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Biochemical and Physiological Parameters in Rats Fed with High-Fat Diet: The Protective Effect of Chronic Treatment with Purple Grape Juice (Bordo Variety)

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Abstract: High-fat-diet (HFD) has been related to metabolic and cardiovascular diseases. Consumption of grapes and their byproducts containing phenolic compounds has been reported due to the benefits they produce for human health. The purpose of this study was to investigate the antioxidant and protective effect of chronic intake of purple grape juice on certain biochemical and physiological changes promoted by the consumption of HFD. Forty male rats were randomly divided into four groups to receive standard or HFD diet and/or conventional (CGJ) or organic grape juice (OGJ) for three months. Dietary intake, body weight gain, cardiometabolic parameters, and serum lipoperoxidation were investigated. Results showed that consumption of CGJ and OGJ changed the pattern of food and drink intake of the animals. There was a reduction in the body weight of animals that consumed grape juices and an increase in the weight gain in HFD and OGJ rats. HFD increased abdominal fat and the abdominal fat/weight ratio, and both grape juices prevented these modifications. HFD increased hepatic enzymes levels (aminotransferase (AST) and gamma-glutamyl transpeptidase (GGT)) and reduced urea. Purple grape juices prevented some of these changes. HFD enhanced lipid peroxidation (thiobarbituric acid reactive substances (TBARS)) in serum and CGJ and OGJ prevented this increase. The consumption of purple grape juice has the potential to prevent and ameliorate most of the alterations provoked by HFD, therefore regular intake of grape products could promote beneficial effects.

Keywords: grape juice; antioxidants; high-fat diet; protection; obesity

1. Introduction

Over the years, changes in lifestyle have promoted a significant increase in the intake of lipids and an increase in body fat, which is largely a result from a positive energy balance, which is favored by a diet with high energy density such as the high-fat-diet (HFD) [1,2]. If this pattern of consumption is continuous it may contribute to the development of obesity, a disease considered a global epidemic,

which is closely related to heart disease, diabetes, kidney disease, hepatic steatosis, metabolic syndrome, and certain types of cancer [3,4].

The accumulation of body fat is not only related to energy intake but also to the kind of nutrient consumed [5,6]. In this context, it has been recommended that the total fat intake should be lower than 40% of total energy, since the consumption of a HFD could provoke disorders associated with lipid metabolism, such as increased visceral fat, hyperlipidemia, and insulin resistance [7,8]. Nowadays, several studies have shown that HFD may be related to an overproduction of reactive oxygen species (ROS) and an increase in lipid peroxidation, leading to an oxidative imbalance in different tissues [9–12].

In this scenario, bioactive phytochemicals, such as phenolic compounds found in grapes and their byproducts, have been highlighted due to their different pharmacological properties [13], especially in diseases such diabetes [14], obesity, and other chronic diseases [15]. Grapes are rich in flavonoids (catechin, epicatechin, quercetin, anthocyanins, and procyanidins), and resveratrol (3,5,4′-trihydroxy-stilbene), which are mainly found in purple grape products [16–18]. It has already been reported, in vivo and in vitro, that purple grape juice and/or its derivatives can prevent platelet aggregation [19], low density lipoprotein (LDL) oxidation [20], oxidative damage to DNA [21], and cardiovascular disease [22]. Nowadays, it is possible to find two distinct classes of grape juice. Conventional grape juice, which is produced from grapes from vineyards that have received chemical treatment, and organic grape juice, produced from grapes harvested in vineyards in which the use of pesticides, genetic engineering, or other chemicals is prohibited. It has already been shown that organic grape juice contains more phenolic compounds than conventional juice [23,24].

In addition, because it has no alcohol content, grape juice ingestion has advantages over wine, as it allows consumption by a larger number of people, including those who have liver disease and children. Therefore, considering the cardiometabolic risks caused by HFD and the potential beneficial effects of grape juice intake, the purpose of this study was to investigate the antioxidant and protective effect of chronic intake of conventional and organic purple grape juices (Bordo variety) on some biochemical and physiological changes promoted by the consumption of HFD in rats.

2. Materials and Methods

Materials: all reagents were from SIGMA (St. Louis, MO, USA). The biochemical determinations were performed using commercial kits from LABTEST® Diagnostica S/A (Lagoa Santa, Minas Gerais, MG, Brazil). All other reagents were of analytical grade and were purchased from local suppliers.

Diets: animals received a standard diet from Nuvilab® (Colombo, Paraná, PR, Brazil) or a HFD containing 59% of kcal in fat, basically saturated fatty acids, from Pragsoluções Biosciences (Jau, São Paulo, SP, Brazil). The compositions of both diets are shown in Table 1.

Grape juices: the purple grape juice samples used in this study were from *Vitis labrusca* grapes, Bordo variety. Organic grape juice was produced with grapes cultivated without pesticides, obtained from Cooperativa Aecia (Antonio Prado, Rio Grande do Sul, RS, Brazil) and was certified by Rede de Agroecologia ECOVIDA. Conventional grape juice, produced with grapes cultivated using traditional methods, was obtained from Vínicola Perini (Farroupilha, Rio Grande do Sul, RS, Brazil). Validity periods were observed, and the same brands were used for the entire study. Grape juices were manufactured in 2010. The juices were manufactured by heat extraction (approximately 50 °C), with a subsequent pressing in order to separate the pulp, and then submitted to pasteurization (at 85 °C). All juices were manufactured by heat extraction, immediately followed by bottling at 80 °C.

Chemical analysis and nutritional evaluation of grape juices: alcoholic grade, total acidity, volatile acidity, and pH were determined using the methods described by Zoecklein et al. [25]. All analyses were performed in duplicate. Carbohydrates (g/100 g), humidity levels, ashes (%), moisture (%), and energy intake (kcal) were determined according to AOAC International official methodologies [26]. Conventional purple grape juice presented higher total sugars and ashes as compared to organic purple grape juice. However, organic purple grape juice demonstrated higher

total acidity, volatile acidity, total phenolic compounds, and resveratrol as compared to conventional purple grape juice (Table 2).

Table 1. Composition of diets.

	Standard Diet			High-Fat Diet		
Composition (p/p)	**% Weight**	**Energy Density (kcal/kg)**	**% Energy**	**% Weight**	**Energy Density (kcal/kg)**	**% Energy**
Proteins	22	880	25.5	26.7	1068	21
Lipids	4.5	400.5	11.7	33.5	3015	59
Carbohydrates	54	2160	62.8	26.0	1040	20
Fibers	8.0	0	0	9.8	0	0
Vitamins/Minerals	5.0	0	0	4.5	0	0
Energy	-	3440	-	-	5123	-

Table 2. Composition of purple grape juices.

	Conventional Grape Juice	**Organic Grape Juice**
Total acidity (g% tartaric acid)	0.72 ± 0.0	1.01 ± 0.01 *
Volatile acidity (g% tartaric acid)	0.02 ± 0.0	0.03 ± 0.00 *
Carbohydrates (g/100 g)	12.60 ± 0.1	11.67 ± 0.11 *
Moisture (g/L)	153.37 ± 0.2	143.30 ± 0.14
Ashes (g/L)	3.30 ± 0.3	2.46 ± 0.62 *
Reducing capacity (mg catechin equivalents/mL)	72.30 ± 0.1	101.19 ± 0.02 *
Resveratrol (ppm)	0.210 ± 0.0	0.850 ± 0.01 *

* $p < 0.05$, Student's t test.

Reduced capacity and content and trans-resveratrol analysis: reduced capacity was measured using Singleton and Rossi's modification of Folin–Ciocalteau's colorimetric method [27]. In order to quantify trans-resveratrol, ultra-pure water and acetonitrile mobile phase (75:25 v/v; pH 3.0; in constant flow of 1.0 mL min^{-1} for 20 min in a controlled-temperature room at 20 °C) were used. The peak was detected at 306 nm after the injection of 20 µL samples [28].

Animals: forty male Wistar rats (21-day-old) were obtained from our own breeding colony. They were maintained at 22 ± 2 °C on a 12 h light/12 h dark cycle with free access to food and drink. The principles of laboratory animal care [29] were followed in all our experiments and the research protocol was approved by the Ethical Committee for Animal Experimentation of the Centro Universitário Metodista—IPA. All efforts were made to minimize animal suffering and to use only the minimum number of animals necessary to produce reliable scientific data.

Treatment: the animals were randomly divided into four groups: standard diet + water, HFD + water, HFD + conventional grape juice, and HFD + organic grape juice. The animals were subjected to 12 weeks of treatment.

Evaluation of food and drink consumption: the diets, water, and grape juices were controlled daily. The consumption of food and drink was measured by the difference between the initial and final weight in a period of 24 h, the results were expressed weekly in grams (g) and total calories (kcal).

Evaluation of capillary blood glucose: after 30, 60, and 90 days of treatment, the glycaemia was measured in fed rats using the glucometer MediSense Optium (point of care testing) (ABBOTT, England, UK).

Sample preparation: after 12 weeks of treatment, rats were euthanized by decapitation and the trunk blood was collected in tubes without any anticoagulant (serum). Serum was obtained by centrifugation at 1000 g for 10 min (hemolyzed serum was discarded). The serum was stored at 20 °C for biochemical determinations.

Body composition: animal body weight was assessed weekly on an electronic balance (Crystal 200, Gibertini, Italy). On the last day of the treatment, body weight and height (naso-anal length) were measured in order to determine the rate of obesity in the rodents (Lee index). Lee index was calculated for all animals, according to Bernardis and Patterson [30]. After, the total abdominal fat was weighted. The total abdominal fat was the weight of visceral and the perigonadal fat in grams (g).

Biochemical parameters: glucose, triglycerides, and cholesterol were used as biochemical markers. Hepatic function was analyzed using alanine aminotransferase (ALT), aspartate aminotransferase (AST), gamma-glutamyl transpeptidase (GGT), and lactate dehydrogenase (LDH) activities as markers of toxicity. Renal function was analyzed by determining urea, creatinine, and uric acid. All assays were carried out using commercial kits in an automated biochemical analyzer (Diaglobe Eos Bravo Forte, Diamond Diagnostics, Holliston, MA, USA). All analyses were performed in fasting rats (8 h).

Thiobarbituric acid reactive substances (TBARS) measurement: TBARS was used to determine lipid peroxidation and was measured according to the method described by Ohkawa et al. [31]. Briefly, 50 µL of 8.1% sodium dodecyl sulfate (SDS), 375 µL of 20% acetic acid (pH 3.5), and 375 µL of 0.8% thiobarbituric acid (TBA) were added to 200 µL of serum and then incubated in a boiling water bath for 60 min. After cooling, the mixture was centrifuged (1000 g/10 min). The supernatant was removed, and absorbance was read at 535 nm on a spectrophotometer (T80 UV/VIS Spectrometer, PG Instruments, Alma Parck, Lutterworth, UK). Commercially available malondialdehyde was used as a standard. Results were expressed as nmol/mg protein.

Protein determination: protein concentrations were determined by the method of Lowry et al. [32] using bovine serum albumin as a standard.

Statistical analysis: data from the experiments were analyzed statistically by one-way analysis of variance (ANOVA) followed by Bonferroni test. Evaluation of food consumption and total calories were analyzed by repeated-measures ANOVA. Grape juices composition and drink consumption were compared by Student's *t*-test. Values of $p < 0.05$ were considered to be significant. All analyses were carried out using the Statistical Package for Social Sciences (SPSS) software (version 17.0, International Business Machines Corporation, New York, NY, USA).

3. Results

3.1. Effect of HFD and Purple Grape Juice Treatment on the Pattern of Food and Drink Intake

The results of food, grape juice, and calorie intake are shown in Figure 1. We observed that, in relation to food consumption, the animals of the control group, fed with the standard diet, consumed more in quantity (g) as compared to the other groups, with statistically significant differences observed during the entire treatment period, except for the second week ($p < 0.001$) (Figure 1A). We also verified that the HFD rats consumed more food as compared to the animals that consumed conventional and organic grape juices from the sixth week until the end of treatment ($p < 0.05$) (Figure 1A). On the other hand, the rats had the same pattern of consumption of both conventional and organic grape juices (Figure 1B). When we observed the profile of juice consumption between the weeks of treatment we verified that from the fourth week until the end of treatment the animals increased juice intake as compared to the first three weeks of treatment ($p < 0.05$) (Figure 1B). In regard to total calorie consumption, we observed that the animals treated with the standard diet and HFD had an increased kcal consumption as compared to the animals treated with HFD and conventional or organic grape juices ($p < 0.05$) (Figure 1C).

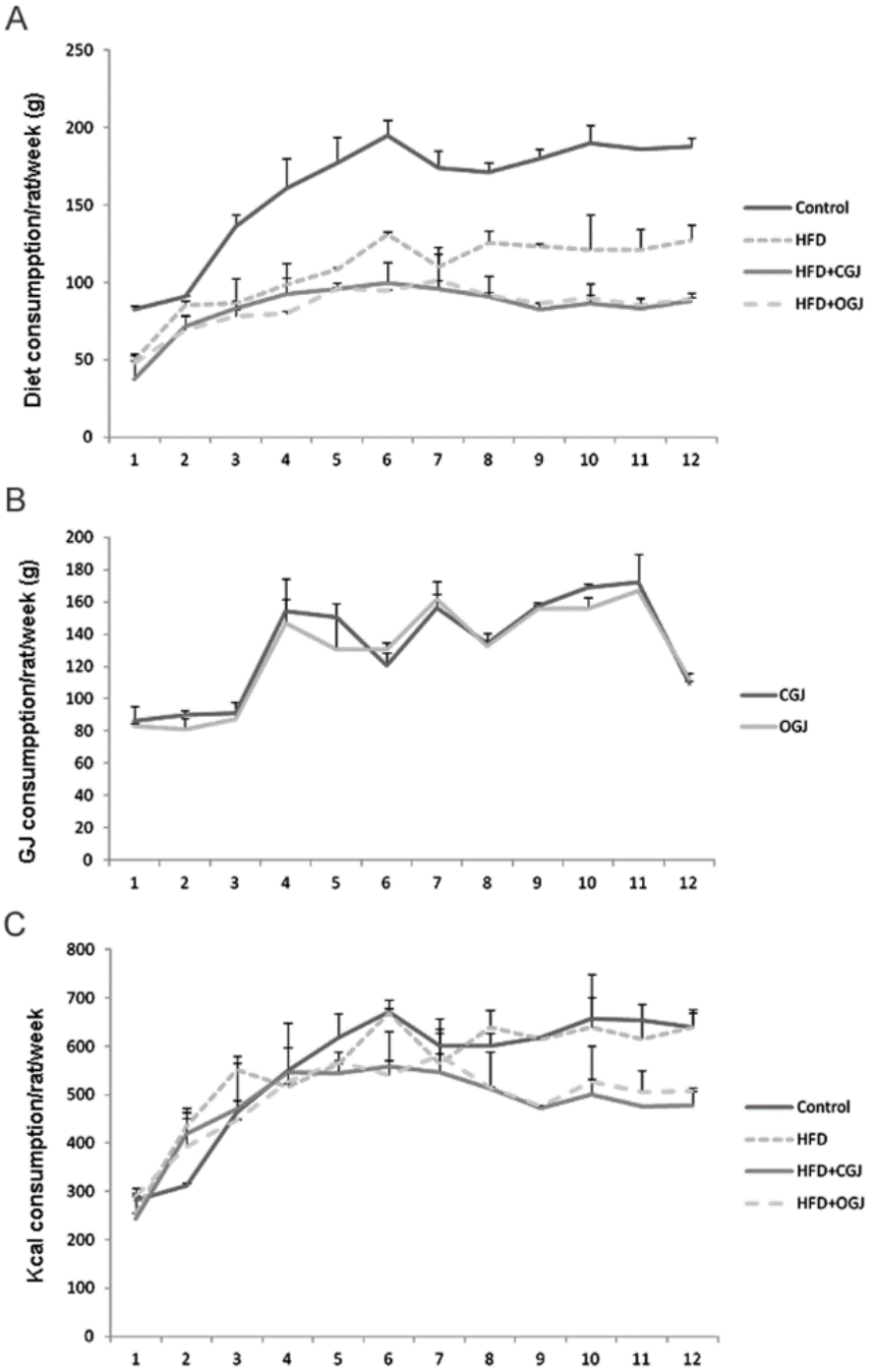

Figure 1. Food consumption/rat/week (**A**), grape juice consumption/rat/week (**B**), and energy intake consumption/rat/week (**C**) during the 12 weeks of treatment. Data are reported as means ± SEM for ten animals per group. Repeated-measures ANOVA, followed by Bonferroni test. HFD: high-fat diet; GJ: grape juice; CGJ: conventional grape juice, OGJ: organic grape juice.

3.2. *Effect of HFD and Grape Juice Treatment on the Animals' Body Composition*

Furthermore, we studied some morphometric parameters after the 12 weeks of treatment (Table 3). We verified that the animals treated with HFD and purple grape juices demonstrated a lower increase in body weight, and in the rats supplemented with HFD and organic grape juice the weight variation (weight gain during the experimental period) was reduced. In the animals treated only with HFD, we observed an increase in the abdominal fat and in the abdominal fat/weight ratio, and we also

verified that both purple grape juices were able to prevent this increase. On the other hand, the Lee index and liver weight were not changed by any treatment.

Table 3. Evaluation of morphometric parameters after 12 weeks of treatment with high-fat diet (HFD), conventional grape juice (CGJ), and/or organic grape juice (OGJ).

	Control	HFD	HFD + CGJ	HFD + OGJ
Weight (g)	328.1 ± 14	317.1 ± 16	278.9 ± 5 *	273.8 ± 10 *
Weight gain (g)	270.2 ± 48	253.2 ± 44	227.4 ± 11	219.0 ± 28 *
Abdominal fat (g)	10.2 ± 1	15.7 ± 2 **	9.6 ± 1	9.0 ± 1
Lee index	35.4 ± 3	33.3 ± 2	35.1 ± 2	34.1 ± 1
Liver weight (g)	9.7 ± 1	9.1 ± 1	8.8 ± 1	8.9 ± 1
Abdominal fat (g) total weight(g)	2.6 ± 1	4.0 ± 1 **	3.1 ± 1	2.7 ± 1
Weight (g)/liver weight (g)	36.6 ± 3	34.7 ± 4	31.6 ± 2	30.1 ± 3 *

Means ± SEM. One-way ANOVA, followed by Bonferroni test, * $p < 0.05$, different from control; ** $p < 0.05$, different from all other groups. $n = 10$.

3.3. Effect of HFD and Grape Juice Treatment on the Capillary Glucose Levels

The effect of HFD and purple grape juice treatments on capillary glucose was measured after 30, 60, and 90 days of treatment and is demonstrated in Figure 2. We observed a significant increase in glucose levels in the animals treated with HFD, regardless of the consumption of purple grape juice.

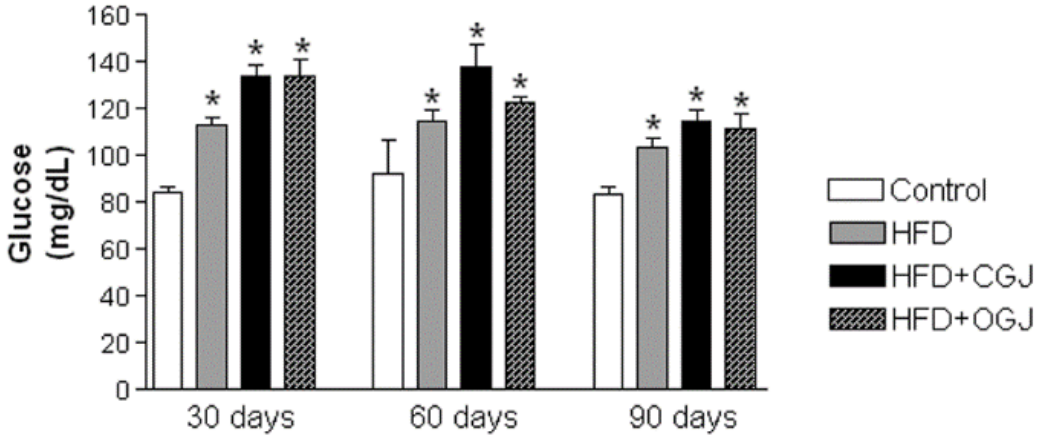

Figure 2. Effect of chronic treatment with high-fat diet and purple grape juice on the capillary glucose levels of rats. Values are means ± SEM for 8–10 samples in each group expressed as mg/dL. Statistically significant differences were determined by ANOVA followed by Bonferroni test: * $p < 0.05$, from control. HFD: high-fat diet; CGJ: conventional grape juice; OGJ: organic grape juice.

3.4. Effect of HFD and Grape Juice Treatment on Biochemical Parameters

We investigated certain biochemical parameters in the serum of the animals tested, such as glucose, total cholesterol, triglycerides, AST, ALT, GGT, LDH, urea, creatinine, and uric acid (Table 4). The animals treated with HFD, regardless of the intake of purple grape juice, had reduced levels of urea. We also observed a significant increase in the AST levels of rats receiving HFD, unrelated to the consumption of purple grape juice. Furthermore, GGT was increased in HFD animals and conventional or organic grape juices were able to prevent this enhance.

Table 4. Evaluation of biochemical parameters after 12 weeks of treatment with high-fat diet (HFD), conventional grape juice (CGJ), and/or organic grape juice (OGJ).

	Control	HFD	HFD + CGJ	HFD + OGJ
Glucose (mg/dL)	74.7 ± 7	93.2 ± 5	99.5 ± 8	88.6 ± 4
Cholesterol (mg/dL)	43.4 ± 4	50.2 ± 3	57.8 ± 3	53.7 ± 4
Triglycerides (mg/dL)	57.9 ± 6	50.4 ± 3	73.77 ± 8	65.60 ± 3
Creatinine (mg/dL)	0.42 ± 0	0.45 ± 0	0.42 ± 0	0.44 ± 0
Urea (mg/dL)	49.5 ± 2	38.9 ± 2 *	39.6 ± 3 *	30.8 ± 2 #
Uric acid (mg/dL)	1.52 ± 0	1.48 ± 0	1.53 ± 0	1.62 ± 0
ALT (U/L)	49.1 ± 3	41.0 ± 2	44.8 ± 4	40.1 ± 2
AST (U/L)	147.2 ± 9	206.8 ± 9 *	215.6 ± 14 *	211.9 ± 21 *
GGT (U/L)	1.2 ± 0	2.3 ± 0 #	1.7 ± 0	1.3 ± 0
LDH (U/L)	346.3 ± 38	351.8 ± 15	355.2 ± 12	340.90 ± 44

Means ± SEM. One-way ANOVA, followed by Bonferroni test, * $p < 0.05$, different from control; # $p < 0.05$, different from all other groups. $n = 10$. ALT: alanine aminotransferase; AST: aspartate aminotransferase; GGT: gamma-glutamyl transpeptidase; LDH: lactate dehydrogenase.

3.5. Effect of HFD and Grape Juice Treatment on TBARS Measurement

HFD enhanced TBARS levels and both purple grape juices were able to ameliorate this effect in serum of rats (Figure 3).

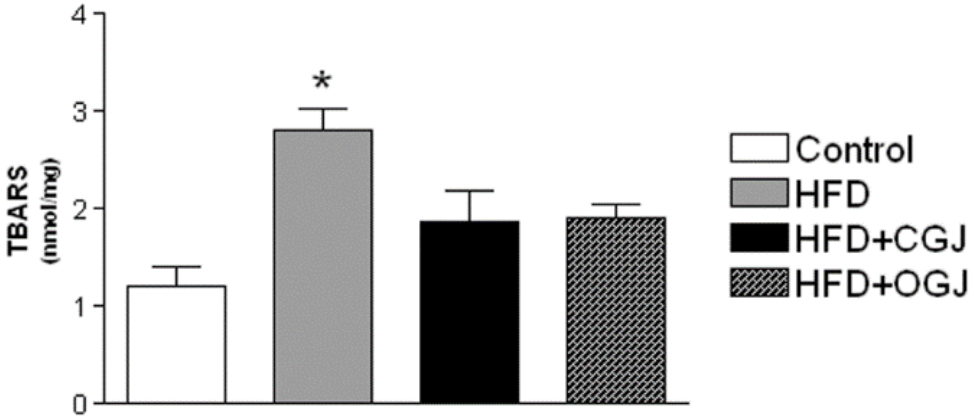

Figure 3. Effect of chronic treatment with high-fat diet and purple grape juices on thiobarbituric acid reactive substances (TBARS) in serum of rats. Values are means ± SEM for 8–10 samples in each group expressed as nmol/mg. Statistically significant differences were determined by ANOVA followed by Bonferroni test: * $p < 0.05$, from other groups. HFD: high-fat diet; CGJ: conventional grape juice; OGJ: organic grape juice.

4. Discussion

It is well described in the literature that grapes and their byproducts have antioxidant properties [23,33–35] and that they can prevent liver disorders [36,37], reduce risk factors related to metabolic syndrome [38], improve insulin signaling in diabetes [39], and prevent cardiovascular disease [40]. Therefore, in the present study, we investigated the effect of chronic intake of conventional and organic purple grape juice on some biochemical and physiological parameters of rats fed with HFD.

First, it was observed that HFD was able to influence the pattern of food and drink intake of animals. Although highly palatable [41], we observed a reduction in HFD consumption in relation to the standard diet, which is in agreement with the findings of Higuchi et al. [42]. The lower intake (g) of HFD may be related to its energy density, in which it has approximately 50% more calories than the standard diet. The intake of both juices seems to have further reduced HFD intake. This could be explained by the fact that the calories contained in the juices complement the daily caloric needs of the animals. However, the stilbenoid resveratrol (a phenolic present in the grape) had been related

to reduction of intake food in obese rats [43]. Franco et al. (2016) showed that the administration of resveratrol (100 mg/kg intraperitoneal) suppressed food intake for 24 and 48 h in mice, an effect related to the improvement of the central action of leptin (food intake regulator) [44]. In addition, resveratrol decreased adipocyte leptin secretion in vitro [45] and in vivo in mice fed with HFD [46].

The weight gain associated with the intake of HFD is controversial, since an increase in body weight in rats fed with HFD is not observed in all studies. Our results showed that HFD did not lead to an increase in final body weight; however, obesity was not notably observed in the animals, which is in accordance with a previous study [47]. However, an increase in abdominal fat deposits was observed, which was prevented by both juices. The increase in abdominal fat was also observed by Kim et al. (2011) and Higa et al. (2014) in mice that received a HFD [46,48]. It also was previously reported that a HFD induced the acceleration of replication of preadipocytes in primary cultures, stimulating a greater expansion of retroperitoneal fat, and inducing the expansion of adipose tissue mass [49]. This result can be harmful to individuals, since increased visceral adiposity is a risk factor for metabolic disorders such as dyslipidemia, diabetes (type 2), inflammation, and fatty liver disease [50,51]. Of note, intake of saturated fat, even without changing body weight, induces insulin resistance, hyperinsulinemia, and visceral adiposity [52,53]. In this context, our results showed that HFD increased blood glucose (after 30, 60, and 90 days of treatment), and both purple grape juices did not prevent this increase. This result is in agreement with previous work, which observed an increase in levels of glucose in mice after 18 months of treatment with HFD [54], and after 28 weeks. On the other hand, Louis et al. (2011) showed that HFD during 17 days increased glycemia, and that resveratrol (2.5 mg/kg body weight) was able to prevent this increase [55].

The excessive consumption of fat leads to several forms of damage, mainly in the liver, causing a loss in metabolic function in this organ, resulting in an increased release of liver enzymes in blood [56]. In our study, we observed that the HFD provoked an increase in AST and GGT serum levels, which is in accordance with a study that analyzed 10 weeks of HFD diet in mice [57]. It could be related with the accumulation of liver lipids, which could cause damage to cellular homeostasis, causing cytotoxicity [58]. Furthermore, HFD increases levels of liver enzymes, however, an extract of green tea was able to reverse this increase in rats [59]. This is in line with our present results, since both purple grape juices were able to prevent the GGT increase. This effect was also observed with grape leaf extracts [60]. This protection was also attributed to the polyphenols content; this is in accordance with another work that also showed that resveratrol was able to attenuate hepatic steatosis in mice [61]. On the other hand, our group recently demonstrated that carbon tetrachloride (CCl4) increased glucose, ALT, AST, and GGT, and decreased the levels of total cholesterol and HDL. In this study, it was also shown that conventional and organic white grape juices prevented the reduction of total cholesterol and HDL, and the enhancement of ALT and AST. However, white grape juices were unable to prevent the increase of glucose and GGT levels [62]. We also observed a difference in blood glucose levels in rats fed and fasted. This result could probably be explained as being due to a combination of factors: the rats were fed at the moment of the analysis that we were measuring the levels of glucose from food, and the HDF animals may have developed resistance to insulin.

In the present study, we observed that the HFD decreased the serum urea levels, which disagrees with an HFD treatment for 6 weeks that increased urea levels [63]. Since urea results from the degradation of protein, an enhancement in urea levels should have been expected, although that was not verified in our study. This is probably related to the difference in time treatments, because a longer HFD treatment time could be related with more liver damage. OGJ and CGJ were not able to prevent this decrease in urea levels. The other biochemical parameters evaluated in our experimental model did not show significant differences between groups (glucose, cholesterol, triglycerides, creatinine, uric acid, ALT, and LDH).

The consumption of a HFD promotes a plasma increase of lipids that stimulates the production of reactive oxygen species (ROS) through the activation of leukocytes, inducing lipid oxidation and atherogenesis [64,65]. The increase in TBARS was also observed in other studies in the liver and brain

of rats [11,12,66]. This enhancement could be attributed to the hyperlipidemia that causes oxidative stress and reduces the antioxidant defense system, thereby elevating lipid peroxides. For example, the increase in ROS levels and lipid peroxidation was also observed in mice that received an intravenous injection of free fatty acids, while those that overexpressed the glutathione peroxidase, a peroxidase enzyme, were protected against lipid damage [67]. Similarly, in our study, increased lipid peroxidation was observed in serum of the rats after chronic consumption of HFD. However, the consumption of CGJ and OGJ prevented this alteration. The antioxidant mechanism of grape juice (CGJ and OGJ) could be attributed to the reducing power of the phenolic hydroxyl group present in the chemical structure of polyphenols, which donates electrons and stabilize the radical species [68]. Phenolic compounds can also act as chelating agents for metals such as iron (Fe^{2+}) and copper (Cu^{2+}), and can improve the endogenous antioxidant systems, inhibiting the production of ROS and contributing to protection against lipoperoxidation [69]. In this context, oxidative stress provoked by a HFD could be prevented with Vineatrol®-enriched red wines in hamsters [70], and polyphenol extract from red grapes in rodents [71].

This antioxidant effect is very important because oxidative alterations in plasma are directly involved with endothelial dysfunction and cardiac injury [72,73]. Moreover, it is possible that this oxidative condition may be related with the increase in the plasma inflammatory markers, since the oxidation of lipids generates metabolites such as malondialdehyde, which induce infiltration and activation of inflammatory cells [74,75]. In view of that, there is a clear necessity for additional interventions to mitigate the impact of these pathologic events that are promoted by excessive consumption of HFD.

5. Conclusions

In conclusion, HFD influenced the pattern of food and drink intake; increased abdominal fat, liver damage, and glucose levels; and induced lipid peroxidation in the rats. Therefore, considering that purple grape juice, a complex mixture that is rich in polyphenol content and vitamins, was able to prevent and improve these alterations, we propose that regular intake of grape products could be considered in order to prevent the damages provoked by HFD.

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Conflicts of Interest: The authors declare no conflict of interest.

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