



Regulation of Biochemical Markers by Soymilk and Physical Exercise on Obese Rats

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Authors' contributions

This work was carried out in collaboration between both authors. Authors MBSD and FNZ conceptualized and designed the study. They have developed the experimental protocol and author MBSD collected data, carried out the analyses, interpreted the data and draft the article. Author FNZ critically reviewed the article. Both authors read and approved the final manuscript.

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ABSTRACT

Background: Obesity is an excess of body fat that cause cardiovascular risk and it prevalence in Cameroon among adults is high.

Aims: This study took place in the animal house of the Department of Biochemistry of the University of Dschang between June 2020 and February 2021 and the purpose was to evaluate the effect of the association of soymilk, diet and swimming in the prevention and treatment of obesity.

Methodology: A cross-sectional study was conducted with 80 rats of 21 days old divided into 6 groups. Thus, we calculate Lee index every two weeks, blood glucose measure and lipid parameters have been dosed in blood sera conserved at -20°C after extraction.

Results: It appears that the high amount of lipid in hyperlipidic diet induces obesity in these rats after 45 days of treatment. This is shown by the body weight gained by hyperlipidic males and females (242.66 ±6.35g and 224.39 ±7.52g), which was significantly higher than that of the standard group (203.06 ±4.9g and 186.31 ±4.04g). This is also indicated in the hyperlipidic males with a Lee index of 301.38 ±0.495, which was significantly higher compared to standard males

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(296.33 ±1.977). The total cholesterol which was higher in the hyperlipidic subjects decreases significantly after treatment of 3.4 % and 26.8 % respectively at 30 and 60 days. Consequently, the other lipid parameters such as HDLc, LDLc and atherosclerosis index become normal within the duration of treatment.

Conclusion: The study results reveal that obesity was significantly prevalent mostly in males. Soymilk with its richness in phytosterols, coupled with swimming a priority source of fat dissipation, can be used efficiently to fight and prevent obesity and its consequences.

Keywords: Obesity; soymilk; hyperlipidic diet; rats; swimming; lee index.

1. INTRODUCTION

In developed countries, as well as in developing countries, food security is linked in particular to bad feeding habits and, poor lifestyle, where there is an increase of fats, salt and sugar intake coupled with reduction of physical activity due to more sedentary work activities, use of motorized transport and growing urbanization [1,2]. Formerly confined in emerging countries, obesity has quickly become a pandemic linked to the improvement of life quality but especially to the development of the food industry [3].

The urgent need to master and control food security is one of the public health priorities. This pathology is the main cause of mortality in populations, once considered as a problem of rich countries (United States 19.8 to 27% obese, 30 to 35% obese in Eastern Europe) [4,5]. In 2005, the World Health Organization (WHO) statistics showed that more than a billion of people in the world were suffering from obesity and that, by 2030 this would increase to half a billion if nothing is done [6]. In 2000, obesity affected about 15% of Africans. Despite its food self-sufficiency, Cameroon is not safe by this pandemic. In fact, obesity is a pathology characterized by an excess of lipid deposition leading to certain changes in the body [7]. Thus, an imbalance in the regulation of physiological variable leads to an accumulation of energy reserves and therefore to obesity [8].

Obesity is develops by hypertrophy and/or hyperplasia of adipocytes. Many studies clearly establish a causal relationship between obesity and its consequences, which are sometimes worrying as hypertension, stroke, diabetes, heart failure. The diagnosis of obesity is made by an evaluation of the weight status of an individual as the body mass index, the waist circumference, skin fold and body density; but also by sophisticated methods that are not widely available in routine such as ultrasonography,

radiography, absorptiometry, magnetic resonance, tomodensitometry [9].

In addition, previous work has shown that the phytosterols and fiber in soya beans help to reduce bad cholesterol level, making soya beans very suitable for cardiovascular conditions [10]. Although works in this area and on swimming are available, locally, no works showing the impact of soymilk and swimming effect combine together exist to contain the extend of the pandemic which negatively influences social performance and hence the development of the country. The general objective was to evaluate the effect of association of soymilk, diet and physical exercise in the prevention and treatment of obesity, in order to improve the population health.

2. MATERIALS AND METHODS

2.1 Plant Material

Soya beans (*Glycine max (L.) Merr.*) were bought in the local market, soaked, then dried before being used on one hand, for the manufacture of soya beans milk and, on the other hand as experimental diet supplement. Palm oil, also purchased in the local market, was used in the formulation of the hyperlipidic food.

2.2 Diet Formulation

The formulation of the standard and hyperlipidic diets was done according to the needs of rats. Base on the lipid contents, the mixture of corn, soya beans, fish and palm oil was done to provide 18% and 7% of lipid for hyperlipidic and standard diets respectively. Other ingredients were bone meal, salt and vitamin. The chemical analyses of those diets were done using the Association of Official Analytical Chemists (1990) methods.

2.3 Production of Bleached Soya Beans Milk

Soya beans (1kg) were washed and bleached with 5 liters of water for 15 minutes, then soaked at 25°C for 12 hours. These seeds were crushed with water (2 liters) and to the resulting dough; 5 liters of water were added, homogenized and filtered. The resulting crude soya beans extract was boiling at 90°C and cooked at 93°C by shaking for 20 minutes. The soya beans milk obtained was then administered to the animals [11].

2.4 Housing and Animal Equipment

The rats were bred and fed at the Biochemistry Department of the University of Dschang located at 1420 m altitude approximately, in a tropical Sudano-Guinean climate and tempered by altitude. Its annual rainfall is 2000 mm of precipitation with an average temperature of 20°C [12]. After the births that occurred in four days interval, weaning occurred when the rats (40 males and 40 females) was 21 days old, then they were acclimatized for 3 weeks with the control food [13] before being randomly distributed into 6 groups of approximately 13 rats for each (4 test groups consumed soya milk and/or swam and 2 control groups did not consume soya milk and did not swim) in plastic cages of about 90 cm in diameter and 20 cm in height, with a feeder and a baby bottle to serve food and water ad libitum, they were covered with wire mesh and placed on the shelves at 25°C. The circadian rhythm was 12 hours of light and 12 hours of darkness. These rats were identified by group and by sex using the markings entered and renewed every three days on the tail. Animals from each group were placed in two cages, one for males and one for females in order to avoid mating which would influence the biochemical profile. The feces accumulated in the cages were cleaned weekly. This included placing them in ventilated and cleaned cages, providing them with food and water ad libitum and also, anaesthetizing them before each sacrifice to minimize suffering. The water in the swimming tank was regularly warmed and changed before and at the end of the swimming session, their coats were wiped clean to keep them warm.

2.5 Swimming Procedure

A glass swimming aquarium was built for this study. The 2/3 filled water was warmed to a

substantial temperature close to the body temperature of the rats (23-26°C) using an electric immersion heater named "multi-thermometer". The first swimming session lasted 10 to 15 minutes, reaching 45 to 60 minutes after two weeks. It has to be noted that only one session was scheduled between 8 a.m. and 11 a.m. during the rest of the experiment. At the end of the session, the rat's coats were wiped with a towel then they were left at room temperature for about 45 minutes before being put back into the cage (Supplementary video File available).

2.6 Data Collection and Conduct of the Experiment

The experiment actually lasted 105 days and began with fasting blood glucose measurements on 45 days-old rats weighing between 80 to 115g. Three groups received standard food and the three others the hyperlipidic diet. The bleached soymilk was administrated by gavage every morning to some rats.

Three groups of rats fed with standard and hyperlipidic diet were practiced swimming three times per week and were received water, food and/or soymilk. The weekly weight and the nose to anus length were measured to determine Lee's index [14].

Animals were slaughtered in three sessions at day 45, day 75 and day 105. Before each session of sacrifice, they were fasted for 12 hours; blood sugar was measured, and they were anesthetized with thiopental by intraperitoneal inoculation. When the animal was asleep, a good measure of the nose to anus length was done. They were finally sacrificed; the blood was drawn by catheterization of the dorsal artery into sterile test tubes and then centrifuged at 1500g for 5 minutes. The supernatant was collected and stored at -20°C.

2.7 Blood Glucose Measurement

The device used was the One Touch® Basic™ brand LIFESCAN blood glucose meter. On One Touch™ brand strips, we placed a drop of fresh blood from the tail of the rat, which allowed in 45 seconds reading the blood glucose value from the beginning to the end of experiment.

2.8 Determination of Lipids Profile

Total cholesterol and HDL cholesterol were determined by the enzymatic colorimetric method from a commercial kit, respectively "INMESCO-

CHOD-PAP monoreagent" and "INMESCO-HDL Cholesterol precipitation" obtained on the local market (https://www.biotec-co.com/images/products/clinical_chemistry/kits/C_cholesterol.pdf). Friedewald's modified formula was used to calculate the concentration of LDL cholesterol in serum [15].

2.9 Statistical Analyses

Statistical analyses were performed using the statistical package for social sciences (SPSS statistic.v17). Data expressed as mean \pm SD were statistically analyzed using one-way analysis of variance (ANOVA). The chi-square test and the Student test were used for comparison between groups. All "P" values less

than 0.05 were considered statistically significant.

3. RESULTS

3.1 Bromatological Analysis of Standard and Hyperlipidic Diets

The results of chemical analysis of the two experimental diets showing that the hyperlipidic diet contains less proteins, carbohydrates, water and minerals, but has a high dry material (90.6% \pm 0.6) and organic material (90.6% \pm 0.8). The table also shows that the hyperlipidic diet is richer in cellulose (11.5% \pm 0.1) and lipids (17.8% \pm 0.9) with a metabolisable energy of 413.6 \pm 3.1 kcal against 354.2 \pm 2.6 kcal for the control diet (Table 1).

Table 1. Bromatological composition of standard and hyperlipidic diets

Constituent	Content (g/100g DM)	
	Hyperlipid diet	Standard diet
DM (%)	90.6 \pm 0.6	90.0 \pm 1.0
OM (%)	90.6 \pm 0.8	89.7 \pm 0.3
Ashes (%DM)	9.4 \pm 0.3	10.3 \pm 0.6
Crude fiber (%DM)	11.5 \pm 0.1	4.7 \pm 0.4
Water content (%)	9.0 \pm 0.3	9.7 \pm 1.7
Crude proteins (%DM)	14.2 \pm 0.1	15.1 \pm 2.0
Total lipids (%DM)	17.8 \pm 0.9	7.1 \pm 0.8
Total carbohydrates (%DM)	49.3 \pm 1.4	57.5 \pm 0.0
Métabolisable energy (Kcal)	413.6 \pm 3.1	354.2 \pm 2.6

DM = Dry Material; OM = Organic Material

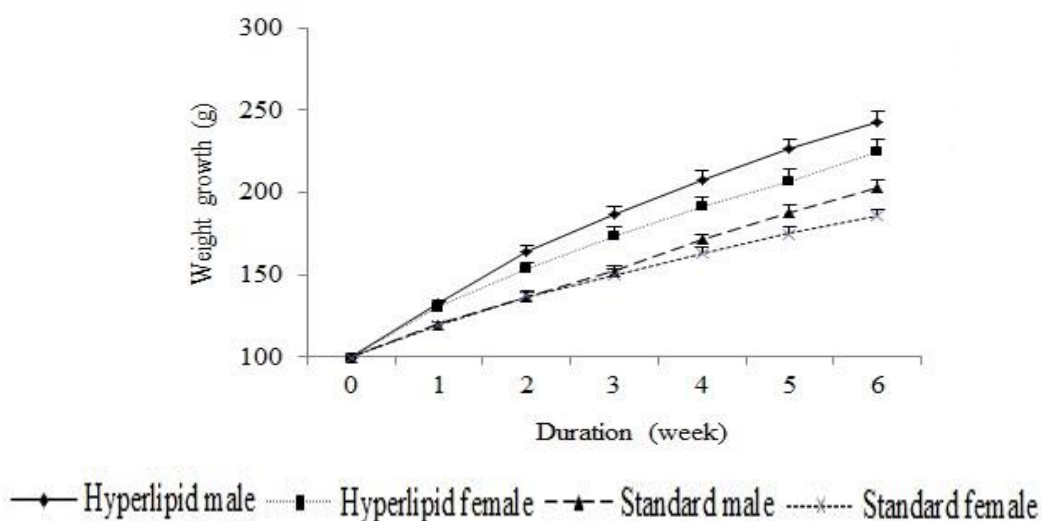


Fig. 1. Evolution of weight growth as a function of sex and diet for 45 days of treatment

3.2 Evolution of Weight Growth for 45 Days of Treatment

After obesity induction, hyperlipidic male's gain more weight ($242.7 \pm 6.3g$) highly significant ($P < .01$) from the second week compared to hyperlipidic females ($224.4 \pm 7.5g$). However, in the standard batch, body growth also increased although it was significant from the 5th week between males and females ($P < .05$) (Fig. 1).

3.3 Effects of Physical Exercise and/or Soymilk on Body Weight Change

The body weight of inactive and none consuming soymilk rats in batches 1 and 5 increased high significantly ($P < .01$) with time (batch 1: $370.7 \pm 21.4g$ for males and $319.9 \pm 12.4g$ for females respectively) after 75 days of treatment, $469.3 \pm 37.9g$ for males and $393.1 \pm 21.9g$ for females respectively after 105 days of treatment. Body growth increased significantly in batches 3, 4 and 6 until 75 days from which it decreased significantly until 105 days of treatment ($P < .05$) (Table 2).

3.4 Dietary Effects on Atherosclerosis Index after 45 Days of Obesity Induction

The atherosclerosis index, which predisposes to cardiovascular disease, was higher in males in

all batches. The difference was highly significant in hyperlipidic males (1.12 ± 0.41) compared to standard males (0.58 ± 0.27) ($P < .01$), also in hyperlipidic females (0.71 ± 0.17) compared to standard females (0.45 ± 0.15) ($P < .01$) (Fig. 2).

3.5 Effects of Physical Activity and Soymilk Consumption on Atherosclerosis Index after 105 Days of Treatment

Lee's index calculated in rats increases high significantly ($P < .01$) in none swimming batches that consumed soya beans milk or not (Batch n°1, n°2, n°5), whereas it decreases significantly ($P < .05$) in batch n°3 during the last 30 days of treatment (302 ± 0.6 to 299 ± 0.9 and 300.8 ± 0.7 to 298 ± 2.2 in males and females respectively). There was a significant decrease in Lee's index during the treatment after 30, 75 and 105 days in Batches n°4 (303.6 ± 0.7 , 300.7 ± 1.0 to 299 ± 0.0 and 300.8 ± 0.5 , 299.7 ± 0.9 to 294 ± 0.8 in males and females respectively) and n°6 (302.3 ± 0.8 , 294.4 ± 0.9 to 284.7 ± 2.2 and 300.6 ± 0.65 , 293.8 ± 0.73 to 286 ± 1.31 respectively in males and females) practicing swimming and consuming soymilk. In the batch n°1 fed with hyperlipidic diet, almost all rats reached or exceeded the Lee's index threshold (300) on day 75 of treatment (Table 3).

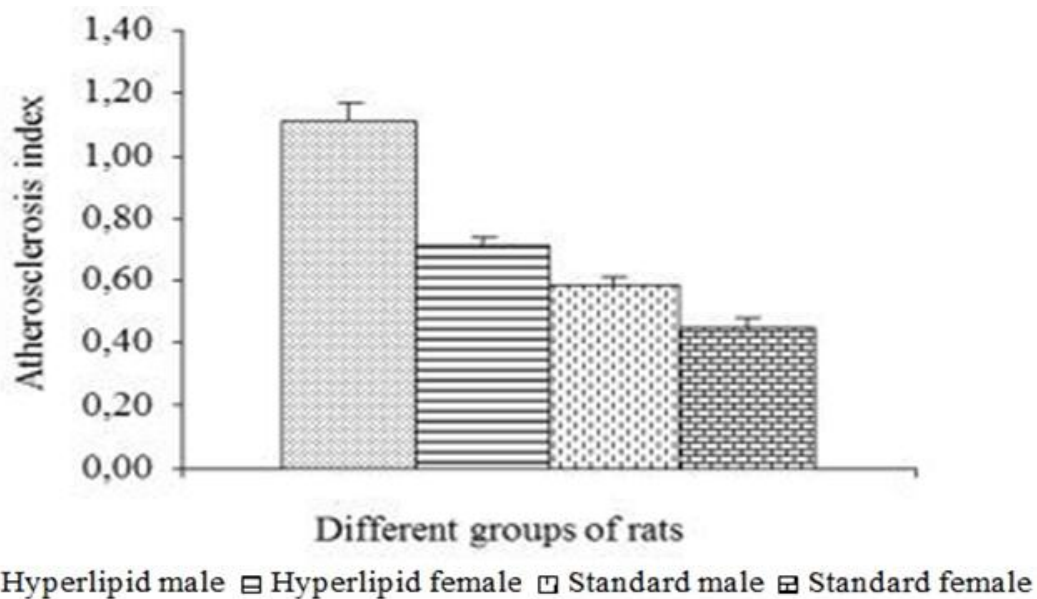


Fig. 2. Value of atherosclerosis index as function of sex and diet for 45 days of treatment

Table 2. Evolution of weight growth as a function of sex, diet and treatment duration

	Batch n°1		Batch n°2		Batch n°3		Batch n°4		Batch n°5		Batch n°6	
	M	F	M	F	M	F	M	F	M	F	M	F
Day 45	296.0	238.6	174.1	169.3	231.2	224.2	219.5	184.1	178.9	185.1	182.3	171.0
(g)	±16.3	±9.40	±9.40	±11.5	±16.3	±16.3	±11.5	±16.3	±11.5	±9.40	±9.40	±9.40
Day 75	370.7	319.9	222.2	206.9	251.2	234.0	231.3	192.9	230.7	223.9	197.7	176.0
(g)	±21.4	±12.4	±12.4	±15.2	±21.4	±21.4	±15.2	±21.4	±15.2	±12.4	±12.4	±11.5
Day 105	469.3	393.0	281.2	257.7	248.8	224.2	224.7	181.4	290.1	281.1	185.3	164.0
(g)	±37.9	±21.9	±21.9	±26.8	±37.9	±37.9	±26.8	±37.9	±26.8	±21.9	±21.9	±16.3

Batch n°1 = Hyperlipidic diet, Absence of soymilk, Lack of exercise ; Batch n°2 = Standard diet, Presence of soymilk, Lack of exercise; Batch n°3 = Hyperlipidic diet, Absence of soymilk, Practice of exercise; Batch n°4 = Hyperlipidic diet, Presence of soymilk, Practice of exercise; Batch n°5 = Standard diet, Absence of soymilk, Lack of exercise; Batch n°6 = Standard diet, Presence of so milk, Practice of exercise; F = Female; M = Male

Table 3. Evolution of Lee index as function sex, diet and treatment duration

	Batch n°1		Batch n°2		Batch n°3		Batch n°4		Batch n°5		Batch n°6	
	M	F	M	F	M	F	M	F	M	F	M	F
Day 45	298.6	296.3	288.7	285.3	301.4	297.3	303.6	300.8	294.6	291.6	302.3	300.6
	±2.0	±1.9	±0.2	±0.5	±0.4	±1.1	±0.7	±0.5	±0.9	±0.9	±0.9	±0.6
Day 75	304.2	299.8	292.2	290.0	302.0	300.8	300.7	299.7	295.8	293.8	294.4	293.8
	±0.6	±1.6	±0.6	±0.3	±0.6	±0.7	±1.0	±0.9	±0.9	±0.9	±0.9	±0.7
Day 105	305.0	301.7	295.5	292.7	299.0	298.0	299.0	294.0	297.0	296.0	284.7	286.0
	±1.5	±0.9	±0.5	±0.3	±1.8	±2.2	±0.0	±0.8	±1.2	±1.2	±2.2	±1.3

Batch n°1 = Hyperlipidic diet, Absence of soymilk, Lack of exercise; Batch n°2 = Standard diet, Presence of soymilk, Lack of exercise; Batch n°3 = Hyperlipidic diet, Absence of soymilk, Practice of exercise; Batch n°4 = Hyperlipidic diet, Presence of soymilk, Practice of exercise; Batch n°5 = Standard diet, Absence of soymilk, Lack of exercise; Batch n°6 = Standard diet, Presence of so milk, Practice of exercise; F = Female; M = Male

Table 4. Evolution of blood sugar as a function of sex, diet and duration of treatment

	Batch n°1		Batch n°2		Batch n°3		Batch n°4		Batch n°5		Batch n°6	
	M	F	M	F	M	F	M	F	M	F	M	F
Day 45	90.1	90.2	98.0	96.5	95.8	94.8	96.5	94.2	93.4	90.4	95.3	92.4
(mg/dl)	±0.1	±0.1	±0.1	±0.4	±0.5	±0.2	±0.2	±0.2	±0.3	±0.8	±0.4	±0.2
Day 75	168.0	158.0	163.7	159.0	131.0	119.5	130.5	117.5	163.3	159.0	128.0	110.3
(mg/dl)	±0.0	±0.3	±0.6	±0.2	±0.2	±0.2	±0.4	±0.5	±0.4	±0.5	±0.1	±0.4
Day 105	156.0	151.0	158.0	144.0	128.0	116.0	127.0	114.0	153.5	143.3	99.0	88.0
(mg/dl)	±0.8	±0.3	±0.2	±0.1	±0.4	±0.8	±0.2	±0.1	±0.0	±0.4	±0.6	±0.2

Batch n°1 = Hyperlipidic diet, Absence of soymilk, Lack of exercise ; Batch n°2 = Standard diet, Presence of soymilk, Lack of exercise; Batch n°3 = Hyperlipidic diet, Absence of soymilk, Practice of exercise; Batch n°4 = Hyperlipidic diet, Presence of soymilk, Practice of exercise; Batch n°5 = Standard diet, Absence of soymilk, Lack of exercise; Batch n°6 = Standard diet, Presence of so milk, Practice of exercise; F = Female; M = Male

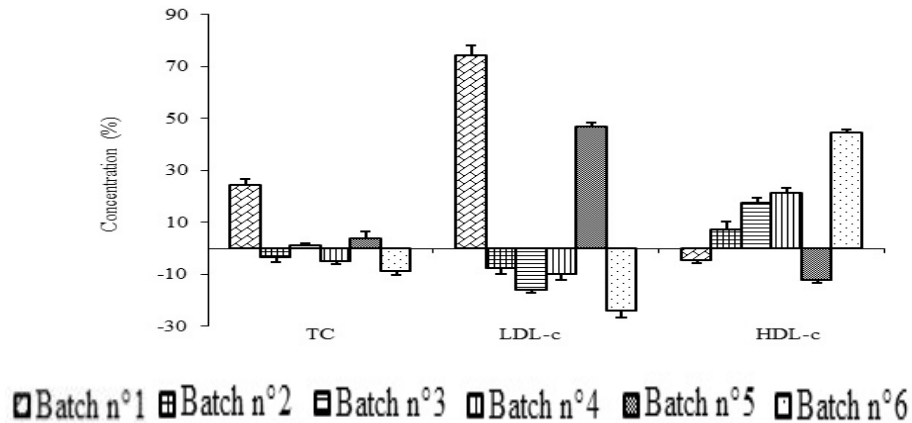


Fig. 3. Effect of treatment on serum total cholesterol, LDLc and HDLc levels on day 105 of the experiment

Batch n°1 = Hyperlipidic diet, Absence of soymilk, Lack of exercise; Batch n°2 = Standard diet, Presence of soymilk, Lack of exercise; Batch n°3 = Hyperlipidic diet, Absence of soymilk, Practice of exercise; Batch n°4 = Hyperlipidic diet, Presence of soymilk, Practice of exercise; Batch n°5 = Standard diet, Absence of soymilk, Lack of exercise; Batch n°6 = Standard diet, Presence of so milk, Practice of exercise

3.6 Effects of Physical Activity and Soymilk on Serum Lipid Changes at the End of Treatment

At the end of the treatment, there was a significant ($P < .05$) increase in total cholesterol in batch n°1 (24.59%) and a non-significant ($P > .05$) increase in batches n°3 (1.2%) and n°5 (3.76%). In the active batches n°4 and n°6 as well as the batch n°2 consuming soymilk, there was a significant ($P < .05$) decrease in total cholesterol levels (- 4.94%, - 8.82% and - 3.49% respectively). The same observation was made for LDLc, which increased very significantly in hyperlipidic batch n°1 (74.46%). As for HDLc, there was a high significant increase ($P < .01$) in all batches except in batches n°1 (- 4.49%) and n°5 (-12.09%) which were inactive (Fig. 3).

3.7 Effects of Physical Activity and Soymilk on Blood Glucose Levels in Rats

The mean of blood glucose level at day zero increased significantly in all batches with age and treatment ($P < .05$). This increase was highly significant ($P < .01$) in the inactive batch n°2 (98 ± 0.1 and 96.5 ± 0.4 in males and females respectively) compared to the active batch n°6 (95.3 ± 0.4 and 92.4 ± 0.2 in males and females respectively). After 75 days of treatment, it starts to decrease in all batches independently of diet. However, the decrease was highly significant ($P < .01$) in the active batch consuming soymilk n°6

(from 128 ± 0.1 to 99 ± 0.6 mg/dl in males and from 110.3 ± 0.4 to 88 ± 0.2 mg/dl in females respectively) (Table 4).

4. DISCUSSION

To the best of our knowledge, the effect of association of soymilk, diet and physical exercise in the prevention and treatment of obesity have not been studied before in Cameroon. The dramatic increase of cardiovascular diseases in developing countries is due to sedentary lifestyles and the explosion in obesity prevalence. The lipid content of hyperlipidic diet which induced obesity in rats has also been shown in their work on the regulation of fertility metabolism in mice [16]. In this study, the weight gain obtained in Fig. 1 was influenced by diet. In 45 days of obesity induction, the rats fed by the hyperlipidic diet had a significantly higher body growth rate compared to the control rats. This is due to the excess of fat contained in hyperlipidic diet leads to an imbalance between food energy intake and the energy expenditure necessary for daily activities; hence the installation of obesity. These results are comparable to those obtained by some scientists [8,17] who have also shown that this weight gain can be achieved by hypertrophy or hyperplasia of adipocytes between the 6th and 16th week of obesity induction.

It also shows that weight gain is more significant in males than in females; suggest that females

have more estrogen hormones than males, that have a similarity of action with the phytochemical elements of soya beans in cholesterol rate normalization process [18]. We could think that physical activity on one hand decreases the energy surplus, and on the other hand amplifies the action of the phytochemical elements of soya beans on the normalization of body weight. Between the 75th and 105th day in hyperlipidic swimming rats, the body weight decreases as well as when soymilk was added. This could be explained by its high protein contents; known to build body mass [19,20]. These results are comparable to those obtained on the indicators of overweight and obesity [21], which could be attributed to regular physical exercise combined with soymilk, would normalize body weight and the metabolic dysfunctions induced [22,23]. Recently it was reported in a study on prevalence of metabolic syndrome in adult men in Dschang Health District in Western-Cameroon that, poor lifestyle, physical inactivity, tobacco consumption, alcoholism, low educational level and poor eating habits are associated to high prevalence of metabolic syndrome [24].

Atherosclerosis index is a marker of aortic wave reflections. In the present study, it increases significantly with diet and gender from the sixth week of obesity induction. Rats in hyperlipidic group have a significantly higher atherosclerosis index compared to standard group, because the hyperlipidic diet is very rich in lipids which induce the development of obesity. These results corroborate another results obtained on fertility and metabolism regulation in adults and children [16,25]. In general, men have a significantly higher Atherosclerosis index than women, as shown by some researchers in their work on rats metabolism [14,17]. This could be explained by the fact that males naturally gain more weight than females.

It was also reported in this study that Lee index is generally higher in males than in females and also higher in sedentary rats consuming hyperlipidic diet than those with permanent physical exercise and appropriate diet after 105 days of treatment. An alternative explanation may be that, bad lifestyle habits predispose to cardiovascular diseases. However, we noted that physical exercise and soymilk significantly lowers the risk rate after 105 days of treatment in males and females compared to males and females without soymilk and sedentary respectively. Similar results have been recently obtained on hypertensive subjects practicing physical

exercise [26,27]. This decrease after 60 days of treatment would suggest the presence of antioxidant substances in soymilk and the effect of physical exercise that have the ability to purify the blood from reactive oxygen's, thus inhibiting the oxidation of β -lipoproteins and therefore reduce the risk of atherosclerosis [26].

Additionally, the distribution of body fat could have strongly influenced metabolic abnormalities in the lipids profiles. The study showed that after obesity induction, TC (Total Cholesterol) level was significantly higher in the hyperlipidic group, and particularly in males, which predisposes them to overweight due to hypercholesterolemia. This leads to the obstruction of the vascular light with the risks of atherosclerosis and coronary diseases [22,28]. This hypercholesterolemia would also be due to the composition of hyperlipidic diet recognized for its richness in saturated fatty acids [29]. Between the 45th and the 75th day, it appears in figure 3 that in obese rats, physical activity decreases the rate of TC, and when combined with soymilk in the same rats, it drops more. The results also reveal that soymilk alone lowers the TC rate of 21.35% [18] through the interaction between soya beans protein and blood lipids. Furthermore, at the 105th day, we observed that TC rate drops significantly of 26.8% with the duration of physical exercise against 3.4% at the 75th day. This is confirmed by the work which showed that the duration and regularity of physical exercise not only helped to reduce body weight, but also normalize blood lipids that increase of 24.59% at the end of treatment in inactive hyperlipidic subjects that were not consuming soymilk [22]. While in those that are active and consuming soymilk, there was a decrease of body weight (5.75%) although it remains lower than the 9.3% [18].

Concerning HDLc, after obesity induction, it was found to be low in hyperlipidic subjects compared to standard subjects, while LDLc was high. This could be justified by the fact that the hyperlipidic diet has caused hypercholesterolemia in obese subjects, with the deposits of cholesterol plaques in the vascular walls [28]. The more obesity is severe, the more HDLc significantly decreases. On day 105 of treatment, HDLc increases in active obese rats, but this increase was not significant compared to the rate in normal rats. As for LDLc, it drops by 1.15% in active obese rats while in normal rats consuming soya beans milk and practicing swimming, the drop in LDLc rate is significant. This drop in good cholesterol

and the increase of bad cholesterol is due to the high blood sugar level which presages uncontrolled diabetes [29]. At the end of the treatment, HDLc increases in general of 9.3% in subjects consuming soymilk as shown in figure 3, this is significantly higher than the 2.4% obtained in another work [18]. A decrease of LDLc (8.3%) is observed in sedentary groups without soymilk but remains below [18] (12.9%). Physical exercise alone decreases by 19.7% and when soymilk is combined, we have a decrease of 28.3%, which leads us to think that good eating habits and the duration of physical activity are likely to normalize all lipid parameters.

Blood sugar increases significantly with age, sex and diet. It is significantly higher in males than females after 45 days of obesity induction; likewise it increases on day 75 of treatment and begins to decrease in all groups. As demonstrated, blood sugar drops slightly with age [8]. However, it decreases very significantly in groups practicing swimming [30]. It is believed that maintaining high blood sugar levels in sedentary groups is due to inactivity and dietary imbalance which promotes storage of carbohydrates with enormous risk of diabetes. Indeed, one of the most important roles of the liver, as mentioned is to regulate blood sugar. So, if the liver does not metabolize the excess of glucose, its concentration can triple, leading to hyperglycemia and consequently to diabetes [31]. The strong and positive correlation between the cumulative weight gain and the consumption of soymilk coupled with swimming shows that the weight loss is strongly related to physical exercise and the consumption of soymilk, as shown in some studies that the soymilk consumption normalizes lipid parameters [18] and that physical exercise has the ability to mainly dissipate fat by normalizing anthropometric parameters [32]. Physical activity and diet are not only factors that affect obesity. A multitude factors, including occupation, stress, smoking, alcohol consumption, socioeconomic status and genetics also impact on a person's weight.

5. CONCLUSION

The study results reveal that the morphological characteristics of males develop considerably and differ significantly from those of females with significant differences observed between the two genders from the second week of obesity

induction with the hyperlipidic diet. Soya beans milk is an excellent nutritional source, with its richness in phytosterols, efficiently to fight against hypercholesterolemia and, coupled with swimming which is a priority source of fat dissipation, can be used to prevent and fight obesity and its consequences.

CONSENT

It is not applicable.

ETHICAL APPROVAL

This study was approved and conducted in accordance with the Guide for the Care and Use of Laboratory Animals of the Department of Biochemistry. All authors hereby also declare that all experiments have been examined and have therefore been performed in accordance with the internationally accepted standard ethical guidelines for laboratory animal's use and care as described in the guidelines of the European Union Institutional Ethics committee on Animal Care (Council EEC 86/609/EEC of the 24th November 1986).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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