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Sweet potato leaf extract inhibits the simulated *in vitro* gastrointestinal digestion of native starch



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ABSTRACT

Several studies have reported the therapeutic use of caffeoylquinic acid (CQA) derivatives in the management of hyperglycemia. This study used a simulated *in vitro* gastrointestinal digestion model to assess the inhibitory effects of CQA derivatives-rich sweet potato leaf extract (SPLE) and a commercially produced green coffee bean extract (GCBE), each with total polyphenols contents of 452 mg g⁻¹ and 278 mg g⁻¹, respectively, against starch digestion. The changes in the amounts of total polyphenols and total CQA derivatives during *in vitro* gastrointestinal digestion were also examined. The results indicated that both extracts contained substantial levels of CQA derivatives (136 mg g⁻¹ and 83.5 mg g⁻¹ of extract for SPLE and GCBE, respectively). The amounts of total polyphenols and total CQA derivatives in 20 mg of SPLE and GCBE samples decreased from 9.04 mg to 0.58 mg and from 5.56 mg to 0.58 mg, and from 2.72 mg to 0.16 mg and from 1.67 mg to 0.10 mg, respectively, following *in vitro* gastrointestinal digestion and subsequent dialysis. When SPLE and GCBE were accompanied with starch for *in vitro* digestion test, they both exhibited inhibitory effect against starch digestion during simulated intestinal digestion, with estimated half maximal inhibitory concentration (IC₅₀) values of 4.91 mg and 6.06 mg polyphenols, respectively. The amount of glucose permeated through dialysis membrane also decreased significantly in comparison with the extract-negative control. Thus, both SPLE and GCBE were capable of modulating the release of glucose from starch digestion in simulated intestinal tract. The observed inhibitory effects against glucose release were presumably due in part to the presence of CQA derivatives in the tested extracts. The SPLE had higher inhibitory effect against *in vitro* starch digestion than the commercially prepared reference GCBE. Therefore, the SPLE might be used to manage hyperglycemia over the long term.

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1. Introduction

Hyperglycemia, a condition characterized by an abnormal excess of sugar in the blood, is one of the major metabolic disorders in people diagnosed with diabetes mellitus or pre-diabetes impaired glucose regulation. Persistent hyperglycemia can result in damage to the kidneys, liver, eyes, nerves, and blood vessels [1], and the complications in some of these organs may lead to death. One of the therapeutic approaches for decreasing hyperglycemia is to retard the hydrolysis of ingested carbohydrates through the inhibition of carbohydrate hydrolyzing enzymes such as α -amylase and α -glucosidase in the digestive tract [2]. Many synthetic inhibitors of carbohydrate hydrolyzing enzymes are currently available (e.g., acarbose and miglitol), but these compounds are reported to have side effects including abdominal distention, flatulence, and diarrhea from undigested starches [3]. Natural products have been medicinally used by humans for thousands of years, and higher plants provided most of these therapeutic agents [4]. Therefore, focus has been shifted to develop effective yet safer antihyperglycemic compounds from dietary plants with minimal side effects.

Polyphenols are the major photochemicals with antioxidant properties in fruits and vegetables. Research evidences have shown that the consumption of dietary polyphenols may influence carbohydrate metabolism at various levels through the inhibition of α -amylase and α -glucosidase [5–7]. Among these polyphenolic compounds, the phenolic acids such as caffeoylquinic acid (CQA) derivatives are reported to exhibit a potent inhibitory effect against pancreatic α -amylase [8] and α -glucosidase [9]. Cui et al [10] also demonstrate the therapeutic use of CQA derivatives in the management of diabetes-related complications. Green coffee bean is a major source of CQA derivatives (50–120 mg g DW⁻¹) in nature [11,12], which is commercially produced for functional food supplements and cosmetics applications [13,14].

Sweet potato (*Ipomoea batatas* L.) leaves are consumed as a fresh vegetable in many countries, and these leaves also possess a variety of phenolic compounds including the CQA derivatives [15]. However, little is known about the bioavailability of these CQA derivatives after they enter the gastrointestinal tract in human body. Therefore, to enable development of sweet potato leaf extract of reliable quality and efficacy, it is important to verify the bioavailability of these functional compounds in the human gastrointestinal tract. An *in vitro* gastrointestinal digestion model has been used as an alternative to the human model in determining the bioavailability of ingested compounds, even though this system is hindered by its inability to fully mimic the complex processes occurring *in vivo* [16,17]. In this study, an *in vitro* model that simulates the process of human gastrointestinal digestion was conducted to investigate the inhibitory effect of sweet potato leaf extract (SPLE) against starch hydrolysis. A commercially available green coffee bean extract (GCBE) recommended to be used for managing the postprandial hyperglycemia [11] was also included to serve as a comparison. Knowledge of these differences should provide useful information on the potential commercial value of SPLE.

2. Materials and methods

2.1. Chemicals and polyphenol-rich extracts

The Folin–Ciocalteu phenol reagent, gallic acid, pepsin, pancreatin, α -glucosidase, neochlorogenic acid (5-CQA), caffeic acid (CA), chlorogenic acid (ChA), and 4-O-caffeoylquinic acid (4-CQA) were purchased from Sigma Chemical Co. (St. Louis, MO, USA). The 4,5-di-O-caffeoylquinic acid (4,5-di-CQA), 3,5-di-O-caffeoylquinic acid (3,5-di-CQA), 3,4-di-O-caffeoylquinic acid (3,4-di-CQA), and 3,4,5-tri-O-caffeoylquinic acid (3,4,5-tri-CQA) were kindly provided by Dr. Rie Kurata of National Agriculture and Food Organization, Koshi, Okinawa, Japan. The glucose test kit was purchased from Merck (CBA086, Darmstadt, Germany). The GCBE was purchased from Echili Biotechnology (Taichung, Taiwan). All other chemicals used were of analytical grade purchased from Merck.

For preparing the SPLE, the aerial parts of sweet potato variety SM-2 were obtained from Agriculture Research Institute of Taiwan (Wufeng, Taichung City, Taiwan). The leaf blades of expanding leaves and fully expanded first and second leaves, which were reported to contain high levels of CQA derivatives [15], were freeze-dried, ground to powders, and then kept at -20°C deep freezer for further extraction. To obtain the SPLE, 100 g of ground leaf sample was mixed with 80% methanol (v/v) for 24 hours at 25°C (ground sweet potato leaf material/80% methanol ratio of 1:5). After 24 hours of soaking, the slurry was filtered through four layers of cheese cloth, and the resultant liquid fraction was collected and evaporated at 35°C for 24 hours to remove methanol. After evaporation, the residue was then freeze-dried, and the content of total polyphenols in the freeze-dried extract was determined. The freeze-dried SPLE was used for *in vitro* digestion studies.

2.2. Simulated *in vitro* digestion of plant extracts

The *in vitro* digestion was carried out according to the procedures described by Bouayed et al [18]. In brief, a mixture of 50 mL of NaCl (0.9%) and 200 mg of SPLE or GCBE were adjusted to pH 2.0 with 0.1 N HCl, and 160 mg of pepsin (simulated gastric digestion) was added. The mixture was incubated at 37°C in a heated water bath for 1 hour with shaking at 100 rpm. After 1 hour, aliquots (4 mL) of the postgastric digestion mixture were removed and centrifuged at 10,000g for 20 minutes. Then the resultant supernatants were collected and kept frozen for total polyphenols analysis. The remaining fraction of mixture subjected to gastric digestion was placed in a 250 mL glass beaker and 18 mL of a mixture containing 2 mg mL⁻¹ pancreatin and 12 mg mL⁻¹ bile salts (simulated intestinal digestion) were added. A segment of cellulose dialysis tubing (molecular weight cutoff at 10 kDa) containing sufficient NaHCO₃ to neutralize the tested sample's titratable acidity was also added, and the beaker was sealed with paraffin film. After 2 hours of incubation at 37°C , the solution outside the dialysis tubing was taken and centrifuged at 10,000g for 20 minutes. The resultant supernatant was

separated and kept frozen for polyphenols analysis. The solution that had diffused into the dialysis tubing was taken as the sample entered the blood circulatory system [19]. Diffusion of NaHCO_3 out of the dialysis tubing represented the simplest and most convenient means to mimic the gradual rise in pH that occurred as the stomach contents entered the small intestine. The pH of the sample remained in the gastrointestinal tract reached neutrality within 30 minutes.

2.3. Determination of total polyphenols

The contents of total polyphenols in SPLE and GCBE samples collected from different phases of gastrointestinal digestion (both soluble and insoluble fractions) were determined with the Folin-Ciocalteu reagent [20] using a Hitachi U-2900 spectrophotometer (Hitachi High-Tech, Tokyo, Japan), and the absorption values were determined in 750 nm with gallic acid used as a standard.

2.4. High-performance liquid chromatography analyses for CQA derivatives

For high-performance liquid chromatography (HPLC) analysis, 1 g of freeze-dried materials was mixed with 20 mL of 800 g kg^{-1} methanol. The mixture was shaken for 24 hours at room temperature, filtered through a Whatman No. 42 filter paper, and was freeze-dried at -40°C until use. Polyphenols profile of SPLE and GCBE samples was determined according to the method of Jeng et al [15]. The polyphenols sample was filtered through a cellulose acetate membrane ($0.20 \mu\text{m}$, Advantec, Tokyo, Japan), and 10 μL of the filtrate was injected into HPLC (Waters 2996, Waters, Milford, MA, USA) using a ODS (Output Delivery System) column (ODS-AM 301 column, $4.6 \times 150 \text{ mm}$, $5\text{-}\mu\text{m}$ particles; YMC, Kyoto, Japan). The temperature was set at 40°C . The mobile phase consisted of water containing 0.2% (v/v) formic acid (A) and methanol (B). Elution was performed with the linear gradient as follows: 2% B from 0 minutes to 15 minutes, 2% to 45% from 15 minutes to 50 minutes, and 45% B from 50 minutes to 65 minutes. The flow rate was 1 mL min^{-1} . Polyphenolic compounds were then compared with the obtained standards.

2.5. Inhibitory effects of plant extracts against simulated *in vitro* starch digestions

For simulated *in vitro* starch digestion measurements, 1 g of uncooked native corn starch was added to the simulated gastrointestinal digestion system along with 200 mg of SPLE. For comparison purposes, a starch sample that was SPLE- and GCBE-negative was used as a control. The amounts of glucose released in the simulated gastric, intestinal, and dialysis phases were determined separately by using the glucose test kit of Merck according to the manufacturer's instructions.

2.6. Statistical analysis

Sigma Plot 10 (Jandel Scientific, San Francisco, CA, USA) was used to fit the models and to plot the data. The concentration needed to inhibit 50% of hydrolysis activity under the described conditions (IC_{50}) was calculated after plotting the inhibition (%) against the amount of extracted dry mass or extracted total

polyphenols by using the regression analysis of SPSS version 10.0 for Windows (SPSS Inc., Chicago, IL, USA). Analysis of variance was performed by using SPSS version 10.0. Values were given as means of four determinations \pm standard deviation (SD), and means were separated using a least significant difference (LSD) test.

3. Results and discussion

3.1. Changes in the amount of total polyphenols during simulated *in vitro* digestion

In this study, the amounts of the total polyphenols in freeze-dried SPLE and commercially produced GCBE samples were 452 mg g^{-1} and 278 mg g^{-1} extract dry weight, respectively, with SPLE having higher total polyphenols than GCBE (Table 1). The value obtained from SPLE was in the ranges of total polyphenols ($312\text{--}553 \text{ mg g}^{-1}$ dry weight) in the sweet potato leaf extracts reported by Fidrianny et al [21]. The simulated *in vitro* digestion system exhibited significant effects the amounts of total polyphenols detectable in the examined plant extracts (Table 1). Miranda et al [22] reported that the amounts of total polyphenols obtained from sweet potato tubes had increased following *in vitro* gastric digestion. In the current study, following the simulated *in vitro* gastric digestion, both SPLE and GCBE showed significant decreases in the amount of polyphenols comparing to its nondigested original, but with SPLE having more detectable total polyphenols than GCBE (Table 1). When the amounts of total polyphenols in the collected intestinal-digested extract samples were determined, significant decreases in the level of total polyphenols were found in both SPLE and GCBE samples comparing to the amounts of total polyphenols in their respective extract samples collected from gastric-digestion phase (Table 1). Again, the detectable total polyphenols in intestinal-digested SPLE was higher than that in intestinal-digested GCBE. The decreased total polyphenols might be associated with the interaction among some hydrolyzed polyphenols and proteins, which occurs under neutral or slightly alkaline conditions, and then causes changes in the bioaccessibilities of the polymerized phenolic molecules [23].

As shown in Table 1, the amounts of total polyphenols in the digested plant extracts potentially capable of reaching to other target tissues through circulatory system were greatly decreased following gastrointestinal digestion, with only 6% (SPLE) to 21% (GCBE) of nondigested original total polyphenols being detectable in the dialysis phase. The reduced amounts of total polyphenols in the tested plant extract samples collected from the dialysis phase are possibly the result of the interactions between polyphenolic compounds and other added compounds during the simulated intestinal digestion; these interactions may favor the formation of large molecular weight complexes that cannot cross the dialysis membrane [24].

3.2. Changes in the amount of CQA derivatives during simulated *in vitro* digestion

As shown in Table 2, both nondigested SPLE and GCBE samples (20 mg) contained a substantial level of total CQA

Table 1 – Contents of total polyphenols (mg) in the tested sweet potato leaf extract and green coffee bean extract (20 mg) sampled from different *in vitro* simulated digestion phases.

	Total phenols content in original plant extract	Nondigested initial	Gastric phase	Intestinal phase	Dialysis phase	LSD _{0.05}
	mg g ⁻¹	mg 20 mg ⁻¹				
Sweet potato leaf extract	452 ± 11.2	9.04 ± 0.08 ^a	6.18 ± 0.21 ^b	4.66 ± 0.14 ^c	0.58 ± 0.11 ^d	0.82
Green coffee bean extract	278 ± 9.1	5.56 ± 0.79 ^a	2.08 ± 0.08 ^b	2.00 ± 0.38 ^b	0.58 ± 0.12 ^c	1.17

Data are presented as mean ± standard deviation (n = 4). Values with same superscript letters within rows are not statistically different at significant level of p = 0.05 by using a least significant difference (LSD) test.

derivatives (2.72 mg and 1.67 mg, respectively). The measured total CQA derivatives in the freeze-dried SPLE and GCBE extracts were 136 mg g⁻¹ and 83.5 mg g⁻¹ dry weight, respectively. These values are close to the ranges of CQA derivatives detectable in the green coffee bean (50–120 mg g DW⁻¹) reported by Farah et al [11]. Therefore, the sweet potato leaves are also a rich source of CQA derivatives in comparison with green coffee beans. Little is known about the bioavailability of these CQA derivatives after they enter the gastrointestinal tract in the human body. In this study, the HPLC chromatograms showed that a total of eight CQA derivatives including neochlorogenic acid (5-CQA), caffeic acid (CA), chlorogenic acid (ChA), 4-O-caffeoylquinic acid (4-CQA), 4,5-di-O-caffeoylquinic acid (4,5-di-CQA), 3,5-di-O-caffeoylquinic acid (3,5-di-CQA), 3,4-di-O-caffeoylquinic acid (3,4-di-CQA), and 3,4,5-tri-O-caffeoylquinic acid (3,4,5-tri-CQA) were detectable in the nondigested SPLE (Fig. 1B) [15], with 80% of total CQA derivatives in SPLE in the fractions of 3,5-di-CQA and 3,4-di-CQA (Table 2). Similar CQA derivatives were also detectable in nondigested GCBE, but with different distribution profile comparing to that of non-digested SPLE (Fig. 1). Perrone et al [25] reported that the 5-CQA, ChA, and 4-CQA were the major components of detected CQA derivatives in green coffee beans. Similar results were also observed in the current study, with about 75% of total CQA derivatives in examined GCBE were 5-CQA (15%), ChA (42.5%), and 4-CQA (16.8%) (Table 2).

The amounts of total CQA derivatives in the tested SPLE and GCBE sampled from different *in vitro* digestion phases are shown in Table 2. Similar to the changes in the amounts of total polyphenols, the amounts of total CQA derivatives in both SPLE and GCBE extracts significantly declined from 2.72 mg (nondigested control) to 0.16 mg (dialysis phase) and from 1.67 mg to 0.1 mg, respectively, during the simulated *in vitro* gastrointestinal digestion. The HPLC chromatogram of sample collected during the dialysis phase also confirmed these findings (Fig. 1C). Moreover, the totality of 3,5-di-CQA and 3,4-di-CQA representing 80% of total CQA derivatives in nondigested SPLE was decreased to 33% in the sample collected from dialysis phase. Conversely, the totality of 5-CQA, ChA, and 4-CQA was increased from 11% (nondigested control) to 53% (sample collected from dialysis phase). However, almost all of the detectable GCBE-CQA derivatives in the extract samples collected during the dialysis phase were 5-CQA, ChA, and 4-CQA (Table 2).

3.3. Inhibitory effects of tested plant extracts against starch digestion during intestinal digestion phase

The release and transport of glucose, across the intestinal brush border membrane and down to the bloodstream, have attracted much attention as potential targets for hyperglycemia control. In this study, the inhibitory effects of SPLE and GCBE against starch digestion were assessed by using the

Table 2 – Contents of total caffeoylquinic acid (CQA) (mg) in the tested sweet potato leaf extract and green coffee bean extract (20 mg) sampled from different *in vitro* simulated digestion phases.

	5-CQA ¹	CA	ChA	4-CQA	4,5-di-CQA	3,5-di-CQA	3,4-di-CQA	3,4,5-tri-CQA	Total CQAs ²
	% of total CQA derivatives								mg
Sweet potato leaf extract									
Nondigested original	0.4	1.9	10.0	0.6	6.0	58.4	21.7	0.8	2.72 ± 0.20 ^a
Gastric phase	0.7	3.3	16.8	1.0	6.4	55.1	16.8	0.1	1.47 ± 0.26 ^b
Intestinal phase	4.1	0.6	11.3	4.5	25.1	22.2	29.9	2.2	1.28 ± 0.17 ^b
Dialysis phase	16.8	0.1	21.7	14.8	11.6	19.4	13.1	2.5	0.16 ± 0.01 ^c
Green coffee bean extract									
Nondigested original	15.0	0.2	42.5	16.8	8.6	5.6	11.2	0.2	1.67 ± 0.23 ^a
Gastric phase	15.3	0.3	43.1	16.9	8.1	5.4	0.9	23.7	0.89 ± 0.04 ^b
Intestinal phase	27.7	0.0	29.7	24.8	8.9	3.0	5.0	0.0	1.01 ± 0.33 ^b
Dialysis phase	33.4	0.0	33.4	33.3	0.0	0.0	0.0	0.0	0.10 ± 0.01 ^c

Data are presented as mean ± standard deviation (n = 4). Values of total CQAs with same superscript letters within rows are not statistically different at significant level of p = 0.05 by using a least significant difference test.

3,4-di-CQA = 3,4-di-O-caffeoylquinic acid; 3,4,5-tri-CQA = 3,4,5-tri-O-caffeoylquinic acid; 3,5-di-CQA = 3,5-di-O-caffeoylquinic acid; 4-CQA = 4-O-caffeoylquinic acid; 4,5-di-CQA = 4,5-di-O-caffeoylquinic acid; 5-CQA = neochlorogenic acid; CA = caffeic acid; ChA = chlorogenic acid; CQA = caffeoylquinic acid.

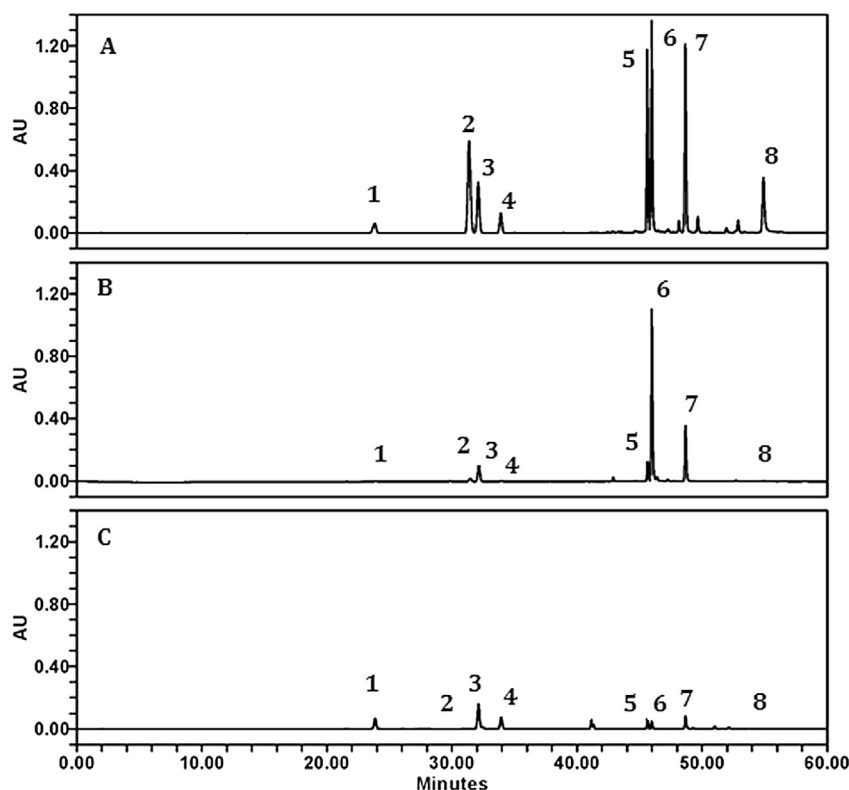


Fig. 1 – High performance liquid chromatography chromatograms of (A) caffeoylquinic acid derivatives detected from standards, (B) nondigested sweet potato leaf extract, and (C) nondigested green coffee bean extract. Peak 1: neochlorogenic acid, peak 2: caffeic acid, peak 3: chlorogenic acid, peak 4: 4-O-caffeoylquinic acid, peak 5: 4,5-di-o-caffeoylquinic acid, peak 6: 3,5-di-o-caffeoylquinic acid, peak 7: 3,4-di-o-caffeoylquinic acid, and peak 8: 3,4,5-tri-o-caffeoylquinic acid.

simulated *in vitro* gastrointestinal digestion (Table 3). Both native and gelatinized starches have been used to assess their *in vitro* digestibility, with cooked starch having a greater hydrolysis rate than native starch [26,27], and the percentages of *in vitro* starch hydrolysis are significantly correlated with the insulin and glycemic responses examined in healthy humans [28]. In this study, a native corn starch was used for *in vitro* gastrointestinal digestion test, and the results indicated that the extract-negative control (starch-added only) sample subjected to *in vitro* gastrointestinal digestion released a total of 11.34 mg of glucose (totality of glucose detected during gastric, intestinal, and dialysis phases) through starch digestion. However, the released glucose was much less than the glucose released from the gelatinized corn starch during *in vitro* digestion [29]. This result is not unexpected because the

granules of native corn starch are semicrystalline and resist hydrolysis by amylases [30]. As shown in Table 3, no glucose was detectable from the extract-negative control sample collected from gastric-digestion phase. These are not surprising because the pepsin added to the simulated gastric-digestion system is an enzyme specific for breaking down protein into amino acids. However, after 2 hours of intestinal digestion, 10.57 mg of glucoses (93% of total released glucose) were detected from the extract-negative control sample, while only 0.77 mg of glucose (7% of total released glucose) were found from the extract-negative control sample collected from dialysis phase (Table 3).

As for the SPLE-added sample, a small fraction of glucose (0.10 mg; 0.88%) was detectable in the gastric digestion phase (Table 3). This small amount of glucose was believed to be

Table 3 – Amounts of glucose released from 1 g of starch, with an addition of 20 mg of tested sweet potato leaf extract and green coffee bean extract, through different digestion phases.

	Sum (G + I + D)	Gastric phase	Intestinal phase	Dialysis phase
Control (nonpolyphenols)	11.34 ± 0.63	0	10.57 ± 0.62 ^a	0.77 ± 0.01 ^a
Sweet potato leaf extract		0.10 ± 0.01 ^b	3.83 ± 0.46 ^d	0.36 ± 0.03 ^c
Green coffee bean extract		0	5.71 ± 0.47 ^c	0.40 ± 0.04 ^c
LSD _{0.05}		0.011	0.399	0.046

Data are presented as mean ± standard deviation (n = 4). Values with same superscript letters are not statistically different at significant level of $p = 0.05$ by using a least significant difference (LSD) test.

released from the added SPLE extract, possibly resulting from the glucose molecules that were released from the hydrolysis of the polymerized polyphenolic glycosides during gastric digestion. Significant differences in the amount of released glucoses were also observed for the extract-added samples collected from intestinal phase (Table 3). The SPLE-added sample only released 3.83 mg of glucose (34% of total released glucose in the extract-negative control treatment) during intestinal digestion. This value was considerably lower than its respective extract-negative control. This result is presumably due in part to the inhibitory effect of accumulated CQA derivatives in the SPLE [8,9]. Narita and Inouye [8] reported that the moncaffeoylquinic and dicaffeoylquinic acids such as 4-CQA, 5-CQA, 3,5-di-CQA, and 4,5-di-CQA showed strong inhibitory effects against pancreas α -amylase. Matsui et al [31] also reported that the 3-CQA, 3,5-di-CQA, 3,4-di-CQA, and 3,4,5-di-CQA exhibited α -glucosidase inhibitory activities. However, some other polyphenolic compounds such as anthocyanins, which were not measured in this study, might also exert an inhibitory effect against starch hydrolysis to some extent [32]. However, no glucose was detectable for the GCBE-added sample in the gastric digestion phase. The amount of released glucose during intestinal digestion was 5.71 mg for the GCBE-added sample (Table 3). As for the dialysis phase (representing the serum available glucose) [19], all the plant extract-added samples showed less amounts of released glucose than the extract-negative control sample (0.77 mg) (Table 3). The amount of glucose release obtained

from the SPLE-added sample was slightly lower than that of the glucose released from the GCBE-added sample.

Various amounts of tested SPLE and GCBE were further tested in order to assess their inhibitory effect against glucose release during the simulated *in vitro* intestinal digestion. The released glucose was reduced by the amounts of added SPLE and GCBE in a dose-dependent manner, with estimated IC_{50} value of 10.86 mg and 21.77 mg extract dry mass, respectively (Fig. 2A and B). The measured inhibitory effects on starch digestion were also calculated and expressed on per unit polyphenols base. The results indicated that the estimated IC_{50} values of the inhibition against starch digestion were 4.91 mg and 6.06 mg of total polyphenols, for SPLE and GCBE, respectively (Fig. 2C and D). These results suggest that both SPLE and GCBE are capable of modulating the starch digestion, but each with different efficacy (SPLE > GCBE).

4. Conclusion

The current study found that both SPLE and GCBE contained considerable amounts of total polyphenols (452 mg g^{-1} and 278 mg g^{-1} of extract, respectively) and total CQA derivatives (136 mg g^{-1} and 83.5 mg g^{-1} of extract, respectively). Significant differences in the profile of CQA derivatives existed between two extracts. The SPLE had 80% of the total CQA derivatives in the fractions of 3,5-di-CQA and 3,4-di-CQA, whereas GCBE had 75% of total CQA derivatives in 5-CQA,

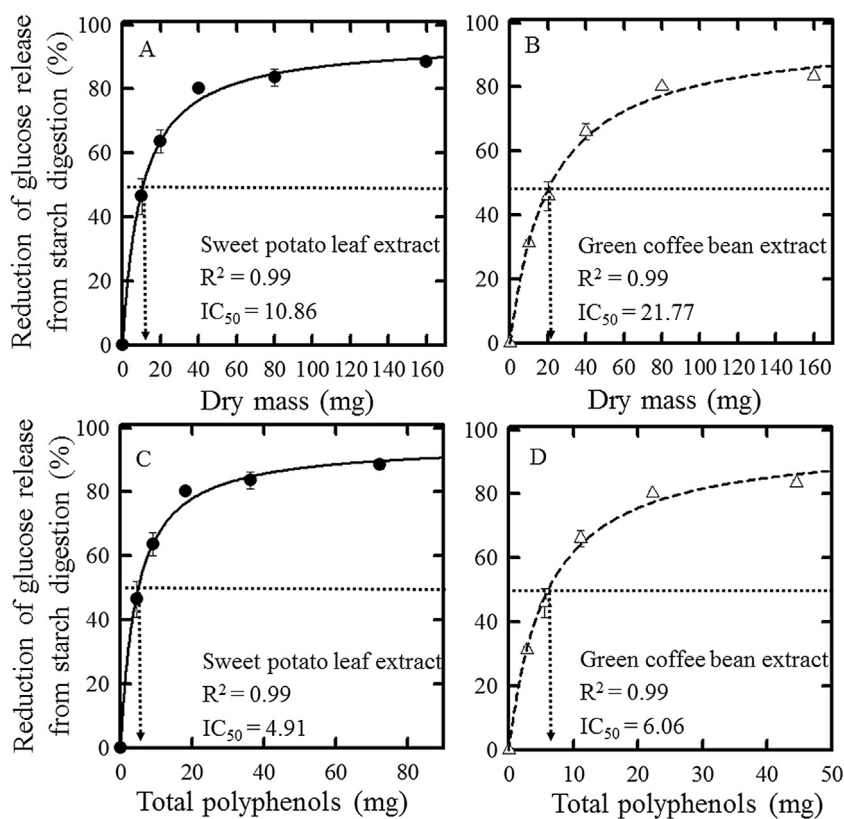


Fig. 2 – Inhibitory effects of sweet potato leaf extract (A,C) and green coffee bean extract (B,D) against starch digestion, expressed on per unit extract dry weight (A,B) and on per unit polyphenols (C,D), during simulated *in vitro* intestinal digestion.

ChA, and 4-CQA. The simulated *in vitro* gastrointestinal digestion significantly affected the amounts of total CQA derivatives in the two tested plant extracts sampled during the intestinal phase. The amounts of total CQA derivatives in 20 mg of SPLE and GCBE decreased from 2.72 mg to 1.28 mg and from 1.67 mg to 1.01 mg, respectively, following *in vitro* gastrointestinal digestion. When native corn starch was digested together with SPLE and GCBE, the relatively lower levels of CQA derivatives remaining in the intestinal digestion phase exhibited potent inhibitory effect against starch digestion. As a result, a relatively lower amount of glucose was released during intestinal digestion, and the amount of glucose permeated through the dialysis membrane were decreased significantly, with SPLE-added sample having a slight lower glucose level than the GCBE-added sample. It appears that both SPLE and GCBE may be capable of modulating the carbohydrate absorption, but with SPLE having a greater efficacy than GCBE. Therefore, the SPLE appears to be an effective starch digestion modulator, which might be used to manage hyperglycemia in the long term.

Conflicts of interest

There is no conflict of interest.

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