Science and Technology Indonesia
e-ISSN:2580-4391 *p*-ISSN:2580-4405
Vol. 10, No. 2, April 2025

Research Paper

Cholesterol-Lowering Effects of Turmeric Effervescent Dosage in Preventing Atherosclerosis

Zulkifli B. Pomalango[1], Mohamad Aprianto Paneo[2*], Nasrun Pakaya[1], La Ode Aman[2], Ariani H. Hutuba[2]

[1]*Department of Nursing, Faculty of Sport and Health, Gorontalo State University, Gorontalo, 96128, Indonesia*
[2]*Department of Pharmacy, Faculty of Sport and Health, Gorontalo State University, Gorontalo, 96128, Indonesia*
***Corresponding author**: apriyanto07@ung.ac.id*

Abstract
This study aims to evaluate the cholesterol-lowering effects of turmeric *(Curcuma domestica)* in an effervescent powder drink formulation to prevent atherosclerosis. The effervescent preparation was produced using standard effervescent techniques, with organoleptic tests revealing an orange color, the characteristic aroma of turmeric, and a slightly sweet taste. The formulation's pH was approximately 5.9, with a flowability test result of 14 seconds, a powder angle of repose of 30°, and a dissolution time of 4 minutes and 20 seconds. Curcumin shows potential as an anticholesterol as a preventive measure of atherosclerosis disease through molecular docking testing using autodock-vina. Qualitative test on turmeric effervescent with Sprektrofotometer UV-VIS, Scanning Electon Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR). Cholesterol testing was conducted on mice induced with cholesterol using margarine over a one-week period, resulting in increased cholesterol levels of maximum 290 mg/dL. Following administration of the converted turmeric dosage, cholesterol levels significantly maximum decreased in the first week to 165 mg/dL. By the second week, further reductions were observed, with cholesterol levels maximum dropping to 143 mg/dL. These results suggest that turmeric effervescent formulation exhibits promising cholesterol-lowering properties and may contribute to the prevention of atherosclerosis.

Keywords
Curcumin, Atherosclerosis, Effervescent, Cholesterol

Received: 21 October 2024, Accepted: 5 February 2025
https://doi.org/10.26554/sti.2025.10.2.482-492

1. INTRODUCTION

Atherosclerosis is a major cardiovascular disease and a leading cause of morbidity and mortality worldwide. The condition is characterized by the accumulation of cholesterol-rich plaques in the arterial walls, leading to a narrowing of the arteries and reduced blood flow to vital organs such as the heart and brain. Cholesterol, particularly low-density lipoprotein (LDL) cholesterol, plays a key role in plaque formation, which eventually results in cardiovascular events such as heart attacks and strokes (Maxfield et al., 2023; Noothi et al., 2023; Pan et al., 2024; Poznyak et al., 2024). Effective control of cholesterol levels, therefore, represents a critical approach in reducing the risk of atherosclerosis, with both pharmacological and non-pharmacological interventions being explored, including the use of natural compounds like turmeric (Fadhilah and Saryanti, 2019; Wilkinson et al., 2023).

Turmeric *(Curcuma domestica)* has been widely recognized for its therapeutic properties, particularly in traditional medicine. Its primary bioactive compound, curcumin, has demonstrated potent anti-inflammatory, antioxidant, and hypocholesterolemic activities (Chavan and Salve, 2023; Cozmin et al., 2024; Rohmah, 2024). Several studies have indicated that curcumin may significantly lower serum cholesterol levels, reduce inflammation, and inhibit the formation of atherosclerotic plaques. Additionally, curcumin is believed to modulate lipid metabolism, which further contributes to its protective effects against cardiovascular disease (Deng et al., 2023; Panknin et al., 2023; Safari and Rahimi, 2023; Zeng et al., 2023).

In recent years, the development of herbal-based functional beverages has gained popularity as a practical means of incorporating natural compounds into daily diets. Effervescent powder drinks, in particular, have garnered attention due to their ease of preparation and consumer-friendly characteristics (Gomez et al., 2023; Sahrawat and Chaturvedi, 2023; Iriyani et al., 2024). Effervescent formulations offer not only convenience but also enhanced organoleptic properties, such as a refreshing fizz upon dissolution, which may increase consumer compliance. Therefore, the development of a turmeric-based effervescent formulation presents a promising strategy

for cholesterol management and atherosclerosis prevention (Singh et al., 2021).

The process of preparing effervescent powders typically involves combining citric acid and sodium bicarbonate, which release carbon dioxide when dissolved in water. This reaction not only provides the effervescent effect but also facilitates the rapid dissolution of active ingredients (Laurent and Sitorus, 2023; Parajuli-Baral, 2023). In this study, turmeric was formulated into an effervescent powder, and its cholesterol-lowering efficacy was evaluated using hypercholesterolemic mice models. The pharmacological effects of the turmeric effervescent formulation were assessed after cholesterol induction through a high-fat diet, simulating hypercholesterolemia in the test subjects (Aydin and Civelek, 2024; Hesson, 2024).

Organoleptic evaluation of the turmeric effervescent formulation was conducted to ensure the quality and acceptability of the product. Parameters such as color, aroma, taste, pH, dissolution time, and powder flow properties were measured to assess the suitability of the formulation for consumer use. Additionally, pharmacological testing in mice aimed to determine the effectiveness of the effervescent formulation in lowering serum cholesterol levels after margarine-induced hypercholesterolemia. This study is expected to provide new insights into the potential use of turmeric in effervescent formulations as a practical and effective means of cholesterol management and atherosclerosis prevention.

The findings from this study will contribute to the growing body of research on the development of herbal-based pharmaceutical products that offer both efficacy and convenience. Given the global burden of cardiovascular diseases such as atherosclerosis, the innovation of functional beverages like effervescent powder drinks may improve patient adherence and outcomes in cholesterol management (Salama et al., 2020; Ray and Saini, 2021; Yudhani et al., 2022; Meng et al., 2023). Thus, this research not only evaluates the cholesterol-lowering potential of turmeric but also explores the potential of effervescent formulations as an innovative and practical solution in the field of pharmaceutical and nutritional sciences.

2. EXPERIMENTAL SECTION

2.1 Materials

Materials used in this study Turmeric simplisia powder, Curcumin Standard (Sigma Aldrich), Sodium bicarbonate (Sentra Kimia Labsains), Citric acid (Merck®), Tatrat acid (Merck®), Lactose (Merck®), Sodium Carboxyl Methyl Celullose (Sigma Aldrich®), Mannitol (Merck®), and Aquadest). The instruments used in this study consist of Spectrofotometer UV-VIS (Thermo Scientific®), Fourier transform Infrared Spectroscopy (FTIR) (Thermo Scientific®), Scanning Elector Microscope (SEM) (TM3000 Hitachi®) Digital pH Meter, Brookfield Viscometer, Blood cholesterol meter (NESCO®). as for the test animals used in this study, namely mice that have been acclimitized beforehand. Initial preparation to see the ability of curcumin as an anticholesterol agent using Autdock-Vina simulation.

2.2 Methods

2.2.1 In Silico Test With Autodock-Vina

This study used the Autodock-vina tool as a first step to predict the ability of curcumin and native ligands to inhibit cholesterol. The parameters assessed were the ability of its affinity energy (Eberhardt et al., 2021; Trott and Olson, 2010).

2.2.2 Effervescent Powder Preparation Procedure

The preparation of effervescent powder drinks from turmeric simplicia powder follows systematic steps to ensure product quality and effectiveness. First, turmeric powder, as the active ingredient, is mixed with sodium bicarbonate as the alkaline phase. Citric and tartaric acids are then added for flavor and effervescence. Sodium carboxymethyl cellulose (Na−CMC) serves as a binder for stability, while lactose acts as a filler to enhance sweetness. Mannitol is included to improve palatability. After mixing the dry ingredients, distilled water forms a homogeneous paste, which is dried in a low-temperature oven to produce an easily dissolvable effervescent powder. The final product undergoes organoleptic and functional quality testing, including pH, flowability, angle of repose, and dissolution time assessments.

2.2.3 Wavelenght Test

The results of the effervescent turmeric preparation will be tested to characterize the curcumin content qualitatively by looking at the suitability of the wavelength produced through a uv-vis spectrophotometer instrument (Yudha and Nurhasanah, 2024).

2.2.4 Morphological Characterization

Characterization of the morphology of turmeric simplicia and turmeric effervescent powder was conducted using Scanning Electron Microscopy (SEM). The samples were prepared by placing small amounts of each powder onto a conductive carbon tape, followed by sputter coating with gold to enhance conductivity. SEM images were captured at varying magnifications to assess particle size, shape, and surface structure, providing insights into the physical properties of both turmeric simplicia and the effervescent powder formulation (Widianingsih et al., 2024).

2.2.5 HPLC Analysis

Molecular characterization of turmeric simplicia and turmeric effervescent powder samples was carried out using Fourier Transform Infrared Spectroscopy (FTIR). The samples were prepared by mixing the powder with KBr and compressing it into thin pellets. FTIR spectra were recorded in the range of 4000–400 cm^{-1} to identify functional groups and obtain information on the chemical structure of each sample. This analysis aimed to detect the presence of active compounds and assess interactions between the components within the samples (Widianingsih et al., 2024).

2.2.6 Organoleptic Test

The organoleptic test on effervescent formulations aims to evaluate physical characteristics that can be directly observed, such as color, taste, aroma, shape, and texture of the tablet or powder before and after dissolution in water. Organoletic testing was given to 25 healthy respondents, with an age range of 20-30 years. and the observations were recorded. (Bisht, 2019; Gillani et al., 2023).

2.2.7 pH Test

The pH test on effervescent formulations aims to determine the acidity or alkalinity of the solution after the formulation is dissolved in water. The goal is to ensure that the formulation has an appropriate pH for oral use, typically ranging between 4.5 and 6.0, making it safe and comfortable for the digestive system (Fadhilah and Saryanti, 2019; Gillani et al., 2023; Laurent and Sitorus, 2023)

2.2.8 Flowability Test

The flowability test of effervescent formulations aims to evaluate the ability of powders or granules to flow smoothly during manufacturing and packaging processes. This test is crucial to ensure that the powder exhibits consistent flow, which affects tablet compression and dose uniformity. The parameters assessed include flow rate, angle of repose, and compressibility index (Mandal et al., 2020; Moravkar et al., 2020; Srivastava et al., 2022).

2.2.9 Tumeric Effervescent Dissolving Time Test

The dissolution time test of effervescent formulations aims to determine the rate at which the formulation dissolves when dissolved in water, which impacts the bioavailability and effectiveness of the product (Zhang et al., 2018).

2.2.10 Animals And Ethical Consideration

In this study, we used mice as animal models, divided into three groups (n = 24) with an average weight of 20-22 grams, adhering to strict ethical guidelines for animal welfare and research validity. All procedures were approved by the animal research ethics committee. The mice were housed in suitable conditions with access to food, water, and a clean environment. We minimized pain and stress during the research, using anesthesia when necessary and conducting regular health monitoring (Cait et al., 2022; Lee et al., 2023). Upon completion of the study, mice were euthanized in a humane manner, following established guidelines. By adhering to these principles, this research aims to produce accurate and relevant data while respecting the rights and welfare of the animals used.

2.2.11 Animals Grouping And Experimental Design

In this study, we used mice as animal models, divided into three groups with an average weight of 20 grams. Group 1 was the negative control and received no induction. Group 2 was fed a margarine diet for one week to induce high cholesterol levels, which were then measured. After a significant increase was confirmed, these mice were administered a 0.2 ml turmeric suspension daily via orogastric tube for two weeks. Group 3, similar to Group 2, continued on the margarine diet without receiving the turmeric suspension. This design facilitated a comparative evaluation of turmeric's effects on cholesterol levels in hypercholesterolemic mice. can be seen in Table 1.

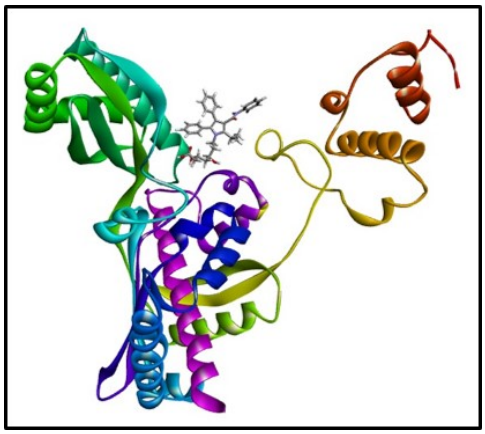

Figure 1. The Complex of HMG-CoA Enzyme and Native Ligand

3. RESULTS AND DISCUSSION

3.1 Molecular Docking Curcumin Reduces the HMG-CoA Enzyme

Prediction of affinity interactions of curcumin which has anticholesterol effects compared to atorvastatin, a statin class whose mechanism reduces the HMG-CoA enzyme. This prediction uses Autodock-Vina. HMG-CoA reductase is a key enzyme in cholesterol biosynthesis, catalyzing the conversion of HMG-CoA (3-hydroxy-3-methylglutaryl-coenzyme A) to mevalonate, the rate-limiting and irreversible step in the cholesterol synthesis pathway. Inhibition of this enzyme plays a crucial role in reducing cholesterol levels in the body. In this complexation illustration, HMG-CoA reductase is represented as a ribbon model with various colors, highlighting the secondary structure of the protein, including α-helices and β-sheets. can be seen in Table 1, Figures 1 and 2.

The natural ligand, which functions as an anti-cholesterol agent, is depicted in a three-dimensional stick model, interacting with the enzyme's active site. The presence of the natural ligand bound to the active site of HMG-CoA reductase suggests that this molecule can inhibit the enzyme's activity by preventing the native substrate (HMG-CoA) from interacting with the enzyme. The binding of this ligand potentially induces conformational changes in the enzyme's active site, resulting in competitive inhibition of the catalytic process. Can be seen in Figure 1.

The docking results, as shown in Table 2, provide insights into the binding affinities of atorvastatin, a well-established synthetic inhibitor, and curcumin, a natural compound, with HMG-CoA reductase. Atorvastatin, serving as the native ligand,

Table 1. Animal Grouping

Groups	Treatment/Doses
Group 1 (Negative control)	Did not receive any treatment only as blood cholesterol control
Group 2	Get special margarine feed + 0.2 ml turmeric suspension every 8 hours (given after the cholesterol value has increased)
Group 3	Get special margarine feed

Table 2. Binding Affinity with Autodock-Vina

Name	Affinity (kcal/mol)
Atorvastatin (Native ligand)	-7.10
Curcumin	-6.33

demonstrated a binding affinity of -7.10 kcal/mol, indicating strong interaction with the active site of the enzyme, consistent with its efficacy as a potent cholesterol-lowering agent through competitive inhibition of HMG-CoA reductase. Curcumin, with a binding affinity of -6.33 kcal/mol, exhibited slightly weaker but still substantial interactions with the enzyme, suggesting its potential as a natural inhibitor.

Atorvastatin exhibits several hydrogen interactions with amino acid residues such as LYS (A:692), ASN (A:686), and ARG (A:590), with interaction distances ranging from 1.79 to 2.89 Å, indicating strong interactions that contribute to the stability of the atorvastatin-HMG CoA reductase complex, which is critical for its enzyme inhibition activity. Key residues like LYS and ASN play a significant role in atorvastatin binding, impacting its efficacy as an inhibitor. In comparison, curcumin shows hydrogen interactions with residues such as GLY (A:685) and TYR (A:687), with interaction distances varying from 2.02 to 4.90 Å. This wider range of interaction distances suggests that curcumin may bind to HMG CoA reductase more flexibly and with weaker interactions than atorvastatin. Despite curcumin's weaker interactions, the presence of several hydrogen bonds suggests potential inhibitory effects, although likely less potent than atorvastatin. Overall, atorvastatin appears to be more effective in binding and inhibiting HMG CoA reductase, while curcumin, though showing some potential, may be less efficacious in the context of enzyme inhibition.

3.2 Wavelength Characterization

Wavelength characterization of curcumin compounds in turmeric effervescent preparations has been carried out with wavelength indicators. Setting the wavelength range of 400-800 nm which can be seen in Figure 3.

The results of the determination of the maximum wavelength using UV-VIS Spectrophotometer showed in Figure 3 that effervescent turmeric and Figure 4 raw curcumin detected the maximum wavelength was on average 430 nm. Other studies have shown that curcumin has a maximum wavelength of 420-430 nm (Chadchan et al., 2017).

3.3 Morphological Characterization

The following are the results of morphological characterization of turmeric simplisia and effervescent morphology at various size magnifications. can be seen in Figure 5.

The SEM analysis revealed significant morphological differences between turmeric simplicia and turmeric effervescent powder. At 68× magnification, the turmeric simplicia exhibited irregular and coarse structures with larger particle sizes, indicative of its unprocessed natural state. At 250× magnification, the simplicia displayed a dense and compact surface morphology with low porosity. In contrast, the turmeric effervescent powder showed more uniform particle sizes at 68× magnification, resulting from the granulation process during formulation. At 250× magnification, the effervescent powder exhibited a porous structure, likely due to the incorporation of effervescent agents such as citric acid and sodium bicarbonate. These structural adaptations not only enhanced the solubility but also facilitated the release of curcumin upon dissolution. The increased porosity of the effervescent powder, combined with its homogeneous granulation, underscores its potential for improved bioavailability, stability, and patient compliance compared to the raw simplicia. These findings highlight the importance of effervescent formulation in optimizing the therapeutic efficacy of turmeric-based products.

3.4 Structure Characterization

Characterization of the chemical structure of turmeric simplicia and turmeric effervescent powder is crucial to understanding their physicochemical properties, which directly influence their therapeutic potential and formulation performance. The following characterization was conducted using Fourier Transform Infrared (FTIR) spectroscopy as the primary instrument to identify functional groups and analyze the chemical structures of turmeric simplicia and turmeric effervescent powder. can be seen in Figure 6 and Figure 7.

The FTIR spectra of turmeric simplicia reveal characteristic peaks indicating the presence of curcumin, the primary bioactive compound in turmeric. The peaks at 1633.225 cm^{-1} and 1513.289 cm^{-1} correspond to the conjugated C=C stretching vibrations and aromatic ring structures, which are distinctive features of curcumin. Additionally, the absorption band at 1148.897 cm^{-1}, associated with C−O stretching vibrations, further confirms the presence of bioactive functional groups.

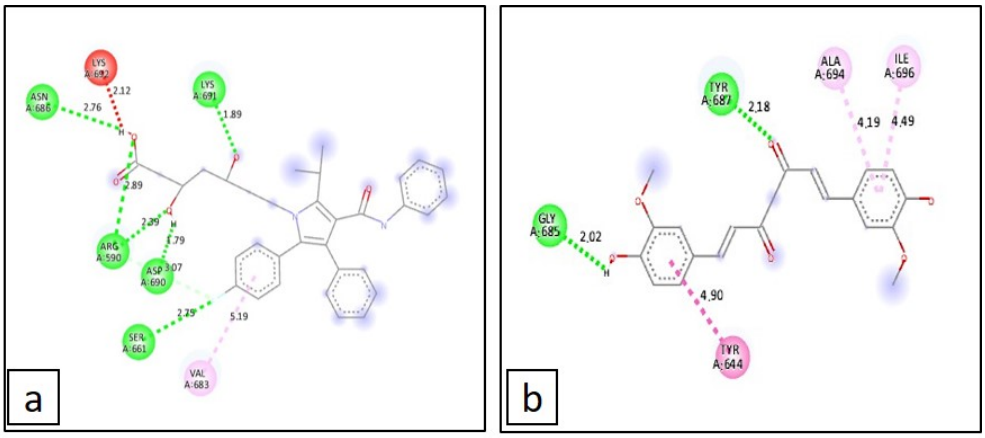

Figure 2. The Interaction of HMG-CoA Reductase with (a) Atorvastatin, and (b) Curcumin

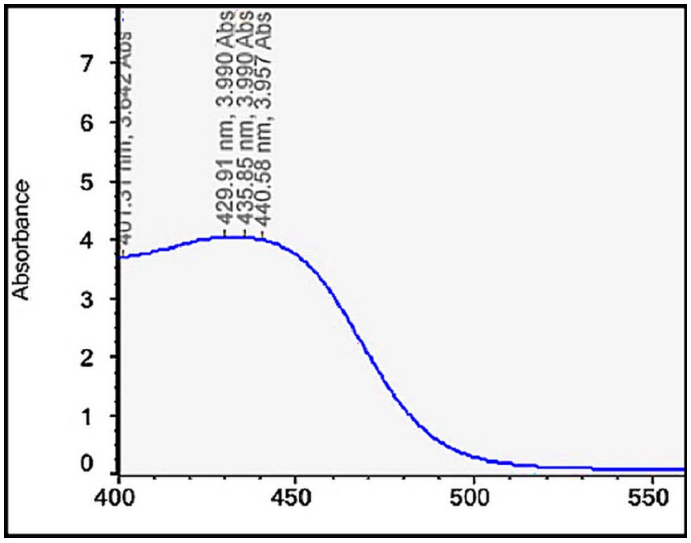

Figure 3. Wavelength of Turmeric Effervescent Preparation (429.91 nm, 435 nm, and 440.85 nm)

Table 3. Organoleptic

Parameters	Description
Color	Bright orange
Aroma	Distinct turmeric aroma
Taste	Typical slightly bitter flavor profile of turmeric, with a hint of sweetness
Sweetness	Resulting from the addition of mannitol and sucrose

These spectral features highlight the natural chemical structure of curcumin in turmeric simplicia, emphasizing its potential as a therapeutic agent. Can be seen in Figure 6.

In contrast, the FTIR spectra of turmeric effervescent powder exhibit significant changes in several absorption bands, such as shifts at 1590.834 cm^{-1} and 1388.103 cm^{-1}, which suggest interactions between curcumin and the excipients used in the effervescent formulation. These modifications imply that the effervescent formulation process alters the chemical environment of curcumin, potentially enhancing its stability and bioavailability. Such transformations are crucial for improving the therapeutic efficacy of curcumin, presenting new opportunities for the development of innovative and functional turmeric-based products. Can be seen in figure 7.

3.5 Organoleptic Test

The results of the assessment of 25 respondent subjects who tested the organoleptic preparation, showed several observations that referred to the following results. The organoleptic evaluation of the effervescent powder revealed a bright orange color, characteristic of the natural compounds present in turmeric *Curcuma domestica*. The detected aroma was distinctively that of turmeric, attributed to the volatile components inherent in the spice. In terms of taste, the suspension exhibited the typical slightly bitter flavor profile of turmeric, complemented by a subtle sweetness. can be seen in Table 3.

The organoleptic evaluation of turmeric *(Curcuma domestica)* effervescent powder highlights key attributes for its acceptance as a health supplement. The bright orange color, due to curcumin, reflects its antioxidant and anti-inflammatory properties, enhancing the product's appeal. The distinct turmeric aroma, linked to volatile compounds like turmerone, influences flavor perception and consumer acceptance. These sensory qualities suggest the powder retains the characteristics of its source, improving user experience and compliance.The taste profile of the suspension is notable, with turmeric's natural bitterness balanced by sweeteners like mannitol and sucrose.

3.5.1 pH Test

The pH of the effervescent formulation was measured three times, yielding results of 5.4, 5.8, and 5.9, indicating an acidic to slightly neutral range. This pH is crucial for the stability and efficacy of the active turmeric compounds, affecting their solu-

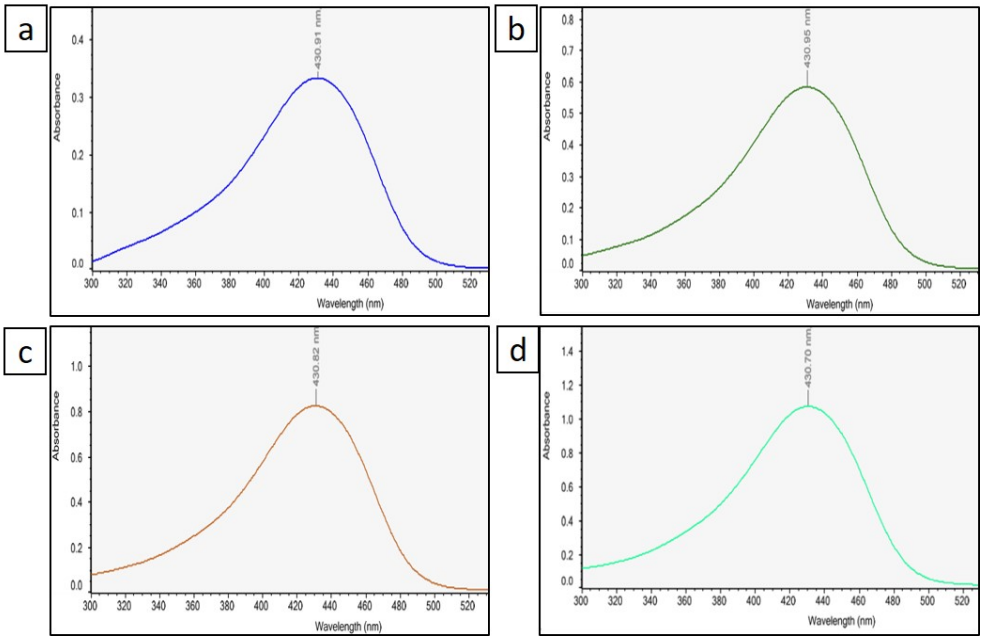

Figure 4. Wavelength of Standard Curcumin. (a) 2 ppm 430.91 nm, (b) 4 ppm 430.95 nm, (c) 6 ppm 430.82 nm and (d) 8 ppm 430.70 nm

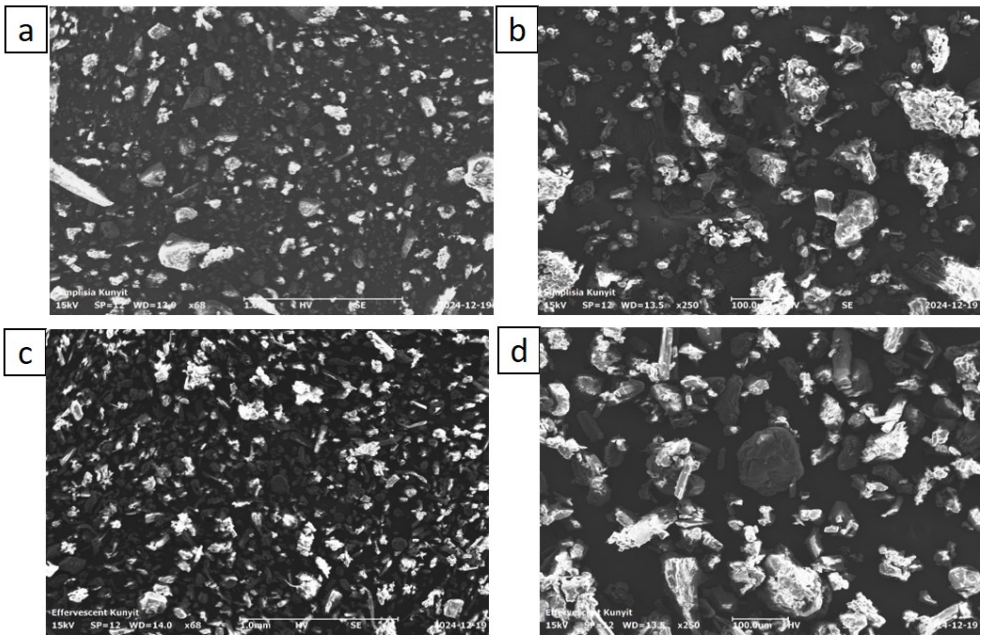

Figure 5. Characterization of The Morphology of Turmeric Simplicia and Turmeric Effervescent Powder was Conducted using Scanning Electron Microscopy (SEM). (a) Turmeric Simplicia 68x, (b) Turmeric Simplicial 250x, (c) Turmeric Effervescent Powder 68x and (d) Turmeric Effervescent Powder 250x

bility, bioavailability, and overall sensory characteristics. Overall, the results highlight the importance of pH in developing effective effervescent formulations (Her et al., 2018). The pH evaluation of the effervescent formulation, conducted through three separate measurements, yielded values of 5.4, 5.8, and 5.9. These results indicate that the formulation maintains an acidic to slightly neutral pH range, which is critical for ensuring the stability and efficacy of the active compounds present in turmeric *(Curcuma domestica)*. The active compounds in this effervescent formulation dissolve better in acidic conditions,

Table 4. Flowability

Parameters	Value	Description
Flowability	5.9	-
Angle of Repose	30°	-
Implications	-	- Essential for efficient processing, handling, and packaging Distinct - Ensures accurate and consistent dosing of the final product - Minimizes risk of clumping or segregation during storage
Significance	-	Highlights the importance of flowability in effervescent formulations, ensuring quality and reliability

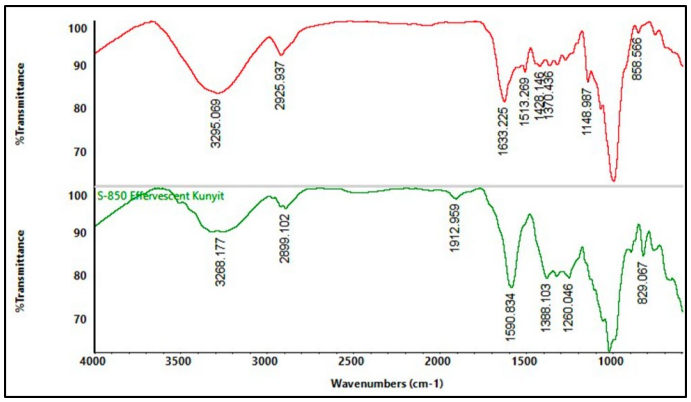

Figure 6. Characterization with Fourier Transform Infrared (FTIR) Spectroscopy. (Red line) Tumeric Effervescent and (Green line) Tumeric simplicia

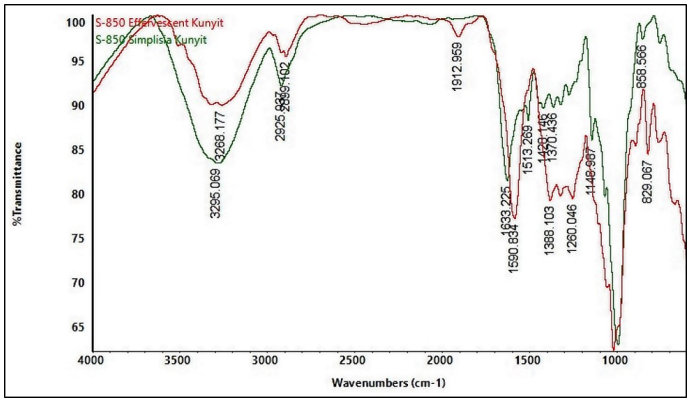

Figure 7. Overlay Fourier Transform Infrared (FTIR) Spectroscopy. (Red line) Tumeric Effervescent and (Green line) Tumeric Simplicia

improving absorption and protecting them from degradation. The pH of this formulation suggests good tolerability and potential appeal as a health supplement.

3.6 Flowability Test

The effervescent powder's flow properties were quantitatively assessed, yielding a flowability rating of 5.9, indicating excellent flow characteristics. The angle of repose was measured at

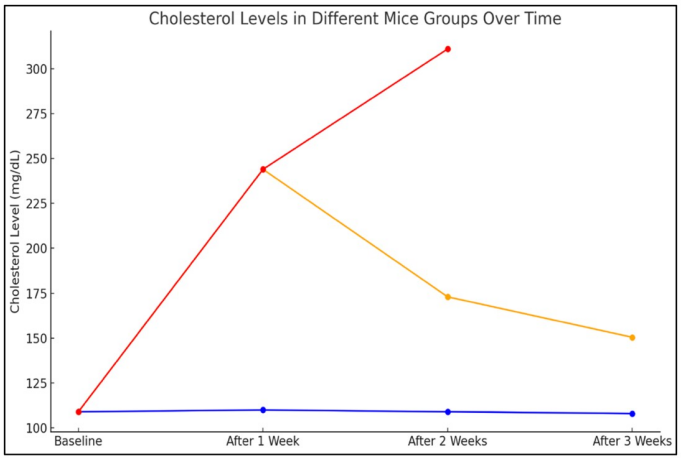

Figure 8. Effects of Turmeric on Cholesterol

Table 5. Dissolving Time

Replication	Dissolution Time (minutes)
1	4.15
2	4.18
3	4.27
4	4.24
5	4.20
Average	4.20

30°, further reflecting optimal flow properties. A good flowability rating ensures accurate and consistent dosing, while optimal flow properties enhance formulation stability by reducing clumping or segregation during storage.

These findings highlight the importance of flowability in developing effervescent formulations, ensuring the final product meets industrial standards and consumer expectations for quality and reliability, as shown in Table 4.

The effervescent powder's flow properties were assessed, resulting in a flowability rating of 5.9, indicating excellent flow characteristics for manufacturing. The angle of repose was measured at 30°, suggesting optimal flow and the ability to settle freely. High flowability ensures accurate dosing, reduces machinery blockages, and enhances production efficiency.

Table 6. Effects of Turmeric on Cholesterol

Group	Treatment	Baseline Choleserol (mg/dL)	Cholesterol After 1 Week (mg/dL)	Cholesterol After 2 Week (mg/dL)	Cholesterol After 3 Week (mg/dL)
Group 1	Control (no treatment)	109	110	109	108
		108	110	108	108
		109	111	109	107
		109	109	107	110
		106	110	107	103
		107	109	108	108
Average		108	109.8333333	108	107.3333333
SD		1.264911064	0.752772653	0.894427191	2.338090389
Group 2	Margarine feed + turmeric suspension	109	209	165	143
		107	230	161	141
		107	288	173	149
		103	290	171	151
		105	270	178	144
		110	275	181	153
Average		106.8333333	260.3333333	171.5	146.8333333
SD		2.562550813	33.19437703	7.582875444	4.833908012
Group 3	Margarine feed only	109	209	303	
		108	257	308	
		109	231	311	Study discontinued (due to health risks)
		106	243	305	
		108	271	317	
		105	279	319	
Average		107.5	248.3333333	310.5	-
SD		1.643167673	26.09725401	6.442049363	-

3.7 Tumeric Effervescent Dissolving Time Test

The solubility test of the effervescent preparation in 250 ml of water showed varied dissolution times of 4 minutes and 15 seconds, 4 minutes and 18 seconds, 4 minutes and 27 seconds, 4 minutes and 24 seconds, and 4 minutes and 20 seconds, with an average of about 4 minutes and 20 seconds. This aligns with the recommended specification of under 5 minutes, indicating adequate dissolution for effective release and bioavailability of the active compounds. These results suggest that the effervescent formulation meets expected standards and may positively impact its therapeutic efficacy, as shown in Table 5.

The solubility test of the effervescent preparation showed varying dissolution times of 4 minutes and 15 seconds, 4 minutes and 18 seconds, 4 minutes and 27 seconds, 4 minutes and 24 seconds, and 4 minutes and 20 seconds, with an average of about 4 minutes and 20 seconds. This meets the recommended specification of under 5 minutes, indicating adequate dissolution time for effective release and bioavailability of the active compounds. These results demonstrate that this effervescent formulation meets the expected standards and has the potential to positively contribute to its therapeutic efficacy.

3.8 Effects of Turmeric on Cholesterol

The in vivo study assessed the effects of margarine-induced cholesterol elevation and turmeric suspension treatment in three groups of mice. After a one-week acclimatization, baseline cholesterol averaged 107.3-109.8 mg/dL. Groups 2 and 3 were then fed a margarine-rich diet for a week, increasing cholesterol levels to between 209 and 290 mg/dL. Group 2 received a 0.2 ml turmeric suspension, while group 3 had no treatment. By the third week, group 2's cholesterol dropped to 165–181 mg/dL, while group 3's rose to 303–319 mg/dL. Group 2 saw further reductions to 143–153 mg/dL, whereas group 3 experienced increased cholesterol, weight gain, and reduced activity, leading to the termination of its treatment to prevent harm. These results highlight turmeric's effectiveness

in reducing cholesterol levels in hypercholesterolemic mice, as shown in Table 6 and Figure 8.

This in vivo study evaluated the effects of margarine-induced cholesterol elevation and turmeric suspension treatment in three groups of mice. After a one-week acclimatization, baseline cholesterol levels averaged 109 mg/dL. A margarine-rich diet for groups 2 and 3 raised cholesterol levels significantly to between 209 and 279 mg/dL, confirming that saturated fat intake can induce hypercholesterolemia, a risk factor for atherosclerosis. Group 2 received 0.2 ml of turmeric suspension for By the third week, group 2 showed a significant reduction in cholesterol levels, dropping to between 165 and 181 mg/dL, while group 3's cholesterol increased to 303–310 mg/dL. This decrease in group 2 highlights turmeric's potential as an effective hypocholesterolemic agent, consistent with literature on curcumin's ability to reduce total and LDL cholesterol, a key contributor to atherosclerotic plaques. Group 3 also exhibited weight gain and decreased physical activity, leading to the termination of treatment to avoid severe health issues. Overall, these findings underscore turmeric's role in managing cholesterol levels and the need for regular monitoring to prevent complications, suggesting turmeric as a promising nutritional intervention for atherosclerosis prevention and management.treatment, while group 3 had no treatment, allowing for a comparative analysis of turmeric's therapeutic effects.

By the third week, group 2 showed a significant reduction in cholesterol levels, dropping to between 165 and 181 mg/dL, while group 3's cholesterol increased to 303–310 mg/dL. This decrease in group 2 highlights turmeric's potential as an effective hypocholesterolemic agent, consistent with literature on curcumin's ability to reduce total and LDL cholesterol, a key contributor to atherosclerotic plaques. Group 3 also exhibited weight gain and decreased physical activity, leading to the termination of treatment to avoid severe health issues. Overall, these findings underscore turmeric's role in managing cholesterol levels and the need for regular monitoring to prevent complications, suggesting turmeric as a promising nutritional intervention for atherosclerosis prevention and management.

4. CONCLUSION

This study found that a margarine-enriched diet significantly increased cholesterol levels and body weight in mice, raising atherosclerosis risk. However, the group receiving turmeric suspension saw a notable reduction in cholesterol, from 279 mg/dL to 143 mg/dL, highlighting turmeric's potential as a hypocholesterolemic agent. These findings support the use of turmeric in effervescent form, which facilitates easier consumption and absorption while ensuring the rapid release of active compounds. Thus, this turmeric effervescent formulation offers a promising solution for preventing atherosclerosis.

5. ACKNOWLEDGEMENT

We would like to express our sincere gratitude to Universitas Negeri Gorontalo for their invaluable support in this research. Their assistance and encouragement have greatly contributed to the success of this study.

REFERENCES

Aydin, B. S. and D. O. Civelek (2024). Development of Curcumin and Turmeron Loaded Solid Lipid Nanoparticle for Topical Delivery: Optimization, Characterization and Skin Irritation Evaluation with 3D Tissue Model. *International Journal of Nanomedicine*, **19**; 1951–1966

Bisht, B. S. (2019). Evaluation of Antianxiety Activity of Zonisamide Based on the Serendipitous Action in Swiss Albino Mice. *International Journal of Current Research in Chemistry and Pharmaceutical Sciences*, **6**(4); 27–32

Cait, J., A. Cait, R. W. Scott, C. B. Winder, and G. J. Mason (2022). Conventional Laboratory Housing Increases Morbidity and Mortality in Research Rodents: Results of a Meta-Analysis. *BMC Biology*, **20**(1); 1–22

Chadchan, K. S., S. N. Das, J. G. Jargar, and K. K. Das (2017). A Comparative Study on Anti-diabetic Effects of Aqueous *Trigonella foenum graecum*, *Hibiscus cannabinus* Linn, and *Cicer arietinum* extracts on Alloxan Induced Diabetic Male Albino Rats. *Journal of Young Pharmacists*, **9**(2); 230

Chavan, R. T. and R. V. Salve (2023). Encapsulated Turmeric: An Innovative Approach for Improving Absorption and Effect. *The Pharma Innovation Journal*, **12**(5); 2294–2301

Cozmin, M., I.-I. Lungu, C. Gutu, A. Stefanache, L. D. Duceac, B. D. Soltuzu, D. Damir, G. Calin, E. R. B. Goroftei, C. Grierosu, and M. Boev (2024). Turmeric: From Spice to Cure. A Review of the Anti-Cancer, Radioprotective and Anti-Inflammatory Effects of Turmeric Sourced Compounds. *Frontiers in Nutrition*, **11**; 1–12

Deng, Z., K. Yang, X. Cai, H. Mei, H. Xiao, and W. Gao (2023). The Beneficial Effects of Curcumin Supplementation on Blood Lipid Levels among Patients with Metabolic Related Diseases in Asia Area: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Frontiers in Sustainable Food Systems*, **7**; 1167913

Eberhardt, J., D. Santos-Martins, A. F. Tillack, and S. Forli (2021). AutoDock Vina 1.2. 0: New Docking Methods, Expanded Force Field, and Python Bindings. *Journal of Chemical Information and Modeling*, **61**(8); 3891–3898

Fadhilah, I. N. and D. Saryanti (2019). Formulation and Physical Stability Test of Bitter Melon (*Momordica charantia* L.) Extract Tablet Preparations by Wet Granulation. *Smart Medical Journal*, **2**(1); 25–30

Gillani, H. A., M. Khalid, S. Said, M. Khalid, S. Umbreen, and S. Tariq (2023). Vitamin C and Cranberry Extract Effervescent Tablet Formulation, Characterization, and Evaluation. *International Journal of Pharmacy and Integrated Health Sciences*, **4**(1); 560605

Gomez, S., C. Anjali, B. Kuruvila, P. Maneesha, and M. Joseph (2023). Phytochemical Constitution and Antioxidant Activity of Functional Herbal Drink from Indian Gooseberry (*Emblica officinalis* Gaertn.) Fruits Containing Spices and

Condiments. *Food Production, Processing and Nutrition*, **5**(1); 12

Her, C., M.-C. Venier-Julienne, and E. Roger (2018). Improvement of Curcumin Bioavailability for Medical Applications. *Medicinal & Aromatic Plants*, **7**(6); 4172

Hesson, J. (2024). The Effectiveness of Turmeric Supplementation in Reducing Low-Density Lipoprotein Cholesterol in Adults. *Revista Mexicana de Endocrinología, Metabolismo y Nutrición*, **11**(2); 60–73

Iriyani, D., I. F. Romadhoni, and A. Bahar (2024). Quality Analysis of Herbal Teabags as Functional Drink. In *Proceeding International Seminar of Science and Technology*, volume 3. pages 109–116

Laurent, O. and R. S. Sitorus (2023). Formulation and Evaluation of Effervescent Granules Ethanol Extract of Andaliman Fruit (*Zanthoxylum acanthopodium* DC) with Combination of Citric Acid-Tartaric Acid and Sodium Bicarbonate. *Eureka Herba Indonesia*, **4**(4); 310–315

Lee, G. H., K. S. Kim, and W. Jo (2023). Stress Evaluation of Mouse Husbandry Environments for Improving Laboratory Animal Welfare. *Animals*, **13**(2); 1–11

Mandal, S., M. Nicolas, and O. Pouliquen (2020). Insights into the Rheology of Cohesive Granular Media. *Proceedings of the National Academy of Sciences of the United States of America*, **117**(15); 8366–8373

Maxfield, F. R., N. Steinfeld, and C.-I. J. Ma (2023). The Formation and Consequences of Cholesterol-Rich Deposits in Atherosclerotic Lesions. *Frontiers in Cardiovascular Medicine*, **10**; 1–6

Meng, T., Y. Zhang, J. Wang, C. H. Leo, Z. Li, J. Zhang, K. Gao, and Q. He (2023). Efficacy and Mechanism of Herbal Medicines and Their Functional Compounds in Preventing and Treating Cardiovascular Diseases and Cardiovascular Disease Risk Factors. *Frontiers in Pharmacology*, **14**; 1236821

Moravkar, K., S. Korde, B. Bhairav, S. Shinde, S. Kakulade, and S. Chalikwar (2020). Traditional and Advanced Flow Characterization Techniques: A Platform Review for Development of Solid Dosage Form. *Indian Journal of Pharmaceutical Science & Research*, **82**(6); 945–957

Noothi, S. K., M. R. Ahmed, and D. K. Agrawal (2023). Residual Risks and Evolving Atherosclerotic Plaques. *Molecular and Cellular Biochemistry*, **478**(12); 2629–2643

Pan, H., S. E. Ho, C. Xue, J. Cui, Q. S. Johanson, N. Sachs, L. S. Ross, F. Li, R. A. Solomon, E. S. Connolly Jr, et al. (2024). Atherosclerosis Is a Smooth Muscle Cell-Driven Tumor-Like Disease. *Circulation*

Panknin, T. M., C. L. Howe, M. Hauer, B. Bucchireddigari, A. M. Rossi, and J. L. Funk (2023). Curcumin Supplementation and Human Disease: A Scoping Review of Clinical Trials. *International Journal of Molecular Sciences*, **24**(5); 4476

Parajuli-Baral, K. (2023). Formulation and Evaluation of Quality Parameters of Effervescent Granules from the Potent Antioxidant Between Two Variants of the Adaptogenic Herb (*Ocimum tenuiflorum* L.). *Scientific World Journal*, **2023**(1); 2050846

Poznyak, A. V., A. A. Yakovlev, M. D. Popov, A. D. Zhuravlev, V. N. Sukhorukov, and A. N. Orekhov (2024). Coronary Atherosclerotic Plaque Regression Strategies. *The Journal of Biomedical Research*, **(in Press)**

Ray, S. and M. K. Saini (2021). Cure and Prevention of Cardiovascular Diseases: Herbs for Heart. *Clinical Phytoscience*, **7**(1); 64

Rohmah, M. N. (2024). Utilization and Content of Turmeric (*Curcuma domestica*) as Medicine in Islamic Perspective. *Es-Syajar: Journal of Islam, Science and Technology Integration*, **2**(1); 178–186

Safari, Z. and M. R. Rahimi (2023). The Effect of Curcumin on Anthropometric Indices, Blood Pressure, Lipid Profiles, Fasting Blood Glucose, Liver Enzymes, Fibrosis, and Steatosis in Non-Alcoholic Fatty Livers. *Frontiers in Nutrition*, **10**; 1163950

Sahrawat, N. and N. Chaturvedi (2023). Quality Evaluation and Consumer Acceptance Test of Functional Fruit-Herb Beverages. *Asian Journal of Dairy and Food Research*; 1–7

Salama, M., S. M. Ezzat, and M. Salem (2020). Natural Products for the Management of Cardiovascular Diseases. *Natural Products in Clinical Trials*, **2**(1-00); 1–52

Singh, L., Y. Zhang, Y. Zhang, Y. Wang, Y. Li, Y. Liu, Y. Chen, Y. Zhao, and Y. Huang (2021). Curcumin as a Natural Remedy for Atherosclerosis: A Pharmacological Review. *Molecules*, **26**(13); 4036

Srivastava, I., Y. Zhang, Y. Zhang, Y. Wang, Y. Li, Y. Liu, Y. Chen, Y. Zhao, and Y. Huang (2022). Flow and Arrest in Stressed Granular Materials. *Soft Matter*, **18**(4); 735–743

Trott, O. and A. J. Olson (2010). Autodock Vina: Improving the Speed and Accuracy of Docking with a New Scoring Function, Efficient Optimization, and Multithreading. *Journal of Computational Chemistry*, **31**(2); 455–461

Widianingsih, S., Y. Zhang, Y. Zhang, Y. Wang, Y. Li, Y. Liu, Y. Chen, Y. Zhao, and Y. Huang (2024). Thermal Conversion of Coral Waste and Its Utilization as Low-Cost Catalyst for Biodiesel Production. *Science and Technology Indonesia*, **9**(4); 866–875

Wilkinson, M. J., N. E. Lepor, and E. D. Michos (2023). Evolving Management of Low-Density Lipoprotein Cholesterol: A Personalized Approach to Preventing Atherosclerotic Cardiovascular Disease Across the Risk Continuum. *Journal of the American Heart Association*, **12**(11); e028892

Yudha, S. and S. Nurhasanah (2024). Molecular Spectroscopic (FTIR and UV-Vis) Analysis and In Vitro Antibacterial Investigation of a Deep Eutectic Solvent of N,N-Dimethyl Urea-Citric Acid. *Science and Technology Indonesia*, **9**(1); 167–172

Yudhani, R. D., K. Fahrurrozi, and D. Indarto (2022). New Cholesteryl Ester Transfer Protein from Indonesian Herbal Plants as Candidate Treatment of Cardiovascular Disease. *Open Access Macedonian Journal of Medical Sciences*, **10**; 1624–1629

Zeng, Y., Y. Luo, L. Wang, K. Zhang, J. Peng, and G. Fan

(2023). Therapeutic Effect of Curcumin on Metabolic Diseases: Evidence from Clinical Studies. *International Journal of Molecular Sciences*, **24**(4); 3323

Zhang, X., H. Xing, Y. Zhao, and Z. Ma (2018). Pharmaceutical Dispersion Techniques for Dissolution and Bioavailability Enhancement of Poorly Water-Soluble Drugs. *Pharmaceutics*, **10**(3); 74