Decaffeinated coffee and green tea extract inhibit foam cell atherosclerosis by lowering inflammation and improving cholesterol influx/efflux balance through upregulation of PPARγ and miR-155 [version 2; peer review: awaiting peer review]

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Abstract

Background: Foam cells, the markers of early atherosclerosis and characterise the advanced atherosclerotic plaque, are stimulated by inflammation due to the excess of lipid in macrophages. The combination of decaffeinated coffee and green tea extract (DCGTE) has been suggested to have a role in foam cell inhibition.

Objective: To investigate the role of DCGTE against foam cell formation, through modulation of the inflammation process and cholesterol metabolism in macrophage colony stimulating factor (M-CSF) and oxidized low-density lipoprotein (oxLDL)-exposed macrophages.

Methods: Coffee and green tea were extracted by filtration and infusion respectively. Both of coffee and green tea underwent decaffeination using active carbon and blanching methods, respectively. Raw 264.7 Cells were administered with 160/160 and 320/320 µg/ml of DCGTE. Foam cell formation was observed using a light microscope after staining with Oil Red O (ORO), and quantified with ELISA. The expression of cluster differentiation 36 (CD36) (lipid influx) and ATP binding cassette transporter A1 (ABCA1) (cholesterol efflux) were determined through immunofluorescence. Tumor
Necrosis Factor α (TNFα) and Interleukin10 (IL10) were quantified with ELISA. Peroxisome proliferator activated response γ (PPARγ) expression and activity were assessed with Polymerase Chain Reaction (PCR) and ELISA, respectively. The expression of microRNA 155 (miR-155) was examined using qPCR.

**Results:** DCGTE at the above concentrations tended to reduce foam cell numbers, significantly inhibited lipid accumulation (p=0.000), reduced CD36 expression (p=0.000) and TNFα secretion (p=0.000) in Raw264.7 exposed to M-CSF 50 ng/ml and oxLDL 50 μg/ml. The PPARγ expression (p=0.000), PPARγ activity (p=0.001), ABCA1 (p=0.002), miR-155 relative expression (p=0.000), and IL10 production (p=0.000) also increased in DCGTE groups.

**Conclusion:** DCGTE lowered foam cell possibly through attenuation of the inflammatory process and improvement of lipid/efflux mechanisms via upregulation of PPARγ and miR-155 in M-CSF and oxLDL-stimulated Raw264.7 cells. Our results suggest DCGTE might help to prevent atherosclerosis-based diseases.

**Keywords**
coffee, green tea, foam cell, inflammation, miR-155, PPARγ

This article is included in the Cell & Molecular Biology gateway.
Introduction
Foam cell macrophages are not only hallmarks of early atherosclerosis process, but also drive the progression of atherosclerosis plaque.\(^1,2\) However, atherosclerosis is the etiologic agent of various cardiovascular diseases that cause high morbidity and mortality worldwide, especially during the ongoing COVID-19 pandemic.\(^3\)–\(^5\) The crosstalk interaction between inflammation and lipid metabolism disturbances in macrophages are two key factors that determine foam cell formation.\(^6,7\) Upregulation of CD36 expression causes oxLDL endocytosis.\(^8,9\) Thus, lipid accumulation inside macrophages leads to endoplasmic reticulum (ER) stress, and stimulates the production of inflammatory cytokines through the activation of nuclear factor kappa B (NF\(\kappa\)B) signalling, and the reduction of anti-inflammatory cytokines. Moreover, the inflammation process gives rise to positive feedback on the increase of oxLDL uptake, thus accumulating the esterified cholesterol content inside the macrophage.\(^10,11\) On the other hand, proinflammatory cytokines provoke the lysosomal activation and apoptosis signalling that leads to the activation of ubiquitin proteasome signalling, where both processes contribute to the failure of cholesterol efflux from macrophages through ABCA1 degradation.\(^12,13\) Another significant issue lies in the fact that PPAR\(\gamma\) and miR-155 are molecules involved in the dual function of inflammation and the impaired lipid metabolism that inhibits the foam cell formation.\(^14\)–\(^20\)

Investigating natural products that may act to reduce foam cell numbers by lowering inflammation and improving the impaired lipid influx/efflux mechanism in macrophages is an important approach for atherosclerosis prevention. Although many studies have revealed the health benefits of coffee, several reports showed opposite, detrimental results. High caffeine and different roasting levels are two factors that might explained the negative effects of coffee consumption.\(^14\)–\(^20\) Based on a previous study, this research tried to optimize the advantages of coffee by performing: (1) light roasting, (2) a decaffeination process, and (3) combination with green tea. Coffee contains several active compounds, mainly chlorogenic acid (CGA), followed by diterpenes (kahweol, cafestol), and trigonelline.\(^21\) Light-roasted coffee yields the highest antioxidant concentration compared with green coffee or full roasted coffee. On the other hand, green tea has higher catechin levels compared to other tea varieties.\(^22\) Moreover, this combination showed a synergistic activity based on a previous study.\(^23\) For the present study, we tried to investigate the anti-inflammatory and modulation of lipid influx/efflux effects of decaffeinated coffee and green tea extract (DCGTE) in suppressing foam cell formation.

Methods
Coffee and green tea extraction
The raw material used in this study was Robusta green coffee beans obtained from the the Dampit area, Malang Regency, Indonesia. The sample used was in the form of powdered green coffee beans that had been roasted at 180° C for 3 minutes (until the first crack of the bean). Three green tea leaves were retrieved from the highest part of trees in the Ciwidey area in Bandung. The selection of dried green tea was based on final appearance: a rolls shape, a pale green colour, and a sweet scent.

Coffee decaffeination was carried out following the Fischer method.\(^24\) The green tea decaffeination process was performed using the blanching method by Liang, 2007,\(^25\) whereas green tea and coffee extraction followed the process performed by Vuong et al., 2011, with a water-to-tea/coffee ratio of 20:1.\(^26\) The optimized boiling time for coffee and tea extraction, boiling water time for tea decaffeination, and addition of agent adsorption of caffeine in coffee decaffeination were decided using response surface methodology (RSM) Box-Behnken design (BBD) in Design Expert 7.1.5 (StatEase) software.

Briefly, the light-roasted ground coffee beans were boiled in mineral water for 10 minutes at 90°C, followed by filtration with fine filter paper. The filtrate then was subjected to the decaffeination process, using activated charcoal for 8 hours at 60°C.\(^27\) The tea dried leaves were boiled in mineral water for 5 minutes at 50°C, then filtered using Whatman paper No 1.\(^25,28\) The filtrate was infused in 90°C water for 30 minutes. Stock solutions were freshly prepared by dissolving the coffee and tea extract (64 mg/ml) and filtering the solution through a 0.22 \(\mu\)m-pore size membrane filter.
Macrophages from the RAW 264.7 mouse cell line were obtained from ATCC (CVCL_0493). The passage number 10-20 was used in this study. RAW 264.7 cells were cultured in complete medium containing Dulbecco’s modified Eagle medium (DMEM) high glucose, Gibco 11965092), supplemented with 10% Fetal Bovine Serum (FBS, Gibco 16000036) and 1% penicillin/streptomycin (P/S, Gibco15140122). The cells were incubated in a humidifier incubator at 37° with 5% CO2. To induce macrophage type 2 (M2) differentiation and ultimately establish a foam cell model, Raw 264.7 cells were cultured with recombinant mouse M-CSF 50 ng/ml (BioLegend 576406) for 24 hours, then stimulated with 50 μg/ml oxLDL (Thermofisher L34357) for another 24 hours. DCGTE was administered at 2 different doses (160/160 and 320/320 μg/ml). The cells were divided into 4 groups, K, K+, P1, P2 as follows: complete medium + 50 ng/ml M-CSF (K), complete medium + 50 ng/ml M-CSF + 50 μg/ml oxLDL (K+); complete medium + 50 ng/ml M-CSF + 50 μg/ml oxLDL + 160/160 μg/ml DCGTE (P1); complete medium + 50 ng/ml M-CSF + 50 μg/ml oxLDL + 320/320 μg/ml DCGTE (P2).

Oil red O staining
Briefly, the cells were cultured at 15.000 cells/well in 24-well plates placed with a coverslip until reaching 60-70% confluency. The medium was discarded and cells were rinsed twice with PBS, then fixed in 10% paraformaldehyde for 10 minutes. The cells were washed with Phosphate Buffer Saline (PBS) twice (for 3 minutes) again, and were incubated with 60% isopropanol for 30 minutes to facilitate the staining of neutral lipids. The cells were stained with filtered Oil Red O (ORO) solution (Sigma-Aldrich, MAK194) at 37°C for 30 minutes in darkness. The cells were washed with 60% isopropanol for 5 seconds, followed by 5 repeated washing steps with PBS. Positively stained (red cytoplasm) cells were macrophage-derived foam cells, which were observed via light microscope (Olympus Bx51), photographed with Optilab Advance Plus MTN016, and analysed using Optilab Viewer v3.0 software.

Lipid absorbance quantification
100% 2-propanol was added to the ORO-stained plates (500 μl per well on the 24-well plates). The plates were incubated for 40 minutes at room temperature on an orbital shaker in darkness. 200 μl eluates were transferred to a clear 96-well microtiter plate (polystyrene). As a control, 3 microtiter plate wells were filled with 200 μl of 2-propanol. Absorption was measured in duplicates at 492 nm.

CD36 and ABCA1 expression
The cells were pipetted into a 24-well plate with a 15.000 cells/well. Cultured cells were stained by plating the cells on glass coverslips. After treatment, the cells were washed 3 times with PBS and fixed with 4% paraformaldehyde for 30 minutes at room temperature. The cells were washed twice with PBS (3 minutes), blocked with 2% bovine serum albumin (BSA) for 1 hour at room temperature, and incubated with anti-CD36 monoclonal antibody 1:150 (Santa Cruz, Cat. No. sc3709) and Rabbit antiphospho-ABCA1 antibody 1:200 (Bioss, Cat. No. bs-12956R) at 4°C overnight. The cells were washed 3 times with PBS and incubated with anti-rabbit IgG antibody rhodamine conjugated (Rockland Cat. No. 6111002-0500, RRID: AB_11181881) and Fab Goat anti-mouse IgG antibody FITC (Rockland Cat. No. 710-1202; RRID: AB_218843) for 1.5 hours in light-shielded conditions. Nuclei were stained with 4, 6-diamidino-2-phenylindole (DAPI; BioLegend Cat. No. 422801 ID = BLG2181) for 5 minutes in the dark. After 3 washes with PBS, coverslips were mounted with glycerol. The cells were visualized using an Olympus IX71 Fluorescent Microscope at 400× magnification, and then photographed with Olympus Cell Sens software version 3.2. The pixel intensities in the cell cytoplasm that reflecting the expression levels were quantified using Image J (fiji) software and presented as percentages of CD36 or ABCA1 expression, then compared statistically.

Tumor Necrosis Factor (TNF) α and Interleukin (IL)10 expression
RAW 264.7 cells were seeded in 24-well plates at 1.5×10^4 cells/well to get confluency 80-100% in 5th day. Media were collected and centrifuged at 2.500 rpm for 7 min. TNFα and IL10 content of the media was then determined by a quantitative sandwich enzyme-linked immunosorbent assay (ELISA) using the Mouse TNFα ELISA Kit (BT Lab E0117Mo) and mouse IL10 ELISA kit (BT Lab E002Mo) according to the manufacturer’s instructions in ELISA reader BioTek ELx808 using Gen5 reader software.

miR-155 expression
This procedure was followed in the following steps: isolation of total RNA, cDNA synthesis, and Real-Time PCR. Total RNA from cells was extracted by using the miRVana (Ambion Thermofisher AM1560) reagent kit according to the manufacturer’s protocol. Reverse transcription polymerase chain reaction (RT-PCR) was conducted in a single process using an RT-PCR kit from Qiagen (miRCURY LNA RT kit 33430): incubation for 60 minutes at 42°C, followed by incubation for 5 minutes at 95°C to heat-inactivate the reverse transcriptases, and cooling at 4°C.
First, we investigated the effects of the decaffeinated coffee and tea extract (DCGTE) on Raw 264.7 macrophages treated with 50 ng/ml M-CSF and 50 μg/ml ox-LDL. The assessment of foam cells characteristics was performed using ORO staining, followed by measuring the absorbance to quantify the lipid content in the cell. Raw 264.7 cells exposed to 50 μg/ml oxLDL) (p = 0.000**, Figure 1).

**The decaffeinated coffee and green tea extract reduced CD36 and increased ABCA1 expression in ox-LDL stimulated macrophages**

Foam cells could be formed due to a dysregulation of the lipid metabolism, which was determined by the continuous uptake of ox-LDL and failure in lipid efflux from macrophages. The endocytosis of ox-LDL is mainly regulated by CD36, whereas ABCA1 plays a significant role in cholesterol efflux. Thus, this study aimed to investigate the effect of the extract in the cells which was examined using the immunofluorescence technique. Figure 2 depicts the CD36 and ABCA1 expression after being incubated with the extract for 24 hours in M-CSF and ox-LDL-stimulated Raw 264.7. One-way ANOVA tests showed significant differences in CD36 (p = 0.000**) and ABCA1 (p = 0.000**) expression in DCGTE group compared to positive control (K+). Therefore, we concluded that the administration of decaffeinated coffee and green tea extract could suppress CD36 and induce ABCA1 expression in Raw 264.7 cells.
The decaffeinated coffee and green tea extract attenuated TNF\(\alpha\) and enhanced IL10 secretion in ox-LDL-stimulated macrophages. Hence, this current study also tried to investigate the effect of the extract in inhibiting the inflammation process, by examining TNF\(\alpha\) and IL10 production. Figure 3 showed a reduced TNF\(\alpha\) concentration in the group administered with 160\(\mu\)g/ml and 320\(\mu\)g/ml extracts compared to control (\(p = 0.012; p = 0.000\)). Consistently with the result from inflammatory cytokine production, the data showed that IL10, an anti-inflammatory cytokine, was higher in groups treated with the 160\(\mu\)g/ml and 320\(\mu\)g/ml extracts compared to control (\(p = 0.002; p = 0.000\)). Therefore, we concluded that administration of DCGTE at concentrations of 160\(\mu\)g/ml and 320\(\mu\)g/ml gradually inhibited TNF\(\alpha\) and stimulated IL10 production in Raw 264.7 cells.

The decaffeinated coffee and green tea extract increased mRNA PPAR\(\gamma\) and PPAR\(\gamma\) activity in ox-LDL-stimulated macrophages. The signalling pathway that mediates DCGTE is also explored in this present study. PPAR\(\gamma\) is an antiatherogenic transcription factor that contributes to the suppression of foam cell formation. Figure 4 demonstrates that both the expression and activity of PPAR\(\gamma\), were increased in DCGTE compared to the K+ group (\(p = 0.000**\) and \(p = 0.001**\)). Additionally, PPAR\(\gamma\) expression and activity showed their lowest level in the K (+) group.

The decaffeinated coffee and green tea extract reduced the miR-155 expression in ox-LDL-stimulated Raw 264.7. Recent reports showed the importance of miRNA in post-transcriptional gene expression regulation. miR-55 plays a significant role in inflammation. In addition, miR-155 has been proven to target CD36, SOCS1, and Vav3 based on \textit{in silico} results. Regarding this function, this study explored the effect of DCGTE on miR-155 expression, and results can be seen in Figure 5. The results demonstrated a significant increase in relative miR-155 expression in cells treated with 160/160 and 320/320\(\mu\)g/ml DCGTE compared to positive control (K+) (\(p = 0.000**\)). Surprisingly, the data showed the expression of miR-155 higher in positive control (K+) (\(p = 0.000**\)) compared to the control group.

Figure 1. Effect of DCGTE on foam cell number and lipid content in ox-LDL-stimulated Raw 264.7 cells. The foam cell was characterized by red color in cytoplasmic part observed with microscope Olympus BX51 200× magnification. * \(p < 0.05\), relative to C, ∧ \(p < 0.05\) relative to C(+), # \(p < 0.05\) relative to P1. Culture groups: complete medium + 50 ng/ml M-CSF (K); complete medium + 50 ng/ml M-CSF + 50 \(\mu\)g/ml oxLDL (K+); complete medium + 50 ng/ml M-CSF + 50 \(\mu\)g/ml oxLDL + 160/160 \(\mu\)g/ml DCGTE (P1); complete medium + 50 ng/ml M-CSF + 50 \(\mu\)g/ml oxLDL + 320/320 \(\mu\)g/ml DCGTE (P2).
Discussion

Our accumulated evidence suggests that inflammation drives the formation of atherosclerotic plaques by disrupting the cholesterol metabolism inside macrophages. The inflammation process could be characterized by the balance production of inflammatory and anti-inflammatory cytokines in macrophages. TNFα is a proinflammatory cytokine that has an important role in the formation of atherosclerotic foam cells. A study using differentiated macrophages from THP-1 exposed to very low-density lipoprotein (VLDL), then incubated with IL-1β and TNFα for 24 hours, showed an increase of intracellular cholesterol and triglyceride retention compared to control. On the other hand, IL-10 as an anti-inflammatory cytokine also contributes to the whole atherosclerosis process, including foam cell formation. Overexpression of IL-10 in macrophages derived from bone marrow low density lipoprotein knockout (LDLR−/−) mice

Figure 2. Effects of DCGTE on CD36 and ABCA1 expression in oxLDL-stimulated macrophages. The blue colour indicated nuclear staining, green for CD36 with FITC, red for ABCA1 with rhodamin fluorochrome. The expression was observed using a fluorescent microscope 400× magnification and quantify with ImageJ as percentage/200 cells. * p < 0.05, relative to C, ∧ p < 0.05 relative to C(+), # p < 0.05 relative to P1. Culture groups: complete medium + 50 ng/ml M-CSF (K); complete medium + 50 ng/ml M-CSF + 50 μg/ml oxLDL (K+); complete medium + 50 ng/ml M-CSF + 50 μg/ml oxLDL + 160/160 μg/ml DCGTE (P1); complete medium + 50 ng/ml M-CSF + 50 μg/ml oxLDL + 320/320 μg/ml DCGTE (P2).
Figure 3. **DCGTE effect on inflammation process.** On the 4th day after seeding, the cell medium was taken and analyzed for cytokine protein content by ELISA. * p < 0.05, relative to K, ∧ p < 0.05 relative to K(+), # p < 0.05 relative to P1. Culture groups: complete medium + 50 ng/ml M-CSF (K); complete medium + 50 ng/ml M-CSF + 50 µg/ml oxLDL (K+); complete medium + 50 ng/ml M-CSF + 50 µg/ml oxLDL + 160/160 µg/ml DCGTE (P1); complete medium + 50 ng/ml M-CSF + 50 µg/ml oxLDL + 320/320 µg/ml DCGTE (P2).

Figure 4. **DCGTE increased mRNA PPARγ expression and activity.** The mRNA expression of PPARγ was analyzed using PCR. The reactions were loaded onto an agarose gel, resolved by size via electrophoresis, and visualized with ethidium bromide. The bands were quantified using Image J and normalized with β-actin. PPARγ activity was analyzed using ELISA. * p < 0.05, relative to K, ∧ p < 0.05 relative to K(+), # p < 0.05 relative to P1. Culture groups: complete medium + 50 ng/ml M-CSF (K); complete medium + 50 ng/ml M-CSF + 50 µg/ml oxLDL (K+); complete medium + 50 ng/ml M-CSF + 50 µg/ml oxLDL + 160/160 µg/ml DCGTE (P1); complete medium + 50 ng/ml M-CSF + 50 µg/ml oxLDL + 320/320 µg/ml DCGTE (P2).
showed inhibition of atherosclerosis by reducing cholesteryl ester accumulation in atherosclerotic sites. Atherosclerotic plaques of patients with a history of coronary heart diseases have been shown to express IL-10. IL-10 inhibits macrophage apoptosis and TNFα production, which is mediated by the inactivation of the NF-κB transcription factor. Furthermore, macrophage apoptosis inhibition causes caspase expression decrease, and causes the COP9 signalosome complex (CSN) to remain intact, thus protecting the ABCA1 protein from ubiquitination. Moreover, experiments with primary macrophages indicated that IL-10 directly stimulated the efflux of cholesterol by activating the PPARγ-LXR-ABCA1/ABCG1 pathway.

In this study, we demonstrated the beneficial effects of DCGTE using Raw 264.7 macrophages under M-CSF-induced M2 differentiation and oxLDL-induced foam cells. The suggested mechanisms involved in foam cell inhibition by DCGTE act by suppressing inflammation, thus driving cholesterol influx and efflux in macrophages. A 24-hour incubation of macrophages with 160/160 and 320/320 μg/ml DCGTE significantly reduced TNFα and increased IL-10 production in oxLDL-stimulated macrophages. Interestingly, there was also significant reduction of foam cell numbers, CD36 expression, and enhancement of ABCA1 in DCGTE-exposed sample groups compared to control. Our study was the first to explore the effect of DCGTE in foam cell atherosclerosis. These findings were consistent with data from several studies investigating the effect of green tea extract or catechin as the main active ingredients in green tea on foam cell formation. Green tea extract has been shown to effectively inhibit lipid peroxidation. Epigallo catechin gallate (EGCG), the main active compound from green tea, upregulated ABCA1 expression through the suppression of TNFα production and NFκB activity in macrophage-derived foam cells. Another supporting evidence related to our findings came from a few reports exploring the effect of coffee in atherosclerosis. Coffee was found to enhance the cholesterol efflux based on in vitro, in vivo and human studies. Another report showed that supplementation with CGA, the main secondary metabolite of coffee, suppressed oxLDL-induced lipid accumulation from RAW 264.7 cells and decreased LDL and inflammatory markers from apolipoprotein E knockout (ApoE-/-) mice.

The more complex mechanism underlying DCGTE-driven foam cell inhibition was also investigated in this study. PPARγ is an antiatherogenic transcription factor that plays an important role in the atherosclerosis process. Our findings showed an increase of PPARγ expression and activity, after administration of 160/160 and 320/320 μg/ml DCGTE. PPARγ has an anti-inflammatory property and affects lipid efflux processes directly or indirectly. PPARγ-deficient macrophages displayed an increased pro-inflammatory phenotype upon long-term LPS stimulation, characterized by an elevated production of the pro-inflammatory cytokines TNFα, IL-1β, IL-6, IL-12, and a reduced production of anti-inflammatory cytokine IL-10 compared to PPARγ wild-type cells. Moreover, PPARγ-deficient macrophages showed impaired phagocytosis. In macrophage lipid metabolism processes, PPARγ directly increases the expression of ABCA1, which was confirmed by our report. These results were consistent with data from another study showing that CGA significantly increased the mRNA levels and transcriptional activity of PPARγ, as well as downstream mRNA LXRα, ABCA1 and ABCG1 signaling levels.
Interestingly, PPARγ also directly increased CD36 expression. Based on other studies, we suggest that CD36 expression is not determined solely by PPARγ expression. However, there are other factors that affect CD36 expression, such as the presence of IL-34, and ER stress. In addition to a direct effect, PPARγ may indirectly work on influx and efflux mechanisms by modulating the inflammatory process. One study reported a suppression of TNFα promoter activity after myocyte were stimulated with lipopolysaccharide in a luciferase assay. Otherwise, no change in TNFα promoter activity was observed in NfκB knockdown and TNFα reporter-transfected cells. Consistently, Bernardo et al., 2021 reported in his study that the administration of the PPARγ antagonist GW9662 significantly prevented phosphorylation of ERK1/2, as well as TNFα.

A second possible regulator of foam cell inhibition is the presence of other molecules that might affect CD36 and ABCA1 expression, inflammatory and anti-inflammatory cytokines production. Our data support the antiatherogenic role of miR-155. This finding supports our previous in silico study, that suggested miR-155 as a potential candidate molecule to inhibit foam cell establishment. The results showed a significant increase of relative miR-155 expression in DCGTE-treated groups compared to control, hence potentially explaining the decrease of CD36 expression, TNFα and the increase of ABCA1 and IL-10, ultimately decreasing foam cell formation. The role of miR-155 in mediating the action of this coffee and tea combination is probably due to its direct action on lipid fluxes, or indirectly through the inflammatory process. The direct action of miR-155 was on 3’ untranslated region (UTR) CD36 mRNA. The indirect action of miR-155 in suppressing foam cell formation was revealed by several studies on the action of miR-155 on inflammatory markers. miR-155 targets and degrades calcium-regulated heat-stable protein 1 (CARHSP1) which causes a decrease in the stability of TNFα mRNA. Inflammatory macrophage production (TNFα and IL-6) was increased in miR-155 inhibitor--transfected macrophages due to the upregulation of p38 and Janus kinase (JNK), extracellular signal related kinase (ERK), mitogen activated protein kinase kinase kinase (MAP 3K) signaling pathway. The transfection of miR-155 mimic showed the opposite results in oxLDL-stimulated macrophages. The third target was the action of miR-155 on the suppressor of cytokine signaling 1 (SOCS1). SOCS1 was expected to be an E3 ligase, part of a ubiquitin protease system, which causes the degradation of ABCA1. Chang et al., 2020 and Li et al., 2015 demonstrated that SOCS1 was the direct target of miR-155–5p, by performing a luciferase reporter assay using HEK293 cells.

Many papers have revealed that various natural products exert cardio-protective effects, either as functional food or source of phytopharmacology products. It has been widely accepted that coffee and tea have many benefits as hypolipidemic, anti-inflammatory, and antioxidant agents. However, some controversy remains regarding the cardiovascular and non-cardiovascular side effects of caffeine components in coffee and tea. The decaffeination process is used to minimize conflicting results. Interestingly, our findings were the first to reveal the combination of decaffeinated coffee and green tea extract could reduce foam cell numbers. However, this study has several limitations. The signaling pathway showing the interaction between PPARγ, miR-155, CD36, ABCA expression, TNFα, and IL-10 could not directly be proven. Existing guidelines on atherosclerosis management mainly include the use of statin and pioglitazone. Unfortunately, the present study design did not compare the efficacy of statin or pioglitazone administration in inhibiting foam cell formation. Therefore, considering the limitations, extensive efforts are required to develop this extract combination as nutraceutical food for the prevention of atherosclerosis.

Conclusions
These findings suggest that DCGTE confers a protection against the formation of foam cell formation by regulation of cholesterol homeostasis and inflammation. Hence, a DCGTE combination could potentially be used as an agent to prevent atherosclerosis.

Data availability statement
Underlying data

This project contains the following underlying data:

- Final untuk F1000.xlsx (dataset containing the optimized extraction time, decaffeination time, water decaffeination temperature for coffee and green tea, lipid absorbance, CD36 and ABCA1 expressions, PPARγ gene expression, PPARγ activity, relative miR-155 expression, TNFα production and IL-10 production measures)

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).
References

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