

***In vitro* starch digestibility and estimated glycemic index of functional rice with cherry (*Muntingia calabura*) leaves extract**

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Abstract

This study aims to investigate *in vitro* starch digestibility and estimated glycemic index (EGI) of functional rice with cherry leaves extract. Functional rice was made from rice flour with addition of cherry leaves extract with concentration percentage of 0% (FR0), 5% (FR5), 10% (FR10), 15% (FR15) and 20% (FR20). The functional rice was made using extrusion technology (a single-screw extruder). The result showed that the addition of cherry leaves extract on functional rice significantly reduced starch digestibility and EGI, and increased resistant starch (RS) of functional rice. Among the concentration of extracts, the lowest starch digestibility (79.58%) and EGI (46.37) were found in functional rice with 20% addition of cherry leaves extract. On the other hand, functional rice with 20% cherry leaves extracts also had the highest RS (5.95%) compared to other concentrations. Thus, there could be potential health associated with the incorporation of phenolic-rich cherry leaves extract into food to slow starch digestion, EGI, and increase RS.

1. Introduction

An unhealthy lifestyle tends to increase the occurrence of degenerative diseases. These diseases occur due to chronic and non-contagious deterioration of organs functions. To date, degenerative diseases which have become the leading cause of death, both in the world and in Indonesia, are dominated by four main types: cardiovascular disease, cancer, chronic respiratory disease, and diabetes. The risk factors that contribute the most to these diseases include unhealthy eating patterns. For example, an unhealthy diet can lead to an increase in glucose, lipids, and blood pressure, as well as obesity that leads to the occurrence of diabetes mellitus (DM). Therefore, dietary control becomes a way to prevent degenerative diseases, especially DM. Thus, a diet low in fat, cholesterol, sugar, and salt, and high consumption of fiber and phytochemicals is recommended (Sadek *et al.*, 2015).

Rice is a staple food that contains high starch. As a staple food, rice contributes significantly to the increase in blood sugar, hence, it becomes one of the risk factors for DM disease (Hu *et al.*, 2013). Decreased digestibility of rice starch can prevent the occurrence of hyperglycemia. Meanwhile, the starch modification

process, a method to reduce the digestibility of rice starch, can cause digestive enzymes unable to recognize the modified starch, hence, inhibit the work of enzymes. Decreased digestibility of starch is positively correlated with the glycemic index (GI) of food (Zhu *et al.*, 2015).

The glycemic index (GI) of food is the level of food according to its effect on blood glucose levels. Foods that are easily digested can quickly increase blood glucose levels so the GI value of the food is classified as high. Conversely, foods with a low GI will slowly raise blood glucose levels. Researches have shown that a low GI diet in people with DM can improve blood glucose control (Miller *et al.*, 1992). Efforts to reduce the value of GI in rice can be done with the addition of anti-nutritional substances such as phytic acid and tannins (Thompson *et al.* 1984; Forester and Siagan, 2004). Tannin compounds or polyphenols are widely found in various plants, including on cherry leaves. The purpose of this study was to determine the effect of cherry leaf extract fortification on *in vitro* digestibility and estimated glycemic index.

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2. Materials and methods

2.1 Materials and reagents

Rice of IR64 variety and cherry leaves were obtained from Sleman Regency of Yogyakarta, Glyceryl Mono Stearate (GMS), Amyl glucosidase (Sigma No. A9913), Sodium acetate buffer pH = 4.75, KOH, Peridochrom Glucose GOD-PAP (Ref 676 543, Boehringer), pepsin, buffer KCl-HCl pH 1.5 (Sigma No. P7012), α -amylase, Tris-maleate buffer pH 6.9 (Sigma No. A-3176), HCl sodium acetate buffer pH 4.75, DNS, PNP-Gluc.

2.2 Extraction of cherry leaves

The cherry leaf was extracted based on the following method by Zakaria *et al.* (2007). Selected fresh cherry leaves were dried using a cabinet drier for 72 hrs. The dried leaves were then ground into small particles. The cherry leaves powder was sifted using the 60-mesh sieve to produce a similar size powder. The extraction process of cherry leaves was carried out by boiling the obtained cherry leaves powder for 10 mins with the ratio of 1:10 (cherry leaves powder:water) (m/v). When the boiled concentrate had cooled down at room temperature, it was then sieved using the sieving fabric to separate it from the residue of cherry leaves extract. Afterward, the cherry leaves pulp was then boiled using distilled water for 10 mins with the ratio of 1:10 (m/v); then, the sieving process was repeated.

2.3 Functional rice making

Functional rice (FR) production was modeled after the production of analog rice (Noviasari *et al.*, 2016). The IR64 rice variety was soaked for 2 hrs, then milled and dried within the cabinet drier with a temperature of 50°C for 12 hrs. When the rice flour was dried, it was meshed using an 80-mesh sieve. Further, the functional rice was produced by evenly mixing 1 kg of rice flour with 2% of GMS as plasticizer from the total dough and 30% of water. Supplementation of cherry leaves extract was added with the following concentration of 0% (FR0), 5% (FR5), 10% (FR10), 15% (FR15), and 20% (FR20) toward the total volume of water used in the production of functional rice. The dough was then poured into a single thread extruder machine to produce rice, then, the produced rice was dried within a cabinet drier for 12 hrs. The dried functional rice was stored in a cool room of 4°C. To analyze total starch, resistant starch and *in vitro* starch digestibility of the functional rice, the rice was meshed and sieved using an 80-mesh sieve.

2.4 Total starch

Total starch was analyzed based on Goni *et al.* (2007). Quadruplicated samples of 50 mg were dispersed

in 6mL of 2M KOH and constantly shaken at room temperature for 30 mins. Then, 3 mL of 0.4 M Sodium acetate buffer with pH = 4.75 of amyl glucosidase (Sigma No. A9913) were added to this suspension and incubated for 45 mins at 60°C in a controlled shaking water bath. Starch glucose was measured with Peridochrom Glucose GOD-PAP (Ref 676 543, Boehringer). It was found that the conversion factor from glucose to starch was 0.9.

2.5 Resistant starch content analysis

Resistant starch (RS) content analyzed based on Goni *et al.* (2007). About 100 mg of grounded samples were incubated with 0.2 mL of pepsin solution (1 g pepsin/10 mL buffer KCl-HCl pH 1.5 (Sigma No. P7012)). The first incubation was done at 40°C for 60 mins with constant shaking. Then, 1 mL of the α -amylase solution (40 mg α -amylase/1 mL Tris-maleate buffer pH 6.9) (Sigma No. A-3176) was added to the solution. The second incubation was performed at 37°C for 16 hrs with constant shaking. The hydrolysates obtained were then centrifuged at 3500 rpm for 15 mins and the residues from centrifugation were washed with 10 mL of distilled water. The centrifugation was repeated two times. Then, 3 mL distilled water was added to the residue. Approximately 3 mL of 4 M KOH was added and kept for 30 mins at room temperature. After 30 mins, 5.5 mL of 2 M HCl and 3 mL of 0.4 M sodium acetate buffer pH 4.75 were added. Then, 80 μ L of amyl glucosidase (Sigma No. A9913) was added and incubated at 60°C for 45 mins with constant shaking. After that, the centrifugation was done at 3500 rpm for 15 mins and the residue was washed with 10 mL of distilled water. The centrifugation was repeated two times and the supernatant was combined with that obtained previously. The final volume was made up of 25-1000 mL depending on the resistant starch content. The glucose content was measured using a glucose oxidase-peroxidase kit. The resistant starch content was calculated as mg glucose \times 0.9. Digestible Starch (DS) has been calculated by the difference between TS and RS.

2.6 *In vitro* starch digestion rate, hydrolysis index, and estimated glycemic index determination

In vitro starch digestion rate, hydrolysis index (HI), and EGI was determined by Goni *et al.* (2007). A 50 mg of grounded food samples were incubated with 10 mL buffer KCl-HCl with a pH of 1.5 and homogenized for 2 minutes. Pepsin solution (0.2 mL) (Sigma No. P7012) was added and incubated at 40°C for 60 mins. Then, the volume was made up to 25 mL with a Tris-maleate buffer solution pH 6.9. Then, 5 mL of Tris-maleate buffer solution containing 2.6 IU α -amylase (Sigma No.

A3176) was added and incubated at 37°C. The aliquot samples (0.1 mL) were taken from each tube every 30 mins from 0 to 180 min and placed in a tube at 100°C. Then, 1 mL of sodium acetate buffer solution pH 4.75 was added. After that, 30 µL of amyloglucosidase (Sigma No. A9913) was added and incubated at 60°C for 45 mins. The glucose content was measured using a glucose oxidase-peroxidase kit. The digestible starch was calculated as mg glucose × 0.9. The *in vitro* starch digestion rate was expressed as the percentage of total starch hydrolyzed at different times. The area under the curve (AUC) was calculated as follows:

$$AUC = C_{\infty} (t_f - t_0) - (C_{\infty} / k) [1 - \exp[-k (t_f - t_0)]]$$

Where C_{∞} corresponds to the concentration at equilibrium (t_{180}), t_f is the final time (180 mins), t_0 is the initial time (0 min) and the kinetic constant. A HI was calculated by comparison with the AUC of a reference food (fresh white bread). The EGI was estimated using the following equation:

$$EGI = 39.71 + (0.549 \times HI)$$

2.7 Determination of glucose-adsorption capacity

Glucose-adsorption capacity of each dietary fiber sample was measured according to the reported method (Zheng *et al.*, 2019). Each dietary fiber sample (0.25 g, recorded as W) was mixed with 25 mL of glucose solution (recorded as V) at different concentrations (0.5–50 mM, recorded as G1). The mixture was stirred and incubated in a thermostatically controlled water bath at 37°C for 6 hrs and then centrifuged at 4000×g for 15 mins. The glucose content in 1 mL of the supernatant was determined using glucose assay kits and recorded as G2. Each test was repeated three times and the glucose-adsorption capacity (µmol/g) was calculated using the following equation:

$$\text{Glucose-adsorption capacity } (\mu\text{mol/g}) = (G1 - G2)/W \times V$$

2.8 Measurement of inhibitory capacity of α -amylase

The α -amylase inhibitory capacity was determined according to the reported method (Zheng *et al.*, 2019) with slight modifications. Briefly, 100 µL of different concentrations of fiber sample (range 0.2–1.0 mg/mL) or acarbose solution (positive control) were added to 1 mL of the assay mixture containing 0.02M sodium phosphate buffer (pH = 6.9) and α -amylase (0.83 µg/mL), then incubated in a water bath at 37°C for 10 mins. This was followed by incubation at 37°C for another 10 mins after adding 200 µL of potato starch solution (1% w/v). The reaction was terminated by adding 2 mL DNS and placing it in a boiling water bath for 5 mins. After cooling down to room temperature, the final mixture was

diluted with 9 mL of distilled water and the absorbance was measured at 540 nm and recorded as A1. The control without any fiber sample was also measured and recorded as A2. The results were expressed as % inhibition calculated using the formula:

$$\alpha\text{-amylase inhibition rate } (\%) = (A2 - A1)/A2 \times 100$$

2.9 Measurement of inhibitory capacity of α -glucosidase

Based on the amount of p-nitrophenol released from PNP-Gluc, the inhibitory capacity of α -glucosidase was measured (Hlila *et al.*, 2015). A mixture consisting of 0.6 mL of phosphate buffer (0.1 M), 0.2 mL of α -glucosidase (5 U/mL) and 0.2 mL of different concentrations (range 0.2–1.0 mg/mL) of fiber sample or acarbose solution (positive control) was prepared. The mixture was pre-incubated in a water bath at 37°C for 10 mins and then mixed with 0.4 mL of PNP-Gluc (20 mM). After 30 mins the reaction was stopped by adding 2 mL of 0.1M of sodium carbonate. In the control tubes, the same amount of buffer was used to replace the fiber sample. The production of p-nitrophenol was quantified by measuring the absorbance at 405 nm, the values for the test and control tubes were recorded as A1 and A2 respectively. The inhibitory percentage was calculated using the following formula:

$$\alpha\text{-glucosidase inhibition rate } (\%) = (A2 - A1)/A2 \times 100$$

2.10 Statistical analysis

All data were expressed as means ± standard deviation. Statistical analyses were performed using SPSS.22 statistical software. An ANOVA followed by Duncan's multiple range test (DMRT) were used to evaluate treatment effects at the significance level of $p < 0.05$.

3. Results and discussion

The functional rice referred to in this study is parboiled rice added cherry leaf extract. Because rice is believed to have functional capabilities as a functional food attribute, it is referred to as functional rice that will be studied in this study, among others, total starch, resistant starch, *in vitro* starch digestibility, and estimated glycemic index.

3.1 Starch fraction

Starch digestion in this study is divided into digested fractions and undigested starch or resistant starch. Functional rice (FR20) has the lowest value for total starch, while control rice (FR0) has the highest value. Inversely proportional to resistant starch the highest value is in the treatment of rice with the addition of 20% cherry leaf extract (FR20). The more concentration of

cherry leaf extract added, the total starch content decreases. This is due to the bond between flavonoids from cherry leaf extract and starch from rice, which forms a starch-flavonoid complex, making it difficult to digest by enzymes and become resistant starch. As a result of the formation of the starch-flavonoid complex, Table 1. Total starch (TS), resistant starch (RS) and digestible rice (DS) of functional rice.

Sample	TS (%dk)	RS (%db)	DS (%db)
FR0	73.97±3.13 ^b	1.98±0.38 ^a	72.00±2.78 ^c
FR5	71.17±0.94 ^{ab}	3.07±1.17 ^a	68.10±1.26 ^c
FR10	68.68±2.09 ^{ab}	3.30±1.24 ^a	65.38±1.08 ^{bc}
FR15	62.10±7.68 ^a	3.56±1.02 ^a	58.54±6.67 ^{ab}
FR20	61.37±3.43 ^a	5.95±0.57 ^b	55.42±3.31 ^a

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

the total amount of starch is reduced as seen in Table 1.

The results showed that the control sample (FR0) had a 1.98% amount of resistant starch, while the sample added with cherry leaf extract was higher than the control that are 3.07% (FR5), 3.30% (FR10), 3.56% (FR15) and 5.95% (FR20). The data showed that the addition of cherry leaves extract had a noticeable effect on the digestibility of functional rice starch. Takahama and Hirota (2018) noted that the presence of flavonoids in products can contribute to the number of resistant starches that may be produced by hydrophobic interactions.

According to Dupuis *et al.* (2014), resistant starch in foodstuffs is divided into five groups: (a) very low (<1%), (b) low (1 – 2.5%), (c) moderate (2.5 – 5%), (d) high (5 – 15%) and (e) very high (>15%). Based on the results of resistant starch testing on control (FR0), it is included in the low group (1.98%). Meanwhile, rice added with cherry leaves extract FR5, FR10 and FR15 belong to the moderate group, whereas FR20 belongs to the high resistant starch group. This, according to Lemlioglu *et al.* (2012) is due to phenolic compounds, which can also directly bind the digestive enzymes (sucrase, amylase, trypsin, chymotrypsin, and lipase), reduce enzyme function, and further, slow down the digestibility rate of starch-based products.

The presence of resistant starch can be influenced by several factors such as processing (heating and cooling), types of starch (comparison of amylose and amylopectin content), the physical state of starch (hydration level, particle size), and the presence of other components, e.g. lipids (Marsono, 1998). The processing of starchy food can change the quantity of RS. Generally, foods with high starch content processed by heating, with or without

the addition of water, before consumption. Heating starch with the presence of excess water results in the gelatinization of starch, which is a process that includes hydration and dissolution of starch. Cooling of starches that have undergone gelatinization can change the structure of starch leading to the formation of new insoluble crystalline structures, or retrogradation. Retrogradation results in a decrease of starch digestibility in the small intestine of humans who consume it (Marsono and Topping, 1993). Starch processing with extrusion process with certain temperature, water content, and speed of the press engine can produce type 3 of resistant starch. Type 3 resistant starch (RS3) is formed due to heating and cooling processes, such as in bread, corn emping, and cooked or refrigerated potatoes, or retrogradation of amylose (Marsono, 2016). RS3 stands for resistant starch, which is a starch fraction that is formed when amylose is retrograded during the cooling phase of starch gelatinization. This is consistent with rice extrusion products made with extruders, in which starch is gelatinized first before being extruded. When the product is dried and chilled, the starch will be retrograded to reduce the water content and achieve a good rice texture.

3.2 *In vitro* starch digestibility

Starch will be absorbed by the body after changing first into glucose. The enzymes needed to perform the task are α -amylase produced by the salivary glands and pancreas. However, the enzyme α -amylase derived from saliva is inactivated by a low pH in the stomach so that it plays little role in the process of starch digestion. α -amylase enzymes derived from the pancreas will play a role in breaking down starch within the small intestine. The process will be completed in the brush border of the small intestine with the help of the enzyme glucoamylase and α -dextrinase. In this section, there will also be the breakdown of disaccharides into monosaccharides (Higgins, 2004).

In this study, starch digestibility testing was conducted *in vitro* using several enzymes. The results of the starch digestibility test can be seen in Figure 1. Digestive data showed that rice treatment with the addition of cherry leaves extract had a lower digestibility compared to control (without the addition of cherry leaves extract). This is because the bond between phenol compounds and rice components results in starch that cannot be recognized by enzymes and inhibits enzyme activity, thereby, decreasing the starch digestibility. The higher the level of phenols that bind to the components of rice, the stronger the inhibition of the enzyme alpha-amylase (starch breaker), and the lower the starch digestibility. These results are similar to studies from Du *et al.* (2019) and Wu *et al.* (2009), which reported that

tea polyphenols (TP) extracted from tea leaves, have the potential to inhibit enzymes that hydrolyze carbohydrates and reduce the digestibility of polysaccharides such as starch. Tea polyphenols influenced the crystalline region of the starch, as well as the starch's X-ray diffraction peak and the type B pattern, which gradually vanished as the concentration of added tea polyphenols. Wang *et al.* (2018) also found in their study that a decrease in

leaves extract. The largest reduction of HI was achieved for FR20 sample.

The glycemic index (GI) is the level of food according to its effect on blood sugar. IG is calculated based on the ratio of the test food glucose response curve to standard foods (glucose or fresh bread). The higher the glucose response, the higher the GI value. Arif and Budiyo (2013) described that low and high GI foods can be distinguished based on the speed of digestion and absorption of glucose and fluctuations in levels in the blood. Foods with low GI experience a slow digestion process, so the rate of emptying of the stomach is slow. This causes food suspense to more slowly reaching the small intestine so that the adsorption of glucose in the small intestine becomes slow. Finally, fluctuations in blood glucose levels are relatively small which is indicated by a strong glucose response curve. Conversely, high GI foods are characterized by the rate of stomach emptying, carbohydrate digestion, and relatively rapid absorption of glucose, so fluctuations in blood glucose levels are also relatively high. This is because glucose absorption mostly only occurs in the upper small intestine.

Value of food GI are grouped into low (<55), medium (55-70), and high (>70) (Rimbawan and Siagian, 2004). The results of the EGI calculation show the highest value is in the FR0 treatment or control and the lowest value is in the FR20 treatment. These results pointed out that the addition of cherry leaves extract to rice, lower the glycemic index of rice. This is because the addition of extracts in functional rice decreases starch digestibility so that the IG value of functional rice becomes low.

The EGI calculation revealed that FR15 and FR20 samples were included in rice with a low glycemic index, whereas FR0, FR5, and FR10 samples were included in rice with a moderate glycemic index. Some factors that affect the glycemic index value of food, as well as the speed of digestion and adsorption of carbohydrates, are the processing, the storage, the proportion of amylose-amylopectin levels, the gelatinization levels, and the particle size. Other food components such as dietary fiber, anti-nutrition substances, and organic acids also affect the glycemic index, digestion speed, and carbohydrate absorption of food (Miller, 1992; Rashmi and Urooj, 2003; Carreira *et al.*, 2004)

High levels of resistant starch due to the addition of cherry leaves extract also resulted in low EGI values. The glycemic index value of functional rice is determined by two main factors; 1) the process of food processing, namely extrusion and 2) the addition of food anti-nutrition substances, namely cherry extract.

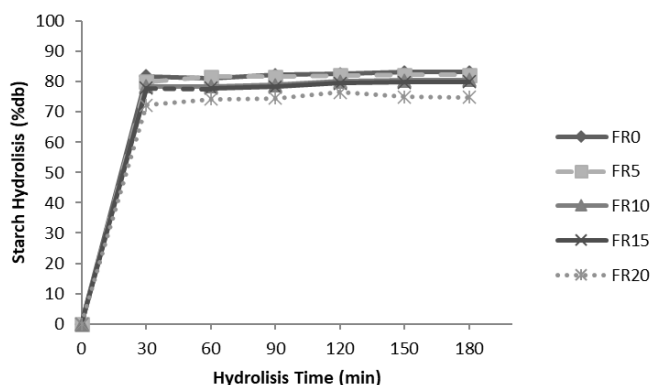


Figure 1. *In-vitro* starch digestibility of functional rice. digestibility is caused by flavonoids that inhibited the α amylase and α glucosidase enzymes.

Further, Lemlioglu *et al.* (2012) found that phenolic compounds formed complexes with proteins and carbohydrates in the diet resulted in changes of chemical structure that have an impact on digestion, thus, reducing starch digestion. Hence, in this case, phenolic compounds act as natural inhibitors. Interactions of starch and flavonoid are mostly non-covalent, hydrophobic interactions, which are governed by molecular weight, solubility, size, and conformational flexibility of phenolic compounds, proteins, and starches.

3.3 Hydrolysis index and estimated glycemic index

The hydrolysis index (HI) represents the portion of starch that is theoretically digestible (under the condition of the study (Ezeogu *et al.*, 2005). Using the HI value in the formula by Goni *et al.* (1997), the (EGI) for all samples was significantly different (Table 2). The HI value significantly decreased with the increase of cherry

Table 2. Hydrolysis index (HI) dan estimated glycemic index (EGI) of functional rice

Sample	HI	EGI
FR0	50.09±1.06 ^c	67.21±0.58 ^c
FR5	34.14±0.80 ^b	58.45±0.44 ^b
FR10	33.46±0.83 ^b	58.08±0.45 ^b
FR15	12.96±0.33 ^a	46.82±0.18 ^a
FR20	12.13±0.62 ^a	46.37±0.34 ^a

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p < 0.05$).

Anugrahati *et al.* (2015) that rice with a high resistant starch content (21.13%) had the lowest hydrolysis index (31.14) and estimated glycemic index (56.80) compared to other cooked rice samples.

3.4 Glucose adsorption capacity

The glucose adsorption capacity of selected rice extracts at different glucose concentrations (0.5 mM, 1 mM, 5 mM, 20 mM and 50 mM) are presented in Figure 2. The glucose adsorption capacity of the sample is directly proportional to the molar concentration of glucose and an increase in glucose concentration binds the larger amount of glucose. All of the samples had favorable results, indicating that glucose absorption occurs even at the lowest concentration (0.5 mM), limiting the amount of glucose accessible for transport across the intestinal lumen and as a result, delaying postprandial hyperglycemia. The results of statistical analysis showed the addition of extract cherry leaves significantly ($p < 0.05$) increase to glucose adsorption. This may be due to the presence of dietary fiber content, both insoluble and soluble fibers. In addition, the

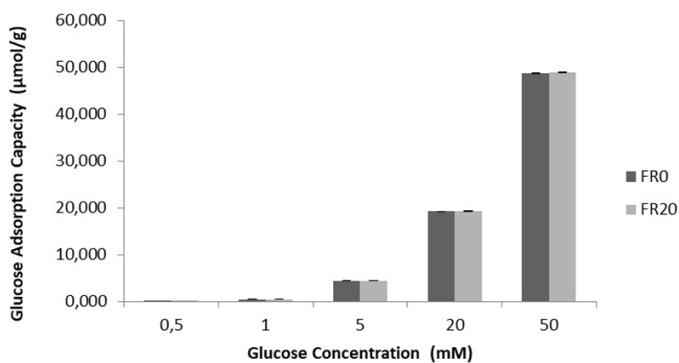


Figure 2. Glucose adsorption capacity of functional rice.

presence of resistant starch content also absorbs glucose in glucose solutions from different concentrations.

Bhutkar (2018) demonstrated *in vivo* and *in vitro* studies of glucose adsorption, the presence of delayed adsorption of glucose in the digestive tract is determined primarily by the viscosity of soluble polysaccharides. This is due to insoluble and soluble fiber. Dietary fiber can bind to glucose so that it does not show adsorption capacity for glucose when glucose concentration decreases. Similar observations were reported by Chau *et al.* (2004), for the insoluble fiber-rich fraction isolated from *Averrhoa carambola*.

3.5 Inhibitory capacity of α -amylase and α -glucosidase

Alpha-amylase and α -glucosidase are known as enzymes responsible for the absorption and hydrolysis starch. It has been well documented that inhibition of α -amylase and α -glucosidase is strongly associated with significant reductions in blood glucose levels after meals.

The released glucose is absorbed throughout the intestinal enterocytes through a specific transporter. Inhibition of digestive enzymes or glucose carriers will reduce the rate of glucose release and absorption in the small intestine and consequently, suppress postprandial hyperglycemia. Acarbose, a popular anti-diabetic drug that can inhibit the activity of α -amylase (Gabbia *et al.*, 2017) is used as a positive control (Figure 3).

Statistical test results showed the addition of cherry leaves extract (FR20) had significantly ($p < 0.05$) on the inhibitory capacity of the enzymes α -amylase and α -glucosidase. This is caused by phenolic compounds in cherry leaf extract that can inhibit the work of both enzymes. The result is in line with Forester *et al.* (2012) which pointed out that EGCG in tea inhibits α -amylase in non-competitive mode with substrates. Similarly, the enzyme α -glucosidase occurs inhibition in a non-competitive mode with the substrate. In addition, Shori (2015) also found that the phenolic components of

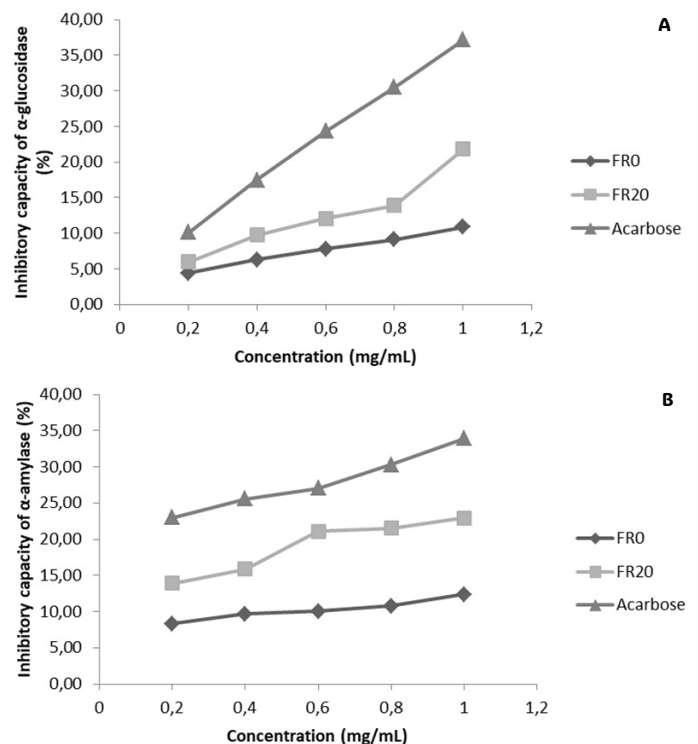


Figure 3. The inhibitory capacity of α -amylase (A) and α -glucosidase (B) of functional rice.

medicinal plants can inhibit the activity of enzymes α -amylase and α -glucosidase so it is very potential in type 2 diabetes mellitus management.

4. Conclusion

This study strongly exhibited that the addition of cherry leaves extract on functional rice significantly reduced starch digestibility and EGI, and increase RS of functional rice. Among the concentration of extract, the lowest starch digestibility (79.58%) and EGI (46.37) were found in functional rice with 20% addition of

cherry leaves extract. Furthermore, functional rice with 20% cherry leaves extracts also had the highest RS (5.95%) compared to other concentrations. Thus, there could be potential health associated with the incorporation of phenolic-rich cherry leaves extract into food to slow starch digestion, EGI, and increase RS.

Conflict of interest

The authors declare that no conflicts of interest exist

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