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Antioxidant activities and glycemic indices of ice creams enriched with orange (*Citrus sinensis*) and shaddock (*Citrus maxima*) peels and effects on rat lipid profiles

Ayokunle Olubode Ademosun[1] | Ganiyu Oboh[1] | Olufunke Florence Ajeigbe[1,2]

[1]Department of Biochemistry, Federal University of Technology, Akure, Nigeria

[2]Department of Physical and Chemical Sciences, Elizade University, Ilara-Mokin, Nigeria

Correspondence
Ayokunle Olubode Ademosun, Department of Biochemistry, Federal University of Technology, P.M.B. 704 Akure 340001, Nigeria.
Email: ayoademosun@yahoo.com

Abstract

This study evaluated the effects of ice creams produced from blends of orange (*Citrus sinensis*) and shaddock (*Citrus maxima*) peels on the blood lipid profile, glycemic index, and antioxidant indices in the liver and heart of rats. Formulated ice cream was produced at a different proportion of citrus (orange and shaddock) blends and fed to rats for 28 days. The result showed that the formulated ice cream enriched with citrus peels blends caused a significant increase in high-density lipoprotein-cholesterol level in the plasma and antioxidant status in the liver and heart homogenates, decreased the glycemic index, concentration of total cholesterol, triglycerides, and low-density lipoprotein in the plasma as against rats fed on plain and commercial ice creams. To conclude, the use of ice creams from blends of orange and shaddock peels could serve as a functional food for weight reduction, glycemic index, management of lipid-related diseases, and prevention of oxidative stress-related complications in the liver and heart.

Practical applications

The consumption of ice creams has increased in many parts of the world. However, there have been limited efforts aimed at improving the medicinal properties of frozen dairy products. Hence, these ice creams could be produced on a large scale under regulated condition since they have improved medicinal properties which would be a good option for preventing/combating degenerative conditions and their related complications.

KEYWORDS

antioxidant, ice creams, lipid profile, orange peels, shaddock peels

1 | INTRODUCTION

Ice creams are sweetened frozen dairy product commonly consumed as snacks or dessert made of milk and milk products and are often added with raw and/or dried form of fruits, and other essential ingredients (Patil & Banerjee, 2017). Although overconsumption of ice creams with dense fat can lead to the deposition of lipid in the circulatory system, they are enjoyable snacks. There are instances of them been used as a functional food to serve beneficial health roles and the fortification of ice cream with nutrients and/or bioactive substances has an increasing product demand in the market (Anal & Singh, 2007).

An in-depth observation of the pathogenesis of cardiovascular diseases (CVDs) has revealed that there is no specific marker in its development. The measure of total cholesterol (TC) in the blood is a known and acceptable parameter used in the assessment of cardiac-related disease including atherosclerosis and other heart diseases (Goldstein & Brown, 2015; Takata et al. 2014). Numerous studies confirm the interlink between TC and CVDs (Das, 2016; Psaty et al., 2004). In addition to this, according to Fleming and Godwin (2013) glycaemic "spikes" is a result of high glycemic index (GI) with a direct impact on cardiovascular health. There is an interlink observed between decreased high-density lipoprotein (HDL) level among those consuming higher GI foods (Oxlund & Heitmann, 2006). The measure of dietary GI serves a beneficial role in the treatment of blood lipids and index in predicting the chances of developing CVD.

Citrus can modulate CVDs by assisting in the inhibition of atheromas in the disease state (Pilar & Victoria, 2010) and protecting against cancer and obesity. Species variants of citrus fruits according to Kim et al. (2016) and Park et al. (2013) have been reported in the amelioration of hypertriglyceridemia by inhibiting lipid absorption and lipogenesis. Also, citrus exerts lipolytic effects on the liver (Pilar & Victoria, 2010). It has been established that flavonoid compounds present in various citrus contribute to its promising therapeutic effect against diseases like obesity, diabetes, and dyslipidemia (Assini et al., 2013; Nakajima et al., 2014). Citrus fruits have a wide range of nutrients such as vitamin C, folate, dietary fiber, and minerals (potassium) which attributes to their health-promoting properties. Hence, due to the phytochemical constituents of citrus fruits, it has encouraged its consistent intake in juice or fruits as therapeutic options in managing diseases. The peels of orange (*Citrus sinensis*) and shaddock (*Citrus maxima*) (Oboh & Ademosun, 2012) are not commonly used for any beneficial purpose and are seen as waste agents constituting environmental menace in many countries. *C. sinensis* is one of the most abundantly consumed citrus fruits, and it is a rich source of bio-active compounds with reports of its peels with inherent phytochemicals. The major phytochemicals found in *C. sinensis* peels are terpenoids, flavonoids, saponins, tannins, and phenols (Thakur et al., 2020), while *C. maxima* peels are rich in organic acids, ester, ketone and sterol as reported by Wang et al. (2015).

However, the comparative effects of citrus fruits peels, orange (*C. sinensis*) and shaddock (*C. maxima*), in ice creams on weight management and lipid metabolism and antioxidant activity are unknown. Therefore, the objective of this study is to determine the lipid profile, GI, and activity of antioxidant potentials of ice creams produced from peel blends of two functional foods (orange and shaddock) in rats.

2 | MATERIALS AND METHOD

2.1 | Materials

Orange (*C. sinensis*) and shaddock (*C. maxima*) fruits were obtained from a farm site at The Federal University of Technology Akure, Nigeria. The commercial ice cream was gotten from a commercial creamery besides The Federal University of Technology Akure, Nigeria. The whipping cream and skimmed milk were purchased from a supermarket in Akure. The reagents used were of analytical grade.

2.2 | Method

2.2.1 | Preparation of ice cream

Orange and shaddock fruits were washed and manually peeled with knife to a thickness of about 2 mm. The peels were oven dried for 24 hr at 70°C. The dried peels were milled to produce free-flowing powder (Figure 1). The ice cream formulations were prepared as illustrated in Figure 2: OP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g orange peel powder; OP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; OP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; SP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g shaddock peel powder; SP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; SP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; Plain—50-g whipping cream + 35-g skimmed milk. Information from the creamery where the commercial ice cream was obtained revealed that it contained milk, cream, sugars, modifying agents, and artificial flavorings. However, further details were not provided for commercial reasons. To make the citrus peels enriched ice creams, the whipping cream was added to a bowl and whipped using a hand mixer for 20 min. Thereafter, the skimmed milk and citrus peels were added, and further mixing was done for additional 10 min to create a consistent texture. The ice cream is then packaged and frozen to allow it to harden.

2.2.2 | Sensory evaluation

Sensory analysis was conducted to measure the acceptability of the ice creams formulations and was approved by the Center for Research and Development (CERAD), Federal University of Technology Akure. The test was done among 80 panelists of both genders within a wide range of age. Panelists were selected based on their familiarity and habit of consuming ice cream. Each panelist was given prepared ice creams in plastic cups, a score sheet for sample attributes which included taste, texture, color, aroma, and overall acceptability with scale range of 1–7, wherein 1 is equivalent to very poor and 7 equivalent to excellent, water provided for mouth rinsing in between successive evaluation and plastic spoons. The sensory report is shown in Table 1.

2.2.3 | Experimental design

Sixty-four mature male Wistar albino rats divided into eight groups with weights between 240 and 250 g were gotten from Animal house, Department of Biochemistry, Federal University of

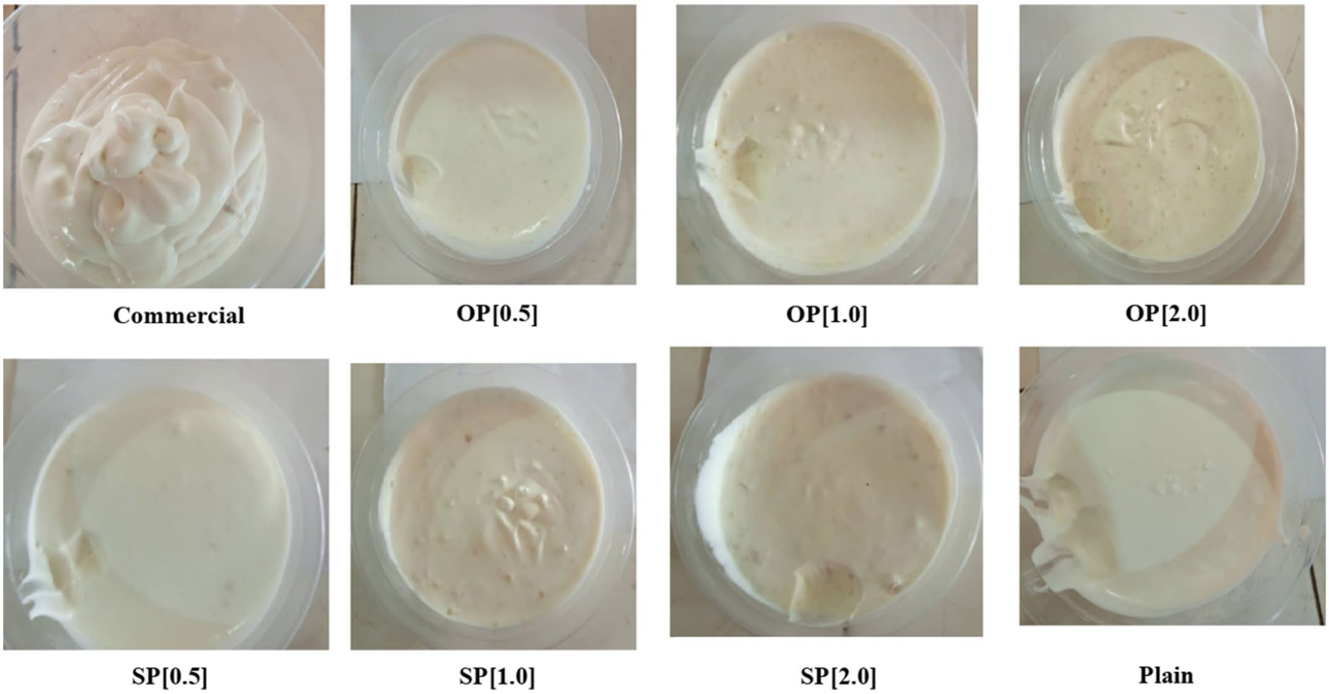

FIGURE 1 Pictures of the ice cream samples. Commercial—Commercial ice cream; OP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g orange peel powder; OP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; OP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; SP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g shaddock peel powder; SP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; SP[2.0]—48-g whipping cream + 35-g skimmed milk + 2g orange peel powder; Plain—50-g whipping cream + 35-g skimmed milk

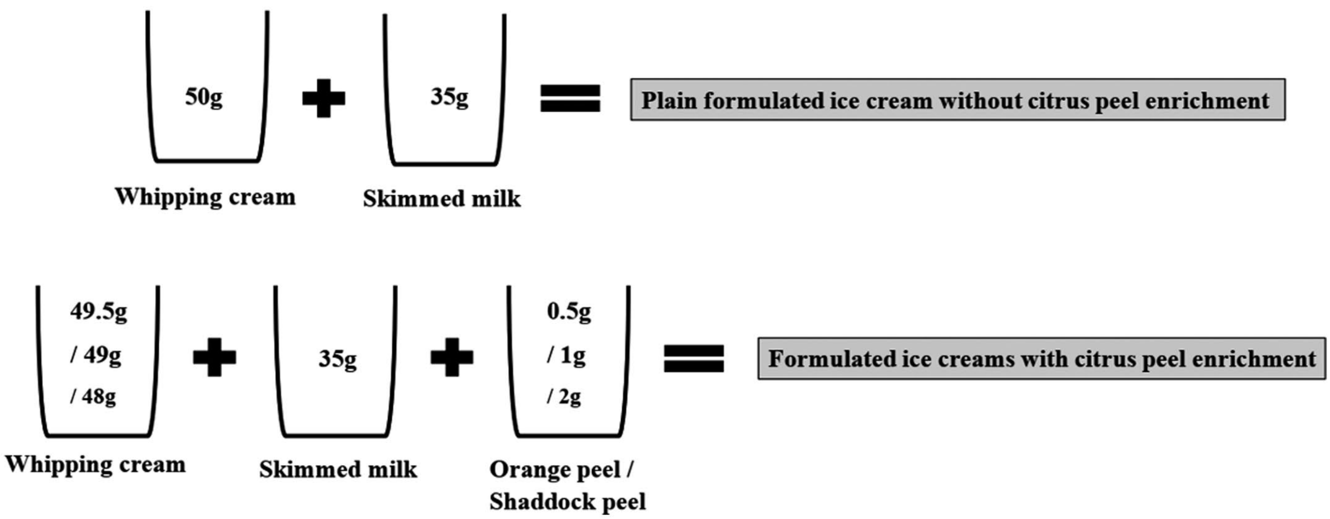

FIGURE 2 Schematic diagram showing the proportion of the ingredients used in making the ice-creams

Technology Akure, Nigeria. They were allowed to have access to free access to a normal diet and water ad libitum and kept in plastic cages. The study was approved by the ethical committee of the Federal University of Technology, Akure, Nigeria. Experimentation started after 14 days of acclimatization. Each rat was made to take 3 g of ice cream and the details of administration are as follows: Group 1—rats were given commercial ice cream; Group 2—rats were given OP[0.5]; Group 3—rats were given OP[1.0]; Group 4—rats were given OP[2.0]; Group 5—rats were given SP[0.5]; Group 6—rats were given SP[1.0]; Group 7—rats were given SP[2.0]; Group 8—rats were given Plain.

The treatment was daily and lasted for 28 days and the weight of the rats measured daily. The lipid profile was monitored after the animals were sacrificed after an overnight fast by cervical dislocation. The liver and heart were rapidly isolated, rinsed in cold saline (0.9%) and homogenized in sodium phosphate buffer (0.1 M, pH 6.9); afterwards, it was centrifuged and used to determine biochemical assays.

TABLE 1 Sensory analysis of formulated ice cream and commercial ice cream samples

Sample	Texture	Taste	Color	Aroma	Overall acceptability
Commercial	6.17 ± 0.81^c	6.30 ± 0.74^c	6.48 ± 0.60^c	6.13 ± 0.99^c	6.52 ± 0.69^c
OP[0.5]	5.78 ± 0.64^c	5.78 ± 0.94^c	5.48 ± 0.95^b	5.74 ± 0.91^b	6.04 ± 0.55^c
OP[1.0]	5.26 ± 0.89^b	5.00 ± 1.00^b	5.04 ± 1.10^a	5.13 ± 1.24^a	5.65 ± 0.82^b
OP[2.0]	4.52 ± 0.89^a	4.65 ± 0.92^a	4.70 ± 1.19^a	4.91 ± 1.06^a	5.00 ± 0.93^a
SP[0.5]	5.00 ± 1.03^b	5.43 ± 1.00^b	5.61 ± 0.97^b	5.61 ± 0.98^b	5.83 ± 0.98^b
SP[1.0]	4.48 ± 1.14^a	4.74 ± 1.15^a	5.43 ± 0.83^b	5.43 ± 0.89^b	5.52 ± 1.05^b
SP[2.0]	4.52 ± 1.39^a	4.52 ± 1.47^a	5.04 ± 1.14^a	5.09 ± 1.32^a	5.17 ± 0.92^a
Plain	6.65 ± 0.66^c	6.52 ± 0.60^c	6.52 ± 0.99^c	6.39 ± 1.14^c	6.57 ± 0.823^c

Note: Values represent mean ± standard deviation. Values with the same superscript number on the same column are not significantly ($p < .05$) different. Commercial—Commercial ice cream; OP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g orange peel powder; OP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; OP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; SP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g shaddock peel powder; SP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; SP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; Plain—50-g whipping cream + 35-g skimmed milk.

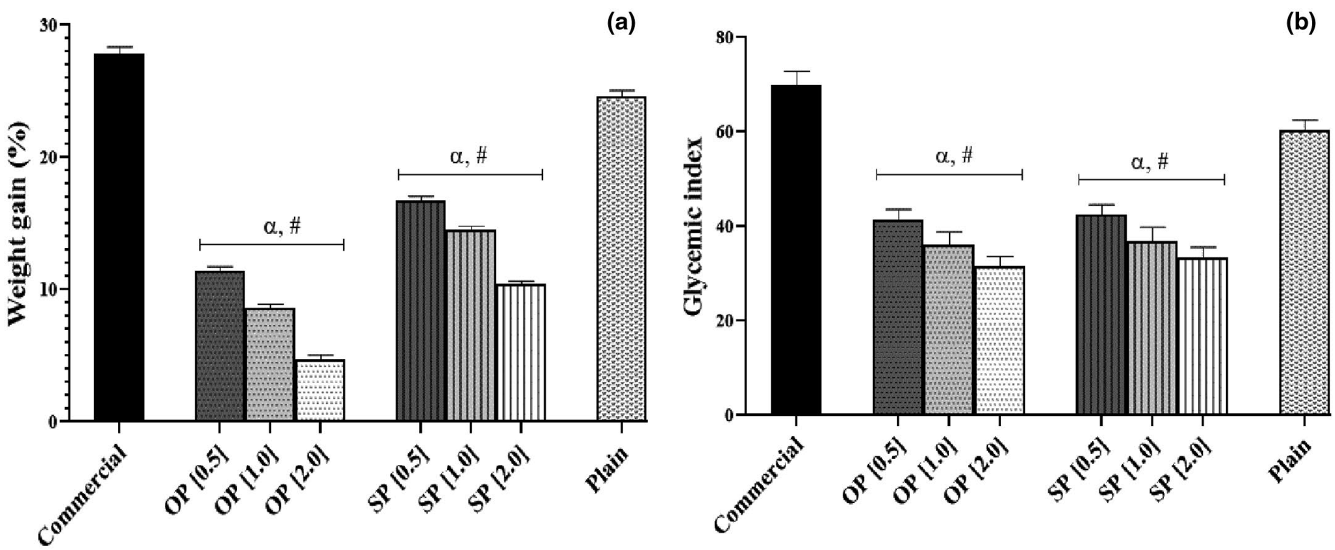

FIGURE 3 (a) Glycemic index of the ice cream samples and (b) Effect of the ice cream samples on rats' body weight following consumption at different doses. Data are presented as mean value ± standard error of mean (*SEM*), $n = 6$. Values are statistically different with α as $p < .05$ versus commercial and values are statistically different with # as $p < .05$ versus plain ice cream respectively. Commercial—Commercial ice cream; OP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g orange peel powder; OP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; OP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; SP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g shaddock peel powder; SP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; SP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; Plain—50-g whipping cream + 35-g skimmed milk

2.2.4 | Biochemical assays

The levels of rat plasma total protein (TP), lipid profile including TC, triglyceride (TAG), HDL-cholesterol (HDL-C), and low-density lipoprotein-cholesterol (LDL-C) were derived using Randox assay kits according to the method of Friedewald et al. (1972). The activities of antioxidant enzymes, superoxide dismutase (SOD), catalase (CAT), and glutathione-S-transferase (GST), in the heart and liver tissue homogenate were determined following the method of Akinyemi et al. (2017) and the and glutathione (GSH) level was according to the method of Ellman (1959).

2.2.5 | Estimated GI

The GI of 25 mg of samples uses 5-ml stomach solution (KCl–HCl buffer pH 1.5), 2.5-ml α-amylase solution, 500-μl sodium acetate pH 4.75, 5 μl of α-glucosidase solution, DNSA solution (200 μl) and reads at an absorbance of 540 nm according to the method of Adedayo et al. (2018). The sum of area under curve for each sample was divided by the sum of area under curve for standard glucose and multiplied by 100.

2.2.6 | Statistical analysis

All the data were analyzed using GraphPad statistical package, version 5 while significance level, which was accepted at $p < .05$ after Tukey's post hoc test using one-way ANOVA. The result was expressed as mean ± standard errors means (*SEM*).

3 | RESULTS AND DISCUSSION

Specific nutrients which are not present in other fruits, namely, flavanones (hesperetin and naringenin, which are glycosides) and carotenoid cryptoxanthin, have been found in significant quantities in citrus fruits (Pilar & Victoria, 2010). Several molecular mechanisms particularly related to lipid metabolism in obesity have been illustrated (Assini et al., 2013; Nakajima et al., 2014). Before administration of ice creams to experimental animals, sensory evaluation with scores for taste, texture, color, aroma, and overall acceptability was gotten from individuals who were blind to the experiment. The overall report in Table 1 revealed that plain ice cream without inclusive extract by far scored the highest as the best ice cream followed by commercially purchased ice cream. However, among the ice creams with peels, OP[0.5] had the best sensory report. This result implies that the addition of orange peels (OPs) and shaddock peels (SPs) to ice cream improved taste, color, appearance and flavor with the most accepted sample as OP[0.5]. Thus, at this concentration, it is a threshold to measure the concentration of peels in ice cream that is appealing for consumption by individuals.

The effect of the oral intake of inclusive OP and SP peels ice creams on body weight gain after 28 days and GI is shown in Figure 3a,b. Rats exposed to OP and SP ice cream diets showed a significant reduction ($p < .05$) in the percentage body weight gain when compared with rats fed with commercial ice cream and plain ice creams respectively. Interestingly, there was a marked reduction in the percentage body weight gain of rats fed with OP[2.0] portion of ice cream when compared with control groups (rats fed with commercial and plain ice creams). The result revealed that both OP[2.0] and SP[2.0] caused low estimated GI in rats at a rate of 31.5% and 33.5% respectively, while commercial and plain ice creams had higher eGI. However, commercial ice cream caused the highest GI value (70.00%) in rats. The advent of excessive body weights leads to increased body mass index (BMI) and obesity (Manna & Jain, 2015). Several mechanisms have linked obesity and dyslipidemia to cardiovascular and liver diseases and oxidative stress have been postulated to be the core or leading factor contributing to vascular complications (Marseglia et al., 2015). The dietary estimated GI is a measure of a physiologic response; it is derived from the rate of glucose uptake as well as the removal of glucose from the bloodstream. Its contributing factors include concomitant fat intake which slows down the gastric emptying process (Englyst & Englyst, 2005). There was a marked reduction in GI in rats fed on [2.0]OP ice creams found to be as low as 31.5%.

According to Yang et al. (2008), a combination of naringin and hesperidin in citrus significantly lowers the level of hepatic cholesterol and TG levels as well as 3-hydroxy-3-methylglutaryl-CoA (HMG-CoA) reductase activity in rats. Figure 4a,b represents the measured cholesterol and triglyceride content in the plasma of control and experimental rats. Feeding rats with commercial and plain ice creams for 28 days led to an elevation in the TC and TGA in the plasma of rats. Exposure of rats to OP and SP ice cream diets caused a significant reduction ($p < .05$) in the levels of TC and TGA when compared with rats fed with commercial and plain ice creams. Hence, this study showed that ice creams made from OP and SP peels administered for only 28 days caused a significant decrease in TC and TGA concentrations in plasma and an elevation in HDL-C level. This could be as a result of decreased hepatic steatosis in the liver and increased fatty acid oxidation which leads to the promotion of apolipoprotein-B degradation; therefore, the amount of LDL and/or LDL particles secreted and circulating cholesterol is reduced (Assini et al., 2013).

Furthermore, the assessment of HDL-C and LDL-C in the plasma after administering OP and SP peels in ice creams was carried out. There was a depleted HDL-C (Figure 5a) and elevated LDL-C (Figure 5b) in the plasma level in rats fed on commercial and plain ice creams. Meanwhile, the level of rat plasma HDL-C increased, while LDL-C significantly reduced ($p < .05$) with increasing concentration in rats fed on OP and SP ice creams as against rats fed with commercial and plain ice creams. Notably, there was an insignificant reduction in LDL-C and HDL-C in rats fed with [0.5]SP. An elevated level of HDL-C comes with reduced chances or risks of developing cardiovascular disease associated since HDL-C attaches to extracellular esterase to contribute to the anti-atherogenic, antioxidant, and anti-inflammatory properties in circulation (Krzystek-Korpacka et al., 2013). This is in line with results gotten from this study, wherein rats fed on ice creams made from OP and SP had elevated levels of HDL-C in rats. Interestingly, rats fed with ice cream made with [2.0]OP was with the highest concentration of HDL-C as compared to other groups, and this implicates that they have reduced tendencies to develop atherosclerosis. The reduced GI observed and an increased level of HDL-C from formulated OP and SP illustrate that they contribute to reduced GI. Furthermore, it confirms the contributing effect of consumption of high-density fat ice creams and the occurrence of decreased HDL level in the plasma of rats. This is in accordance to findings by Slyper et al. (2005), who revealed the inverse relationship between glycemic indices and HDL

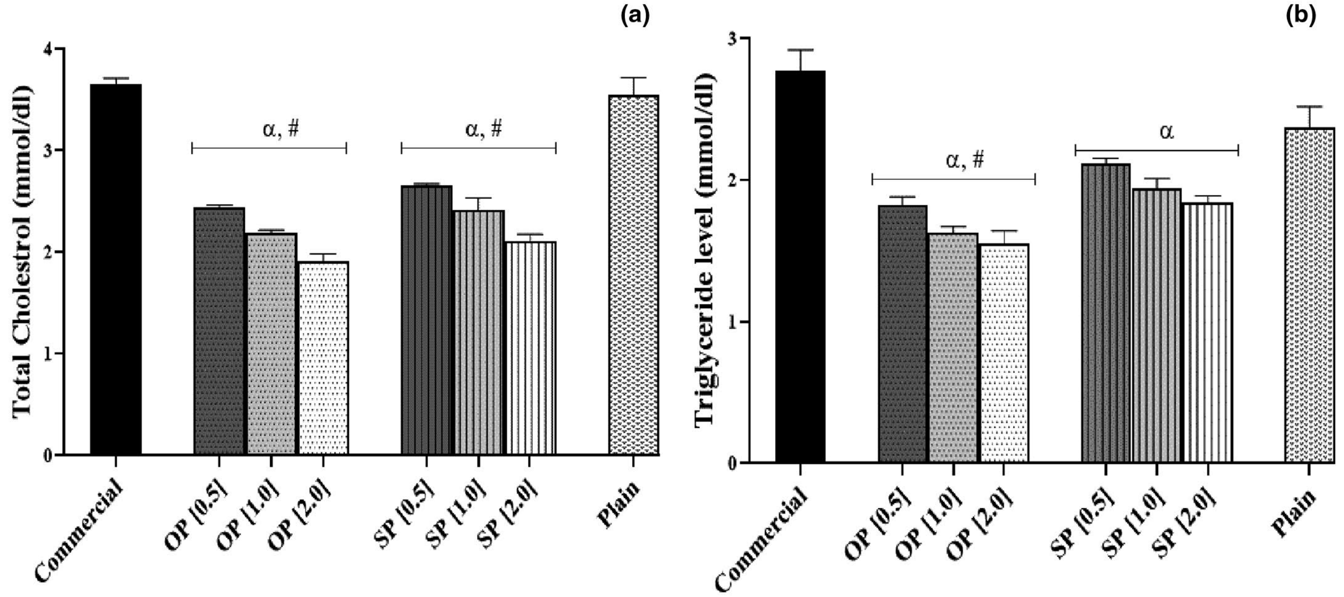

FIGURE 4 Effect of the ice cream samples on (a) plasma total cholesterol and (b) plasma triglyceride concentration following consumption at different doses. Data are presented as mean value ± standard error of mean (*SEM*), $n = 6$. Values are statistically different with α as $p < .05$ versus commercial and values are statistically different with # as $p < .05$ versus plain ice cream respectively. Commercial—Commercial ice cream; OP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g orange peel powder; OP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; OP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; SP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g shaddock peel powder; SP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; SP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; Plain—50-g whipping cream + 35-g skimmed milk

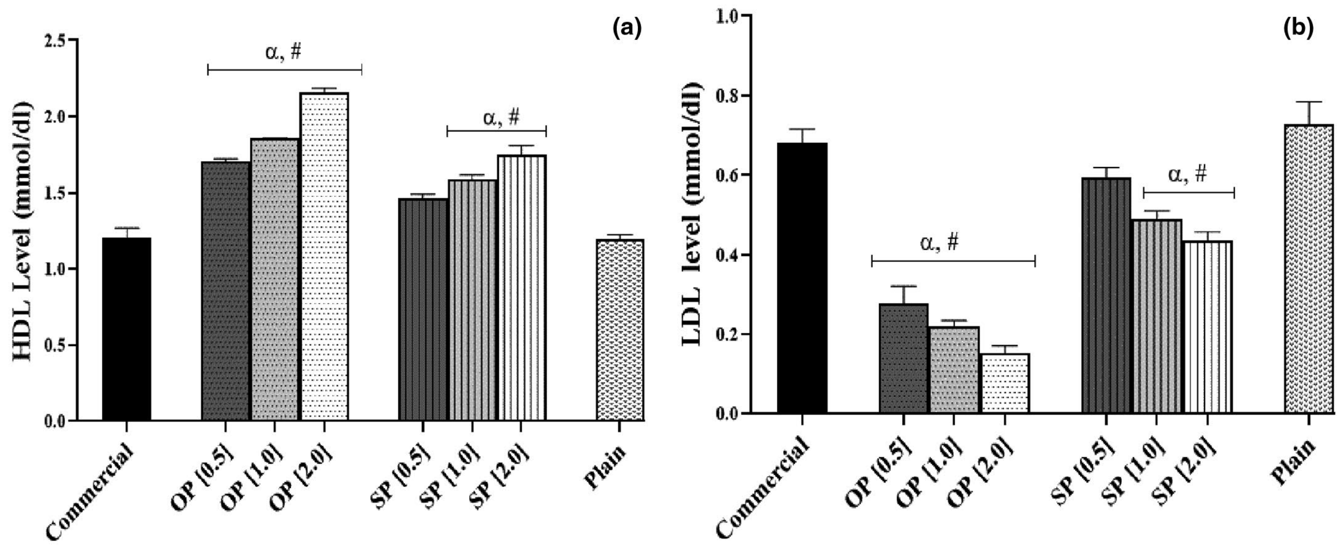

FIGURE 5 Effect of the ice cream samples on (a) plasma HDL levels and (b) plasma LDL levels following consumption at different doses. Data are presented as mean value ± standard error of mean (*SEM*), $n = 6$. Values are statistically different with α as $p < .05$ versus commercial and values are statistically different with # as $p < .05$ versus plain ice cream respectively. Commercial—Commercial ice cream; OP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g orange peel powder; OP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; OP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; SP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g shaddock peel powder; SP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; SP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; Plain–50-g whipping cream + 35-g skimmed milk

cholesterol in a group of hyperlipidemic and normolipidemic older children, teenagers, and young adults.

The activities of antioxidants in the experimental animals, the measure of antioxidant biomarkers, CAT, SOD, GST enzymes, and reduced glutathione level were determined in the liver (Figure 6a-d) and heart in Figure 7a-d, respectively. There was a marked reduction at $p < .05$ in activities of CAT, SOD, GST, and GSH level in the liver and heart of rats fed on commercial ice cream and plain ice cream.

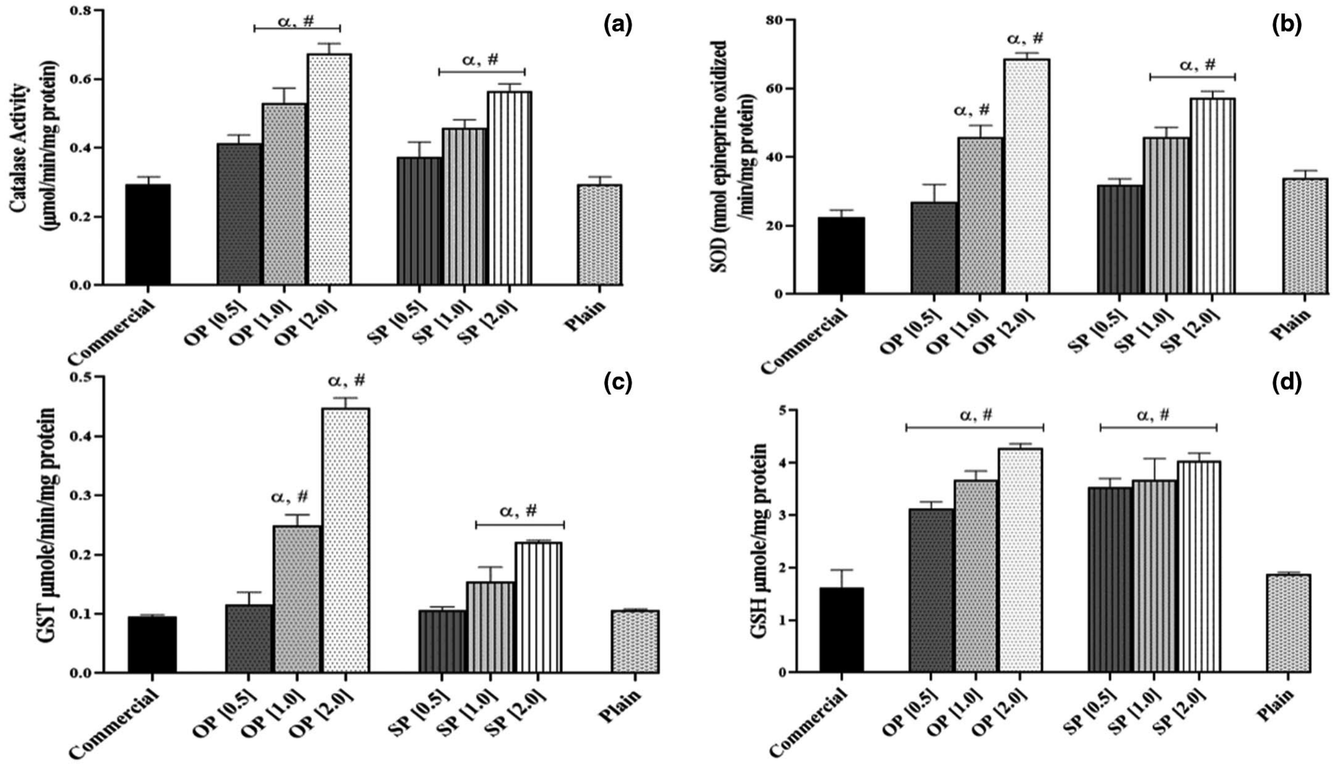

FIGURE 6 Effect of the ice cream samples on (a) catalase, (b) SOD, (c) GST, and (d) GSH levels in liver tissues following consumption at different doses. Data are presented as mean value ± standard error of mean (*SEM*), $n = 6$. Values are statistically different with α as $p < .05$ versus commercial, and values are statistically different with # as $p < .05$ versus plain ice cream respectively. Commercial—Commercial ice cream; OP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g orange peel powder; OP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; OP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; SP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g shaddock peel powder; SP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; SP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; Plain—50-g whipping cream + 35-g skimmed milk

Conversely, the CAT, SOD, and GST activities and GSH level in the liver and heart rats fed with [1.0] and [2.0]OP and SP ice cream increased significantly when compared with control groups. The activities of antioxidants enzymes in the liver and heart of rats fed with commercial, plain, blended peels of orange, and shaddock were estimated in this study. Citrus fruits are rich sources of dietary fiber and antioxidants (Nassar et al., 2008). Reduction in antioxidant activities or levels contributes to the decline in systemic organ function. Reports on the antioxidant properties of SP in cell-free systems have been studied (Oboh & Ademosun, 2012) attesting to its antioxidant potency. Reduced glutathione (GSH molecule) is a non-enzymatic antioxidant capable of scavenging free radicals generated and can also act as a substrate for other antioxidant enzymes such as glutathione peroxidase owing to its sulfide group. When the measure of GSH is low, it can be due to the overwhelming consumption of free radicals or an increase in the amount expedited by the system.

It is important to note that cholesterol accumulation attributes to coupled elevated reactive oxygen species (ROS) generation and the reduction of glutathione reductase antioxidant activities (Afonso et al., 2013). Antioxidant enzymes function to protect against oxidative damage. Oxidative stress sets in when pro-oxidants levels outweigh antioxidants (Adeyemi & Orekoya, 2014). The antioxidant enzyme, SOD, acts as the first lines of defense in the dismutation of superoxide radicals thereby releasing hydrogen peroxide and molecular oxygen. Further action by the CAT enzyme decomposes hydrogen peroxide yielding non-toxic water and oxygen, thus, neutralizing the toxic effect caused by radicals (Ighodaro & Akinloye, 2018). The reduced CAT, SOD, and GST activities in rats fed on commercial and plain ice cream imply the high tendencies of having deleterious oxidative organ damage from oxidative stress as stated by Manna and Jain (2015). Abnormal lipid profile of dyslipidemia promotes ROS generation in the endothelial (Tilg et al., 1997). Adding citrus peels to ice creams caused elevated antioxidant activities in the heart and liver of rats leading to an abundance of the antioxidant system owing to the addition of inclusive peels in ice creams. However, these antioxidant activities are more pronounced in rats' heart and liver at [2.0]OP concentration in the formulated ice cream. Thus, revealing its effectiveness in improving the antioxidant system and possibly reducing the number of ROS produced in the liver and heart which can eventually lead to a low chance of oxidative organ damage. Therefore, it is reasonable to say that formulated ice cream diet of citrus peels, namely, orange and shaddock serves as antioxidants.

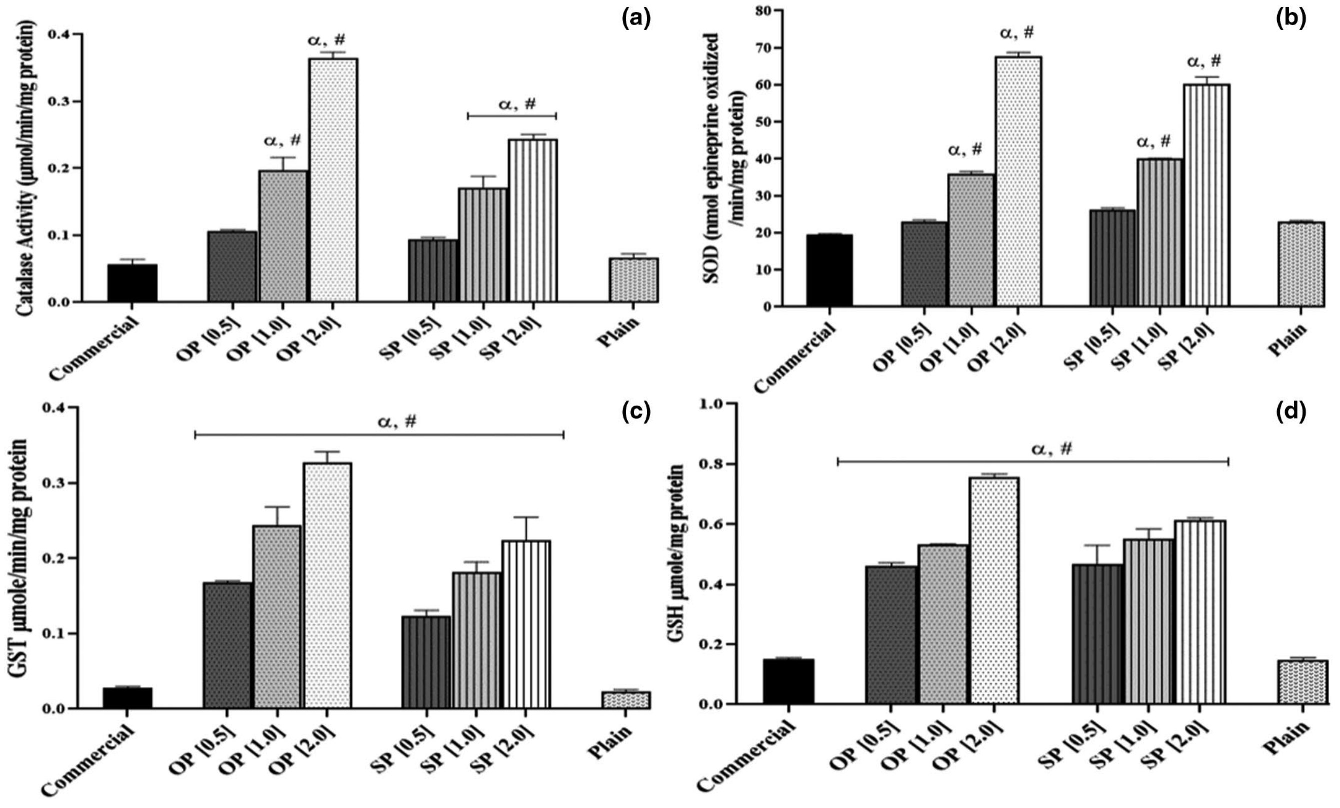

FIGURE 7 Effect of the ice cream samples on (a) catalase, (b) SOD, (c) GST, and (d) GSH levels in heart tissues following consumption at different doses. Data are presented as mean value ± standard error of mean (*SEM*), $n = 6$. Values are statistically different with α as $p < .05$ versus commercial and values are statistically different with # as $p < .05$ versus plain ice cream respectively. Commercial—Commercial ice cream; OP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g orange peel powder; OP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; OP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; SP[0.5]—49.5-g whipping cream + 35-g skimmed milk + 0.5-g shaddock peel powder; SP[1.0]—49-g whipping cream + 35-g skimmed milk + 1-g orange peel powder; SP[2.0]—48-g whipping cream + 35-g skimmed milk + 2-g orange peel powder; Plain—50-g whipping cream + 35-g skimmed milk

4 | CONCLUSION

It was observed that formulated ice creams from blended peels of orange and shaddock deplete the estimated body weight gain, GI, concentration of TC, TGA, and LDL-C and enhanced the level of HDL-C, activities of SOD, CAT, and GST, activities and GSH level in the liver and heart of rats. The role of citrus peels on biochemical markers reveals their medicinal efficacy when compared to rats fed on commercial and plain ice creams. The medicinal benefits of orange and shaddock citrus peels in ice creams fed to rats can be ascribed to their inherent phenol compounds and antioxidant properties. Thus, formulated ice creams from citrus peels could be regarded as a functional food for the management of increased body weight gain, GI, blood lipids, and oxidative damage.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Ayokunle Olubode Ademosun: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Supervision; Validation; Visualization; Writing-original draft; Writing-review & editing. **Ganiyu Oboh:** Conceptualization; Data curation; Funding acquisition; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing-review & editing. **Olufunke Florence Ajeigbe:** Data curation; Formal analysis; Funding acquisition; Investigation; Resources; Validation; Visualization; Writing-original draft; Writing-review & editing.

DATA AVAILABILITY STATEMENT

Data associated with this paper can be accessed by contacting the corresponding author with the mail: ayoademosun@yahoo.com.

ORCID

Ayokunle Olubode Ademosun https://orcid.org/0000-0001-9767-1844
Olufunke Florence Ajeigbe https://orcid.org/0000-0002-4277-3859

REFERENCES

Adedayo, B. C., Adebayo, A. A., Nwanna, E. E., & Oboh, G. (2018). Effect of cooking on glycemic index, antioxidant activities, α-amylase, and α-glucosidase inhibitory properties of two rice varieties. *Food Science and Nutrition*, *6*(8), 2301–2307.

Adeyemi, O. S., & Orekoya, B. T. (2014). Lipid profile and oxidative stress markers in Wistar rats following oral and repeated exposure to Fijk herbal mixture. *Journal of Toxicology*, *2014*, 7 pages, Article ID 876035. https://doi.org/10.1155/2014/876035

Afonso, M. S., Mara de Silva, O. A., Carvalho, E. B. T., Rivelli, D. P., Barros, S. B. M., Rogero, M. M., Lottenberg, A. M., Torres, R. P., & Mancini-Filho, J. (2013). Phenol compounds from Rosemary (*Rosmarinus officinalis* L.) attenuate oxidative stress and reduce blood cholesterol concentrations in diet-induced hypercholesterolemic rats. *Nutritional Metabolism*, *10*, 19–27.

Akinyemi, A. J., Oboh, G., Oyeleye, S. I., & Ogunsuyi, O. (2017). Antiamnestic effect of curcumin in combination with donepezil, an anti-cholinesterase drug: Involvement of cholinergic system. *Neurotoxicity Research*, *31*(4), 560–569. https://doi.org/10.1007/s12640-017-9701-5

Anal, A. K., & Singh, H. (2007). Recent advances in microencapsulation of probiotics for industrial applications and targeted delivery. *Trends Food Science Technology*, *18*, 240–251. https://doi.org/10.1016/j.tifs.2007.01.004

Assini, J. M., Mulvihill, E. E., & Huf, M. W. (2013). Citrus flavonoids and lipid metabolism. *Current Opinion in Lipidology*, *24*(1), 34–40.

Das, R. N. (2016). Relationship between diabetes mellitus and coronary heart disease. *Current Diabetes Reviews*, *12*(3), 1–12.

Ellman, G. L. (1959). Tissue sulfhydryl groups. *Archives of Biochemistry and Biophysics*, *82*(1), 70–77. https://doi.org/10.1016/0003-9861(59)90090-6

Englyst, K. N., & Englyst, H. N. (2005). Carbohydrate bioavailability. *British Journal of Nutrition*, *94*(1), 1–11. https://doi.org/10.1079/BJN20051457

Fleming, P., & Godwin, M. (2013). Low-glycaemic index diets in the management of blood lipids: A systematic review and meta-analysis. *Family Practice*, *30*, 485–491. https://doi.org/10.1093/fampra/cmt029

Friedewald, W. T., Levy, R. I., & Fredrickson, D. S. (1972). Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clinical Chemistry*, *18*, 499–502. https://doi.org/10.1093/clinchem/18.6.499

Goldstein, J. L., & Brown, M. S. (2015). A century of cholesterol and coronaries: From plaques to genes to statins. *Cell*, *161*, 161–172. https://doi.org/10.1016/j.cell.2015.01.036

Ighodaro, O. M., & Akinloye, O. A. (2018). First line defence antioxidants-superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPX): Their fundamental role in the entire antioxidant defence grid. *Alexandria Journal of Medicine*, *54*(4), 287–293. https://doi.org/10.1016/j.ajme.2017.09.001

Kim, G. N., Shin, M. R., Shin, S. H., Lee, A. R., Lee, J. Y., Seo, B. I., Kim, M. Y., Kim, T. H., Noh, J. S., Rhee, M. H., & Roh, S. S. (2016). Study of antiobesity effect through inhibition of pancreatic lipase activity of *Diospyros kaki* fruit and *Citrus unshiu* peel. *BioMed Research International*, *2016*, Article ID 1723042, 7.

Krzystek-Korpacka, M., Patryn, E., Hotowy, K., Czapinska, E., Majda, J., Kustrzeba-Wojcicka, I., Noczynska, A., & Gamian, A. (2013). Paraoxonase (PON)-1 activity in overweight and obese children and adolescents: Association with obesity-related inflammation and oxidative stress. *Advance Clinical Experimental Medicine*, *22*, 229–236.

Manna, P., & Jain, S. K. (2015). Obesity, oxidative stress, adipose tissue dysfunction, and the associated health risks: Causes and therapeutic strategies. *Metabolic Syndrome and Related Disorders*, *13*(10), 423–444. https://doi.org/10.1089/met.2015.0095

Marseglia, L., Manti, S., D'Angelo, G., Nicotera, A., Parisi, E., Di Rosa, G., Gitto, E., & Arrigo, T. (2015). Oxidative stress in obesity: A critical component in human diseases. *International Journal of Molecular Sciences*, *16*(1), 378–400. https://doi.org/10.3390/ijms16010378

Nakajima, V. M., Macedo, G. A., & Macedo, J. A. (2014). Citrus bioactive phenolics: Role in the obesity treatment. *LWT- Food Science and Technology*, *59*(2), 1205–1212. https://doi.org/10.1016/j.lwt.2014.02.060

Nassar, A. G., AbdEl-Hamied, A. A., & El-Naggar, E. A. (2008). Effect of citrus byproducts flour incorporation on chemical, rheological and organoleptic characteristics of biscuits. *World Journal of Agricultural Science*, *4*(5), 612–616.

Oboh, G., & Ademosun, A. O. (2012). Characterization of the antioxidant properties of phenolic extracts from some citrus peels. *Journal of Food Science and Technology*, *49*(6), 729–736.

Oxlund, A. L., & Heitmann, B. L. (2006). Glycaemic index and glycaemic load in relation to blood lipids - 6 years of follow-up in adult Danish men and women. *Public Health Nutrition*, *9*, 737–745. https://doi.org/10.1079/PHN2005916

Park, H. J., Jung, U. J., Cho, S. J., Jung, H. K., Shim, S., & Choi, M. S. (2013). *Citrus unshiu* peel extract ameliorates hyperglycemia and hepatic steatosis by altering inflammation and hepatic glucose- and lipid-regulating enzymes in db/db mice. *The Journal of Nutritional Biochemistry*, *24*(2), 419–427.

Patil, A. G., & Banerjee, S. (2017). Variants of ice creams and their health effects. *MOJ Food Processing and Technology*, *4*, 2.

Pilar, C. F., & Victoria, V. B. (2010). Citrus as functional foods. *Current Topics in Nutraceutical Research*, *8*(4), 178–184.

Psaty, B. M., Anderson, M., Kronmal, R. A., Tracy, R. P., Orchard, T., Fried, L. P., Lumley, T., Robbins, J., Burke, G., Newman, A. B., & Furberg, C. D. (2004). The association between lipid levels and the risks of incident myocardial infarction, stroke, and total mortality: The cardiovascular health study. *Journal of the American Geriatrics Society*, *52*, 1639–1647. https://doi.org/10.1111/j.1532-5415.2004.52455.x

Slyper, A., Jurva, J., Pleuss, J., Hoffmann, R., & Gutterman, D. (2005). Influence of glycemic load on HDL cholesterol in youth. *American Journal of Nutrition*, *81*, 376–379. https://doi.org/10.1093/ajcn.81.2.376

Takata, Y., Ansai, T., Soh, I., Awano, S., Nakamichi, I., Akifusa, S., Goto, K., Yoshida, A., Fujii, H., Fujisawa, R., & Sonoki, K. (2014). Serum total cholesterol concentration and 10-year mortality in an 85-year-old population. *Clinical Intervention of Aging*, *9*, 293–300. https://doi.org/10.2147/CIA.S53754

Thukar, P., George, N., & Chakraborty, M. (2020). Qualitative phytochemical screening of sweet orange (*Citrus sinensis*) peel extract- A preliminary study. *Plant Cell Biotechnology and Molecular Biology*, *21*(17–18), 29–34.

Tilg, H., Dinarello, C. A., & Mier, J. W. (1997). IL-6 and APPs: Anti-inflammatory and immunosuppressive mediators. *Immunology Today*, *18*, 428–432. https://doi.org/10.1016/S0167-5699(97)01103-1

Wang, H., Kang, H., Zhang, L., Cheng, S., Liu, H., Liu, H., & Sun, B. (2015). Composition of ethyl acetate extracts from three plant materials (shaddock peel, pomegranate peel, pomegranate seed) and their algicidal activities. *Polish Journal of Environmental Studies*, *24*(4), 1803–1807. https://doi.org/10.15244/pjoes/36986

Yang, G., Lee, J., Jung, E. D., Ham, I., & Choi, H. Y. (2008). Lipid lowering activity of Citri unshii pericarpium in hyperlipemic rats. *Immunopharmacology and Immunotoxicology*, *30*(4), 783–791. https://doi.org/10.1080/08923970802279167

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