0.02^{i}	15.00±0.80^{e}	20.52±0.88^{e}	15.70±0.34^{e}	16.39±0.35^{e}	6.24±0.33^{gh}	9.34±0.47^{ef}
Flacourtia indica (Burm.f.)	51.37±1.66^{e}	7.93±0.18^{b}	29.67±0.27^{d}	36.82±0.30^{d}	23.38±0.89^{c}	24.67±1.19^{d}	18.47±0.52^{e}	27.10±1.44^{d}
Irvingia malayana Oliv.	121.57±3.70^{a}	4.63±0.03^{f}	52.04±1.57^{b}	65.53±1.70^{b}	31.64±0.37^{b}	32.48±0.95^{b}	54.29±2.35^{b}	78.52±3.36^{b}
Phyllanthus emblica L.	106.49±4.90^{c}	6.75±0.01^{c}	58.47±1.47^{a}	72.66±1.63^{a}	34.04±0.92^{a}	34.86±2.48^{a}	60.23±1.77^{a}	87.71±2.75^{a}
Polyalthia debilis (Pierre)	24.85±1.36^{h}	0.50±0.03^{i}	15.77±0.83^{e}	21.38±0.92^{e}	11.83±0.42^{f}	16.14±0.46^{e}	8.76±0.26^{fg}	12.97±0.38^{e}
Spondias pinnata (L.f.)	50.95±1.40$_{e}$	6.08±0.28^{e}	30.05±0.90^{d}	37.23±1.00^{d}	21.47±0.88^{d}	29.89±0.97^{c}	45.46±2.01^{d}	66.22±2.89^{c}
Terminalia chebula Retz.	113.04±4.21^{b}	8.73±0.14^{a}	49.84±0.73^{c}	63.08±0.80^{c}	30.81±0.90^{b}	32.01±0.47^{b}	46.79±1.89^{d}	68.34±5.49^{c}

Difference letters in each column represent significant differences (p<0.05). TPC; Total phenolic content, TFC; total flavonoid content, DPPH; 1,1-diphenyl-2-picrylhydrazyl, ABTS; 2,2'-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid), FRAP; Ferric reducing antioxidant power.

Table 2. *Phyllanthus emblica* L. showed strongest DPPH and ABTS scavenging, and highest FRAP values, with DPPH scavenging 58.47 mg TE g^{-1} and 72.66 mg VC g^{-1}, whereas ABTS exhibited 34.04 mg TE g^{-1} and 34.86 mg VC g^{-1}, while FRAP values were 60.23 mg TE g^{-1} and 87.71 mg $FeSO_4$ g^{-1}. *Diospyros mollis* Griff. had the lowest DPPH scavenging (11.53 mg TE g^{-1} and 16.68 mg VC g^{-1}), with ABTS 9.18 mg TE g^{-1} and 9.53 mg VC g^{-1} and FRAP values 8.63 mg TE g^{-1} and 12.39 mg $FeSO_4$ g^{-1}.

***Cytotoxicity on cancer cells*:** The cytotoxicity of dried edible wild fruits on MCF-7 and HepG2 cancer cells is shown in Fig. 1A and 1B. Dried edible wild fruits (500 µ g mL^{-1}) significantly inhibited MCF-7 and HepG2 cancer cell lines (p<0.05) at all incubation times. Cytotoxicity of both cancer cell lines increased at longer incubation time from 24 – 72 h. Cell growth inhibition at 72 h incubation was higher than at 48 h and 24 h. Percentage cytotoxicity values of MCF-7 cancer cells treated with extracts of *Terminalia chebula* Retz., *Diospyros mollis* Griff. and *Antidesma ghaesembilla* Gaertn. were 79.81, 76.67 and 76.00, respectively whereas lowest cytotoxicity was found in *Canarium subulatum* Guillaumin at 23.05%, at 72 h incubation. Highest percentage cytotoxicity on HepG2 cancer cells was found in extracts of *Diospyros mollis* Griff., *Terminalia chebula* Retz. and *Spondias pinnata* (L.f.) Kurz at 83.42, 81.38 and 81.33, respectively with lowest in *Polyalthia debilis* (Pierre) (40.96%) at 72 h of incubation.

***Cancer cell morphology*:** The cell morphology of MCF-7 and HepG2 cancer cells is shown in Fig. 2. Dried edible wild fruit extracts treated with MCF-7 and HepG2 cancer cells induced cell death compared to the control. Cell morphology of both cancer cells showed shrinking and the membrane blebbing pattern and cells broke down to smaller sizes, similar to apoptosis. Apoptosis is single-cell programmed cell death (suicide program) when the cell is activated or stimulated by certain stimuli until the DNA within the nucleus is damaged beyond repair. Extracts treated with MCF-7 and HepG2 cancer cells at 72 h incubation time were strongly effective in inducing apoptosis leading to cell death compared with other incubation times (data not shown).

***α-amylase and α-glucosidase inhibition*:** The effect of edible wild fruit (EWF) extracts on α-amylase and α-glucosidase inhibitory activity is shown in Fig. 3. Results indicated that dried edible wild fruits significantly inhibited α-amylase and α-glucosidase (p<0.05). Inhibitory activity against α-amylase ranged from 8.92% – 31.75%, while α-glucosidase inhibition ranged from 6.30% – 48.98%. The most potent extracts against the activity of α-amylase were *Canarium subulatum* Guillaumin (31.75%) followed by *Terminalia chebula* Retz. (29.00%) and *Spondias pinnata* (L.f.) Kurz (16.75%), with the lowest α-amylase inhibition found in *Ficus carica* L., (8.92%). For α-glucosidase inhibition, the strongest extract was *Canarium subulatum* Guillaumin (48.98%) followed by *Spondias pinnata* (L.f.) Kurz (30.76%) and *Dialium cochinchinense* Pierre (20.21%), with the lowest inhibition found in *Phyllanthus emblica* L., (6.30%).

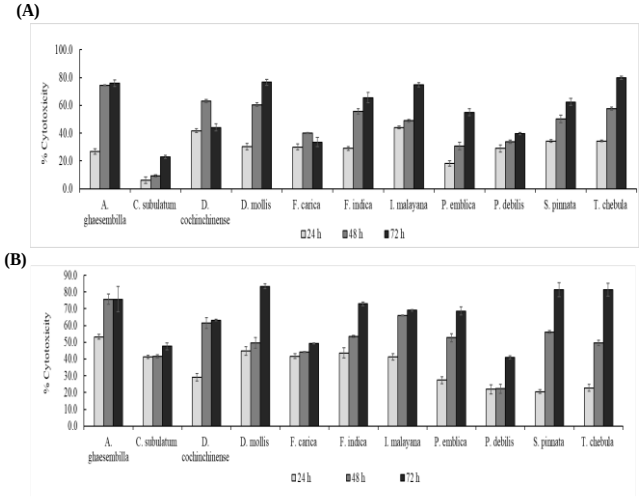

Figure 1. Percentage cytotoxicity (MCF-7) (A) and (HepG2) (B) of edible wild fruit extracts. A. *ghaesembilla*; *Antidesma ghaesembilla* Gaertn., C. subulatum; *Canarium subulatum* Guillaumin, D. cochinchinense; *Dialium cochinchinense* Pierre., D. mollis; *Diospyros mollis* Griff., F.

carica; *Ficus carica* L., *F. indica*; *Flacourtia indica* (Burm. f.) Merr., I. malayana; *Irvingia malayana* Oliv., P. emblica; *Phyllanthus emblica* L., P. debilis; *Polyalthia debilis* (Pierre), S. pinnata; *Spondias pinnata* (L.f.) Kurz, T. chebula; *Terminalia chebula* Retz.

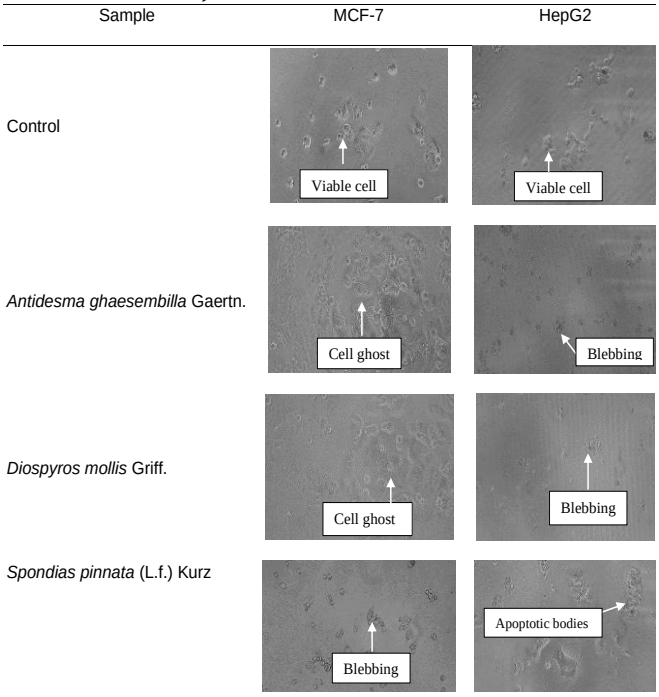

Figure 2. Morphology of MCF-7 and HepG2 cancer cells of some fruits showing highest cytotoxicity after incubation for 72 h compared with the control. A. *ghaesembilla*; *Antidesma ghaesembilla* Gaertn., D. mollis; *Diospyros mollis* Griff., S. pinnata; *Spondias pinnata* (L.f.) Kurz.

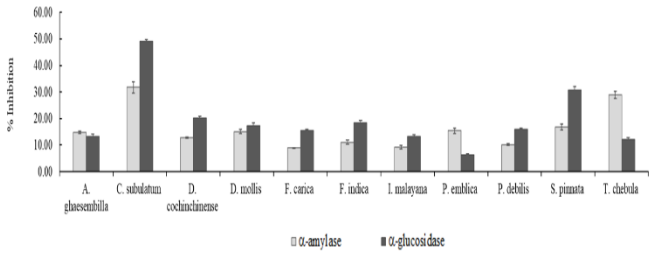

Figure 3. α-amylase and α-glucosidase inhibition. A. *ghaesembilla*; *Antidesma ghaesembilla* Gaertn., C. subulatum; *Canarium subulatum* Guillaumin, D. cochinchinense; *Dialium cochinchinense* Pierre., D. mollis; *Diospyros mollis* Griff., F. carica; *Ficus carica* L., *F. indica*; *Flacourtia indica* (Burm. f.) Merr., I. malayana; *Irvingia malayana* Oliv., P. emblica; *Phyllanthus emblica* L., P. debilis; *Polyalthia debilis* (Pierre), S. pinnata; *Spondias pinnata* (L.f.) Kurz, T. chebula; *Terminalia chebula* Retz.

DISCUSSION

The chemical compositions of the dried wild fruits concurred with Rybicka *et al*. (2021) who studied nutritional values of twelve commercially available dried fruits. They found that the goji berry had high protein content (13.3%), whereas dates and raisins contained the highest carbohydrates (more than 70%). Total dietary fiber contents significantly differed. Lowest fiber was found in raisins (4.4%), with dates, prunes, goji berry and berberis ranging 10% – 21%, chokeberry, sea buckthorn, physalis, haritaki and juniper ranging 30% – 38% and rose hip and noni highest at 53% – 56%. *Polyalthia debilis* had the highest protein content (15.28%) and higher than that recorded by Judprasong *et al*. (2013). All wild fruits were important human food sources and contained a significant amount of nutrients. Wild edible fruits have diverse nutritive values and significant levels of micronutrients and minerals (Mahapatra *et al*., 2012). Hence, the intake of wild fruits promotes health (Judprasong *et al*., 2013). Edible wild fruits were also an excellent source of phytochemicals. Kubola *et al*. (2011) found that Thai wild fruits showed potential as sources of phytochemicals and antioxidant activity. They recorded TPC and TFC of Thai wild fruits as *Phyllanthus emblica* Linn. (65.2 mg GAE g^{-1} and 21.38 mg RE g^{-1}), *Spondias pinnata* (L.f.) Kurz (46.78 mg GAE g^{-1} and 5.39 mg RE g^{-1}), *Terminalia Chebula* Retz. (14.03 mg GAE g^{-1} and 12.69 mg RE g^{-1}) and *Elaeocarpus hygrophilus* Kurz (11.67 mg GAE g^{-1} and 11.13 mg RE g^{-1}), respectively. Judprasong *et al*. (2013) reported TPC of *Phyllanthus emblica* L. as 167 mg GAE g^{-1}, with *Spondias pinnata* (L.f.) Kurz 36.01 mg GAE g^{-1}) whereas TPC of 33 Thai fruits, vegetables and local food plants ranging from 61.16 – 416.07 mg GAE g^{-1} extract, with highest in *Phyllanthus emblica* L. and lowest in banana was reported by Nanasombat *et al*. (2019). Phenolic and flavonoid contents are influenced by several factors such as different growing locations/conditions, harvest time and fruiting stage (Judprasong *et al*. 2013). These studies demonstrated that wild fruits were rich in phytochemicals including phenolic and flavonoid contents as the major types. Consumption of wild fruits provides benefits to health because of their bioactive properties such as antioxidant, antimicrobial, anticancer and anti-inflammatory activity, and DNA protective effect (Li *et al*., 2016).

For the biological activity assessment of the dried wild fruits, it was found that dried wild fruits exhibited strong antioxidant capacity as a result of their contained bioactive compounds. *Phyllanthus emblica* L. presented the strongest radical scavenging according to Judprasong *et al*. (2013), with antioxidant activity using DPPH, FRAP and ORAC higher than *Spondias pinnata* (L.f.) Kurz and *Antidesma velutinosum*

Blume, while Kubola *et al*. (2011) reported that *Phyllanthus emblica* Linn. had DPPH, FRAP and ascorbic acid equivalent antioxidant capacity (AEAC) higher than *Spondias pinnata* (L.f.) Kurz. Wild fruit extracts exhibited significant antioxidant activity but with no toxicity to human kidney cells (Tshikalange *et al*., 2017), while water and lipid soluble antioxidant in fruit pulp was higher than in leaves and fruit shells (Vertuani *et al*., 2002). Phenolic compounds in plants are highly correlated with their antioxidant activity, with the effectiveness of radical scavenging generally dependent on the amount and location of the hydroxyl groups on the aromatic rings of phenolics and flavonoids donated electrons in their structure to free radicals to become inactive radicals (Cai *et al*., 2004).

Moreover, dried wild fruits were an interesting anticancer source with the capability to reduce cancer cells and cell proliferation. Cancer cell inhibition was influenced by the phytochemicals in each fruit variety. Wild fruits possess potent anticancer properties. This finding was supported by Tshikalange *et al*. (2017) who showed that wild fruit pulp extracts were effective against human kidney cells and also showed powerful antioxidant and antimicrobial activity. *Phyllanthus emblica* exhibited strong antioxidant and anticancer activities against HT-29 colon cancer cell lines (Sumalatha, 2013), whereas *Ficus carica* reduced the viability of Hela cells (Khodarahmi *et al*., 2011). *Terminalia chebula* (Combretaceae), *Terminalia bellirica* (Combretaceae), *Phyllanthus emblica* (Euphorbiaceae) and *Terminalia arjuna* (Combretaceae) as the main ingredients of rejuvenators "Jatu-Pha-La-Ti-Ga" possessed high phenolic and flavonoid contents with strong antioxidant and significant anticancer activity against MCF-7 cancer cells (Chusri *et al*., 2015). All dried wild fruits were effective against MCF-7 and HepG2 cancer cells through the extracting mechanism on cytotoxicity. This finding concurred with Chen *et al*. (2016) who studied the impacts of *Calophyllum inophyllum* fruit extract on the proliferation and morphological characteristics of human breast cancer cells MCF-7. The dried wild fruit extracts showed growth inhibition in MCF-7 and HepG2 cancer cells, confirming the results of previous studies using a variety of plant extracts. *Rubus fairholmianus* root extract inhibited MCF-7 cell growth and induced apoptosis (George *et al*., 2016), while *Leccinum vulpinum* induced DNA damage, reduced cell proliferation and generated apoptosis in MCF-7 cells (Reis *et al*., 2016) and *Magnolia officinalis* contained phytochemicals that showed an antiproliferative effect on HepG2 cell proliferation (Maioli *et al*., 2018).

The dried edible wild fruits also showed potential antidiabetic activity evaluated through enzyme inhibitory activity. This might be due to they contain high TPC and TFC that exhibited significant roles in α-amylase and α-glucosidase inhibition (Temviriyanukul *et al*., 2021; Sirichai *et al*., 2022). Numerous fruits, vegetables and some Thai local foods were excellent sources of antioxidant, antidiabetic and anti-acetylcholinesterase activity (Nanasombat *et al*., 2019). α-Amylase and α-glucosidase are carbohydrate hydrolytic enzymes that ameliorate postprandial hyperglycemia and diabetes. α-Amylase can be hydrolyzed as linear α-(1→4) glycosidic linkages to obtain maltodextrin, maltose, maltotriose, maltotetraose and glucose. α-Glucosidases can also be hydrolyzed by maltose and sucrose to obtain smaller molecules of glucose and fructose (Papoutsis *et al*., 2021).

***Conclusion*:** Dried edible wild fruits were an interesting source of nutrients and phytochemicals with high biological activity including antioxidant, anticancer, and antidiabetic activity. Dried Chebula fruit contained high phytochemicals and antioxidants, and expressed high cytotoxicity and inhibitory effects on α-amylase and α-glucosidase. Dried *I. malayana* and *P. emblica* were good sources of TPC, TFC, and antioxidants, whereas *S. pinnata* showed the greatest cytotoxicity (HepG2) and inhibitory effect on α-amylase and α-glucosidase. The study suggested that dried edible wild fruits had health-related attributes, therefore, they could be harvested to prepare processed food through a suitable processing technique i.e. drying in this study. Dried edible wild fruits had the potential as alternative healthy food products which could promote and increase their utilization as a sustainable food source.

***Conflict of Interest*:** Authors declare no competing interests.

***Authors' Contributions statement*:** Jintana Sangsopha performed the experiments, analyzed the data and writing - original draft, writing - review and editing. Anuchita Moongngarm conceptualization, supervision, project administration, funding acquisition, writing - original draft, writing - review and editing. Suchada Pornchaiyaphum, Ariya Bandorn, Rattiyakorn Khaejonlarp and Bossarin Pluemjia performed the experiments.

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