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Potential therapeutic effects of green tea on obese lipid profile – a systematic review

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Abstract

Background: Green tea, obtained from the plant *Camellis sinensis*, is one of the oldest drinks in the world and contains numerous bioactive compounds. Studies have demonstrated the efficacy of green tea in preventing obesity and cardiovascular diseases that may be related to the reduction of lipid levels. **Aim:** This study aimed to evidence, through a systematic review, the therapeutic potential of green tea on the lipid profile in preclinical studies in obese animals and clinical studies in obese individuals. **Methods:** This systematic review follows the recommendations of the preferred report items for systematic reviews and meta-analyses. The electronic databases, PubMed (Medline), Science Direct, Scopus, and Web of Science were consulted. Articles from January 2009 to December 2019 were selected. **Results:** This search resulted in twenty-nine articles were included cirtically reviewed. In experimental studies, green tea administration has been shown to reduce total cholesterol, triglycerides and low-density lipoprotein cholesterol in animals exposed to obesity-inducing diet. In humans' studies green tea was not shown to be effective for obese lipid control. Because supplementation with green tea extract reduced total cholesterol, triglycerides, low-density lipoprotein for three months at a specific dose. **Conclusion:** Therefore, green tea appears to act as a protective agent for dyslipidemia in obesity-induced animals. In human studies, green tea has not been shown to be effective in controlling obese lipids.

Keywords

Camellia sinensis, green tea, cholesterol, obesity, dyslipidemia

Introduction

Green tea, obtained from the *Camellis sinensis* plant, is one of the oldest drinks in the world (Mancini et al., 2017). The habit of consuming tea has been referred to since antiquity, when plants were used as medicines for the prevention or treatment of humans and animals' disease (Asadbeigi et al., 2014).

Green tea contains several bioactive compounds, among them catechins are the plant chemical markers, compraising the main flavonoid group present in green tea (Zhang et al., 2018), and, these compounds have recently attracted attention to their therapeutic applications (Cabrera et al., 2006; Poswal et al., 2019). The main catechins present in green tea are: epicatechin (EC), epicatechin gallate (ECG) and epigallocatechin (EGC) (Zhang et al., 2018).

Several studies have demonstrated the efficacy of green tea in reducing body weight and body fat, as well as in

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preventing obesity and cardiovascular diseases that may be related to the reduction of lipid levels (Hayat et al., 2015; Pan et al., 2018; Yuan et al., 2018).

The main functional properties of this tea are attributed to epigallocatechin-3-gallate (EGCG), which accounts for approximately 59% of the total catechin content of green tea (Mancini et al., 2017; Pan et al., 2018). The beneficial effects of EGCG can be attributed to its various biological activities, such as antioxidant, anti-inflammatory and hypolipidemic activities (Eng et al., 2018).

Therefore, the objective of the present study is to evaluate, through a systematic review, the therapeutic potential of green tea utilization on the lipid profile in preclinical studies in obese animals and clinical studies in obese individuals

Methodology

Study design and search strategy

The systematic review was constructed following the recommendations of *PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (Moher et al., 2009).

The electronic databases PubMed (Medline), Science Direct, Scopus and Web of Science were consulted and all the manuscripts were critically reviewed during the period compraisinf from January 2009 to December 2019. This period was delimited based on previous reviews and published scientific research on the topic.

The following MESH terms were used: *green tea, catechin, epigallocatechin gallate, Camellia sinensis, Thea sinensis, dyslipidemia, lipids, lipids profile, cholesterol, triglycerides, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, therapeutic, therapy, treatment, obese* and *obesity*. The Boolean operators "AND" and "OR" were used to cross the terms as follows: (*green tea* OR *Camellia sinensis* OR *catechin*) AND (*dyslipidemia* OR *lipids*) AND (*therapeutic* OR t*reatments*).

Selection process/criteria

The evaluation of the titles, abstracts, and complete works was done following the steps of identification, screening, eligibility and inclusion in December 2019. The selection of articles was carried out by two researchers, adopting the following inclusion criteria: experimental studies in animals (rats and mice) induced to obesity and exposed to green tea infusion, green tea extract or catechins; research on obese humans, considering body mass index greater than or equal to 30 $kg.m^{-2}$, who consumed green tea infusion, green tea extract or catechins; and the studies that determined the plasma concentrations of the lipid profile of the groups studied and published in Portuguese or English.

Exclusion criteria were: studies that use green tea combined or comparative use of green tea with another herbal medicines and/or drug and/or any additional therapy, used a positive control group on medication, studies with fermented green tea and enriched with others substances, experimental studies in dogs, flies and monogenic animals, experimental studies in which the method of inducing obesity was not diet or induced to obesity in the gestation and lactation period, observational studies and those published outside the period recommended in the present review.

Subsequently, the triage was carried out and the duplicate records were also eliminated. In the next step, the eligible articles were considered by evaluating the methodology. Those articles that did not correspond to experimental or clinical studies were also eliminated. After reading the entire articles, the records in the chosen databases were selected according to the inclusion criteria. In the selected articles, the following items were evaluated: animal species or population studies, type of study (animal or human), green tea administration method, dosage, use of extract or isolated catechins, total catechins and the main results obtained (Figure 1).

Results

Relevant aspects of the studies were extracted and organized into two tables. Tabulated data include authors, year, used animal species, green tea formulation and administration, administered dose, catechin content, duration and main results (as shown in Table 1). Table 2 includes authors, year, type of study, population studied, green tea formulation and administration, administered dose, catechin content, studies time of duration, and main results. After tabulation of the data, 23 experimental studies in animals and 6 clinical studies were found in humans.

The most commonly animal tested were mice of the C57BL/6 strain followed by Wistar rats, Swiss mice and Sprague-Dawley rats. CD1 mice were used in only one study.

The high-fat diet was the most used for obesity induction. The percentage of fat ranged from 20% to 60% fat. Some studies did not show fat percentage (Cunha et al., 2013; Santamarina et al., 2015; Santana et al., 2015) and another it brings only the information of 15% saturated fat and 1% cholesterol, but not the total percentage (Yan et al., 2013). In another that used a diet high sucrose and fat, without informing the percentage of both (Kumazoe et al., 2017) and high-fat and high fructose diet (45% fat and 10% fructose) (Mi et al., 2017). Other types of diet used were: high cholesterol and sucrose diet, individually or in combination (Ahmad et al., 2015); high energy (Chen et al., 2017), cafeteria diet containing 38% lipids, 14% protein and 48% carbohydrate (Rocha et al., 2016) and high fructose diet (Thomas and Thomas, 2013).

The green tea form administered in the experimental studies was given mainly under the extract formulation. The decoction was used in only one experimental study (Snoussi et al., 2014). Epigallocatechinagallate (EGCG) is the most commonly used catechin in the articles. Epicatechin (Gutiérrez-Salmeán et al., 2014; Moreno-Ulloa

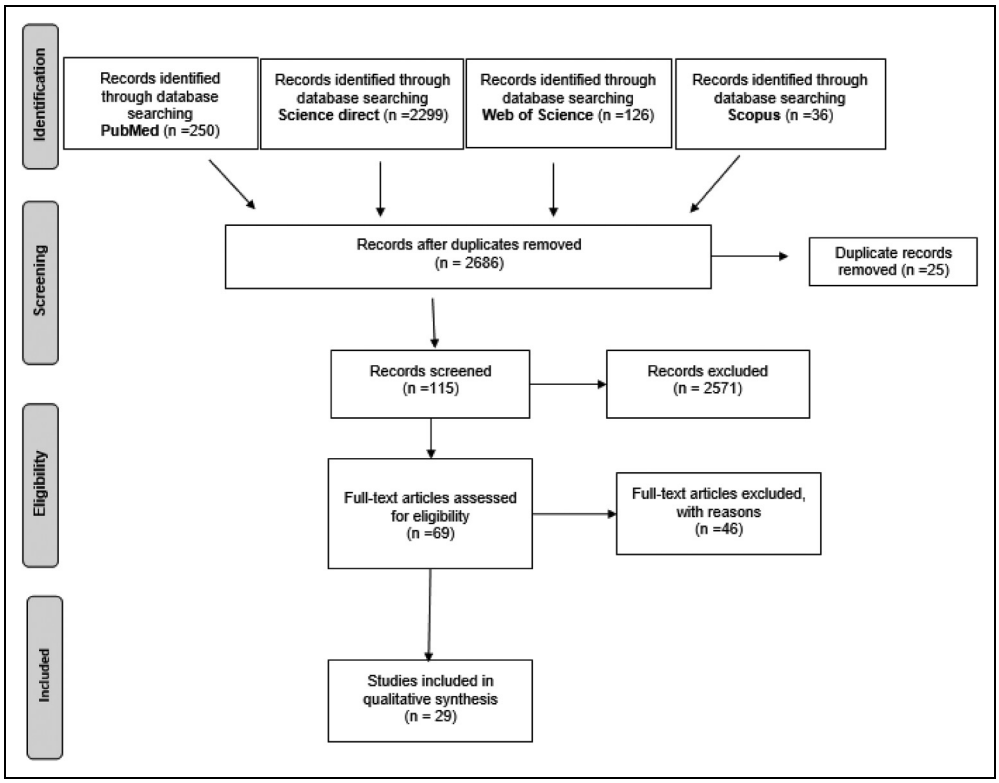

Figure 1. Flowchart of the selection stages of articles (adapted from PRISMA).
Source: Own authorship.

et al., 2018) and total catechins (Ahmad et al., 2015; Lee et al., 2015; Yan et al., 2013) are less commonly used.

The dose administered varies greatly in these studies. The dosage extracts more commonly administered is in the form mg per kilogram of animal body weight, ranging from 50 to 600 $mg.kg^{-1}$ by oral gavage. Some studies add extract to the animal's diet. The percentage ranges from green tea added from 0.2% to 2.0% of the diet. The reduction in total cholesterol (TC), triglycerides (TG) and LDL-c was observed with the 0.2% dose of EGCG in the diet (Lee et al., 2009). However, only the aqueous extract at the 2.0% concentration had an LDL-c reduction (Bajerska et al., 2011). Epicatechin was administered in doses of 0.003 to 20 $mg.kg^{-1}$ animal's weight (Gutiérrez-Salmeán et al., 2014; Moreno-Ulloa et al., 2018) and the total catechins in the following doses: 550 $mg.500\ mL^{-1}$ of catechins in one drink (Ahmad et al., 2015), 100 $mg.kg^{-1}$ of animal weight (Yan et al., 2013) and 0.4% of diet (Lee et al., 2015).

About EGCG, the diet of the animal was added in the percentage of 0.2% to 1.0% (Lee et al., 2009; Zhou et al., 2018), and in the proportion of 3.2 g of EGCG per kilogram of the diet (Chen et al., 2011). In addition to the diet, liquids were also vehicles for the supplementation of EGCG in the drink offered to the animals, in the proportion of 550 $mg.500\ mL^{-1}$ (Ahmad et al., 2015) and 2 $g.L^{-1}$ in water (Mi et al., 2017). Administration of EGCG, according to animal weight, ranged from 0.9 to 50 $mg.kg^{-1}$ (Kumazoe et al., 2017; Moreno et al., 2014; Santamarina et al., 2015; Santana et al., 2015). It is important to take note that the majority of the articles evaluated did not bring specific informations about the total dose of catechins administered to the animals. The percentage of total catechins in the preparations ranged from 25 to 98% (Chen et al., 2011; Dey et al., 2019; Lee et al., 2015; Yan et al., 2013).

The duration of the studies varied between 2 and 17 weeks. For the majority of the studies evaluated, the protocols induced obesity in parallel with the treatment, except for two studies. In which the green tea extract was supplemented four weeks for prevention then exposed the consumption of the high-fat diet for eight weeks (Rocha et al., 2016). Another study with five weeks of induced obesity protocol, submitted the animals to the treatment in the following two weeks after the obesity induction, maintaining the consumption of the high-fat diet (Gutiérrez-Salmeán et al., 2014).

Reduction of plasma total cholesterol (TC) was observed in several articles with green tea extract supplementation (Chen et al., 2017; Choi et al., 2016; Dey et al., 2019; Kim et al., 2012; Lee et al., 2015; Rocha et al., 2016; Thomas and Thomas, 2013; Zhou et al., 2018) or EGCG (Ahmad et al., 2015; Chen et al., 2011; Lee et al., 2009; Mi et al., 2017; Santana et al., 2015) or epicathecin (Moreno-Ulloa et al., 2018). Similarly, the reduction of triglycerides plasma levels (TG) with green tea extract supplementation (Chen et al., 2017; Dey et al., 2019; Lee et al., 2015; Rocha et al., 2016; Santana et al., 2015; Thomas

Table 1. Experimental studies in rodents that use green tea to control the lipid profile.

Author/year	Species	Diet's type for obesity induction	Method of administration	Administered dose per day	Catechin content	Duration	Results
Ahmad et al. (2015)	Rats (Sprague Dawley)	High cholesterol (1% cholesterol) High sucrose diet (40% sucrose)	Added drink of catechins or EGCG	550 $mg.ml^{-1}$ of catechins or EGCG	550 $mg.ml^{-1}$ of catechins or EGCG	8 weeks	Significant reduction of TC and LDL-c in the group high cholesterol diet and the group high cholesterol diet + high sucrose diet; Significant reduction of TG by functional drink; Unable to raise HDL-c.
Bajerska et al. (2011)	Rats (Wistar)	High fat diet (51.2% lipids)	Aqueous green tea extract	1.1% aqueous extract of green tea added in the diet 2.0% aqueous extract of green tea in the diet	-	8 weeks	1.1% aqueous GTE to diet - Increased HDL-c; 2.0% aqueous GTE to diet – LDL-c reduction.
Chen et al. (2011)	Mice (C57BL/6)	High fat diet (60% lipids)	EGCG added to the animal's diet	3.2 $g.kg^{-1}$of diet	-	17 weeks	EGCG treatment significantly decreased the elevation in TC.
Chen et al. (2017)	Rats (Sprague Dawley)	High energy diet (28% sucrose, 22% lipids, 20% fructose)	Green tea extract	77.5 or 155 $mg.kg^{-1}$ by oral gavage	83.5% total catechins	8 weeks	Significant reductions in TG, TC, LDL-c, and an increase in HDL in the groups supplemented with GTE compared to the high-energy group.
Choi et al. (2016)	Mice (C57BL/6)	High fat diet (60% lipids)	Green tea extract	0.25% of the green tea extract added in the diet	-	12 weeks	Significant reductions in TC in the group supplemented.
Cunha et al. (2013)	Mice (Swiss)	High fat diet	Green tea extract	400 $mg.kg^{-1}$ of body weight		8 weeks	TC and TG did not differ between any of the group; HDL-c was increase in the high fat-GTE compared with high fat group.
Dey et al. (2019)	Mice (C57BL/6)	High fat diet (60% lipids)	Green tea extract	2% of the green tea extract added in the diet	30% total catechins	8 weeks	TC, TG and NEFA were decreased in mice fed a high-fat diet containing GTE compared with the group high fat diet.
Gutiérrez-Salmeán et al. (2014)	Rats (Wistar)	High fat diet (60% lipids)	Epicatechin	1 $mg.kg^{-1}$ by oral gavage	1 $mg.kg^{-1}$	5 weeks (obesity induction) + 2 weeks (treatment)	No alterations the plasma triglycerides.

(continued)

Table 1. (continued)

Author/year	Species	Diet's type for obesity induction	Method of administration	Administered dose per day	Catechin content	Duration	Results
Kim et al. (2012)	Mice (C57BL/6)	High fat diet (60% lipids)	Green tea extract Green tea extract Nanoemulsified	1% de GTE or NGTE added in the diet	-	4 weeks	Reduction of TC and LDL-c intragroup NGTE; Reduction of CT in the NGTE group was significantly higher than GTE levels.
Kumazoe et al. (2017)	Mice (C57BL/6)	High-fat + high-sucrose diet	EGCG	0.9 mg EGCG added in the diet	-	8 weeks	EGCG abrogated the increase TG and ratio LDL-c/HDL-c induced by diet.
Lee et al. (2009)	Mice (C57BL/6)	High fat diet (60% lipids)	EGCG	0.2 or 0.5% added in the diet	-	8 weeks	Significant reductions in TG, TC, LDL-c in EGCG groups compared to control Could not change HDL-c.
Lee et al. (2015)	Mice (C57BL/6)	High fat diet (60% lipids)	Green tea extract or catechins	0.5% or 1% GTE added in the diet; 0.4% of catechin	75% total catechins	11 weeks	Significant reductions in TG, TC in the group with 1% of the GTE compared HFD group.
Li et al. (2017)	Mice (C57BL/6)	High fat diet (60%)	Green tea extract	2% of the green tea extract added in the diet	30% total catechins	8 weeks	NEFA were decreased in mice fed a high-fat diet containing GTE compared with the group high fat diet.
Mi et al. (2017)	Mice (C57BL/6)	High fat and high fructose diet (45% fat and 10% fructose)	EGCG	2 $g.L^{-1}$	2 $g.L^{-1}$	16 weeks	Significant reduction in the TC, TG, LDL-c with the group HFFD. Significant increase in the HDL-c with the group HFFD.
Moreno et al. (2014)	Mice (Swiss)	High fat diet (59%)	EGCG	50 $mg.kg^{-1}$	50 $mg.kg^{-1}$	4 or 8 weeks	60 days – Significant reduction in TG the HFD + EGCG compared to the HFD group Increased HDL-c in the HFD + EGCG compared to the HFD group Increased HDL-c compared to the HFD group and control 30 days – TC increase in the HFD + EGCG compared to the HFD group.
Moreno-Ulloa et al. (2018)	Mice (CD1)	High fat diet (60% lipids)	Epicatechin Epicatechin + catechin	0.003 $mg.kg^{-1}$ 0.01 $mg.kg^{-1}$ 0.03 $mg.kg^{-1}$ 0.1 $mg.kg^{-1}$ 0.3 $mg.kg^{-1}$ + 0.1 $mg.kg^{-1}$	0.003 $mg.kg^{-1}$ 0.01 $mg.kg^{-1}$ 0.03 $mg.kg^{-1}$ 0.1 $mg.kg^{-1}$ 0.3 $mg.kg^{-1}$ + 0.1 $mg.kg^{-}$	2 weeks	Significant reduction in TG levels was observed at the lower dose. Reductions in CT were observed at doses of 0.01 $mg.kg^{-1}$.

(continued)

Table 1. (continued)

Author/year	Species	Diet's type for obesity induction	Method of administration	Administered dose per day	Catechin content	Duration	Results
Rocha et al. (2016)	Rats (Wistar)	Cafeteria diet (38% lipids, 14% protein and 48% carbohydrate)	Green tea extract	500 $mg.kg^{-1}$ of body weight by oral gavage	-	4weeks (prevention) + 8 (obesity induction)	TC, LDL-c were reduced and HDL-c were increased in the green tea group compared to the obese group.
Santana et al. (2015)	Mice (Swiss)	High fat diet	EGCG	50 $mg.kg^{-1}$ of body weight by oral gavage	50 $mg.kg^{-1}$	8 weeks	Reduction of TG in the control + EGCG group compared to the control group.
Santamarina et al. (2015)	Mice (Swiss)	High fat diet	EGCG	50 $mg.kg^{-1}$ of body weight by oral gavage	50 $mg.kg^{-1}$	16 weeks	LDL-c level was also reduced in the HFD + EGCG group as compared with the HFD.
Snoussi et al. (2014)	Rats (Wistar)	High fat diet (43% lipids, 18% protein and 38% carbohydrate)	Decoction of green tea	5 $mg.kg^{-1}$	6.15 mg.0.5 ml^{-1}	6 weeks	Reduction of TC and TG.
Thomas and Thomas (2013)	Rats (Wistar)	High fructose diet	Green Tea Extract	300, 450 e 600 $mg.kg^{-1}$ of body weight by oral gavage	-	3 weeks	Reduction of TG, TC, VLDL-c, LDL-c in a dose-dependent manner Does not change HDL-c.
Yan et al. (2013)	Mice (Sprague Dawley) induced obesity by diet	High fat diet (15% saturated fat and 1% cholesterol)	Green Tea catechin	100 $mg.kg^{-1}$ of body weight per day	98%	4 or 6 weeks	Reduction of TG in the HFD + GCT group compared to the HFD group.
Zhou et al. (2018)	Mice (C57BL/6)	High fat diet (60%)	EGCG	1% of EGCG added in the diet	-	4 weeks	Reduction of TC in the HFD + EGCG group compared to the HFD group.

Source: Own authorship.

TC: Total cholesterol, TG: Triacylglycerol, LDL-c: Low density lipoprotein cholesterol, HDL-c: High density lipoprotein cholesterol, LDL: Low density lipoprotein, HDL: High density lipoprotein, EGCG: Epigallocatequinagalate, GTE: Green tea extract, HFD: High fat diet, NGTE: Nanoemulsified green tea extract, HFFD: high fat and fructose diet.

Table 2. Studies in obese adults who used green tea to control the lipid profile.

Author / Year	Type of study	Study population	N	SEC	Age (Mean)	Placebo	Method of administration	Administered dose per day	Catechin content	Duration	Results
Bajerska, Mildner-Szkudlarz and Walkowiak (2015)	Randomized single-blind placebo-controlled	Obese adults with metabolic syndrome	44	Men and women	49–65 years (53)	Rye Bread	Rye bread enriched with green tea extract	188.3 and 242.1 mg of EGCG for women and men, respectively	188.3 and 242.1 mg of EGCG for women and men, respectively	20 weeks	Increased significant HDL-c compared to baseline; TG unchanged.
Basu et al. (2010)	Randomized controlled simple-blind and permuted	Obese with metabolic syndrome	35	Men and women	42.5	-	Green tea extract + water Infusion Water	2 capsules + 4 cups 4 cups 4 cups	800.0 mg 928.0 mg	8 weeks	Did not promote changes in the lipid profile.
Bogdanski et al. (2012)	Randomized double-blind, placebo-controlled	Obese and hypertensive individuals	56	Men and women	30–60 years (50.35)	Cellulose	Encapsulated Green Tea Extract	One capsule contains 379 mg green tea extract	208 mg of EGCG	12 weeks	Significant reductions in TC, LDL-c, TG, and there was a significant increase in HDL-c compared to baseline.
Mielgo-Ayuso et al. (2014)	Randomized, double-blind, placebo-controlled	Obese premenopausal	83	Women	19–49 years	Lactose	EGCG	300 mg of EGCG	300 mg of EGCG	12 weeks	Did not promote changes in the lipid profile.
Nogueira et al. (2017)	Randomized, crossover, double-blind, placebo-controlled	Obese pre-hypertensive	20	Women	18–59 years (41.1)	Cellulose	Encapsulated Green Tea Extract	3 capsules of 500 mg	260 mg of polyphenols	4 weeks	Did not promote changes in the lipid profile.
Suliburska et al. (2012)	Prospective, randomized, double-blind, placebo-controlled	Obese	46	Men and women	30–60 years (50.41)	Cellulose	Encapsulated Green tea extract	One capsule contains 379 mg green tea extract	208 mg of EGCG	12 weeks	Significant reductions in TC, LDL-c, TG, and there was a significant increase in HDL-c compared to baseline.

Source: Own authorship.

TC: Total cholesterol, TG: Triacylglycerol, LDL-c: Low density lipoprotein cholesterol, HDL-c: High density lipoprotein cholesterol, LDL: Low density lipoprotein, HDL: High density lipoprotein, EGCG: Epigallocatequinagalate.

and Thomas, 2013; Yan et al., 2013) EGCG (Ahmad et al., 2015; Kumazoe et al., 2017; Lee et al., 2009; Mi et al., 2017; Santana et al., 2015) or epicathecin (Moreno-Ulloa et al., 2018). Green tea decoction green tea reduction TC and TG [20].

Low density lipoprotein cholesterol (LDL-c) presented reduction with both green tea extract (Bajerska et al., 2011; Chen et al., 2017; Dey et al., 2019; Kim et al., 2012; Li et al., 2017; Moreno et al., 2014;Rocha et al., 2016; Santamarina et al., 2015; Thomas and Thomas, 2013; Yan et al., 2013) and EGCG (Ahmad et al., 2015; Lee et al., 2009; Li et al., 2017). High-density lipoprotein (HDL) measurements were less evaluated than the lipid parameters mentioned above. An increase in HDL-c was reported in some articles that evaluated it with green tea extract (Bajerska et al., 2011; Chen et al., 2017; Cunha et al., 2013; Rocha et al., 2016) and EGCG (Moreno et al., 2014) but not in others studies (Ahmad et al., 2015; Lee et al., 2009; Thomas and Thomas, 2013; Yan et al., 2013). The LDL-c/HDL-c ratio was analyzed in one study and the supplementation with EGCG prevented its increase (Kumazoe et al., 2017). The non-esterified fatty acids (NEFA) were evaluated in three studies, which showed a reduction in this parameter (Dey et al., 2019; Li et al., 2017; Santamarina et al., 2015).

The human research studies were mostly randomized and placebo-controlled, double-blind, and only two were single-blind The number of obese analyzed in the studies ranged from 20 to 83; the age ranged from 18 to 60 years (Bajerska et al., 2015; Basu et al., 2010; Bogdanski et al., 2012; Mielgo-Ayuso et al., 2014; Nogueira et al., 2017; Suliburska et al., 2012).

Two articles evaluated only women (Mielgo-Ayuso et al., 2014; Nogueira et al., 2017). All the studies selected were performed on obese adults, but in two studies, obese individuals had already developed the metabolic syndrome (Bajerska et al., 2015; Basu et al., 2010); in another, besides being obese, were hypertensive (Bogdanski et al., 2012). A scientific publication was developed with obese and prehypertensive women (Nogueira et al., 2017). A highlight was found in a study with premenopausal women (Mielgo-Ayuso et al., 2014).

Human studies used the encapsulated green tea extract (Bogdanski et al., 2012; Nogueira et al., 2017; Suliburska et al., 2012) and EGCG in capsules (Mielgo-Ayuso et al., 2014). A single study used the infusion and other group was supplemented with encapsulated green tea extract (Basu et al., 2010). Only one study used food as a method of administration, which was bread enriched with green tea extract (Bajerska et al., 2015). The placebo for encapsulated green tea extract was lactose or cellulose (Bogdanski et al., 2012; Mielgo-Ayuso et al., 2014; Nogueira et al., 2017; Suliburska et al., 2012), and rice bread without green tea extract (Bajerska et al., 2015).

The dose of total catechins administered was determined only in one study and ranged from 800 to 928.0 mg per day (Bajerska et al., 2015). Four publications presented EGCG dosage ranging from 188.3 to 300 mg (Bajerska et al., 2015; Bogdanski et al., 2012; Mielgo-Ayuso et al., 2014). One study does not show the amount of catechins, only the total number of polyphenols 260 mg (Nogueira et al., 2017). The duration of the research ranged from 4 to 20 weeks.

Regarding changes in lipid profile, two studies showed a reduction of CT, LDL-c and TG compared to the placeb (Bogdanski et al., 2012; Suliburska et al., 2012). Another observation was an increase in HDL-c compared to baseline (Bajerska et al., 2015; Bogdanski et al., 2012; Suliburska et al., 2012). In three studies, green tea not promote changes in the lipid profile in obese individuals (Basu et al., 2010; Mielgo-Ayuso et al., 2014; Nogueira et al., 2017).

It is important to note that only one article had a dietary intervention for the participants and the only parameter altered was increased in HDL-c compared to baseline (Bajerska et al., 2015). Therefore, this result can be influenced by the change in dietary patterns.

Discussion

Tea consumption initially widespread due to its health benefits, such as stimulating action, reducing body mass, preventing cancer, strengthening the immune system and reducing cardiovascular disease (Moraes et al., 2009). Scientific evidence indicates that green tea has a beneficial effect on cardiovascular function, possibly related to a reduction in the risk of cardiovascular diseases (CVD), such as the improvement of the lipid profile (Mittwede et al., 2016). To investigate the impact of tea consumption on the lipid profile and other parameters, experimental studies are widely used.

Experimental animals used for obesity models can be classified into monogenetic and polygenetic models. Obese monogenetic laboratory animals are characterized by mutations in unique genes that play important roles in metabolism, for example, ob/ob (obese) mice and db/db (diabetic) mice. The polygenetic models of obesity are strains of mice or other animals that differ in body weight and fat deposition from multiple genes, each contributing to the obesity phenotype (Chu et al., 2017).

As we found, the most commonly used animal species in the articles were mice of the C57BL/6 strain (Chen et al., 2011; Choi et al., 2016; Dey et al., 2019; Kim et al., 2012; Kumazoe et al., 2017; Lee et al., 2015; Lee et al., 2009; Li et al., 2017; Mi et al., 2017) which are susceptible to the development of obesity and potentially hyperglycemic and hyperinsulinemic (Chu et al., 2017). The rat species Wistar and Sprague Dawley (SD) are more commonly used in diet-induced obesity (DIO) models because it was shown that as well as C57BL/6 strain the genetic basis favors the gain of body weight (Fuchs et al., 2018). Just as Swiss mice are genetically linked to obesity and diabetes (Moraes et al., 2009).

The CD1 mouse strain was used less because these animals are most commonly used in studies on toxicity and not for obesity induction. However, in this study, one of the objectives was to evaluate the safety of epicatechin use. These findings corroborate with what has been described in the literature regarding the most used species in diet-induced obesity models (Mittwede et al., 2016).

High-fat diet was the most adopted as a model to induce obesity in laboratory animals. These diets are known to be directly related to the development of obesity. Recently, it has been shown that long chain saturated fatty acids, found mainly in red meat, are the most harmful lipids in fat mass accumulation (Tschöp and Heiman, 2001). Diets usually high in fat are used 30%–78% of total energy intake (Hariri and Thibault, 2010). In contrast to the findings in this review, the percentage was 20% to 60%. This variation is very important because the total amount of gorud consumed by the animal results in different metabolic.

Other types of diet were used with hypercalorics (Chen et al., 2017; Rocha et al., 2016). This particular model is extremely useful in research on obesity in laboratory animals because of its strong resemblance to the genesis and metabolic responses caused by obesity in humans, i.e. obesity is the consequence of a positive energy balance generated by environmental factors, such as excessive intake of calorie-rich foods and sedentary lifestyle (Tschöp and Heiman, 2001). Carbohydrate diets such as fructose and sucrose (Ahmad et al., 2015; Kumazoe et al., 2017; Mi et al., 2017; Thomas and Thomas, 2013) are also used to induce obesity, according to the literature, these diets are not as effective as high fat diets. A high cholesterol diet was used in just one article (Ahmad et al., 2015), this type of diet is best used for atherosclerosis models (Breslow, 1996).

The diversity of green tea formulations used in the evaluated studies reflect the heterogeneity of the data found. Mainly used as an extract (Bajerska et al., 2011; Chen et al., 2017; Choi et al., 2016; Cunha et al., 2013; Dey et al., 2019; Kim et al., 2012; Li et al., 2017; Rocha et al., 2016; Santamarina et al., 2015; Santana et al., 2015; Thomas and Thomas, 2013). Moreover, the variation in dose and concentration of the extract makes it difficult to reproduce the methodology, as well as the lack of standardization, which may be related to the diversity of the showed results.

Herbal medicines are widely evaluated for quality to ensure their safety. The final products of the drug depend directly on the quality and chemistry of raw herbal medicines. However, the phytochemical profiles of herbal raw materials are qualitatively and quantitatively variable and define the quality of herbal medicinal raw materials. Therefore, it is important to define quality criteria that are intrinsically linked to the constancy of phytochemicals (Govindaraghavan and Sucher, 2015). The quality of green tea extract may vary widely depending on the methods employed in its production, due to plant growth conditions, harvested leafage, and processing (Dekant et al., 2017). Thus, standardization and quality control of green tea extract are important. Studies have been found ranging from 30% to 98% of catechins (Chen et al., 2017; Dey et al., 2019; Li et al., 2017; Santana et al., 2015; Yan et al., 2013). Strict adherence to the harmonization of quality assessments will allow consistent pharmacological activity and facilitate meaningful comparison and meta-analysis of clinical data (Tschöp and Heiman). In this sense, nanoemulsification of green tea extract was an innovation that has already been demonstrated as a tool for the supply of bioactive compounds with potential application in the pharmaceutical and nutraceutical industries (Saratale et al., 2018).

Epigallocatechin gallate (EGCG) is the most important catechin present in green tea for her functional properties (Eng et al., 2018). For this is the catechin more used in scientific research. EGCG positively altered the lipid profile in all the studies that supplemented it, promoted reduction of total cholesterol (TC) (Ahmad et al., 2015; Chen et al., 2011; Lee et al., 2009; Mi et al., 2017), triglycerides (TG) (Chen et al., 2011; Kumazoe et al., 2017; Lee et al., 2009; Mi et al., 2017; Moreno et al., 2014), low-density lipoprotein cholesterol (LDL-c) (Chen et al., 2011; Lee et al., 2009; Mi et al., 2017; Santamarina et al., 2015), NEFA (Santamarina et al., 2015), as well as increased high-density lipoprotein cholesterol (HDL-c) (Moreno et al., 2014). Inhibition of cholesterol absorption by catechins is believed to involve inhibition of cholesterol solubility in bile acid micelles into the small intestine. EGCG does not bind directly to cholesterol but forms a complex with phosphatidylcholine, which then decreases the micellar solubility of cholesterol (Kobayashi et al., 2014). However, there was a 30-day increase in total cholesterol (TC) in Swiss mice fed a high-fat diet and supplemented with EGCG (Moreno et al., 2014). Yet in the same study, the control group presented the TC higher than the high-fat diet group, indicating that it may be a standard of the group of animals studied and suggests the need to determine the baseline of the animals.

The epicatechin used after the development of obesity is not able to alter the lipid profile of animals. For two weeks at a dose of 1 $mg.kg^{-1}$ epicatechin after induction of obesity for seven weeks did not cause any changes in the lipid profile (Gutiérrez-Salmeán et al., 2014). Although, at the dose of 0.003 $mg.kg^{-1}$, in parallel with the high-fat diet for 15 days, the epicatechin showed a triglycerides reduction, and at the dose of 0.01 $mg.kg^{-1}$, on the supplementation group, showed only TC reduction. Under the same conditions, there was total cholesterol reduction (Moreno-Ulloa et al., 2018). These results lead us to believe that time may be a limiting factor since it is unlikely to induce obesity with only 15 days of consumption of the high-fat diet. Thus, researchers who analyzed the supplementation of 20 $mg.kg^{-1}$ epicatechin by weight of the animal (a dose much higher than those previously mentioned), associated to the consumption of a high fat diet

for eight weeks, verified that there was a significant TC/HDL-c ratio increase (Moreno et al., 2014).

The decoction of green tea presented a reduction of TC and TG (Snoussi et al., 2014). However, none study in animals used the infusion, which contrasts with the fact that most people consume tea as an infusion (by adding hot water). However, in some countries, including India, China, and Egypt, tea is drunk as a decoction (tea and water are cooked together). An infusion usually brings the soluble ingredients into solution, while a decoction brings all soluble ingredients and non-soluble constituents together (Abd et al., 2014). The total contents of phenols, flavonoids, and tannins were determined by spectrophotometric methods in the decoction of green tea and presented the highest values of 290, 180 and 145 $mg.g^{-1}$, respectively. The infusion of green tea also presented high values, from 242 $mg.g^{-1}$, 150 $mg.g^{-1}$ and 101 $mg.g^{-1}$, respectively (Rodrigues et al., 2016). Similarly, another study evaluating green tea decoction and infusion obtained similar results for total polyphenols (107 and 91.7 mg per cup, respectively), flavonoids (48.8 and 47.8 mg per cup of respectively) and tannins (73.7 and 67.3 mg per cup of tea, respectively) (Pereira et al., 2017). Even though it is one of the best ways to reproduce the human consumption of green tea and the good profile of antioxidant phytochemicals, infusion and decoction are less used or unused. One of the factors limiting the use of these herbal preparations is due to the greater complexity of the process of administration by gavage to the animal for long periods.

When it comes to the dose of catechin given to animals few articles include the total dose of catechin. This is considered a limitation of the articles because catechin derivatives are the main bioactive compound of green tea. It was observed that the percentage of catechins all ranged from 25% to 98% (Chen et al., 2011; Dey et al., 2019; Lee et al., 2015; Li et al., 2017; Yan et al., 2013). At concentration below 30%, no changes were observed in the lipid profile (Lee et al., 2015). The concentration of 30% of catechins promoted significant reductions on TG, TC and NEFA in the groups supplemented with green tea extract (Dey et al., 2019; Li et al., 2017). With 83.5% of total catechins in the green tea extract supplementation, were observed a significative reduction on TG, TC, LDL-c and an increase in HDL-c when compared to the high-fat diet for eight weeks (Chen et al., 2011). The 98% dose promoted the reduction of plasma triglycerides, but in this article, the only lipid parameter determined was plasma triglyceride (Bogdanski et al., 2012). Based on these results, it can be observed that the extract of green tea with 83.5% of catechins for eight weeks can promote changes in all the parameters of the lipid profile in animals induced to obesity by a high-fat diet.

The duration of the studies is a methodological difference that makes it difficult to compare the results and the reproducibility of these data for humans. Nevertheless, with 15 days of conduction of the experimental research, it was possible to observe a reduction of TC and TG (Moreno-Ulloa et al., 2018). However, in the literature, the high-fat diet can induce obesity in a short time, seven weeks (Chrysostomou et al., 2017; Shang et al., 2017). Thus, likely, the consumption of the high-fat diet for 15 days was not enough period to promote animaĺs obesity.

For the majority of the evaluated scientific works, studies that induced obesity in parallel with the treatment, except for two studies, in which the green tea extract was supplemented four weeks before animaĺs high-fat diet consumption. In the same protocol, they maintained the extract administration and the consumption of the high-fat diet for eight weeks (Rocha et al., 2016), which resulted in a reduction of TC, LDL-c, and an HDL-c increase. Another study induced obesity for five weeks and submitted the animals to the treatment in the following two weeks, maintaining the consumption of the high-fat diet, with no plasma triglycerides alterations (Gutiérrez-Salmeán et al., 2014). These data suggest that green tea can only act in prevention but not in the treatment of the animal's dyslipidemia.

Reduction of plasma total cholesterol (TC) was observed in several articles with green tea extract supplementation (Chen et al., 2017; Choi et al., 2016; Dey et al., 2019; Kim et al., 2012; Lee et al., 2015; Rocha et al., 2016; Thomas and Thomas, 2013; Zhou et al., 2018) or EGCG (Ahmad et al., 2015; Chen et al., 2011; Lee et al., 2009; Mi et al., 2017; Santana et al., 2015). The results of green tea extract can be attributed to EGCG. Since it is a catechin found in greater quantity in green tea (Pan et al., 2018). Epigalatocatequinagalate has direct inhibitory effects on cholesterol synthesis, as already mentioned, EGCG inhibits the solubility of cholesterol in bile acid micelles in the small intestine (Breslow, 1996). Besides, EGCG has high specificity for the enzyme hydroxy-3-methyl-glutaryl-CoA reductase (HMGR). This enzyme is responsible to the control of cholesterol synthesis rate. EGCG acts by inhibiting it and consequently reduces cholesterol synthesis (Cuccioloni et al., 2011).

Epicatechin was analyzed in two articles with a lower dose (0.003 $mg.kg^{-1}$ of animal weight) for 15 days promoted TC reduction (Moreno-Ulloa et al., 2018). There is main limitation of this research is the time of exposure to diet. Scientific evidence indicates that seven to eight weeks is the period for the hyperlipid diet to have an obesogenic effect (Hariri and Thibault, 2010). Other research that analyzed epicatechin submitted the animals after obesity induction (Gutiérrez-Salmeán et al., 2014). As already mentioned, with the obesity condition already installed, there was no positive change in lipid profile, suggesting that epicatechin only has a preventive action on metabolic changes in obesity.

Similarly, the reduction of triglycerides plasma levels (TG) with green tea extract supplementation (Chen et al., 2017; Dey et al., 2019; Lee et al., 2015; Rocha et al., 2016; Santana et al., 2015; Thomas and Thomas, 2013; Yan et al., 2013) and EGCG (Ahmad et al., 2015; Kumazoe et al., 2017; Lee et al., 2009; Mi et al., 2017; Santana et al., 2015). Just as green tea acts on cholesterol,

this herbal medicine inhibits the intestinal absorption of dietary lipids, including triacylglycerol and lipophilic compounds. It is also suggested that EGCG can regulate several enzymes related to lipid metabolism, such as gastric and pancreatic lipase (Walkowiak et al., 2013).

Epicatechin promoted TG reduction in the 0.01 $mg.kg^{-1}$ of animal weight for 15 days. There is main limitation of this research is the time of exposure to diet. Importantly, the period of obesity induction is a limit of this research. Possible mechanisms associated with regulation of the Insig-1-SREBP-SCAP pathway and other genes related to lipid metabolism, including LXRα, fatty acid synthase (FAS) and SIRT1 (Cheng et al., 2017).

Low-density lipoprotein cholesterol decreased in several studies (Ahmad et al., 2015; Chen et al., 2017; Dey et al., 2019; Gutiérrez-Salmeán et al., 2014; Kim et al., 2012; Lee et al., 2009; Li et al., 2017; Moreno et al., 2014; Rocha et al., 2016; Snoussi et al., 2014; Yan et al., 2013). Besides, some studies point to green tea as an agent that prevent LDL oxidation by acting on the arterial wall. They also reduce LDL oxidation by increasing the antioxidant status or inhibiting the enzymes oxidizing activities. Therefore, LDL oxidation seems to be another important parameter to be evaluated by the articles (Tijburg et al., 1997).

The HDL-c increase in some of the articles that evaluated it (Bajerska et al., 2011; Chen et al., 2017; Cunha et al., 2013; Moreno et al., 2014; Rocha et al., 2016), as well as no alteration in a similar number of studies analyzed (Ahmad et al., 2015; Lee et al., 2009; Thomas and Thomas, 2013; Yan et al., 2013). Thus, green tea is not effective in increasing HDL-c. However, other factors that influence serum HDL-c levels. The genetic component is associated with low levels of HDL-c. However, further analysis of HDL is required, since there are several types of HDL particles transporting cholesterol (Haroun et al., 2018). The scientific work needs to deepen the biochemical analysis of HDL particles.

The LDL-c/HDL-c ratio is considered as a specific target of LDL-c and HDL-c to determine the risk of CVD and to evaluate the efficacy of lipid-lowering therapies (Fernandez and Webb, 2008). The supplementation with EGCG prevented its increase of LDL-c/HDL-c ratio (Kumazoe et al., 2017).

Beside that EGCG decreases the expression of lipogenic enzymes genes such as FAS. FAS catalyzes the last step in the biosynthetic pathway of fatty acids. Therefore, it is believed to be a determinant of the maximum capacity of a tissue to synthesize fatty acids by lipogenesis. Increases in FAS levels are attributed to elevated serum levels of TG and NEFAs. Thus, negative regulation of FAS expression may lead to a reduction in plasma lipid levels in rodents (Yang et al., 2016). For this the NEFA were determined by three studies and a reduction was observed (Dey et al., 2019; Li et al., 2017; Santamarina et al., 2015).

Human research was conducted exclusively on adults. Probably due to the high prevalence of obesity in adults, although this epidemiological indicator is increasing in children and adolescents (Engin, 2017). Two articles evaluated only women (Mielgo-Ayuso et al., 2014; Nogueira et al., 2017). It is a possible confounder factor because men and women have different metabolic responses, for example, altered blood glucose and triglycerides are more common in men, while abdominal obesity and low HDL cholesterol in women (Engin, 2017).

Besides obesity, the participants had developed hypertension (Bogdanski et al., 2012), and, in a scientific publication, they were pre-hypertensive women (Mielgo-Ayuso et al., 2014). Among all comorbidities related to obesity, hypertension is probably the best known. There is an enormous number of epidemiological evidences that demonstrate this relation. Two hemodynamic disturbances are commonly observed in hypertension associated with obesity: increased intravascular volume and peripheral vascular resistance. Besides, the renin-angiotensin-aldosterone system (RAAS) probably plays a crucial role in hypertension in obese patients. The RAAS appears to be hyperactivated in obesity, despite the increased intravascular volume and sodium retention. However, as not all obese are hypertensive and the association between obesity and hypertension is commonly observed in families, a genetic predisposition to express these disorders is likely to be necessary (Formiguera and Cantón, 2004).

In the others studies, obese individuals had already developed the metabolic syndrome (Bajerska et al., 2015; Suliburska et al., 2012). Metabolic syndrome is a condition resulting from the complications of obesity. There are five screening variables used to identify it: waist circumference, circulating levels of TG and HDL-c, fasting blood glucose and blood pressure. Obesity is a risk factor for insulin resistance, type 2 diabetes and CVD. The increase in the amount of total body fat, especially in the visceral region, has a substantially higher risk of being characterized by insulin resistance a feature of the metabolic syndrome (Després and Lemieux, 2006).

There has been a study of obese and premenopausal women (Bogdanski et al., 2012) of paramount importance it constitutes a group with numerous risk factors for the development of dyslipidemia, being of importance the evaluation of the tea in the same. Hormonal changes during the menopause transition accompany a change in the distribution of gynoid-type body fat to the android, which is associated with an increase in adipocyte diameter, reduced lipolytic activity, increased secretion of proinflammatory adipokines, and insulin resistance. These modifications are factors for the development of several diseases, such as obesity, diabetes mellitus type 2 (DM2) and cardiometabolic disease (Maestrini et al., 2018).

Most people consume tea as an infusion (Cabrera et al., 2006) but a single study used infusion and compared with capsule extract, both infusion, and encapsulated extract do not promote alteration in lipid profile (Basu et al., 2010). Also, in the article by Basu et al. (2010), the researchers used the infusion, to minimize errors in the preparation of

the infusion, it was delivered to the participants daily, but green tea was consumed close to the time of delivery or 6 to 8 h after delivery. However, the authors do not report analyzes on the microbiology quality and catechin content of this tea after that time is a possible confounder factor.

Human studies used the encapsulated green tea extract (Basu et al., 2010; Bogdanski et al., 2012; Nogueira et al., 2017; Sulibursk a et al., 2012)., EGCG in capsules (Mielgo-Ayuso et al., 2014). However, the contemporary lifestyle has led many consumers to opt for the version in capsules or food enriched with phytochemicals (Pot, 2018). Only one study used food as a method of administration, which was bread enriched with green tea extract (Bajerska et al., 2015). In this context, consumer health demands have boosted the market for nutraceuticals and herbal dietary supplements. These products represent new ways of supplying bioactive compounds to consumers, making it a relevant strategy to ensure health benefits and allow the increased daily intake of bioactive compounds (Bresciani et al., 2017).

The dose of total catechins administered was determined in only one study and ranged from 800 to 928.0 mg per day (Bajerska et al., 2015). However, the limitation of tea standardization persists. For example, one study did not show the number of catechins, only the total amount of polyphenols 260 mg (Nogueira et al., 2017), which, in four weeks, did not promote changes in the lipid profile in hypertensive women.

As in animal studies, in humans, the catechin most administered is the EGCG. Four publications presented the EGCG dosage ranging from 188.3 to 300 mg (Bajerska et al., 2015; Bogdanski et al., 2012; Mielgo-Ayuso et al., 2014; Sulibursk a et al., 2012); At a dose of 208 mg EGCG, for three months, it promoted the reduction of TC, TG, and LDL-c (Bogdanski et al., 2012; Sulibursk a et al., 2012). However, at a higher dosage, 300 mg EGCG at the same time interval (three months), was not able to modify the lipid profile in premenopausal women. EGCG appears to be ineffective in controlling the lipid profile in premenopausal women, probably because the menopausal transition is also associated with changes in body composition, including increased trunk fat mass, waist circumference, visceral and abdominal subcutaneous fat associated with dysfunction metabolic syndrome that increases the risk of metabolic syndrome and a number of comorbidities due to the hormonal changes inherent to this stage of life (Brown et al., 2017).

When it comes to the duration of the studies, it is observed that encapsulated green tea containing 208 mg EGGC for 12 weeks promotes a reduction in TG, TC and LDL between groups and increase HDL in compared with baseline (Bogdanski et al., 2012; Sulibursk a et al., 2012). However over longer periods of time at 20 weeks, at a lower dose 188.3 of EGCG for women increases HDL, but does not alter TG (Bajerska et al., 2015). This data suggests that the dose, the form of administration and the time of use directly influence the results. Studies lasting 4 and 8 weeks showed no changes in lipid profile, suggesting that green tea supplementation should be longer (Basu et al., 2010; Bogdanski et al., 2012). Green tea extract supplementation with 97% EGCG showed no effective results in the lipid profile of obese for 12 weeks (Mielgo-Ayuso et al., 2014), while the 54.8% EGCG reduced TC, TG and LDL-c for same period (Bogdanski et al., 2012; Sulibursk a et al., 2012). This is likely to happen due to the synergistic action of catechins. The cholesterol-lowering effects are likely due to decreased absorption or resorption of cholesterol by catechins, as well as decreased cholesterol synthesis through inhibition of HMGR (mediated by activation of AMPK) (Yang et al., 2016). Another found that may have contributed to this are the studies published by Bajerska et al. (2015), and Mielgo-Ayuso et al. (2014) which used low-calorie diets as an intervention. The diet may be confusing and the calorie restriction a factor that minimizes the effects of green tea. Besides that, these data can be influenced by several factors, including the genetic one. The hypocholesterolemic effect of tea is associated with the type of apoE isoform, which is expressed primarily by the individual. There are three isoforms of apoE (e.g. ApoE2, ApoE3, and apoE4) although all are encoded in the same location on chromosome 19, individuals that primarily express the apoE4 isoform have high plasma cholesterol levels and hardly respond to therapies. Those individuals who express apoE2 and apoE3 isoforms are more likely to respond and generally regulate lower plasma cholesterol levels. Tea consumption has beneficial effects only in those individuals expressing apoE2 and apoE3 isoforms (Loktionov et al., 1998).

Green tea in compared with baseline promoted the increase HDL-c (Bajerska et al., 2015; Bogdanski et al., 2012; Sulibursk a et al., 2012). The HDL has been highlighted for its importance in protecting against atherosclerosis. However, recent findings suggest a multifunctional role of HDL, including inflammation, oxidative stress, nitric oxide production and the regulation of plasma glucose homeostasis (Papachristou et al., 2017). To date, the possible mechanisms by which green tea may stimulate increased HDL-c have not been elucidated. However, it is known that HDL is a mixture of lipoprotein particles with densities in the range of 1.063 to 1.21 $g.mL^{-1}$, and the main protein component of HDL is apolipoprotein A-I (APOA-I), which plays a role in the biogenesis and functions of HDL. Other apolipoproteins, such as apolipoprotein E (APOE) and apolipoprotein CIII (APOC-III), have been shown to promote the HDL biogenesis in a pathway like that of APOA-I (Loktionov et al., 1998). In this way, more studies should be done to investigate whether green tea can influence or not apolipoproteins genes.

Conclusion

Green tea is rich in bioactive compounds, such as catechins, of which epigallocatequinagalate is present in greater

amounts. In experimental studies, the administration of green tea has been shown to lower total cholesterol, triglycerides and low-density lipoprotein cholesterol in animals exposed to obesity-inducing diet. Nevertheless, green tea was not able to promote high-density lipoprotein cholesterol increase in these animals. Based on this, green tea appears to act as a protective agent for dyslipidemia in obesity-induced animals. In human studies, green tea has not been shown to be effective in controlling obese lipids; however, only supplementation of green tea extract containing 208 mg epigalatocatequinagalate for twelve weeks reduced total cholesterol, triglycerides, low-density lipoprotein cholesterol and increased high-density lipoprotein cholesterol. Future scientific studies for the evaluation of green tea hypocholesterolemic activity should consider the methodologies for standardization, as well as, route of administration, type of formulation (e.g. infusion, extract, and decoction), dosage and time of exposure, green tea phytochemical analysis, and the lipid parameters to be analyzed.

Availability of data and materials

The study data and materials of this study are available upon request.

Authorship

Ana Paula Azevedo Macêdo - Drafting the article and substantial contributions to conception and design, data acquisition, analysis and interpretation.

Mariane Gonçalves dos Santos - Substantial contributions to conception and design, data acquisition, analysis and interpretation.

Jairza Maria Barreto Medeiros - Revising it critically for important intellectual content.

Jorge Mauricio David - Revising it critically for important intellectual content.

Cristiane Flora Villarreal - Revising it critically for important intellectual content.

Simone Garcia Macambira - Revising it critically for important intellectual content.

Milena Botelho Pereira Soares - Revising it critically for important intellectual content.

Ricardo David Couto - Revising it critically for important intellectual content and final approval of the version to be published.

Consent for publication

All authors have approved the version of the manuscript submitted and agreed to publish this in Nutrition and Health. All authors also declare that this study is not published or submitted elsewhere for peer review.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical statement

This study was exempted from approval by the Ethics Committee because there was no direct involvement of animals or humans.

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Supplemental Material

Supplemental material for this article is available online.

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