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Antioxidant Capacity and Pancreatic Lipase Inhibition of Basil Leaves, Tamarind Leaves, and Gelugur Fruits

Rizky Putra Kandi[1)], Hasim[1)]*, Didah Nur Faridah[2)], Laksmi Ambarsari[1)], Fitria Slameut[1)], Diya Aghnia[1)]

[1)] Department of Biochemistry, Faculty of Mathematics and Science, IPB University, Bogor, Indonesia
[2)] Division of Food Science and Technology, Faculty of Engineering and Technology, IPB University, Bogor, Indonesia

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ABSTRACT

Obesity has become a reasonably high contributor to death in the world, with a prevalence showing a stable increase. The research aimed to determine total phenolic content (TPC), total flavonoid content (TFC), antioxidant capacity, and pancreatic lipase inhibitory activity of some extracts from basil (Ocimum basilicum) leaves, tamarind (Tamarindus indica) leaves, and gelugur (Garcinia atroviridis) fruits. They have been reported able to show anti-obesity effects by inhibiting the activity of pancreatic lipase. The extracts were prepared by ultrasonication with 70% ethanol and tested for TPC, TFC, DPPH, and FRAP antioxidant capacity, as well as pancreatic lipase inhibitory activity. The results showed that tamarind extracts showed the highest TPC, and this was in line with DPPH and FRAP antioxidant capacity, i.e., 38.84 µmol TE/g dried weight (dw) and 741.43 µmol TE/g dw, respectively. Meanwhile, the pancreatic lipase inhibition activity of the samples was still lower than that of the positive control (orlistat), with tamarind leaf extracts having the highest activity(IC_{50} 154.63 µg/mL). Furthermore, phenolic compounds have a strong correlation to pancreatic lipase enzyme inhibition activity. Based on the results, tamarind had the highest TPC, antioxidant capacity, and pancreatic lipase inhibitory activity compared to basil leaves and gelugur fruit extracts.

***Keywords**: antioxidant, basil leaves, gelugur fruits, pancreatic lipase, tamarind leaves*

INTRODUCTION

Basil (*Ocimum basilicum*), tamarind (*Tamarindus indica*), and gelugur (*Garcinia atroviridis*) plants have been traditionally known for their use in medicine. Extracts from basil leaves have been reported to regulate blood glucose levels, improve lipid profiles, and promote facial health. In addition, compounds in their leaves can increase the immune response in the body and reduce stress, depression, and anxiety (Singletary, 2018). According to Joshi *et al*. (2023), tamarind leaves are traditionally used to treat inflammatory diseases, asthma, wounds, eye pain, colds, and arthritis. It was reported, in the latest research, that the fruit, seeds, leaves, and bark of the tamarind plant have pharmacological activities, such as antimicrobial, antioxidant, anti-inflammatory, anti-hypercholesterolemic, antidiabetogenic, antivenom, and antiemetic (Silalahi, 2020). Gelugur fruit is reported to have antibacterial, antifungal, antioxidant, anticancer, and anti-inflammatory activities (Shahid *et al*., 2022). Research conducted by Lim *et al*. (2020) reveal that obese mice treated with gelugur fruits extracts showed lower body weight and improved lipid profiles compared to the untreated.

In our previous work, Basil leaves, tamarind leaves, and tamarind fruit are three of the ten plants that have the highest potential to inhibit pancreatic lipase enzymes based on a meta-analysis conducted by Hasim *et al*. (2023). The pancreatic lipase enzyme hydrolyzes food triacylglycerols into fatty acids, monoacylglycerols, and diacylglycerols to be absorbed by intestinal cells. Orlistat (tetrahydrolipstatin) is a commercial drug that works as a pancreatic lipase inhibitor. This drug is a derivative of the lipstatin compound produced by the bacteria *Streptomyces toxytricini*. Orlistat has been reported to effectively reduce about 30% of fat absorption in the intestine but still causes gastrointestinal side effects such as incontinence and fecal urgency (Seyedan *et al.,* 2015).

Reducing fat absorption in the intestine can be very beneficial in preventing and treating obesity. Obesity is a condition of excessive body fat accumulation that can interfere with health. According to Yumuk *et al*. (2015), there were 600 million adults in

*Corresponding Author: E-mail: hasim@apps.ipb.ac.id

the world who suffered from obesity in 2014, and this number is three times higher than 40 years ago. Obese people are susceptible to many health risks, such as raise of blood glucose, lipid, and tension, oxidative stress, coronary heart disease, and early mortality (Safaei *et al*., 2021). Although diet and exercise are the most recommended methods for preventing and treating obesity, they are difficult to practice, especially for those with sedentary lifestyles. While bariatric surgery can provide significant weight loss effects, the method can only be performed on patients with severe obesity and requires high costs (Ahmad *et al*., 2020).

The compounds contained in basil leaves, tamarind leaves, and gelugur fruit affect the bioactive abilities of the three plants. Based on previous research, phenolic and flavonoid compounds, in addition to having antioxidant abilities, can inhibit pancreatic lipase enzymes (Rajan *et al.,* 2020). However, the relationship between TPC, TFC, and antioxidant capacity in inhibiting pancreatic lipase enzymes from the three plants is not yet known. Better extraction to obtain phenolic and flavonoid compounds is needed to improve the results. Ultrasonication is an extraction method that utilizes sound waves with an ideal frequency between 20 kHz to 40 kHz (Thilakarathna *et al.,* 2023). This method increases the yield by 15.14% more than maceration (Puspawati *et al.,* 2018). In addition to the extraction method, the choice of solvent also dramatically affects the yield value obtained. Ethanol solvents are known to dissolve almost all substances, both polar, semi-polar, and non-polar (Erviana *et al*., 2016). Based on Hakim and Saputri (2020), ethanol is a relatively non-toxic solvent compared to acetone and methanol, is cheap, easy to obtain, efficient, safe for the environment, has a high extraction rate, and can be used in various extraction methods. In addition, this solvent can precipitate proteins and inhibit enzyme activity to prevent hydrolysis and oxidation processes (Erviana *et al.,* 2016). This work aimed to determine the phytochemical content (phenolic and flavonoid), antioxidant capacity, and pancreatic lipase inhibitory activity of basil leaves (*Ocimum basilicum*), tamarind leaves (*Tamarindus indica*), and gelugur fruits (*Garcinia atroviridis*). Therefore, the novelty of this study lies in evaluating the relationship between TPC, TFC, DPPH, and FRAP values and the pancreatic lipase inhibitory activity of basil leaves, tamarind leaves, and gelugur fruit extracted using the ultrasonication method.

MATERIALS AND METHOD

Materials

The materials used in this study were basil leaves (Balai Penelitian Tanaman Rempah dan Obat, Lembang, Indonesia), tamarind leaves (Biofarmaka, Bogor, Indonesia), and gelugur fruit (Biofarmaka, Bogor, Indonesia), ethanol (Merck, Germany), aquadest, Folin-Ciocalteu reagent (Merck, Germany), sodium carbonate, gallic acid (*Fisher*, USA), quercetin, $AlCl_3$ (Merck, Germany), glacial acetic acid (Merck, Germany), hexana (Merck, Germany), chloroform (Merck, Germany), ethyl acetate (*Merck*, Germany), DPPH (Sigma Aldrich, USA), *2,4,6-tripyridyl-s-triazine* (TPTZ) (Sigma Aldrich, USA), $FeCl_3$ (Merck, Jerman), HCl, trolox, acetate buffer, fosfate buffer, pancreatic lipase enzyme (Sigma-Aldrich L3126, USA), p-nitrophenylbutyrate (Sigma-Aldrich, USA), acetonitril (Merck, Jerman), dan orlistat (Novell, Indonesia).

Extract preparation

Basil leaves and tamarind leaves were sorted from damaged leaf parts, while gelugur fruits were thinly sliced. The three plant samples were then dried using an air-drying method (a combination of solar heat and a fan) for 3–7 days, depending on weather conditions and sample thickness. Samples were considered dry if their water content was below 10%. Tamarind and basil leaves were ground using a blender and sieved using a 60-mesh sieve, while gelugur fruits were sliced as thinly as possible. All samples were then stored in a dry pouch container in a freezer at -18 °C.

Extraction was carried out using the ultrasonication method following Kousar *et al*. (2023) with modifications. Ten grams of the dried powder was extracted with 70% (v/v) ethanol (Merck, Germany) solvent 100 mL using an ultrasonicator (Decon SpectraLab Scientific Inc, Canada), for 30 min. The residue obtained from the extraction was then re-extracted. The filtrate of each step extraction, obtained by filtration using filter paper with the aid of a vacuum pump, was mixed and then evaporated until no solvent remained using a rotary evaporator (Hanshin, South Korea) at 40–50 °C and stored at 4 °C for further analysis.

Determination of total phenolic content (TPC)

Total phenolic content was determined by the Folin-Ciocalteu reduction activity, referring to Marliani *et al*. (2022). A total of 20 μL of extracts with a concentration of 1000 μg/mL was reacted with 120 μL of 10% Folin-Ciocalteu reagent (Merck, Germany) and 80 μL of 10% Na_2CO_3 solution in a 96-well microplate and then incubated for 30 min in the dark. Absorbance reading was taken at the wavelength (λ) 750 nm with a nanospectrometer (BMG Labtech, Germany), and gallic acid was used to make a standard curve at a concentration of 20–300 μg/mL. Total phenolic content was expressed in mg gallic acid equivalents (GAE) per gram (g) dry weight (dw).

Determination of total flavonoid content (TFC)

Total flavonoid content was determined by the complex formation reaction between $AlCl_3$ and flavonoid compounds, based on Marliani *et al*. (2022). A total of 10 *µ*L of 1000 *µ*g/mL extracts, 10 *µ*L of 10% $AlCl_3$ (Merck, Germany), 50 *µ*L of ethanol, 120 *µ*L of distilled water, and 10 *µ*L of 1 M glacial acetic acid (Merck, Germany), were reacted in a 96-well microplate, then incubated in the dark for 30 min. The absorbance of the extracts was read at λ 415 nm. Quercetin concentrations of 10-100 *µ*g/mL are used to make a standard curve. Total flavonoid content was presented in mg quercetin equivalents (QE)/g dw.

Determination of antioxidant capacity DPPH• radical scavenging assay

Antioxidant capacity was quantified based on the ability of antioxidant compounds to capture *2,2-diphenyl-1-picrylhydrazyl* radicals (DPPH•) by using a method prescribed by Tunnisa *et al*. (2022). A total of 100 *µ*L of 1000 *µ*g/mL extracts was reacted in a 96-well microplate with 100 *µ*L of 125 *µ*M DPPH (Sigma Aldrich, USA) solution and then incubated for 30 min in the dark at room temperature. Absorbance was measured at λ 518 nm, and Trolox concentrations of 10–120 *µ*M were used as standards. The results were presented in *µ*mol Trolox equivalents (TE)/g dw.

Determination of antioxidant capacity FRAP assay

The ferric reducing antioxidant power (FRAP) assay was applied to determine antioxidant capacity, using a method of Tunnisa *et al*. (2022). It was measured based on the oxidation-reduction reaction between antioxidant compounds and the iron-*2,4,6-tripyridyl-s-triazine* complex $[Fe(III)(TPTZ)]^{3+}$ to form an iron complex $[FeII(TPTZ)]^{2+}$. A total of 10 mM TPTZ solution (Sigma Aldrich, USA), 20 mM $FeCl_3$ (Merck, Germany) solution, and 300 mM acetate buffer (pH 3.6) with a volume ratio 1:1:10 (v/v/v) were prepared as FRAP reagents. A sample of 20 *µ*L of 1000 µg/mL extracts was then reacted in a 96-well microplate with 180 *µ*L of FRAP reagent and then incubated for 15 min at 37 °C. Absorbance was measured at λ 595 nm. The standard solution used was Trolox with a concentration of 25-1600 *µ*M, and the results was presented in *µ*mol TE/g dw.

Determination activity of pancreatic lipase inhibition

Pancreatic lipase inhibitory activity was quantified spectrophotometrically following the work of Lankatillake *et al*. (2021) and Pinto *et al*. (2024) by measuring the formation of nitrophenol from the hydrolysis of p-nitrophenylbutyrate (p-NPB) by pancreatic lipase enzyme. The reaction system used is presented in Table 1. Five different concentrations of extracts and positive control orlistat (Novell, Indonesia) (25 *µ*L) were mixed with 25 *µ*L of pancreatic lipase enzyme 50 *µ*g/mL (100-650 unit/mg protein) (Sigma-Aldrich L3126, USA) in a saline phosphate buffer solution (pH 7.2) and incubated for 5 min at 37 °C. The mixture was added with 50 *µ*L of p-NPB substrate 0.01 M (Sigma-Aldrich, USA) in acetonitrile (Merck, Germany) and incubated for 53 min at 37 °C. Absorbance was measured at λ 400 nm. The activity of inhibition was expressed as inhibitory concentration 50 (IC_{50}) and was calculated from the following Equation 1.

$$\text{Inhibition Percentage (\%)} = \left(1-\frac{A1 - A2}{A3 - A4}\right) x\ 100 \text{ .. (1)}$$

Where, A1= absorbance of sample, A2= absorbance of blank sample, A3= absorbance of control, A4= absorbance of blank control

Table 1. Pancreatic lipase enzyme reaction system

Reagent	Control	Blank Control	Sample	Blank Sample
Solvent (*µ*L)	25	25	-	-
Sample (*µ*L)	-	-	25	25
Pancreatic lipase enzyme (*µ*L)	25	-	25	-
Buffer (*µ*L)	-	75	-	75
p-NPB (*µ*L)	50	-	50	-

Statistical analysis

All data were calculated as mean ± standard deviation of at least three independent experiments. By using Microsoft Excel and R software (version 4.3.2), one-way analysis of variance (ANOVA) with Duncan *posthoc* test was performed for significant differences ($p<0.05$). The correlation between antioxidant assays, TPC, TFC, and pancreatic lipase inhibition was analyzed using Pearson correlation tests.

RESULTS AND DISCUSSION

Total phenolic and flavonoid content

Phenolics are a group of secondary plant metabolite compounds characterized by one or more aromatic rings that bind one or more hydroxyl groups. Meanwhile, flavonoids are phenolic derivative compounds with based on fifteen carbon atoms (C6-C3-C6) arranged in two rings of benzene connected by a heterocyclic pyrane ring (Albuquerque *et al*., 2021). The yield value of basil leaves extract, tamarind leaves, and gelugur fruits varies greatly. Gelugur fruit has the highest yield value, 55.61%, followed by tamarind leaf at 34.60% and basil leaf at 18.12%. Based on Table 2, the TPC of basil and tamarind leaves is higher than that of gelugur fruit,

whereas the TFC values of the three samples do not differ significantly. Nadeem *et al*. (2022) found that the TPC of basil leaves extracts reached 191.2 mg GAE/g extract while the TFC 13.3 mg QE/g extract. Meanwhile, research by Ouédraogo *et al*. (2020) reported that the TPC of tamarind leaves extracts reached 202.40 mg GAE/g extract while the TFC 99,00 mg QE/g extract. The significant difference between TPC and TFC can occur because there are derivatives of other phenolic groups besides flavonoids, such as benzoic acid, cinnamic acid, stilbene, tannin, and lignin (Rahman *et al.,* 2022). In the case of gelugur fruit extracts, these results indicate the presence of flavonoid compounds in the gelugur fruits.

TPC and TFC are highly dependent on the extraction method. Organic solvents such as ethanol, methanol, acetone, and isopropanol have been widely used to extract plants' polyphenolic and antioxidant compounds. Both are easily hydrolyzed and oxidized at high temperatures (exceeding 60 °C), mainly when extracted for a long time (Dzah *et al*., 2020). Differences in phenolic and flavonoid content can also be caused by other factors, such as species and growing environment (Kumar *et al*., 2023). Cultivars within a plant species can contain different secondary metabolite capacities, as seen in a study Adámek *et al*. (2021), finding differences in TPC in basil plants of the *Ocimum basilicum* cultivar. Other than that, reported by Wiyono *et al*. (2022)The TPC of tamarind leaves cultivated in the monsoon and savanna climate zones was more excellent, namely 55.9 and 52.3% GAE, compared to those in the rainforest climate zone, namely 35.9% GAE. Those results showed that plants produce more metabolites in areas with high environmental stress than those plants in nutrient-rich areas.

Antioxidant capacity

Figure 1 showed that tamarind leaves extrats had the highest DPPH antioxidant capacity compared to basil leaves extracts and gelugur fruits extracts. Meanwhile, in the FRAP antioxidant capacity, the results are relatively comparable with the DPPH assay. Tamarind leaves extract showed the highest antioxidant capacity, followed by basil leaves and gelugur fruits. Other than that, Figure 1 also shows that antioxidant capacity by FRAP was more significant than DPPH. Previous studies are in accordance with the results. Erviana *et al*. (2016) stated that the DPPH IC_{50} value was 52.68 *μ*g/mL in basil leves extracts, while Kuddus *et al*. (2020) reported DPPH IC_{50} value of tamarind leaves extracts reaching 26.54 *μ*g/mL. Meanwhile, the antioxidant capacity of gelugur pericarp was assessed by DPPH IC_{50} value reaching 628.25 *μ*g/mL, as reported by Chatatikun *et al*. (2020). Nadeem *et al*. (2022) reported FRAP antioxidant capacity reached 237 *μ*mol Fe/g extract in basil leaves extracts, while Kuddus *et al*. (2020). The reported FRAP antioxidant capacity of tamarind leaves extracts reached 593.06 *μ*mol Fe^{2+}/g extract.

The high antioxidant capacity of FRAP compared to DPPH implies that the three extract antioxidant mechanisms follow the FRAP method. the FRAP antioxidant mechanism, namely, through single electron transfer between antioxidant molecules with metal ions, carbonyl groups, and free radicals. Meanwhile, the DPPH method antioxidant mechanism eliminates stable chromophores through hydrogen atom transfer, single electron transfer, or proton-paired electron transfer (Munteanu and Apetrei, 2021). Similar results were also shown by Ouédraogo *et al*. (2020). The DPPH antioxidant activity of tamarind leaves extracts was smaller at 360.02 *μ*mol ascorbic acid equivalent/g extract compared to the FRAP antioxidant activity at 677.26 *μ*mol ascorbic acid equivalent/g extract.

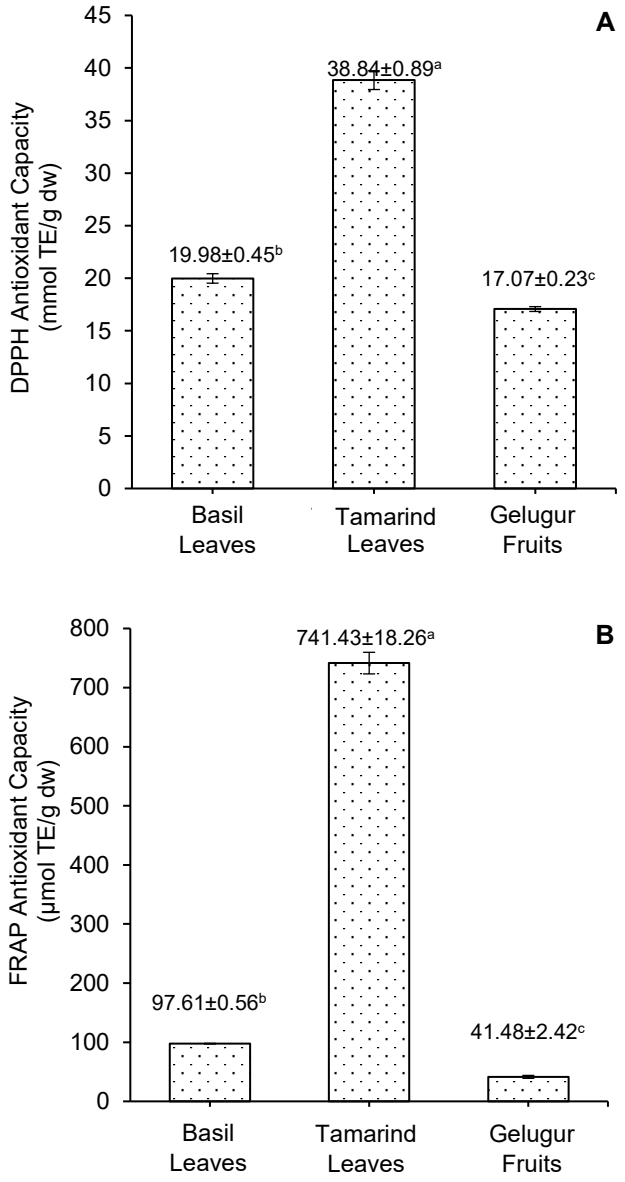
Oxidative stress is a condition of imbalance between high free radicals and low antioxidants in the body (Neha *et al*., 2019). Oxidative stress has been linked to more than 100 diseases, such as coronary heart disease, stroke, cancer, high blood pressure, high blood glucose, Parkinson, dementia, and aging (Kotha *et al*., 2022).

Antioxidants can prevent, inhibit, or reduce the oxidation process. Common antioxidants include vitamins C and E, carotenoids, tannins, phenolic acids, and flavonoids (Sookying *et al.,* 2022). Plants that are rich in secondary metabolites, such as phenolic and flavonoid compounds, can be a primary source of antioxidants (Ouédraogo *et al*., 2020). However, this study remains unable to determine the specific compounds within the three plant samples that are responsible for their antioxidant activity, indicating the need for further research.

Table 2. Total phenolic and flavonoid contents as well as pancreatic lipase inhibition activity of the extracts

Plant Samples	Total Phenolic Content (mg GAE/g dw)	Total Flavonoid Content (mg TE/g dw)	IC_{50} (*μ*g Crude Extract/mL)
Basil leaves	19.94±0.05^{b}	4.73±0.56	328.64±7.23^{b}
Tamarind leaves	84.97±9.31^{a}	7.44±3.30	153.32±21.16^{c}
Gelugur fruits	22.92±1.80^{b}	14.93±5.44	707.23±9.18^{a}

Note: All data were presented as mean ± standard deviation. The same letters on the same column indicate results that are not significantly different (p>0.05) in the Duncan test. Flavonoid results are not significantly different



Note: Data were presented as mean ± standard deviation. The same letters on the same graph indicate results that are not significantly different (p>0.05) in the Duncan test. DPPH= *2,2-diphenyl-1-picrylhydrazyl,* FRAP= ferric reducing antioxidant power

Figure 1. DPPH (A) and FRAP (B) antioxidant capacity of the extract

Pancreatic lipase inhibition activity

Even though IC_{50} values were significantly different for all tested extracts (Table 2), their values were less powerful than the positive control orlistat, 50.41±4.82 μg/mL. The IC_{50} value of basil leaves extracts was better than previous studies of Noor *et al*. (2019), which the IC_{50} of 399.92 μg/mL. The IC_{50} value of tamarind leaves extracts was better from the study of Alias *et al*. (2017), finding that the tamarind leaves extracts at a concentration of 500 μg/mL could inhibit 28% of pancreatic lipase enzyme activity. Meanwhile, the gelugur fruits extracts IC_{50} was not better than the study of Iswantini *et al*. (2021), with an IC_{50} value of 640.62 μg/mL.

The search for drugs to prevent and treat obesity can be done by intervening in fat digestion, storage, and metabolism. The search for drugs with a strategy to intervene in the fat digestion process can be done by inhibiting the pancreatic lipase fat-digesting enzyme. This enzyme catalyzes the hydrolysis reaction of 50-70% of food triacylglycerol into fatty acids and glycerol (Liu *et al.,* 2020). The pancreatic lipase enzyme has two structural domains, namely the N-terminal domain with a length of 336 amino acids, which is catalytically active, and the C-terminal domain with 113 amino acid residues, which functions as a binding site for colipase (Kumar and Chauhan, 2021). The inhibition in pancreatic lipase will be significant if it interferes with the catalytic site area (Liu *et al.,* 2020).

Plant samples can inhibit pancreatic lipase enzymes due to the activity of their bioactive compound. Several groups of compounds that are known to inhibit pancreatic lipase enzymes include flavonoids, alkaloids, saponins, and terpenoids (Rajan *et al.,* 2020). Phenolic and flavonoid compounds are found in large quantities in basil leaves, tamarind leaves, and gelugur fruit. However, their ability to inhibit pancreatic lipase enzymes are different based on the composition of phenolic and flavonoid compounds in the three samples. Structural changes in flavonoids, for example, significantly impact their ability to suppress the activity of pancreatic lipase enzymes. Based on Li *et al*. (2023), hydrogenation at the C2-C3 bond, glycosylation, and isoflavone formation can decrease the inhibitory ability, while hydroxylation and ketone bodies in the C ring increase inhibition. Based on Martinez-Gonzalez *et al*. (2017), phenolic compounds showed a mixed inhibition mechanism with two inhibitory components (competitive and non-competitive) against pancreatic lipase enzyme. The interaction of compounds with amino acid residues near the active site is a competitive component of mixed inhibition. At the same time, the non-competitive component can be explained by the presence of active site binding in several compounds that do not affect substrate binding but only the catalytic process. The same type of inhibition was also stated by Wiyono *et al*. (2022), that tamarind leaves extract can inhibit pancreatic lipase enzyme in mixed inhibition mode. The ability of a compound to cause inhibition both competitively and non-competitively is influenced by the structure of the compound. However, this study was not able to determine the specific compounds within the three plant samples that are responsible for their pancreatic lipase inhibitory effects. Therefore, further investigation is required.

Correlation between TPC, TFC, DPPH, FRAP, and IC_{50}

The correlation of various tests in this study showed mixed results (Table 3). The correlation coefficient with a value in the range of 0.9–1 is very strongly correlated, 0.7–0.89 is strongly correlated, 0.4–0.69 is moderately correlated, 0.1–0.39 is weakly correlated, and 0.0–0.1 is said to be uncorrelated (Schober *et al.,* 2018). Table 3 shows a moderately negative correlation between total phenolic and total flavonoid levels. The correlation among TPC and antioxidant capacity, both DPPH and FRAP, was directly proportional, but inversely proportional to TFC, namely. Meanwhile, the correlation related to the IC_{50} of pancreatic lipase enzymes was negative except for TFC.

Table 3. Correlation coefficients (r) of TPC, TFC, antioxidant capacity (DPPH and FRAP) and pancreatic lipase inhibition (IC_{50})

Correlation	TPC	TFC	DPPH	FRAP	IC_{50}
TPC	1.000	-0.416	0.768	0.982*	-0.916
TFC		1.000	-0.212	-0.320	0.283
DPPH			1.000	0.689	-0,957
FRAP				1.000	-0.869
IC_{50}					1.000

Note: (*) indicates the significant correlation (p<0.05) between the in vitro assays. TPC= total phenolic content, TFC= total flavonoid content, DPPH= *2,2-diphenyl-1-picrylhydrazyl,* FRAP= ferric reducing antioxidant power, IC_{50}= inhibitory concentration 50

The correlation test results showed some similarities and differences with previous studies. The negative correlation between TPC and TFC indicates that increasing phenolic levels will decrease total flavonoid levels. Wairata *et al*. (2022) also reported the same results with a correlation value between phenolic and flavonoid levels of r= -1. Correlation results between TPC, TFC, and antioxidant capacity are the same as those reported by Wiyono *et al*. (2022), that the antioxidant capacity of tamarind leaves extract correlates better with TPC (r= 0.998) than TFC (r= −0.379). Statements related to the lack of correlation between antioxidant capacity and total flavonoid levels were also explained by Tahirović *et al*. (2019). It could happen because non-flavonoid phenolic compounds can also act as antioxidants. In addition, flavonoid compounds are generally able to form bonds with sugar groups to produce glycosides, thereby reducing DPPH radical scavenging activity (Benjamin *et al.,* 2022).

The correlation between pancreatic lipase enzyme inhibition (IC_{50}) and plant extracts showed a strong negative relationship with total phenolic content and antioxidant capacity, but only a weak positive relationship with total flavonoid content. This suggests that the compounds responsible for pancreatic lipase inhibition are primarily phenolic in nature and also possess antioxidant properties. These findings are consistent with Huang *et al.* (2020), who reported a significant negative correlation between IC_{50} values and total phenolic content, indicating that higher phenolic levels are associated with lower IC_{50} values. Similarly, Maser *et al.* (2023) observed that in three out of four plant samples tested, pancreatic lipase inhibition activity exhibited a moderate to strong positive correlation with total phenolic content.

CONCLUSION

The basil leaves, tamarind leaves, and gelugur fruit extracts contained phenolic and flavonoid compounds with antioxidant capacity and pancreatic lipase inhibition activity. Tamarind leaves extracts, with 84.97 mg GAE/g dw, exhibited the highest TPC, and this was also true for antioxidant capacity, both DPPH (38.84 *μ*mol TE/g dw) and FRAP (741.43 *μ*mol TE/g dw). Meanwhile, gelugur fruit extract showed the most abundant content of TFC (14.93 mg QE/g dw). The tamarind leaves extracts also had the best pancreatic lipase inhibition activity with an IC_{50} of 153.32 *μ*g crude extract/mL compared with basil leaves and gelugur fruit. Correlation results showed that phenolic compounds have a strong correlation to pancreatic lipase enzyme inhibition activity.

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