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EVALUATION OF ANTI-OBESITY EFFECT OF AQUEOUS EXTRACT OF *SOLANUM INDICUM* L. FRUITS ON HIGH FAT DIET-INDUCED OBESE RAT

Nadine Joissy Epoh, Olivette Laure Matafack Dongmo, Reine Audrey Mache, Phelix Bruno Telefo*, Félicité Mbiapo Tchouanguep

Department of Biochemistry, Dschang University, Research Unit of Biochemistry of Medicinal Plants, Food Sciences and nutrition, P.O Box 67, Dschang, Cameroon.

***Corresponding Author: Phelix Bruno Telefo**
Department of Biochemistry, Dschang University, Research Unit of Biochemistry of Medicinal Plants, Food Sciences and nutrition, P.O Box 67, Dschang, Cameroon.

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ABSTRACT

Background: *solanum indicum Linn* is a solanaceae family found mainly in India as well as in tropical and subtropical African regions. Different parts (fruits, leaves, roots) of this plant are used by the traditional practitioners in the treatment of abdominal pain and worm infestation, pain and fever, inflammation, insomnia, urinary complications, cardiac weakness... the aim here is to investigate the anti-obesity effect of the aqueous extract of *S. indicum* fruits in high fat diet induce obese rats. **Methods:** During 16 weeks obesity was induce in rats by high fat diet. Then, animals were treated during 42 days with plant extract at the doses of 25, 50,100, 200 mg/kg and Orlistat at 5mg/kg. The effect of the treatment was evaluated on food intake, body weight, Lee index, biochemical parameters and atherogenic index. Then organ and fat weights were taken. **Results:** The oral administration of extract leads to a decrease in body weight, but most significant in females. We also observe a significant decrease in fat weight and food intake as well as the serum levels of triglycerides, total cholesterol, LDL-cholesterol, atherogenic and Lee index in the obese animals treated. Those treated with the doses of 50 and 100 mg/kg of body weight showed significant variations of these parameters compared to orlistat (standard drug). **Conclusion:** This results show that the aqueous extract of *S. indicum* fruits possess significant anti-obesity potential on high fat diet induce obese rat.

KEYWORDS: *Solanum indicum Linn*, obesity, Lee index, Lipid profile, high-fat diet.

INTRODUCTION

Obesity is defined as an abnormal or excessive accumulation of fat in adipose tissue that can lead to health problems[1] Once considered as a specific problem in high-income countries, obesity is now increasing in low- and middle-income countries, where it coexists with malnutrition.[1] Its prevalence in the world always increases. The number of obese people in the world rose from 3.2% in 1975 to 10.8% in 2014 among men, and 6.4% to 14.9% among women.[2] In 2016, more than 1.9 billion adults, 18 years and older, were overweight. Of these over 650 million were obese. 39% of adults aged 18 and over were overweight in 2016 and 13% were obese[1] Overweight and obesity are responsible for many deaths around the world. Worldwide, there are more obese people than those who are underweight. Observation made in all regions except sub-Saharan Africa and Asia.[1] In Cameroon, obesity is observed in both rural and urban areas.[3] More than 25% of people living in urban areas are obese, and if overweight is taken into account, more than 55% of this population is either threatened or obese.[4] This prevalence was estimated at 11.1% in 2008 and 16.4% in 2013 in the Cameroonian population in general.[5] The Cameroon Heart Foundation's report confirms in 2015 that more than 35% of the population is obese.

Several measures are used for the management of obesity such as: physical activity, diet, surgical methods, medicines developed by modern medicine, as well as medicinal plants.[6] There are pharmaceutical drugs that have been approved for the treatment of obesity. However, most (sibutramine, rimonabant, ...) have been withdrawn from the market due to their serious side effects.[7] Orlistat is one of the marketed pharmaceutical drugs. It is used in this study as a reference medicine. It can, however, cause unwanted side effects, such as faecal incontinence, flatulence and steatorrhea.[8] It is therefore important to find a new way to fight against this scourge that makes life uncomfortable.

The effectiveness of medicinal plants in the treatment of many diseases has been proven.[9,10,11,12,13] They have been solicited in the management of obesity for several reasons. They may contain various natural compounds (secondary metabolites) with slimming effects or anti-obesity activity. Most of them are more accessible and cheaper than modern medicines. They sometimes have

little or no side effect. In this concern, the slimming effect of certain medicinal plants from the Cameroonian pharmacopoeia, *Laportea ovalifolia, Brillantaisia vogeliana* has already been demonstrated.[14,15] On regard to *Solanum indicum Linn* informations on the slimming effect of its fruits are not yet reported. But its roots are indicated in the treatment of bronchitis, its leaves are used for ear infections, angina and skin problems.[16]

Studies have demonstrated hypolipidemic and antiobesity activity in rats such as *Hypericum perforatum L.*[12] others are used as dietary supplements in the prevention of diabetes and obesity: *Salacia reticulata,* which thanks to its polyphenolic constituents, has lipolytic and hypoglycemic effects in obese rats.[9] Some plants showed their effectiveness in reducing body weight by having inhibitory effects on pancreatic lipase in vitro and thus retard the intestinal absorption of fats. They are also involved in lowering the level of blood glucose. These are: *platycodi radix*[17]; *Aesculus turbinata Blume*[10]; *Panax ginseng*[18] *Panax japonicus rhizomes.*[19]

Therefore, it would be possible that the active metabolites present in those medicinal plants could also be present in the *Solanum indicum Linn.* fruits. This is what prompted us to undertake the present study during which the anti obesity of the aqueous extract of *Solanum indicum Linn* (AESI) would be investigated. This would be done by evaluating its effects on anthropometrical and biochemical parameters of the lipids metabolism of high fat diet-induced obese rats.

1- MATERIALS AND METHOD

1.1. Chemicals and reagents

Triglyceride, Total cholesterol, HDL cholesterol and transaminases Kits were purchased from INMESCO/ Cameroon. Orlistat, purchased from Pharmaceutical industries of Pakistan, was available for oral administration as capsule and each capsule contained a pellet formulation consisting of 120 mg of the active ingredient.

1.2. Collection and identification of plant material

samples of fresh fruits of Solanum indicum were harvested in the locality of Foumban located in the Noun Division of the West region of Cameroon during the month of July 2016. The plant was identified and authenticated at the National Herbarium, Yaounde, in comparison with the reference voucher specimen number (60814/HNC). Moreover samples of fresh fruits were then dried at room temperature, and crushed into powder.

1.3. Aqueous extract preparation

500 gr of *Solanum indicum Linn* powder obtained were infused in 1L of distilled water for 5 minutes in accordance with the traditional therapist's method. The extract was then filtered using a coffee filter paper and dried in a ventilated oven and thermostated at 45 ° C. The resulting powder (71 g) was considered as our extract with an extraction yield of 14.2% (w/w). It was used in the preparation of various feeding solutions. Then, it were daily administered at different doses (25, 50, 100 and 2 00 mg/kg respectively) to the animals in accordance to their body weight.

1.4. Experimental animals

Albino Wistar rats were bred in the animal house of the Biochemistry Department (University of Dschang), housed under uniform husbandry conditions of light (12-h cycle) and temperature (22 ± 2°C). Some animals were fed with food composition proposed by Telefo[20], while others received a high fat diet. All animals received food and tap water ad libitum. Experimental protocols used were accepted by the local ethical committee of our Faculty (Faculty of sciences, University of Dschang, Cameroon) and were designed in strict concordance with the internationally accepted standard ethical guidelines for laboratory animal use and care as described in the European Community guidelines; EEC Directive 86/609/EEC, of the 24th November 1986.

1.5. Obesity induction in animals

After the parturition of female rats previously mated with males, pups obtained were weaned at the age of 1 month and submitted to a 22% fatty food with composition described in Table 1. In order to follow the obesity state of animals during the induction period of 16 weeks, their Lee index (IL) were calculated using the body weight taken every Two days, and Naso-anal length taken every week. This index was calculated using the equation below.[21] Rats with Lee index higher or equal to 300 (Li ≥ 300) were considered obese.

$$\mathbf{IL} = \left(\sqrt[3]{P}/L\right) \times \mathbf{1000}$$

Table 1: Food composition (gm).

Ingrédients	Normal Diet (ND)	High Fat Diet (HFD)
Corn powder	678	576
Soya beans powder	200	170
Fish powder	100	85
Born powder	10	10
Kitchen salt	10	10
Beef tallow	-	139
Vegetal oil	1	/
Vitamins	1	10

1.6. Animals distribution and treatment

After the induction period, seventy (70) rats made of sixty (60) obese and ten (10) non obese rats were randomly divided into 7 groups of 10 animals each (5 males and 5 females). The first group (group 1) was made of normal rats fed with standard diet and they received distilled water. The second group (group 2) was made of obese rats fed with high fat diet and received distilled water. The third group (group 3) was made of obese rats fed with high fat diet and received standard drug (orlistat at 5 mg/kg). The other groups (4, 5, 6 and

7) were obese rats fed continuously with high fat diet (HFD) and received aqueous extract of *Solanum indicum* (AESI) at different doses of 25, 50,100 and 200 mg/kg respectively for 42 days. The animals were then treated as described below:

- Group 1: Normal diet control (ND).
- Group 2: High fat diet control (HFD)
- Group 3: HFD + Orlistat 5 mg/kg b.w
- Group 4: HFD + AESI 25 mg/kg b.w
- Group 5: HFD + AESI 50 mg/kg b.w
- Group 6: HFD + AESI 100 mg/kg b.w
- Group 7: HFD + AESI 200 mg/kg b.w

1.7. Determination of body weight, lee index and food intake

During the 42 days of treatment carried out, the body weight and length (nose to base of tail) was measured every two and seven days respectively to determine Lee index which were calculated following the formula mentioned above. The food intake was calculated daily. The evaluation of the average of food intake per rat was recorded daily by subtracting the quantity of remaining food everyday from the initial quantity provided the previous day.

1.8. Evaluation of biochemical parameters and estimation of organs and fats weight

Twenty-four hours after the last treatment (day 43), animals were sacrificed under chloroform anesthesia. Their blood extracted from the heart were collected into test tubes without anticoagulant and allowed to stand for 6 hours at room temperature before being centrifuged at 4000 rpm for 5 min to obtain serum. The serum collected was stored at -18°C and used for biochemical analysis. The following organs: heart, liver, kidneys, spleen and pancreas; abdominal and ovarian fats were isolated, rinsed in physiological saline (0.9%), dewatered and weighed using SCOUT PRO brand scales. For lipid profiles estimation, the serum was used for determination of following biochemical parameters: seric level of triglycerides (TG), total cholesterol (TC) and HDL-Cholesterol (HDL-C). These parameters were estimated through colorimetric methods with commercially available test kits according to the manufacturer's recommendations. LDL-Cholesterol (LDL-C) level was estimated by the formula describe by Friedewald[22], (see below).

LDL-C = TC – [HDL-C+ (TG/5)]

The atherogenic index (AI) was calculated by using the method of Muruganandan and Suanarunsawat.[23,24] Apartate aminotransaminase (ASAT), Alanine aminotransaminase (ALAT) enzymes levels were estimated Via commercial kits according to manufacturer's protocol (DiaLab).

1.9. Statistical analysis

The test data were recorded as mean ± esm (standard error of the mean). The statistical differences between the tests were established using analysis of variance (ANOVA) and post hoc analyzes by the LSD test at the significance level $p < 0.05$.

2. RESULTS

2.1. AESI effect on food intake

It appears that throughout the treatment and regardless of the groups, in both sexes, the obese rats treated consume less food than HFD control (fig.1A et 1B). However, there was a significant decrease ($p < 0.01$) in food intake among obese males treated with EASI at a dose of 100 mg / kg compared to HFD control. This decrease is much more marked from week 2 until the end of treatment (fig. 1A). In females, there was also a significant decrease ($p < 0.01$) in food intake among those treated at doses 25 and 100 mg/kg at week 3 compared to HFD control (fig.1B).

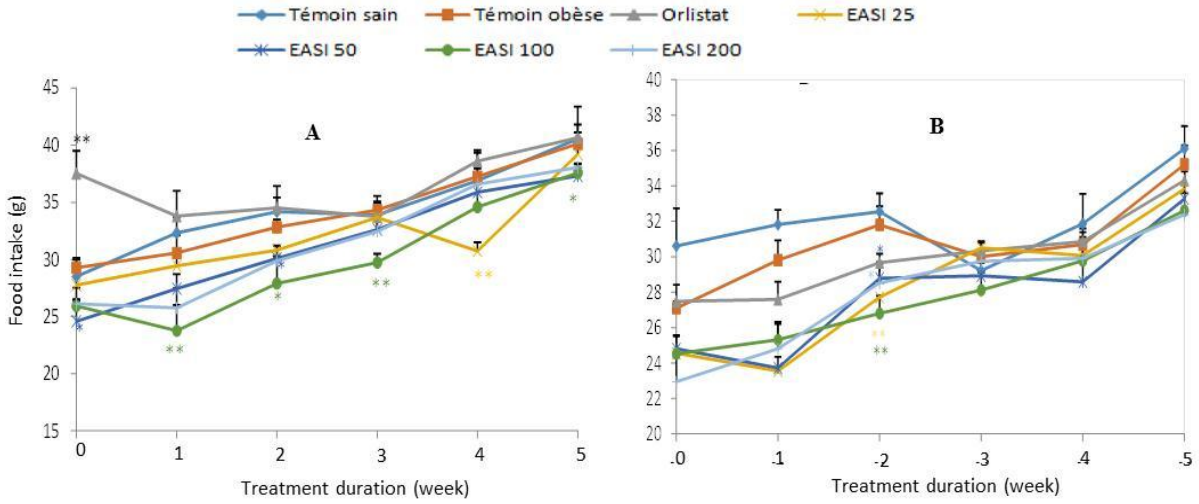

Figure 1: Effect of administration of aqueous extracts of *Solanum indicum* on food intake of male (A) and female (B) obese rats. Each point represents the mean ± S.E.M. For n=10 animals per group. Significant values different from that of HFD control at * p <0.05 and ** p <0.01. EASI: aqueous extract of *Solanum indicum*. ND: Normal Diet control. HFD: High Fat Diet control.

2.2. AESI effect on body weight

During the experimental period, there was a decrease in body weight in obese male rats treated at 50 and 100 mg / kg compared to HFD control although the difference was not significant (fig.2 A). The same observation is made in ND control as compared to HFD control. In females (fig.2B), however, there was a significant decrease (P <0.05) in the body weight of the females treated at the dose of 100 mg / kg at weeks 3 and 6.

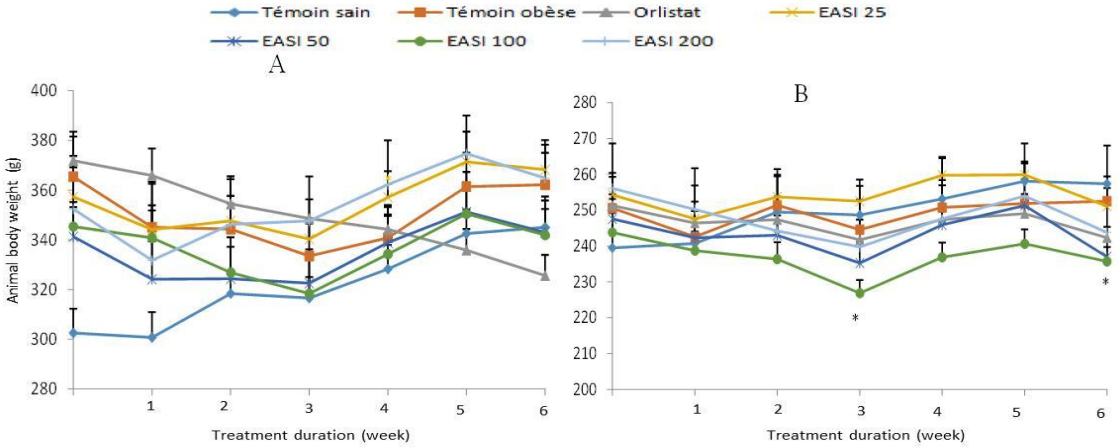

Figure 2: Effect of the administration of aqueous extracts of *Solanum indicum* on the body weight of obese male (A) and female (B) rats Each point represents the mean ± S.E.M. For n=10 animals per group. Significantly different values from that of HFD control at * p <0.05. EASI: aqueous extract of *Solanum indicum*. ND: Normal Diet control. HFD: High Fat Diet control.

2.3. AESI effect on Lee index

During the experimental period, both sexes (fig.3A and 3B) independently of the groups and substances administered showed a significant decrease (p <0.05, 0.01 and 0.001) of the Lee index compared with HFD control. This decrease is more observed in animals treated at doses of 50 and 100 mg / kg from week 1 to week 6.

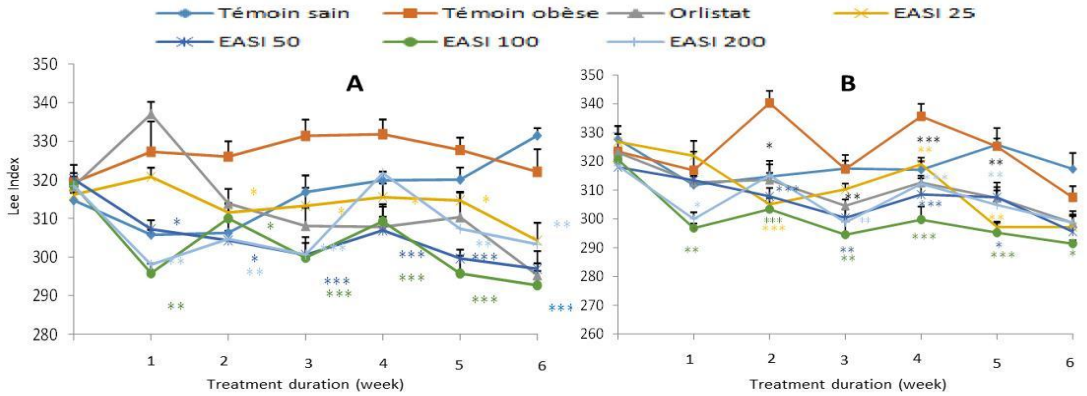

Figure 3: Effect of the administration of aqueous extracts of *Solanum indicum* on the Lee index of obese male (A) and female (B) rats Each point represents the mean ± S.E.M. For n=10 animals per group. Significantly different values from that of the obese control at * p <0.05, ** p <0.01 and *** p <0.001. EASI: aqueous extract of *Solanum indicum*. ND: Normal Diet. HFD: High Fat Diet.

2.4. AESI effect on organs and fats weight

In treated male obese rats, there was a significant (p <0.05) decrease in kidney weight at 50 mg / kg and an increase in heart weight (p <0.01) at 200 mg/kg compared to HFD controls. In addition, there was a significant (p <0.01) decrease in spleen weight at all doses except at the 200 mg/kg where there was a very significant increase (p <0.001) (table 1). In females, there was a significant (p <0.01) increase in spleen weight at 100 mg/kg compared to the HFD control. Then no significant difference is observed for the other organs (table 1).

For abdominal fat, in males there was a significant decrease (P <0.05, P <0.01 and P <0.001) at all doses compared to HFD control. In females, however, there was a significant decrease (P <0.01) at the dose of 200 mg / kg and a non significant decrease at the dose of 100 mg/kg. There is no significant difference for ovarian fats. compared to HFD control (table 1).

Table 1: Effect of administration of AESI on the organs and fats weight of male and female rat.

mg/kg	Liver (g)	Heart (g)	Kidneys (g)	Spleen (g)	Abdominal Fats (g)	Ovary Fats (g)
Male						
ND control	9.49 ± 0.55	0.85 ± 0.04	2.15 ± 0.12	0.60 ± 0.03***	7.008 ± 0.93**	/
HFD control	10.86 ± 0.41	1.00 ± 0.04	2.19 ± 0.08	1.164 ± 0.10	15.14 ± 0.48	/
Orlistat 5	9.82 ± 0.51	0.98 ± 0.02	2.16 ± 0.04	0.83 ± 0.02**	12.16 ± 1.20*	/
EASI 25	9.96 ± 0.40	1.02 ± 0.05	2.24 ± 0.05	0.82 ± 0.06**	7.84 ± 0.61***	/
EASI 50	9.22 ± 0.48	0.98 ± 0.01	1.96 ± 0.08*	0.73 ± 0.03**	11.63 ± 0.69**	/
EASI 100	9.62 ± 0.50	1.04 ± 0.06	1.99 ± 0.05	0.84 ± 0.05**	11.2 ± 0.56**	/
EASI 200	10.19 ± 0.50	1.17 ± 0.05**	2.19 ± 0.07	1.62 ± 0.08***	8.70 ± 0.55***	/
Female						
ND Control	7.41 ± 0.30	0.76 ± 0.01	1.73 ± 0.11	0.52 ± 0.02***	2.89 ± 0.22	3.77 ± 0.70
HFD Control	7.18 ± 0.49	0.75 ± 0.01	1.65 ± 0.04	0.59 ± 0.04	4.58 ± 0.44	3.92 ± 0.80
Orlistat 5	8.56 ± 0.75*	0.76 ± 0.01	1.74 ± 0.06	0.53 ± 0.03	3.86 ± 0.33	3.64 ± 0.59
EASI 25	6.77 ± 0.16	0.75 ± 0.01	1.62 ± 0.03	0.67 ± 0.04	5.21 ± 0.39	4.17 ± 0.68
EASI 50	6.87 ± 0.20	0.77 ± 0.038	1.55 ± 0.03	0.49 ± 0.07	5.3 ± 0.96	2.88 ± 0.25
EASI 100	6.83 ± 0.18	0.74 ± 0.05	1.65 ± 0.04	0.82 ± 0.05**	3.48 ± 0.16	3.90 ± 0.43
EASI 200	7.13 ± 0.40	0.81 ± 0.04	1.67 ± 0.05	0.66 ± 0.03	2.26 ± 0.28 *	3.18 ± 0.33

Each value represents the mean ± S.E.M. for n=10 animals per group. Values significantly different from that of HFD control at * p <0.05, ** P <0.01 and *** P <0.001. ND: Normal Diet, HFD: Hight Fat Diet. AESI: aqueous extract of *Solanum indicum*.

2.5. AESI effect on biochemical parameters and atherogenic index

The effects of AESI on the biochemical parameters (TAG, LDL-C, CT and C-HDL) of treated obese rats demonstrate that in obese males treated at doses of 50 and 200 mg / kg, there was a significant decrease (P <0.05 and P <0.01) in seric levels of TAG, C-LDL and CT compared to HFD control (fig. 4A, 5A and 6A). Similar results were recorded in treated obese females rats where the significant decrease (p <0.05, P <0.01) is observed for all these parameters (TAG: at Doses of 100 and 200mg/kg; LDL-C at 200mg/kg, CT at 25, 50 and 200mg/kg) compared to HFD control (fig. 4B, 5B and 6B). In addition, treatment with orlistat (5 mg/kg) leads to a reduction in the seric level of these parameters in both males and females, but more significant decrease (P <0.01) in females for TAG, and in males (P <0.001) for C- LDL compared to HFD control (fig. 4B, 5A). For HDL-C, there was a significant (P <0.001) increase in this parameter after administration of AESI at doses of 25 and 50 mg / kg in male rats. This increase is significant (P <0.01) in females at a dose of 100 mg/kg. The administration of orlistat 5mg/kg resulted in a significant increase (P <0.001) of HDL cholesterol in male and female compared to HFD control (fig. 7 C and D).

For the atherogenicity index, the significant decrease (p <0.05, P <0.01 and P <0.001) of this parameter is observed in male and female obese rats treated at doses of 25, 50 and 100 mg / kg compared to HFD controls. Similar results were recorded in both sexes where a significant (P<0.001) reduction of this parameter was observed after administration of orlistat 5 mg/kg (fig.8 C and D). Similar results were also observed with control receiving Normal Diet (ND) when compare to HFD control (Fig. 8 C,D).

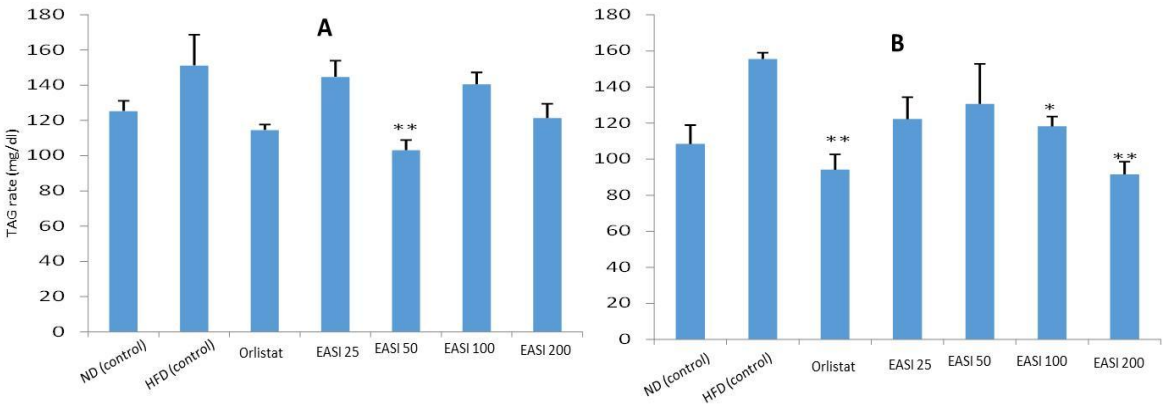

Figure 4: Seric concentration of triglyceride in male (A) and female (B) obese rats treated with AESI for 42 days. Each point represents the mean ± S.E.M. For n=10 animals per group. Values significantly different from that of HFD control at * p <0.05 and ** p <0.01. AESI: aqueous extract of Solanum indicum. ND: Normal Diet control. HFD: High Fat Diet control.

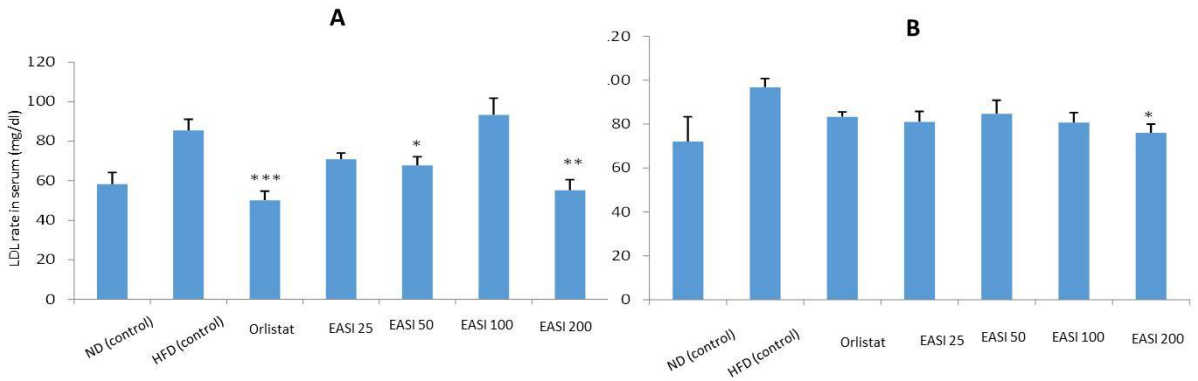

Figure 5: Seric concentration of LDL cholesterol in male (A) and female (B) obese rats treated with AESI for 42 days. Each point represents the mean ±S.E.M. For n= 10 animals per group. Values significantly different from that of the HFD control at * p <0.05, ** p <0.01 *** p <0.001. AESI: aqueous extract of *Solanum indicum*. ND: Normal Diet control. HFD: High Fat Diet control.

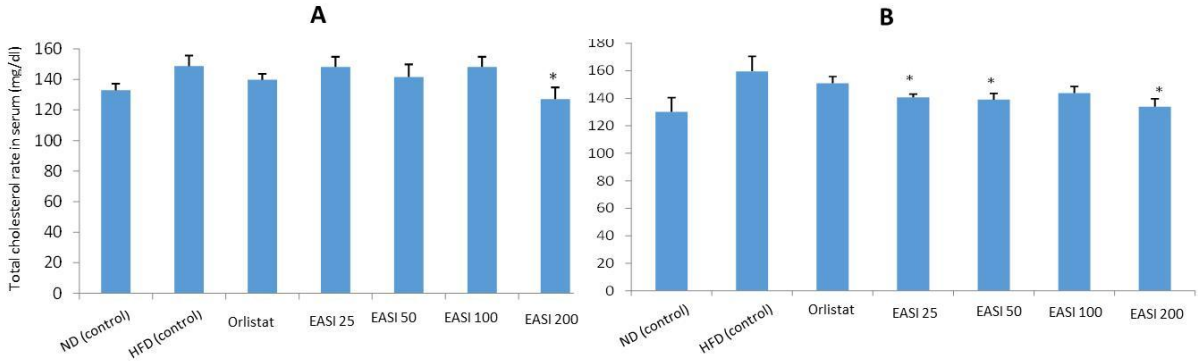

Figure 6: Seric total cholesterol concentration [males (A) and females (B)] in obese rats treated with AESI for 42 days. Each point represents the mean ± S.E.M. For n=10 animals per group. Values significantly different from that of HFD control at * p <0.05, ** p <0.01 *** p <0.001. AESI: aqueous extract of *Solanum indicum*. ND: Normal Diet control. HFD: High Fat Diet control.

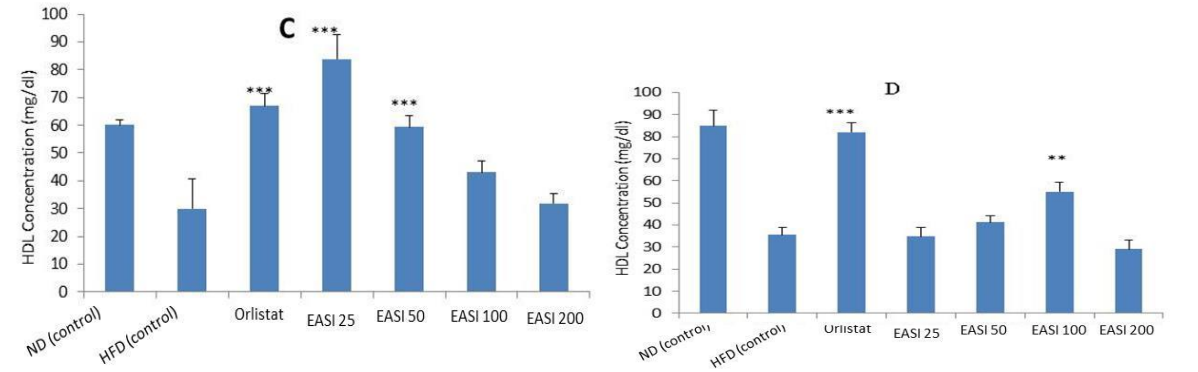

Figure 7: Seric concentration of HDL cholesterol [(males (C) and females (D)] in obese rats treated with EASI for 42 days, each point represents the mean ± S.E.M. For n=10 animals per group, values significantly different from that HFD control at * p <0.05, ** p <0.01 *** p <0.001 EASI: aqueous extract of *Solanum indicum*. ND: Normal Diet control. HFD: High Fat Diet control.

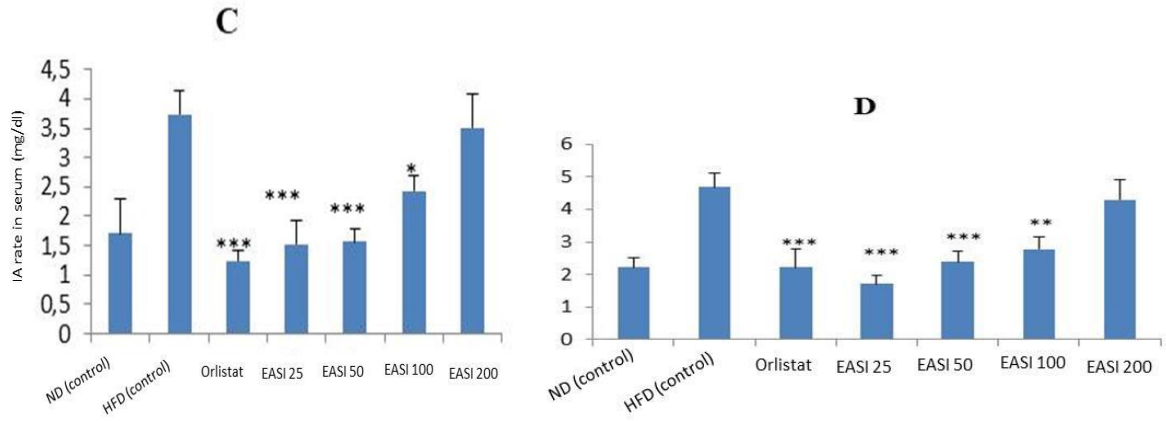

Figure 8: Seric concentration of the arthérogenicity index in Males (C) and females (D) treated with AESI for 42 days. Each point represents the mean ± S.E.M. n= 10 animals per group. Values significantly different from that of HFD control at * p <0.05, ** p <0.01 *** p <0.001. AESI: aqueous extract of *Solanum indicum*. ND: Normal Diet control. HFD: High Fat Diet control.

2.6. Effect of AETT on some enzymatic parameters of liver function in male and female rats.

With regard to the activity of the transaminases ALAT (Alanine Amino Transferase) and ASAT (Aspartate Amino Transferase): obese males have a significant (p <0.05) increase in serum ALAT at 25 mg / kg (Figure 9A) and a significant (p <0.05) increase in serum ASAT at doses of 25 and 100 mg / kg compared to the obese control group (Fig. 10A). In obese female rats treated at different doses of the extract, a non-significant decrease in serum transaminase levels (ALAT and ASAT) compared to the obese control group was observed (Fig. 9B and 10B).

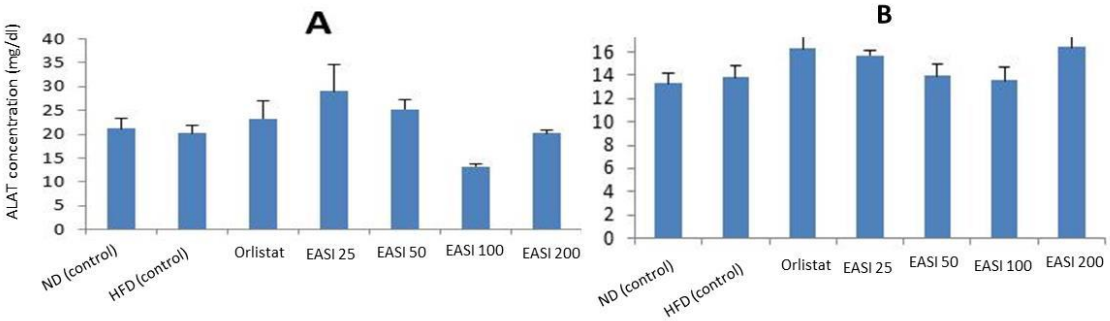

Figure 9: Serum concentration of ALT level in experimental animals [males (A) and females (B)] treated with EASI for 42 days. Each point represents the mean ± E.S.M. For n=10 animals per group. Significantly different values from that of HFD control at * p <0.05. EASI: aqueous extract of *Solanum indicum*. ND: Normal Diet control. HFD: High Fat Diet control.

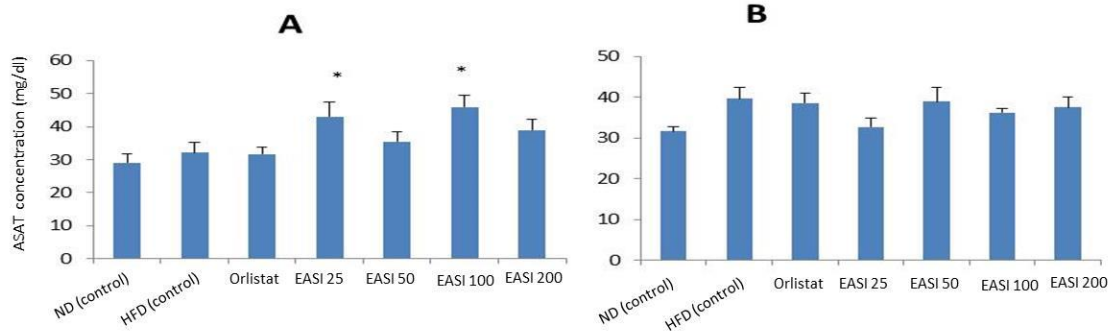

Figure 10: Seric concentration of ASAT in experimental animals [males (A) and females (B)] treated with EASI for 42 days. Each point represents the mean ± S.E.M. For n=10 animals per group. Significantly different values from that of the obese control at * p <0.05. EASI: aqueous extract of Solanum indicum. ND: Normal Diet control. HFD: High Fat Diet control.

3- DISCUSSION

Obesity is defined as the condition of excessive fat accumulation to such an extent that affects the individual's health. It is recognized as an energetic imbalance caused mainly by increased consumption of high calorie-foods. It is considered a social problem and entails serious health risk.[25]

Rats are the most used animal models for obesity research because they gain weight quickly when fed high fat foods.[26] In general, they are used in the laboratory to test products intended for the care of men because their digestive tract and their digestion are very similar to that of man, and the fundamental intestinal structures of human beings and those of rats are similar despite the disparity in the length and volume of the intestinal tract.[26]

In the present study, HFD model was used to induce obesity in wistar rats in order to evaluate the antiobesity activities of aqueous extract of *Solanum indicum* (AESI). Anthropometric factors constitute the important markers of obesity diagnosis.

Among these factors, body weight, food intake and Lee index were evaluated in this work. The results revealed that, oral administration of AESI significantly reduced food intake, body weight and Lee index in the experimental rats males and females as compared to HFD control. The observed reduction in these anthropometric measures in obese rats as a result of treatment with *Solanum indicum* may be due to the inhibition of dietary lipid utilization as reported by Nahar and collaborators[27] on the anti-obesity activity of *Moringa oleifera* leaves in obeses rats induced by high fat diet. Even by *Nazish et al*[28]on the evaluation of the anti-obesity effects of aqueous extract of *Zingiber officinal leaves* in obeses rats induced by high fat diet.

The reduction in food intake during the treatment could be due to the suppression of appetite, which can explain the body weight loss. Similar results were recorded by Kuaté *et al.*,[29] who showed that administration of the hydroethanolic extract (400 mg / kg) of *Tetrapleura tetrapera* fruit reduced body mass and food intake in type 2 diabetic obese rats.

In addition, Rizwan *et al*[16] revealed that ethanolic and water extracts of fruits of *Solanum indicum Linn*. contain metabolites such as flavonoids, steroids, glycosides, alkaloids, sugars, and tannins. The reduction in food intake observed in the treated rats could be due to the presence of the alkaloids contained in *Solanum indicum Linn.* fruits. These metabolites are responsible for increasing energy expenditure and reducing appetite. They inhibit the differentiation of adipocytes and pancreatic lipase. They are for the most part adrenergic agonists.[30]

The decrease in body weight observed in the treated obese rats would result in the presence in this extract of the weight-loss secondary metabolites which would have acted by activation of thermogenesis.[31] Indeed, flavonoids and saponins are known for their anti-inflammatory, antioxidant, antidiabetic and slimming properties.[32] Terpenoids, flavonoids, sterols and saponins have been shown to be responsible for reducing body weight. Their main role would be to activate lipolysis, which corresponds to an activation of lipases that catalyze the hydrolysis of triglycerides and release non-esterified fatty acids and glycerol into the bloodstream.[33] The decrease in the Lee index observed in the animals treated at different doses of extract compared to the control group is due to the presence of slimming principles in these extracts. The mechanisms of weight loss and Lee's index of *Solanum indicum* are almost similar to that of Orlistat which inhibits intestinal lipases and decreases by about 30% the absoption of ingested fats.[34]

Fat cell formation or adipogenesis is a differentiation process by which undifferentiated preadipocytes are converted in to fully differentiated adipocytes which store energy as fat and make the subjects obese.[23] The adipose tissue is a set of tightly packed cells (adipocytes) that store fat. It is at the heart of setting up metabolic abnormalities related to obesity. It is found under the skin, in different parts of the body: around the kidneys, in the abdomen, in the breasts.[35]

Nazish *et al.*,[28] have reported that feeding with a high fat diet in wistar rats leads to increase in weight of body organs such as liver, heart, spleen and both kidneys as also show our results. It is also reported that high fat diet induces substantial increase in deposition of fat in the mesenteric, perirenal and uterine region in wistar rats.

Our results show that our extract reduce the weight of kidneys and spleen in the male. They are in agreement with Nazish *et al*[28] who have proved that feeding obese rats with *Zingiber officinale* for 6 weeks has led to a significant decrease in the weight of heart organs, kidneys, liver, spleen and adipose tissue.

Decreases in the weight of abdominal fat in male and female rats could be explained by the fact that the metabolites of our extract would have burned fat in the adipose tissue and organs; these results corroborate with those of Mopuri *et al*[36], which achieved a significant decrease in adipose tissue in rats after administration of the aqueous extract of *Terminalia paniculata*.

Dyslipidemia is observed when there is a change in the normal level of one or more blood lipids. This is total cholesterol and its fractions: HDL-cholesterol, LDL-cholesterol; triglycerides.[37] It is directly related to obesity and positively correlated with an unfavorable lipid profile[38]; Similarly, at the end of the induction, LDL-C, Triglycerides, total cholesterol and

transaminases were significantly elevated in the obese control compared to the healthy control; which would indicate that the hyperlipidic food contributed to the elevation of the lipid profile. Moreover, Yash and Prashar[39] have shown that once obesity is established, significant increases in serum glucose, protein, total cholesterol, LDL cholesterol, VLDL cholesterol, triglycerides and transaminases are observed. Especially, hypercholesterolemia results from increased absorption of cholesterol from the intestine or enhanced endogenous synthesis.[40] Therefore, there could be two possible underlying mechanism of observed hypolopidemic actvity of plant extract, that is the blockade of biosynthesis of cholesterol or decrease in dietary cholesterol absorption from the intestine by binding with the acids within the intestine and increasing bile acids excretion.[40]

Phenolic compounds are widely distributed in plants. They have been reported to have beneficial effects against obesity. For example, dietary polyphenols could regulate adipocyte metabolism to inhibit the growth of adipose tissue.[41] Otherwise, Rizwan *et al*.,[16] demonstrated that aqueous and ethanolic extracts of *Solanum indicum* contain antioxidant activities and phenolic compounds.

In the present study, a significant reduction in the seric levels of triglycerides, total cholesterol, LDL and a significant increased in the level of HDL were observed after the administration of AESI in rats feed with HFD. Then, this improvement observed in lipid profile corroborates the significant reduction of the atherogenic index obtained in male and female rats at all doses.

The reduction in seric level of triglycerides registered could be explain by the presence in the plant extract of phenolic compounds that may act as inhibitor of fatty acid synthase and acetyl CoA carboxylase, enzymes involved in lipogenesis and therefore inhibit the accumulation of fats in adipose tissue.[42]

The reduction of total cholesterol level may be due to the presence of phyto-active constituents such as saponins, alkaloids and flavonoids able of inhibiting the activity of 3-Hydroxy-3-Methyl Glutaryl Coenzyme A réductase **(**HMG CoA reductase) which plays a very important role in the synthesis of cholesterol.[43]

similar results obtained by Ali Aberoumand[44] showed that consumption of *Solanum indicum* leaves by chickens contributed to the decrease in blood triglycerides due to the presence of phytochemicals such as alkaloids, polyphenols and saponins, thus inhibiting the synthesis of cholesterol.

Liver function tests are important indicators that reveal the functional status of liver since it is the vital organ involved in detoxification of compounds and metabolism in general. In this study, there was a non-significant decrease in transaminases in hepatic transaminases (ASAT and ALAT) of females AESI treated groups. This result may be related to polyphenols that are known to alleviat liver damage. Similar result was observed with Mopuri *et al.*,[36] who demonstrated that, the ethanolic extract of *Terminalia paniculata bark* reduced the seric level of ASAT.

In males we observed a significant increased of hepatic enzyme ASAT at the dose of 25mg/kg and 100mg/kg, and ALAT at the dose of 25mg/kg. It should be noted that those different fluctuations observed could be explained by haemolysis during blood sampling or during centrifugation.[45]

4- CONCLUSION

From the present study it can be concluded that the aqueous extract of Solanum indicum Linn fruits is beneficial for the management of obesity. Therefore, it has a protective effect against weight gain, triglycerides, and cholesterol on obese rats induce by high fat diet. Otherwise, further studies must be done to evaluate the diuretic potential of *Solanum indicum Linn.*

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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