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Effects of Some Varieties of *Ananas Comosus* on Obesity and Insulin Resistance Induced by Oxidised Palm Oil and Sucrose Diet in Albino Rats

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Abstract

Obesity is a worldwide health caused by high food intake. Management of obesity is based on chemotherapy, surgery and nutritherapy. Pineapple is a tropical fruit highly consumed for its nutritive properties. Evaluate the effect of juice fruit of some varieties of pineapple on obesity and insulin resistance in albino rats under OPOS diet. Healthy males and females Wistar rats received during 13 weeks every day a supplement of oxidised palm oil (25%) sucrose (25 %). After induction, animals presenting characteristics of obesity and insulin resistance were randomly separated into 6 groups. Among these three groups; satellite control group (SC), OPOSA 1 and OPOSAN 1 received supplement of smooth cayenne and spanich variety of pineapple (1 ml/100g) respectively during 13 weeks. Three other groups were continuously feed with OPOS diet and consider as OPOS control group (OPOSC), OPOSA 2 and OPOSAN 2 receiving same treatment. OGTT was performed, insulin sensitivity was assessed by performing insulin tolerance test and determining insulin index (K_{itt}). Several parameters were evaluated including anthropometrical parameters and lipid profile. Animals receiving OPOS diet showed insulin resistance and significant ($P< 0.001$) increase of Lee index, BMI compared to normal control group. Treatment with pineapple fruit significantly ($P< 0.001$) reduced these parameters. In addition, fruit ameliorated glucose tolerance and insulin sensitivity. It was also observed significant improvement of lipid profile and atherogenic risk compared with untreated groups in both sexe. These study highlighted obesogenic and hyperglycaemic character of OPOS diet and confirm beneficial metabolic effects of pineapple.

Keywords: Pineapple (*Ananas comosus*); Oxidised Palm oil; Sucrose; Obesity; Insulin resistance

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Introduction

Increasing prevalence of obesity is a worldwide health concern because excess weight gain causes an increased risk for several diseases, most notably cardiovascular diseases and diabetes[1]. Obesity and its comorbidities, characterized by hyperglycaemia, insulin resistance, dyslipidaemia, low-grade systemic inflammation, elevated plasma triacylglycerol and total cholesterol, may lead to the onset of metabolic syndrome, a serious threat to the population health[2,3]. Obesity is a reflection of the development of adipose tissue linked to massive storage of lipids in the form of triglycerides and due to an imbalance in the energy balance. Obesity is the root cause of psychosocial, metabolic, cardiovascular and respiratory complications. The global food system drivers interact with local environmental and genetics factors to create a wide variation in obesity prevalence populations. On the other hand, obesity has achieved outbreak rate where over than one billion worldwide are overweight and no less than 0. 3 billion of them are diagnosed as corpulent. The predominance of obesity in youths is about 5–14% in males and from 3 to 18% in women[4]. Many reasons could induce corpulence including here dietary components, medical reasons and psychiatric illness however the central cause is the combination between extreme intake of high energy food and absence of physical activities[5]. The cost of obesity is based on several treatments including: chemotherapy, herbal medicine, surgery and nutritherapy. The latter turns out to be accessible to the vast majority of the population and consists of a healthy and balanced diet with therapeutic properties. Fruit, due to its richness in phenolic compounds and fibers, could be used in the prevention and treatment of obesity and its comorbidities. Pineapple (*Ananas comosus*) fruit is rich in nutrients include calcium, potassium as well as vitamin C and vitamin A, bromelain and phenolic compounds which may have an antioxidant activity and anti-inflammatory function act as anti-inflammatory . Pineapple has progressed toward becoming a favourable fruit in obesity and dyslipidaemia treatment as it contains ahigh amount of bromelain, which has a role in lipolysis and diminishing the severity of cardiovascular syndromes. Fresh fruits have been known for their defensive impact against cardiovascular diseases. They have the benefit of containing high amounts of specific dietary fiber, which decreases cholesterol uptake by the organism[9]. Fat binding capacity (FBC), important for the detection of anti obesity property in food, was very high in pineapple. A couple of clinical investigations demonstrate the helpful impacts of bromelain in stoutness treatment[10]. This study was therefore, conducted to investigate ameliorative effects of two varieties of pineapple fruit on obesity and insulin resistance in rats.

Material and Methods

Juice preparation

Pineapple fruits collection and preparation pineapple juice: Two varieties (Spanich and Smooth cayenne) of fresh pineapple fruits (*Ananas comosus* (L) Merrill. (*Bromeliaceae*)) were collected from Djombe-Penja Subdivision (Littoral region - Cameroon) and Awae Subdivision (Centre region – Cameroon), identified at the Cameroon National Herbarium, where a specimen has been deposited under the number 18648/SRF cam. The fruits were washed and peeled; then, the edible portion was cut into tiny pieces and placed in a semi-industrial juice extractor (Moulinex). Juicing process somehow preserved fibers. After processing, the juice obtained was lyophilized.

Animals

Eighty-four adult male and female Wistar rats (forty-two males and forty-two females, 8 weeks old) were obtained from experimental animal centre, Faculty of Science of University of Douala. The rats were retained under controlled states of temperature (23 ± 2°C), humidity (50 ± 5%) and 12 h light-dim cycle. Rats were acclimatized for a week before beginning the experiment. They were kept in sanitized polypropylene cages containing sterile husk as bedding with free access to standard pellets as basal diet and water ad libitum. All procedures approved by with the European Union on Animal Care (CEE Council 86/609) guidelines adopted by the Institutional Ethics Committee of the Cameroon Ministry of Scientific Research and Technology Innovation.

Experimental design

After one-week of acclimatization, rats (both sexes) were divided randomly into two main groups. Group 1 (control, n = 6) that was kept on normal diet. OPOS (Oxydised Palm Oil Sucrase) group (n = 36) that was fed on OPOS (1 kg ration contained 250 g oxidized oil, 250 g of sucrose and 500 g of standard diet (corn 40%, soybeans 20%, fish 20%, peanut 8%, wheat 7%, cotton 2%, bone 2% and vitamins 1%) according to the modified method of Ngueguim et al.[11]. Animals of this group gained free access to water for 13 weeks until the point that obesity was affirmed by low faeces weight, high BMI, high Lee index, high abdominal circumference and high blood level. OPOS group were divided into 6 groups (each group contained 6 rats). Untreated obesity group that received OPOS (OPOSC) with distilled water (1mL/100 g), the 2nd group as an obesity group received normal diet after induction (SC) and distilled water (1mL/100 g), the 3rd group as obesity group received normal diet after induction and 1 mL/100 g of pineapple fruit juice of smooth cayenne variety, 4th group as obesity group with 1 mL/100g of pineapple fruit juice of smooth cayenne variety, the 5th group as obesity group received normal diet after induction and 1 mL/100 g of pineapple fruit juice of spanich variety, 6th group as obesity group with 1 mL/100 g of pineapple fruit juice of spanich variety. Anthropometrical parameters of each group were recorded weekly throughout the experimental period (13 weeks). Serum glucose levels of each rat was assessed at the beginning of the experiment (W_0) and then after thirteen weeks (W_{13}) and twenty-five weeks (W_{26}) and to evaluate insulin resistance at the period, insulin tolerance test was performed[12] and insulin sensitivity index calculated[12]. After 12h, of fasting, the glycemia was evaluate at 0h and animals received 2 UI/kg of insulin and blood was obtained from tail at 12, 20, 30 and 60 min after insulin injection, serum glucose was measured and K_{itt} value was obtained using the following formula

K_{ITT}= (C0-Cmin) /C0
C0= concentration at 0h, minimal concentration

Twenty-four hours after the last treatment, oral glucose tolerance test was evaluated according to the method of Tritos and Manzoros[12] and the animals were scarified through terminal exsanguination under ketamine (80 mg/kg) and xylazine (10mg/kg) anaesthesia. Fasting blood samples were collected through cardiac puncture into labelled tubes and the sera were stored at -80°C for blood lipid analyses. Then, the rats were sacrificed and dissected, certain organs and abdominal fats harvested and weighted.

Serum biochemical assays

Serum total cholesterol (TC), triacylglycerol (TAG), HDL-cholesterol were determined spectrometrically according to the commercial instruction for the kits, insulin resistance and atherogenic index determined by the ratio of LDL-cholesterol/HDL-c[13].

Statistical analysis

All data are expressed as mean ± standard error mean. Statistical significance was determined by applying one-way ANOVA with post-test turkey using statistics software package (graph pad prism V. 8. 01. Difference ware considered significant at P value < 0. 05 in each group.

Results

Effects of supplement of oxidised palm oil and sucrose on anthropometrical parameter

Figure (1) to figure (4) and table 1 show that, after 13 weeks of experiment period, food supplement with oxidised palm oil (25%) and 25% of sucrose (OPOS) induced in the both sex an increase of abdominal fat mass more than 78. 83% (8. 54 ± 0. 68 vs 2. 68 ± 0. 26, 10. 96 ± 0. 77 vs 2. 32 ± 0. 32;P<0. 001 respectively for males and females), BMI 26. 98% (0. 63 ± 0. 02 vs 0. 46 ± 0. 02, 0. 6 ± 0. 02 vs 0. 46 ± 0. 02; P<0. 001 respectively for males and females), abdominal circumference 47. 57% (35. 92 ± 0. 72 vs 24. 34 ± 0. 28, 35. 92 ± 0. 87 vs 24. 32 ± 0. 72;P<0. 001 respectively for males and females), Lee index 15. 63% (0. 32 ± 0. 01 vs 0. 27 ± 0. 00, 0. 32 ± 0. 01 vs 0. 27 ± 0. 01; P<0. 001 respectively for males and females), liver and kidney relative weight 61. 31% (6. 1 ± 0. 4 vs 2. 36 ± 0. 1, 5. 25 ± 0. 47 vs 2. 98 ± 0. 16; P<0. 001 respectively for males and females). OPOS also induced a decrease of naso-anal length 20. 18% (19. 06 ± 0. 36 vs 23. 88 ± 0. 36, 18. 1 ± 0. 06 vs 20. 4 ± 0. 24; P<0. 001 respectively for males and females), faeces weight (P<0. 001) in control group compared to the OPOS groups.

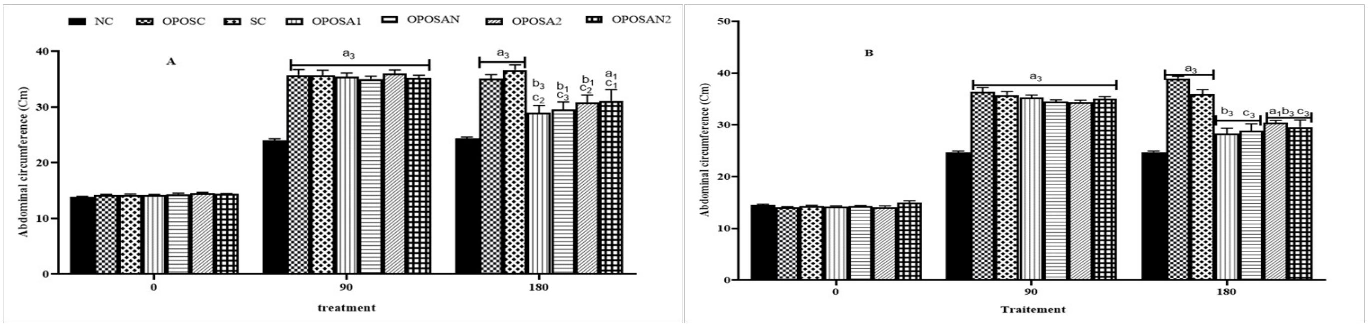

Figure 1: Abdominal circumference in animals during experiment period.

A: Males; B: Females NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanish variety. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively withNC, OPOSC and SC.

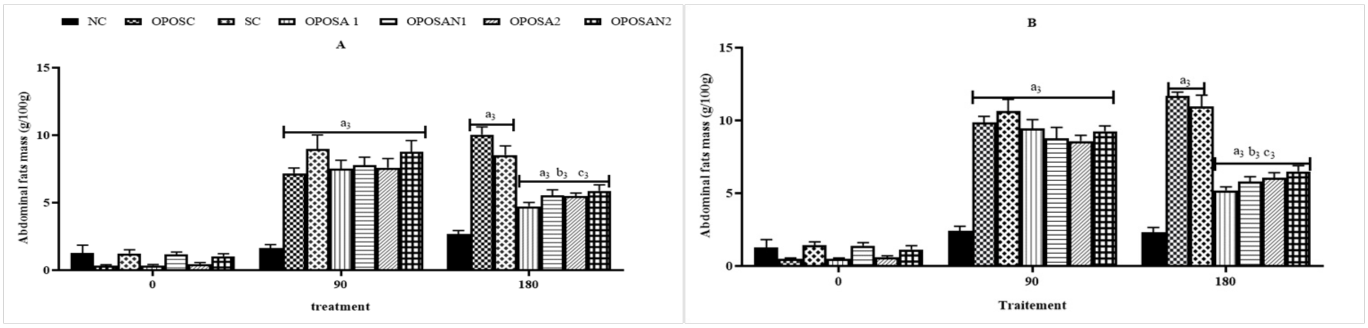

Figure 2: Abdominal fats mass in Animals during experiment period.

A: Males; B: Females; NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanish variety. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively with NC, OPOSC and SC.

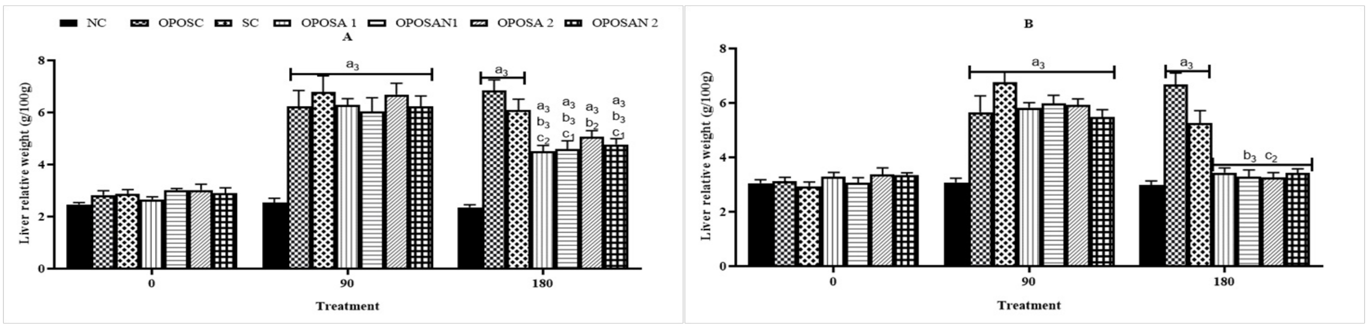

Figure 3: Liver relative weight in animals during experiment period.

A: Males; B: Females; NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanish variety. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively with NC, OPOSC and SC

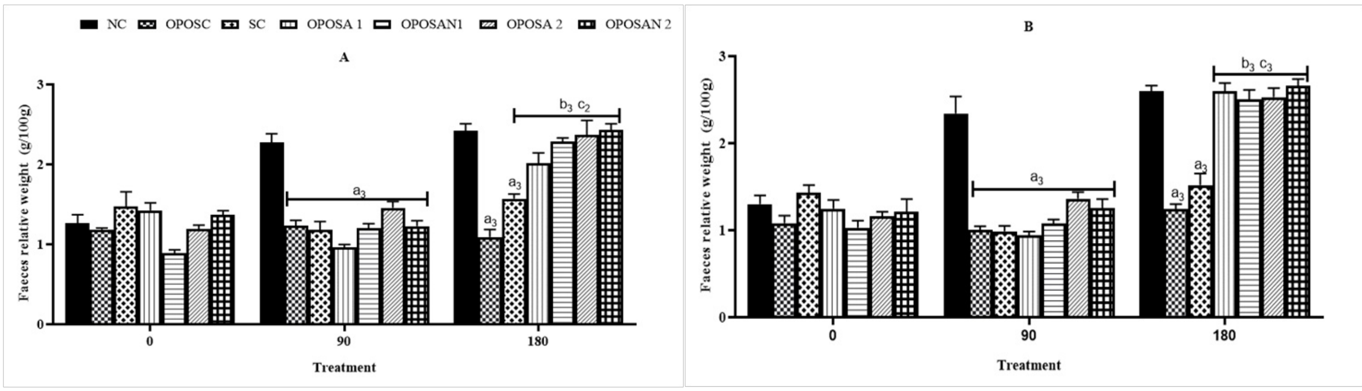

Figure 4: faeces weight in animals during experiment period.
A: Males; B: Females; NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanish variety. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively with NC, OPOSC and SC.

Effects of supplement of oxidised palm oil and sucrose on insulin sensibility

Figure (5) represents Area under curve of insulin sensitivity and insulin index (Figure 6). After subcutaneous injection of insulin (2 UI/kg) to animal receiving OPOS diet, the glycemia remained significantly higher throughout the experimental period in comparison with rats reviving standard diet (in both sex). The insulin sensitivity index was 0.44 and 0.51 (respectively for males and females) for normal rats versus 0.16 and 0.09 (respectively for males and females) for animals reviving OPOS diet. A significant decrease of 63.64 and 82.35 (respectively for males and females) of insulin sensitivity index for animals receiving OPOS diet as compared to the normal control (standard diet).

Table 1: Effects of concomitant administration of Ananas comosus (Smooth cayenne and Spanich varieties) juice extract and oxidised palm oil + sucrose on Naso-anal length, Body mass index and Lee index

		Males			Females		
Weeks	Groups	0	13	26	0	13	26
NAL (cm)	NC	17.38±0.24	22.74±0.50	23.88±0.32	17.22±0.50	20.4±0.22	20.8±0.20
	OPOSC	17.06±0.11	19.06±0.32^{a3}	19.1±0.33^{a3}	17.81±0.46	18.1±0.06^{a2}	18.4±0.1^{a2}
	SC	16.9±0.27	18.92±0.23^{a3}	19.5±0.14^{a3}	18.1±0.22	18.88±0.27^{a2}	19.0±0.27^{a2}
	OPOSA 1	16.9±0.38	19.8±0.17^{a3}	21.76±0.52^{b3c2}	17.92±0.22	19.18±0.10^{a2}	19.42±0.19^{b2c1}
	OPOSAN 1	17.24±0.25	18.94±0.13^{a3}	19.5±0.25^{a1b1}	18.63±0.31	18.94±0.29^{a2}	19.06±0.34^{a2b1}
	OPOSA 2	17.44±0.25	18.68±0.66^{a3}	20.97±0.56^{a3}	18.23±0.11	18.71±0.20^{a2}	19.0±0.26^{a2}
	OPOSAN 2	17.12±0.19	20.1±0.41^{a3}	20.7±0.71^{a3}	17.88±0.20	18.90±0.13^{a2}	19.14±0.22^{a2}
BMI (g/cm^2)	NC	0.45±0.01	0.47±0.01	0.46±0.001	0.44±0.001	0.47±0.02	0.46±0.01
	OPOSC	0.48±0.01	0.66±0.03^{a3}	0.68±0.03^{a3}	0.44±0.03	0.61±0.02^{a3}	0.64±0.02^{a3}
	SC	0.49±0.01	0.67±0.02^{a3}	0.63±0.02^{a3}	0.4±0.02	0.58±0.01^{a3}	0.6±0.02^{a3}
	OPOSA 1	0.48±0.02	0.66±0.02^{a3}	0.51±0.02^{b2c2}	0.42±0.01	0.58±0.01^{a3}	0.51±0.01^{b2c2}
	OPOSAN 1	0.49±0.02	0.65±0.02^{a3}	0.48±0.02^{b2c2}	0.41±0.01	0.57±0.02^{a3}	0.51±0.01^{b2c2}
	OPOSA 2	0.50±0.01	0.6±0.02^{a3}	0.52±0.00^{b2c2}	0.44±0.03	0.56±0.01^{a3}	0.52±0.01^{b2c2}
	OPOSAN 2	0.48±0.02	0.61±0.02^{a3}	0.54±0.01^{b2c2}	0.41±0.02	0.57±0.01^{a3}	0.52±0.01^{b2c2}
Lee index (g/cm^3)	NC	0.30±0.01	0.27±0.00	0.27±0.00	0.29±0.00	0.28±0.01	0.27±0.01
	OPOSC	0.3±0.00	0.33±001^{a3}	0.33±0.01^{a3}	0.29±0.01	0.33±0.00^{a3}	0.34±0.01^{a3}
	SC	0.3±0.01	0.33±0.02^{a3}	0.31±0.02^{a3}	0.28±0.02	0.32±0.00^{a3}	0.31±0.00^{a3}
	OPOSA 1	0.3±0.01	0.32±0.00^{a3}	0.29±0.00	0.29±0.00^{b3c3}	0.31±0.00^{a3}	0.29±0.00^{a1b2c1}
	OPOSAN 1	0.3±0.01	0.32±0.01^{a3}	0.28±0.00	0.28±0.00^{b3c3}	0.31±0.01^{a3}	0.3±0.00^{a1b2c1}
	OPOSA 2	0.3±0.01	0.32±0.02^{a3}	0.3±0.00	0.29±0.03^{a3c2}	0.31±0.00^{a3}	0.3±0.00^{a1b2c1}
	OPOSAN 2	0.3±0.01	0.32±0.00^{a3}	0.3±0.00	0.28±0.00^{a3c1}	0.31±0.00^{a3}	0.3±0.00^{a1b2c1}

NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanish variety;NAL: Naso-anal length; BMI: Body Mass Index. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively with NC, OPOSC and SC.

Effects of A. *comosus* on anthropometrical parameter

Figure (1) to figure (4) and table 1 show that, after effects of food supplement with oxidised palm oil (25%) and 25% of sucrose (OPOS), *A. comosus* induced in the both sex a significant decrease of abdominal fat mass more than 52. 94% (4.73 ± 0.25 vs 10.05 ± 0.68, 5.19 ± 0.24 vs 11.69 ± 0.68; P<0.001 respectively for males and females), BMI 27.27% (0.48 ± 0.02 vs 0.66 ± 0.03, 0.51 ± 0.01 vs 0.61 ± 0.03; P<0.01 respectively for males and females), abdominal circumference 27.24% (28.18 ± 1.3 vs 37.88 ± 1.03, 28.32 ± 0.4 vs 28.32 ± 1.02; P<0. 01 respectively for males and females), Lee index 12.12% (0.29 ± 0.01 vs 0.33 ± 0.01, 0.3 ± 0.00 vs 0.32 ± 0.01; P<0.001 respectively for males and females), liver and kidney relative weight 34.06% (4.51 ± 0.22 vs 6.84 ± 0.42, 3.26 ± 0.1 vs 6.67 ± 0.43; P<0.01 respectively for males and females). OPOS also induced a decrease of naso-anal length 5.79% (19.06 ± 0.36 vs 23.88 ± 0.36, 18.1 ± 0.06 vs 20.4 ± 0.24; P<0. 01 respectively for males and females), faeces weight (P<0. 001) in control group compared to the OPOS groups.

Effects of A. *comosus* on oral glucose tolerance test, insulin sensitivity and insulin sensitivity index

Effects of all varieties of *Ananas comosus* on oral glucose tolerance test, insulin sensitivity and insulin sensitivity index are resumed in figure (5, 6, 7). It was observed that, concomitant oral administration of the juice fruit (all varieties of *A. comosus*) with OPOS diet inhibited significantly (P<0.001) the increase of area under curve of oral glucose tolerance test with a minimal on OPOSA 1 group (288.6 versus 474.15; 432.1 versus 490.75 respectively for males and females) compared to OPOSC groups. However, a significant difference (P<0.001) was observed between NC group and OPOSA 2, OPOSA 1 and 2. The administration of juice fruit of all varieties with OPOS diet provoked a significant (P<0.001) decrease of area under curve of insulin sensitivity with a minimal on OPOSA 1 (353.6 versus 486.75;432.1 versus 490.75 respectively for males and females) compared to OPOSC groups. On the other hand, a supplement of oxidised palm oil and sucrose induced a significant decrease (p< 0.001) of insulin sensitivity index of 63.64% and 85.32% respectively for males and females compared to NC group (fig. 9). Moreover, all varieties of *A. comosus* juice extract administered in association with SOPO + S diet induced a significant increase (p< 0.001) in the insulin sensitivity index with a maximal on OPOSAN 1 group in males (0.47 versus 0.16), on OPOSA 1 in females (0.43 versus 0.09) compared to OPOSC groups. The inhibition was 193.75% and by 377.78% respectively for males and females.

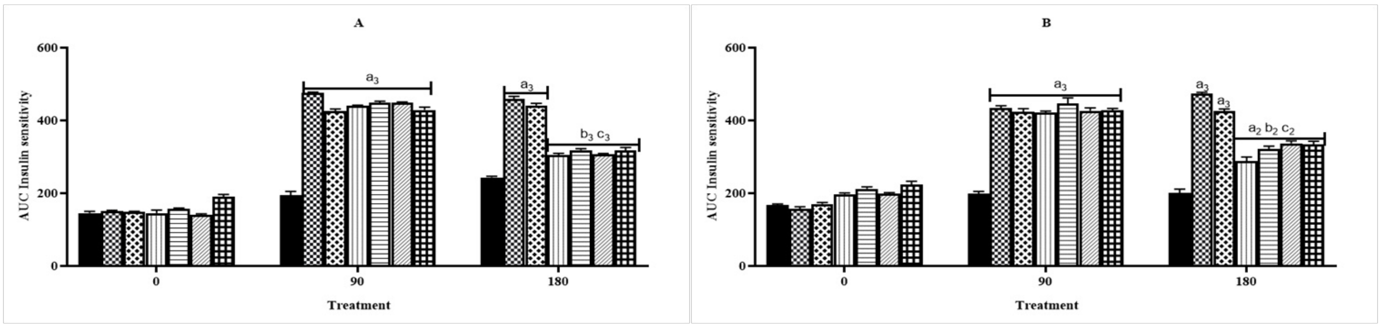

Figure 5: Area under curve of insulin sensitivity in animals during period.

A: Males; B: Females; NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanish variety. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively with NC, OPOSC and SC.

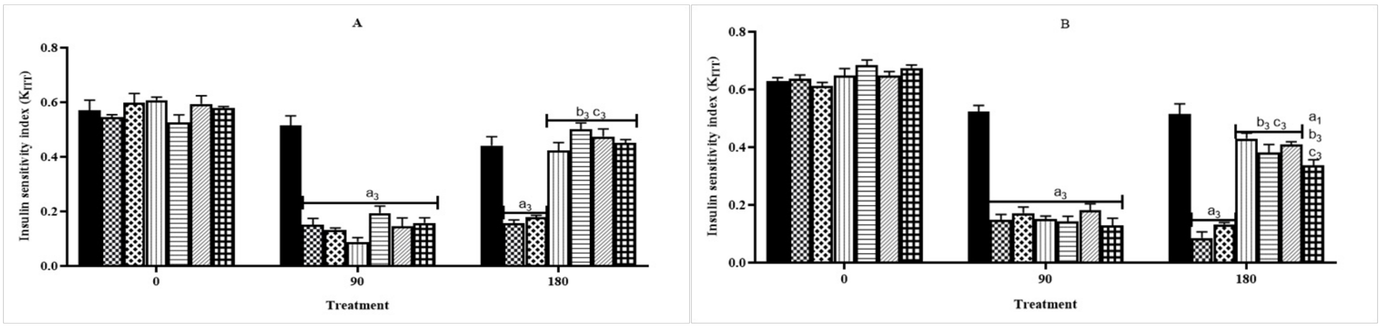

Figure 6: Insulin sensitivity index in animals during experiment period.

A: Males; B: Females; NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanich variety. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively with NC, OPOSC and SC.

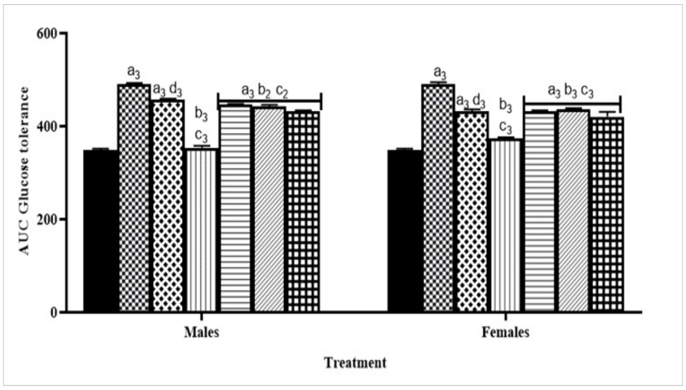

Figure 7: Area under curve of glucose tolerance in animals during experiment period.
NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanish variety. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively with NC, OPOSC and SC

Effects of some varieties of *A. comosus* on serum lipid profile

Supplementation of OPOS diet in the both sexes contributed to a significant increase of triglycerides (47.74% and 45.47% respectively for males and females), total cholesterol (51.5 and 32.84% respectively for males and females), LDL-c (78.17 and 40.96% respectively for males and females) and atherogenic index ration (66.77 and 64.5% respectively for males and females). The fruit extract administered during the last 12 weeks of experimental period induced a decrease of triglycerides, total cholesterol, LDL-c and atherogenic index as compared to the OPOS control. The decrease in triglycerides maximal was 54.37 and 53.32% in OPOSAN 1group (180.2 versus 394.9 and 162.2 versus 347.5 respectively for males and females). On the other hand, serum total cholesterol decreased with a maximal of 51.98% and 40.80% in OPOSAN 1 respectively for males and females, LDL-c by 63.68% and 52.98% in the same groups respectively for males and females. HDL-c which was significantly low of 52.94% and 60.23% (respectively for males and females) compared to animals receiving OPOS diet. A significant increase in atherogenic index was observed when compared to normal control. The treatment with all varieties juice fruit receiving OPOS diet significally reduced these parameters near normal values range (Table 2).

Table 2: Effects of concomitant administration of Ananas comosus (Smooth cayenne and Spanish varieties) juice extract and oxidised palm oil + sucrose on lipid profile, atherogenic index and insulin resistance in rats.

	Males						
Groups	NC	OPOSC	SC	OPOSA 1	OPOSA2	OPOSAN1	OPOSAN2
TG	150. 8±10. 98	394.9±14.64^{a3}	287±16.75^{a3}	195.7±6.73 ^{b3c3}	187.3±3.89 ^{b3c3}	180.2±6.69 ^{b3c3}	186.2±2.45 ^{b3c3}
HDL-c	92. 7±1. 81	35.35±1.42^{a3}	41.6±1.08^{a3}	88.4±4 ^{b3c3}	84.45±5.24 ^{b3c3}	84.3±1.92 ^{b3c3}	74.1±0.63 $^{a3\ b3c3}$
TC	393±2. 29	865.9±73.61^{a3}	810.3±83.29^{a3}	446.1±16.62 ^{b3c3}	466.4±21.01 ^{b3c3}	415.8±20.36 ^{b3c3}	494.8±31.45 ^{b3c3}
LDL	270. 9±2. 7	768.9±99.54^{a3}	704.5±101.5^{a3}	308.8±2326 ^{b3c3}	329.7±18.59 ^{b3c3}	279.7±22.20 ^{b3c3}	379.6±38.07 ^{b3c3}
AI	4. 25±0. 06	25.02±2.81^{a3}	19.47±2.74^{a3}	4.99±0.38 ^{b3c3}	5.37±0.18 ^{b3c3}	4.77±0.33 ^{b3c3}	6.63±0.53 ^{b3c3}
IR	1. 63±0. 12	11.28±0.79^{a3}	6.9±0.35^{a3}	2.224±0.15 ^{b3c3}	2.25±0.14 ^{b3c3}	2.14±0.08 ^{b3c3}	2.51±0.04 ^{b3c3}
	Females						
TG	151. 1±9. 40	347.5±35.12^{a3}	277.1±12.06^{a3}	175.8±2.25 ^{b3c3}	176.9±7.24 ^{b3c3}	162.2±9.41 ^{b3c3}	176.4±2.42 ^{b3c3}
HDL-c	85. 65±3. 53	37.65±0.89^{a3}	43.55±1.85^{a3}	94.05±1.83 ^{b3c3}	109.5±4.39 $^{a3\ b3c3}$	90.5±2.74 ^{b3c3}	109.8±1.1 $^{a3\ b3c3}$
TC	387. 6±5. 31	707.4±47.63^{a3}	577.6±26.03^{a3}	418.8±15.97 ^{b3c3}	472.2±6.71 ^{b3c3}	429.5±11.86 ^{b3c3}	435.2±26.19 ^{b3c3}
LDL	269. 8±8. 38	598.2±68.37^{a3}	457±15.9^{a3}	281.9±18.89 ^{b3c3}	332.4±8.23 ^{b3c3}	297.3±11.86 ^{b3c3}	253.1±12.07 ^{b3c3}
AI	4. 54±0. 22	18.76±1.84^{a3}	12.79±0.21^{a3}	4.37±0.19 ^{b3c3}	4.38±0.15 ^{b3c3}	4.65±0.15 ^{b3c3}	3.63±0.11 ^{b3c3}
IR	1. 77±0. 11	9.34±1.15^{a3}	6.42±0.41^{a3}	1.87±0.02 ^{b3c3}	1.63±0.08 ^{b3c3}	1.81±0.15 ^{b3c3}	1.61±0.02 ^{b3c3}

NC: Normal control; SC: Satellite control; OPOSC: oxidised palm oil and sucrose control; OPOSA 1 and 2: obese rats treated with pineapple fresh juice of Smooth cayenne variety; OPOSAN 1 and 2: obese rats treated with pineapple fresh juice of Spanish variety; TC: total cholesterol, TG: triglyceride; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; AI: atherogenic index; IR: insulin resistance. Each value represent mean ± Standard error, n = 6. p<0. 05= significant difference; α, b, c: significant difference when compared respectively with NC, OPOSC and SC.

Discussion

Excessive intake of OPOS diet induced metabolic disorders including obesity, dyslipidaemia, and consequently insulin resistance[14,15]. Palm oil, at room temperature is the most important vegetable oils with high oxidant stability fatty composition and good plasticity[16]. Continual heating of palm oil loses these characters and became harmful to organism. In fact, palm oil used repetitively induced the oxidation fatty acids and increasing the rate of fats which is involved in accumulation of cytotoxic fatty acid and resulting in alteration of insulin response[17]. Moreover, diet rich in sucrose resulted in insulin resistance[18]. Oxidised palm oils combined to sucrose could react synergically to cause abnormalities including glucose tolerance, insulin resistance and hyperlipidaemia. The present investigation showed that, standard diet associated with oxidised palm oil and sucrose during 13 weeks induced an increase of abdominal circumference, BMI and Lee index. This would be due to the presence of fructose, oleic and palmitic acid within the diet. It was also observed an increase of abdominal fat strengthen the lipogenic character of the diet and explains the hypertrophy and hyperplasia of adipocytes. Animals receiving OPOS diet presented hyperglycaemia, glucose intolerance and insulin insensibility. Sucrose can be metabolized into glucose and fructose which may be transformed into lipid through lipogenesis *de novo* pathway and in turn induce lipo-toxicityand glucotoxicity; preventing insulin action or secretion at cellular levels resulting in a hyperglycaemia[19,20]. In addition, oxidised palm oil increases the level of mono and polyunsaturated fatty acids and thus increase the rate of fats. Thus, oxidised palm oil and sucrose contribute to cytotoxic fatty acid accumulation and the alteration of insulin response[17]. The insulin resistance observed in this study is related to the increase of abdominal fats[19,21] and corroborate the insulin sensitivity index (K_{itt}) which was dramatically dropped in animals receiving OPOS diet. Administration of juice fruits extracts of all varieties of *A. comosus* with OPOS diet inhibited an increase of blood glucose levels in OGTT (oral glucose tolerance test) and IST (insulin sensitivity test). This could be due to the act of our fruits extracts at peripheral levels by reducing glucose absorption from the gastrointestinal tract and/or stimulating peripheral glucose utilization. Moreover, during twelve weeks of treatment with spinach and smooth cayenne varieties of pineapple fruits we are also observed anti-hyperglycaemic effects. Pineapple fruits extracts (spanich and smooth cayenne varieties) after twelve weeks of treatment involved a decrease of serum triglycerides, total cholesterol, LDLc and an increase of HDLc. These results are involved in prevention of development atherosclerosis and coronary heart disease. These results were in accordance with those of [22,23]. *Ananas comosus* fruit extract significantly reduced serum triglycerides, total cholesterol and LDL cholesterol and show that, these fruits could modulate blood lipid abnormalities, suggesting that, fruit would be helpful to prevention of obesity and comorbidities by reduction of dyslipidaemia. *A. comosus* significantly reduced serum triglycerides, total cholesterol and LDL cholesterol. Juice fruit extract could modulate blood lipid abnormalities, suggesting that, all varieties of *A. comosus* in this study would be helpful to the prevention of obesity and complications through reduction of dyslipidaemia, amelioration of insulin sensitivity. The effects of these varieties of *Ananas comosus* could be due to the existence of bromolein that having lipolytic and proteolytic activity and to the contents of high amount of fiber and polyphenol compound in raw juice which induced hypocholesterolaemia[24].

Conclusion

A supplement of oxidised palm oil (25%) and sucrose (25%) during thirteen weeks induced metabolic alteration. Treatment with smooth cayenne and spanich varieties of pineapple considerably restored glucose tolerance, insulin sensitivity, lipidaemia and ameliorated anthropometrical parameters. This study justifies the recommendation by nutritionist pineapple to fight metabolic diseases. Further studies are in progress to elucidate the effects of these fruit on obesity complication and comorbidities.

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