Int J Clin Exp Physiol. 2024;11(3):100-106.
https://www.ijcep.org

Original Article

Impact of *Musa acuminata* Sap on Leptin and Adiponectin Concentration in High Fat Diet Induced Obesity on the Offspring of Wistar Rat

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ABSTRACT

Background and Aim: The prevalence of obesity and its associated metabolic disorders is a significant global health challenge, necessitating the exploration of novel therapeutic strategies to improve the health and wellbeing of individuals battling this ill health. This study investigated the impact of *Musa acuminata* sap (MAS) on serum leptin and adiponectin concentration and overall body weight of Wistar rats subjected to High Fat Diet (HFD) induced obesity and also on the offspring of the experimental group. **Methods:** A total of 50 Wistar rats were procured of which group A-served as the normal control and received rats chow and water *ad libitum*, Group B=Obesed+pregnant untreated and were all fed with normal rat chow and water *ad libitium*. Groups C, D, E, F, G and H of five rats each were obese and were selected and divided into the five groups viz; Group C- obese without treatment, Group D-obese+100 mg/kg MAS, Group E-obese+200 mg/kg of MAS, Group F-obese+pregnant+100 mg/kg of MAS, Group G-obese+pregnant+200 mg/kg of MAS and Group H-obese+pregnant+1.2 mg/kg of Xenical IP. Induction of pregnancy was carried out and varying doses of MAS and standard drug Xenical IP was administered for another period of 4 weeks and their effects were analyzed. Data for body weights, concentration of serum leptin and adiponectin were collected and analyzed. Post-partum, body weight and length of offspring were also measured and recorded. Data from experimental and control groups were evaluated and compared to determine differences in the various groups. **Results:** *Musa acuminata* sap had statistical $p<0.05$ significant decrease in body weight and serum leptin concentration while increasing serum adiponectin concentration compared to the normal control. **Conclusion:** These findings suggest that *Musa acuminata* sap possesses potential anti-obesity properties possibly through modulation the of leptin and adiponectin concentration, highlighting it as a possible therapeutic agent for the management of obesity and metabolic disorders. Therefore, Public awareness should also be made and encouraged to help people prevent and manage obesity.

Keywords: Adiponectin, High-fat diet, Leptin, Musa acuminate, Obesity, Wistar rats.

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Received: 29-06-2024;
Revised: 02-08-2024;
Accepted: 17-09-2024.

INTRODUCTION

The World Health Organization (WHO) defined overweight and obesity as abnormal or excessive fat accumulation that presents a risk to health. The Body Mass Index (BMI), calculated by dividing the body weight in kilograms by the square of height in meters, is a simple metric used to indicate overall body fatness. For adults, current guidelines from the US Centers for Disease Control and Prevention (CDC) and the WHO define a normal BMI range as18.5 to 24.9, whereas a BMI≥25 kg/m^2 is considered to be overweight and a BMI≥30 kg/m^2 is classified as obese, with severe obesity defined as a BMI≥40 kg/m^2. Despite this relatively simplistic definition, obesity is a multifactorial disease that results from chronic positive energy balance, i.e. when dietary energy intake exceeds energy expenditure. Excess

DOI: 10.5530/ijcep.2024.11.3.19

energy is converted to triglyceride which is stored in adipose tissue depots that expand in size, thereby increasing body fat and causing weight gain. The globalization of food systems that produce more processed and affordable food and promote passive over consumption from energy-dense, nutrient-poor foods and beverages has been identified as a major driver of the obesity epidemic, although a decrease in physical activity owing to the modernization of lifestyles is also likely involved.[1] Obesity can occur at any age. Previous studies assessing trends in obesity found that its prevalence has increased in both adults and children of all ages, indiscriminate of geographical locality, ethnicity or socioeconomic status. In low-income countries, obesity is generally more prevalent among middle-aged adults from wealthy and urban environments (especially women); whereas, in high-income countries, it affects both sexes and all ages, but its prevalence is disproportionately greater among disadvantaged groups.[1]

Adipose tissue has become an extremely active endocrine organ, having the ability to secrete a good quantity of biologically active adipokines, such as leptin, adiponectin, Tumor Necrosis Factor-α (TNF-α), or Interleukin-6 (IL-6), these hormones are involved in physiological processes. These adipokines play an important role in the pathophysiological link between increased adiposity and cardio-metabolic alterations.[2] Leptin is primarily produced by adipose tissue in proportion to the amount of body fat stores being involved in the regulation of food intake, neuroendocrine function, reproduction, angiogenesis and blood pressure, among others.[3] Circulating leptin levels is directly proportional to the level of body fat. Adiponectin is an insulin sensitive hormone almost exclusively secreted by the adipose tissue with anti-inflammatory and anti-atherogenic properties. Adiponectin has cardio-protective functions, protecting against insulin resistance and excessive hepatic lipid accumulation and exerting also anti-inflammatory effects.[4] Adiponectin expression in adipose tissue and serum adiponectin levels are decreased in obese patients. Therefore, obesity-associated alterations in these adipokines, leptin and adiponectin, are playing major contributions in the development of a dysfunctional adipose tissue, characterized by unresolved inflammation, besides to inappropriate extracellular matrix remodeling and impaired angiogenesis.[5]

Musa acuminata, commonly known as 'Banana,' is a trendy and widely consumed fruit, especially in tropical and subtropical regions. It contains lots of minerals and nutrients that are beneficial to health. Banana cultivars have been recorded for their alpha-amylase and alpha-glucosidase inhibitory activities, promoting the recommendation in the management of diabetes.[6] Moreover, bananas and their flower have been documented to have antioxidant and free radical scavenging activities.[7] Recently, lupeol, an anti-inflammatory agent, has been reported in the ethanol extract of banana flowers.[8] Besides, various plant-based extracts and compounds have been attempted to inhibit obesity and obesity-induced metabolic syndromes.[9]

Musa acuminata has been found to contain high levels of dietary fibre and phenolic compounds. Moreover, *Musa acuminata* has been demonstrated to exhibit potent antioxidant capacity, antimicrobial and antibiotic properties.[10] Phenolics are important secondary metabolites and are found in high levels in banana peel compared to other fruits. Phenolic compounds have been linked with various health benefits, such as prevention of cardiovascular diseases, cancer, diabetes and obesity.[10]

There is a growing focus on the specific effects of maternal High Fat Diet (HFD) induced obesity on offspring of both animal and human studies. A large body of studies suggest that there are critical windows of development (preconception, early gestation, late gestation) in which maternal obesity can induce programming effects on offspring physiology and organ development.[11] Novel therapeutic treatment for the management of obesity is highly required and this study will focus on how *Musa acuminata* sap can influence body weight, leptin and adiponectin concentrations, aiming to provide more insight on its therapeutic effect on obesity.

Despite available data on this research topic, impact of *Musa acuminata* sap on leptin and adiponectin concentration in high fat diet induced obesity on the offspring of Wistar rat remains inadequately understood. Investigating the potential influence of *Musa acuminata* sap on these adipokines in the context of maternal obesity could provide valuable insights into the developmental origins of obesity and related health diseases.

MATERIALS AND METHODS

Ethical Clearance

All experimental procedure was conducted in accordance with National Institute of Health Guide for care and use of Laboratory Animal Science as stated in the guide to care and use of Laboratory Animal Resources. Ethical clearance for this study was obtained from Faculty of Basic Medical Sciences Research and Ethical Committee, College of Medicine, University of Nigeria, Enugu Campus.

Collection of Plant Materials

Mature and productive stems of *Musa acuminata* whose fruits were identified and freshly cut from a field belonging to Mr. Ikenna Okeke located at Emene, Enugu-East Local government Area, Enugu state, Nigeria.

Extraction of *Musa Acuminata* Crude Sap

The freshly cut stems were immediately washed with clean tap water after the rotten parts of the stems were removed. The pseudo stems were unfolded and washed twice with clean tap water. The stems were then chopped into smaller pieces using a cutlass and the sap was extracted with mortar and pestle and a very clean

cheese cloth for straining the sap. About 1.2 L of *Musa acuminata* sap were acquired and retained in a clean rubber container, it was immediately stored in the refrigerator at temperature of about -18°C.[12]

Procurement and Preparation of High Fat Diet

Commercial chow was acquired and fed to the normal control group.

Preparation of High Fat Diet (HFD)

For every 1 kg of HFD contained: 300 g of lard, 200 g of dried cassava starch, 200 g of dried fish, 100 g of margarine and 300 g of commercial chow. The contents were now mixed in a blender to ensure homogeneity of the mixture.[13]

Experimental Animals

A total of 40 female Wistar rats weighing 110-130 g at 7-8 weeks old were acquired and accommodated in the Animal House Unit of Enugu State University College of Medicine (ESUCOM), Enugu state. The rats were placed in well-ventilated aluminum cages and were acclimatized for seven days under standard laboratory conditions with room temperature of 27°C±2°C and relative humidity of 40-55%, having free access to water and commercial chow before grouping.

Induction of Obesity in Wistar Rats

The rats were fed with high fat diet and clean water *ad libitum* for a period of 4 weeks.[13] There were regular monitoring of the following parameters; body weight, food intake and water intake.

Induction of pregnancy in Wistar rats

The female Wistar rat's estrous cycles were closely monitored under light microscopy. The male rats were introduced into the cages of the female rats that were in their estrus phase within 12 hr light/ dark cycle at a female to male ratio of 3:1. The male rats were placed with the females for 2 days. The day dead spermatozoa were confirmed in the vagina smear of the female rats was taken as day one of pregnancy.[14]

Experimental Design

The animals were divided into eight groups after 7 days of acclimation, viz:

Group A: served as the Control group, fed commercial rat chow and water,

Group B: served as the positive control group (pregnant), fed commercial rat chow and water,

Group C: Obese without treatment,

Group D: Obese+non-pregnant+100 mg/kg of *Musa acuminata* sap,

Group E: Obese+non-pregnant+200 mg/kg of *Musa acuminata* sap,

Group F: Obese+pregnant+100 mg/kg of *Musa acuminata* sap,

Group G: Obese+pregnant+200 mg/kg of *Musa acuminata* sap,

Group H: Obese+pregnant+1.2 mg/kg of Xenical IP.

Measurement of Body Weight

A digital electronic weighing scale was used to determine the weight of dams weekly and also for the weight of offspring. A weighing container was placed on the balance and tare (zero) to exclude the weight of the container, then the rats were gently placed in the weighing container and we waited for the scale to stabilize before taking the reading. All the rats were measured at the same time of the day to minimize variations due to circadian rhythms.

Measurement of Fluid and Water Intake

The quantity of food and water being administered daily was weighed and recorded using metabolic cages. The quantity of food or water administered was weighed and recorded and then subtracted from the previous quantity of food or water.

Biochemical Analysis

Collection of blood samples and tissue extraction

At 2 weeks interval, the animals were fasted overnight and subsequently anesthetized using proparacaine topical anesthesia. Blood samples were collected by orbital puncture using heparinized capillary tube inserted into the medial canthus of the eye (30 degrees to the nose). Plasma was separated by centrifugation at 3000 rpm and stored at -80°C until assayed.[15]

Analyses of leptin and adiponectin concentration

Quantification of adiponectin and Leptin concentration in serum was performed using Enzyme-Linked Immunosorbent Assay (ELISA) kit (Aviva systems Biology, San Diego, CA, USA), leptin Elisa kit for rat catalog No. OKRC01444 and adiponectin Elisa kit for rat catalog No. OKRC01381 and according to the manufacturer's instructions. The analyses were done in the laboratory of the department of chemical pathology, Enugu State University Teaching Hospital, Parklane Enugu, with the assistance of a medical laboratory scientist. Process of quantifying leptin and adiponectin using ELISA Kit:

- Blood samples of the rats were collected and serum extracted,
- Standard of known leptin and adiponectin concentration and controls were prepared (blank and quality control samples),

- Elisa plates were coated with antibodies specific to leptin or adiponectin and prepared samples were added to the coated plates,
- The plates were incubated for 1hr before the plates were washed to removed unbound samples,
- Antibodies detection (HRP-conjugated) specific to leptin or adiponectin were then added to the plates,
- The plates were incubated the second time for 1 hr and then the substrate (chromogen) that reacts with detection antibody were added,
- The absorbance of each well was then measured using a spectrophotometer and the concentration of leptin and adiponectin was calculated using a standard curve.

Statistical Analysis of Data

All the analysis was carried out using the Statistical Package for Social Sciences (SPSS) version 25.0 analytical software for Windows. All data were tabulated and analyzed and the results were presented as mean±standard error of mean. The results were analyzed using one-way Analysis of Variance (ANOVA) followed by students Tukey *post-hoc* test. Values of $p<0.05$ were taken as statistically significant.

RESULTS

Table 1 illustrates the effect of MAS on mean leptin concentration, showing that leptin levels increased as body weight decreased. Analysis using one-way ANOVA and post-hoc Tukey test for week 8 revealed a statistically significant difference ($p<0.05$) between group A (control) and all other groups, as well as between group B and the other groups. Statistically significant differences ($p<0.05$) were observed in groups D, E, G and H compared with group C. Similarly, groups F, G and H showed statistically significant differences ($p<0.05$) compared with group E, but no significant difference was noted when comparing groups F, G and H among themselves. Group B exhibited the highest percentage increase (124.13%) in leptin concentration, followed by group F (85.78%), group G (83.79%) and group H (77.06%). Group C showed the highest percentage increase (88.98%) compared to groups D and E.

Table 2 presents the effect of MAS on mean adiponectin concentration, indicating that adiponectin levels decreased as body weight increased. Analysis using one-way ANOVA and post-hoc Tukey test for week 8 showed statistically significant differences ($p<0.05$) between most groups and group A, except for groups D and C. Group H demonstrated a statistically significant difference ($p<0.05$) when compared with all other groups. Groups C, F, G and H exhibited statistically significant differences ($p<0.05$) compared to group B, while groups D, G and H differed significantly ($p<0.05$) from group C. Group D showed a statistically significant difference only with group H. Among the groups, group C recorded the highest percentage decrease in adiponectin levels (175.86%), while group A had the lowest decrease (7.0%). Groups D and E, treated with MAS, showed a smaller percentage decrease compared to group C (which received no treatment), with group D (44.98%) exhibiting a greater increase in adiponectin levels than group E (19.44%), suggesting that higher MAS dosages significantly elevated adiponectin levels.

Table 3 shows a substantial increase in body weight across the various groups. Using one-way ANOVA and post-hoc Tukey test for week 8, statistically significant differences ($p<0.05$) were observed in all groups compared to group A. Additionally, significant differences ($p<0.05$) were noted in groups A, B, C and G compared to group H. Groups C, F, G and H also exhibited significant differences ($p<0.05$) compared with group B. Groups D, E and H differed significantly ($p<0.05$) from group C, while group D showed statistically significant differences with groups F and G. Groups F and G also displayed statistically significant differences ($p<0.05$) compared with group E. Group C, which received no treatment, had the highest percentage weight gain (261.6%), likely due to the absence of any intervention. Group A recorded the lowest percentage weight gain (106%), as it was fed with commercial rat chow instead of a high-fat diet. Groups

Table 1: Effect of *Musa acuminata* sap on Leptin Concentration (ng/mL).

Groups	Week 4	Week 6	Week 8	% Change
A	8.2±1.7	11.5±1.7	12.2±1.5	48.78↑
B	8.7±1.9	13.7±2.3	$19.5\pm1.8^{\alpha}$	124.13↑
C	23.6±2.5	39.0±3.5	$44.6\pm2.9^{\alpha\beta}$	88 .98↑
D	17.9±1.5	33.0±2.9	$26.1\pm1.6^{\alpha\beta\psi}$	45.81↑
E	21.6±1.2	28.9±1.9	$25.0\pm3.2^{\alpha\beta\psi}$	15.74↑
F	22.5±1.7	35.7±3.0	$41.8\pm3.0^{\alpha\beta\delta\epsilon}$	85.78↑
G	21.6±2.00	33.5±3.2	$39.7\pm2.7^{\alpha\beta\psi\delta\epsilon}$	83.79↑
H	21.8±1.8	30.0±1.5	$38.6\pm3.2^{\alpha\beta\psi\delta\epsilon}$	77.06↑

Values are expressed as mean±SD. $p<0.05$ are taken as statistically significant.$\alpha p<0.05$ compared with Group A; $\beta P<0.05$ compared with Group B; $\psi p<0.05$ compared with Group C; $\delta p<0.05$ compared with Group D; $\epsilon p<0.05$ compared with Group E; $\varphi p<0.05$ compared with Group F; $\gamma p<0.05$ compared with Group G.

Table 2: Effect of Musa acuminata Sap on Adiponectin Concentration (µg/mL).

Groups	Week 4	Week 6	Week 8	Week 10
A	12.2±1.5	11.6±2.1	11.4±2.0	7.01↓
B	11.7±0.5	10.5±0.5	8.7±1.3$^{\alpha}$	34.48↓
C	8.0±1.2	5.0±1.2	2.9±1.5$^{\alpha\beta}$	175.86↓
D	10.0±0.9	5.8±2.0	6.9±1.5$^{\psi}$	44.98↓
E	8.6±1.7	6.5±0.5	7.2±2.0$^{\psi}$	19.44↓
F	8.7 ±1.2	5.6±1.7	3.2±1.6$^{\alpha\beta}$	171.87↓
G	7.9±1.4	5.9±1.9	3.5±1.3$^{\alpha\beta}$	125.71↓
H	8.9±1.5	6.2±0.9	4.9±0.5$^{\alpha\beta\psi\delta\epsilon\varphi}$	81.63↓

Values are expressed as mean±SD. $p<0.05$ are taken as statistically significant.$\alpha p<0.05$ compared with Group A; $\beta p<0.05$ compared with Group B; $\psi p<0.05$ compared with Group C; $\delta p<0.05$ compared with Group D; $\epsilon P<0.05$ compared with Group E; $\varphi p<0.05$ compared with Group F; $\gamma p<0.05$ compared with Group G.

Table 3: Effect of *Musa acuminata* Sap on Body Weight (g).

Groups	Week 0	Week 4	Week 6	Week 8	% Change (G)
A	120±0.01	210±0.01	230±0.01	248±12$^{\beta}$	106↑
B	125±0.03	220±15	250±12	306±15$^{\alpha}$	144.8↑
C	125±0.02	310±0.02	380±25	452±30$^{\alpha\beta}$	261.6↑
D	130±0.00	280±0.01	365±0.02	343±18$^{\alpha\psi}$	163.8↑
E	128±0.01	300±15	350±15	335±12$^{\alpha\psi}$	161.7↑
F	118±0.12	290±0.01	370±15	424±25 $^{\alpha\beta\delta\epsilon}$	259.3↑
G	126±0.12	310±0.01	362±18	412±28$^{\alpha\beta\delta\epsilon}$	226.9↑
H	130±0.10	300±13	355±13	387±17$^{\alpha\beta\psi\gamma}$	197.7↑

Values are expressed as mean±SD. $p<0.05$ are taken as statistically significant.$\alpha p<0.05$ compared with Group A; $\beta p<0.05$ compared with Group B; $\psi p<0.05$ compared with Group C; $\delta p<0.05$ compared with Group D; $\epsilon p<0.05$ compared with Group E; $\varphi p<0.05$ compared with Group F; $\gamma p<0.05$ compared with Group G.

H (197.7%), G (226.9%) and F (259.3%), which was all pregnant and fed a high-fat diet, showed significant weight gain compared to the control group B (144.8%) and groups D and E, which were not pregnant. Among groups H, G and F, group F treated with Xenical IP exhibited the greatest weight loss, followed by group G (200 mg/kg MAS) and group F (100 mg/kg MAS). Group D (163.8%) gained more weight than group E (161.7%), likely due to the increased dosage (200 mg/kg) for group D compared to 100 mg/kg for group E. Both groups demonstrated significant weight loss compared with group C, which received no treatment.

Table 4 highlights variations in pup body weight and length among the pregnant groups. Using one-way ANOVA and *post-hoc* Tukey test for week 8, statistically significant differences ($p<0.05$) were found between groups F and G compared to group B. Similarly, significant differences ($p<0.05$) were observed between groups G and H compared to group F. No statistically significant differences ($p<0.05$) were noted for pup length values. Group F recorded the highest pup body weight and length, followed by groups G, H and then B. Group B, fed with commercial chow, had the lowest pup body weight and length.

DISCUSSION

Globally, obesity has a high prevalence rate affecting all ages and gender. According to WHO, 2018,[16] about 1.9 billion adults internationally were overweight or obese and almost 3 million deaths caused by obesity and obesity-related diseases. This calls for leading research in development of novel treatment and management of obesity. This study analysed the effect of *Musa acuminata* sap on body weight and adipokines concentration on diet induced obesity in Wistar rats. Also studying its effects on the body weight and length of offspring of Wistar rat in obese models.

Leptin and adiponectin which are secreted by adipocytes are important in the regulation of energy balance and could serve as a parameter for the measurement of adiposity. Leptin being an anorexic hormone, signals the hypothalamus during positive energy balance suppressing appetite. When fat stores are sufficient, leptin levels are high and vice versa. Leptin resistance is akin to occur during high secretions of leptin and according to Zhoa *et al.*, 2019,[13] leptin resistance leads to desensitization of the hypothalamus and a loss of its function to suppress appetite, food intake does not reduce although energy in the form of adipose tissue is abundant and this generally leads to high level of leptin in the blood. Adiponectin enhances insulin sensitivity,

Table 4: Effect of *Musa acuminata* Sap on Pup Weight and Length.

Groups	Pup Weight (g)	Pup Length (cm)
B	6.5±0.04	4.4±0.20
F	7.0±0.06$^{\beta}$	4.9±0.40
G	6.9±0.50$^{\beta\varphi}$	4.6±0.60
H	6.6±0.09 $^{\varphi}$	4.6±0.60

Values are expressed as mean±Standard Deviation (SD). $p<0.05$ is considered statistically significant. $\beta p<0.05$ compared with Group B; $\varphi p<0.05$ compared with Group F.

promotes fatty acid oxidation and has anti-inflammatory properties. Many studies show that higher levels of adiponectin are typically associated with better metabolic health, lower risk of type-2 Diabetes and Cardiovascular diseases and lower levels of adiponectin are observed in individuals with obesity, insulin resistance and metabolic syndrome. According to Nigro *et al.*, 2014,[17] after weight loss, adiponectin levels rise together with a specific increase of the most biologically active high molecular weight oligomers suggesting a functional recovery of adipose tissue after weight loss in severely obese patients. It is indeed that natural product-based molecules will provide new and more appropriate platform for anti-obesity treatment.[18] Dietary flavonoids can reduce fat and carbohydrate intake by regulating their hydrolysis and absorption in the gastrointestinal tract.[19]

The results from our research suggest that *Musa acuminata* sap has positive therapeutic effects on management of obesity. The various parameters analyzed were mean adiponectin concentration, mean leptin concentration, mean body weight, pub body weight and length. A total of 40 Wistar rats were divided into eight experimental groups to provide valuable results for this experiment. Following acclimatization, the experimental groups were fed with high fat diet for a period of 4 weeks to induce obesity before induction of pregnancy and administration of treatment was carried out for another 4 weeks.

Table 1 analyzed the impact of *Musa acuminata* sap on mean leptin concentration and showed that generally as body weight increased, leptin concentration also increased. Comparing the mean leptin concentration at week 8 between the obese and non-pregnant group which are group C, D and E, Group C has the highest concentration followed by group E then D. The three groups were fed high fat diet for the same length of time but had varying leptin concentrations, this is because the D and E were treated with *Musa acuminata sap* which lowered their leptin concentration and it is notable that Group E which was treated with a higher dose of MAS had a lower leptin concentration than D which also shows that increasing dosage of MAS has a significant effect on leptin concentration., this is also true comparing Group F, G. The effect of Xenical IP is notable as Group H had a lower leptin concentration when compared with F and G meaning that Xenical IP was more effective. It was also deduced from the table that there's no statistically significant difference ($p<0.05$) between group G and H meaning that 200 mg/kg of MAS was also as effective as Xenical IP. According to Bluher *et al.*, 2015,[3] leptin is primarily produced by adipose tissue in proportion to the amount of body fat stores.

Table 2 analyzed the impact of *Musa acuminata* sap of mean adiponectin concentration and shows that adiponectin concentration generally decreases as body weight increases and vis versa. Comparing mean adiponectin concentration at week 8 between the treated and untreated group it showed that there's a statistically significant difference between them. Comparing Group C with D and E, the treated group (D and E) had a higher adiponectin concentration than C and increasing dosage of MAS was effective as E has a higher adiponectin concentration than D. The effect of Xenical IP was also notable when Group F, G and H was compared, as Group H had a higher adiponectin concentration. According to Nigro *et al.*, 2014,[17] adiponectin expression and serum levels are decreased in obese patients, rodents and pigs. Adiponectin plays a pivotal role in energy metabolism, concentration of both of both total adiponectin and high molecular weight adiponectin decreases in obesity and increases after weight loss.[17]

Table 3 analyzed the impact of *Musa acuminata* sap on the mean body weight, Group A that was fed with normal commercial rat chow had mean body weight that was within the range for lean body weight. Group B which were pregnant and also fed normal chow showed increase in body weight more than Group A, this increase in weight can be attributed to gestational weight gain. For Group F, G and H which are pregnant and fed with high fat diet following different treatments, group H had the lowest body weight followed by group G then group F meaning that Xenical IP was a more effective treatment and also shows that increasing the dosage of *Musa acuminata* sap has a significant effect on body weight. Comparing Group C, D and E which are non-pregnant and obese, group C which was untreated had the highest body; group E had a lower body weight than group D. The table also shows that there's a statistically significant difference ($p<0.05$) between Group D and E which shows that increasing dosage of MAS has a significant impact on body weight. According to Singh *et al.*, 1997,[20] *Musa acuminata* sap has a high content of polyphenols, flavonoids, soluble and insoluble dietary fiber, antioxidant capacity, free radical scavenging capacity and phytochemicals which are bioactive compounds that has been demonstrated to ameliorate obesity and metabolic related diseases by regulating specific metabolic pathways.

Table 4 shows the impact of gestational body weight on the offspring (pub) body weight and length which were measured at birth, it can be deduced that maternal body weight directly affects the weight of the offspring. Comparing Group B, F, G and H; offspring of group B which was fed commercial rat chow and not obese had the lowest mean body weight and length whereas Group F which was obese and treated with 100 mg/kg of MAS

had the highest. According to Ratnasiri *et al.*, 2019,[21] maternal pre-pregnancy obesity is independently associated with fetal overgrowth, total body adiposity, abdominal fat accumulation and lower free mass of neonates, these features are aggravated with excessive gestational weight gain during mid and late pregnancy at the time of higher fat accretion in the fetus. *Musa acuminata* sap due its high content of phytochemicals and dietary fiber, has possible therapeutic value in the management of obesity and other related diseases, improving hormonal balance and insulin sensitivity. This study provides valuable contribution to the growing body of evidence supporting the use of natural plant-based remedies for obesity management and improving overall health. Further research: more studies are recommended to understand the mechanisms of action, optimal dosage and long-term effects of *Musa acuminata* sap in different models and potentially humans. Public awareness: many individuals are not academically inclined in the understanding of obesity and its various causes, so awareness should be carried out especially in rural areas to improve their knowledge on the prevention and management of this disease promoting regular exercise, eating balance diet and good lifestyle changes.

CONCLUSION

This study highlights the therapeutic potential of *Musa acuminata* sap in managing diet-induced obesity by regulating body weight, leptin and adiponectin concentrations in Wistar rats and their offspring. The findings suggest *Musa acuminata* sap could serve as a natural anti-obesity agent, warranting further exploration for its mechanisms, optimal dosing and clinical applications.

ACKNOWLEDGEMENT

Nil.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

WHO: World Health Organization; **BMI:** Body Mass Index; **CDC:** Centers for Disease Control and Prevention; **TNF-α:** Tumor Necrosis Factor-alpha; **IL-6:** Interleukin-6; **MAS:** *Musa acuminata* sap; **HFD:** High-fat diet.

REFERENCES

1. Yu CC, Cherlyn D, Faidon M. The epidemiology of obesity. Metabolism. 2019;92(1):6-10.
2. Frühbeck G, Catalán V, Rodríguez A, Ramírez B, Becerril S, Portincasa P, *et al.* Normalization of adiponectin concentrations by leptin replacement in ob/ob mice is accompanied by reductions in systemic oxidative stress and inflammation. Sci Rep. 2017;7(1):2752. doi: 10.1038/s41598-017-02848-0, PMID 28584304.
3. Blüher M, Mantzoros CS. From leptin to other adipokines in health and disease: facts and expectations at the beginning of the 21st century. Metabolism. 2015;64(1):131-45. doi: 10.1016/j.metabol.2014.10.016, PMID 25497344.
4. Stern JH, Rutkowski JM, Scherer PE. Adiponectin, leptin and fatty acids in the maintenance of metabolic homeostasis through adipose tissue crosstalk. Cell Metab. 2016;23(5):770-84. doi: 10.1016/j.cmet.2016.04.011, PMID 27166942.
5. Crewe C, An YA, Scherer PE. The ominous triad of adipose tissue dysfunction: inflammation, fibrosis and impaired angiogenesis. J Clin Invest. 2017;127(1):74-82. doi: 10.1172/JCI88883, PMID 28045400.
6. Adedayo BC, Oboh G, Oyeleye SI, Olasehinde TA. Antioxidant and antihyperglycemic properties of three banana cultivars (Musa spp.). Scientifica. 2016;2016(1):8391398. doi: 10.1155/2016/8391398, PMID 27872791.
7. Amarasinghe NK, Wickramasinghe I, Wijesekara I, Thilakarathna G, Deyalage ST. Functional, physicochemical and antioxidant properties of flour and cookies from two different banana varieties (*Musa acuminata* cv. Pisang awak and *Musa acuminata* cv. Red dacca). Int J Food Sci. 2021;2021(1):6681687. doi: 10.1155/2021/6681687, PMID 34124236.
8. Mostafa HS. Banana plant as a source of valuable antimicrobial compounds and its current applications in the food sector. J Food Sci. 2021;86(9):3778-97. doi: 10.1111/1750-3841.15854, PMID 34337757.
9. Lee J, Kim AR, Lee JJ. Ramie leaf extracts suppress adipogenic differentiation in 3T3-L1 cells and pig preadipocytes. Asian Aust J Anim Sci. 2016;29(9):1338-44.
10. Karuppiah P, Mustaffa M. Antibacterial and antioxidant activities of Musa sp. leaf extracts against multidrug-resistant clinical pathogens causing nosocomial infection. Asian Pac J Trop Biomed. 2013;3(9):737-42. doi: 10.1016/S2221-1691(13)60148-3, PMID 23998016.
11. Fall CH, Kumaran K. Metabolic programming in early life in humans. Philos Trans R Soc Lond B Biol Sci. 2019;374(1770):20180123. doi: 10.1098/rstb.2018.0123, PMID 30966889.
12. Mahammad SI, Susilawati K, Adibah MA, Hun TG, Alam KM, Haque MA. Banana-pseudostem sap growing media as a novel source of phytochemicals and mineral nutrients: influence on seedling growth of sweet corn. Chil J Agric Res. 2022;82(1):11-2.
13. Zhou W. Development of high-fat diet-induced diabetes in mice. Rev Cient Fac Cienc. 2020;30(1):24.
14. Choi SH, Cho YS, Kim MJ, Lee CH, Seong HH, Baek SH, *et al.* Studies on the induction of pregnancy and the number of fetuses during pregnancy in rats. J Anim Reprod Biotechnol. 2020;35(3):232-8. doi: 10.12750/JARB.35.3.232.
15. Parasuraman S, Raveendran R, Kesavan R. Blood sample collection in small laboratory animals. J Pharmacol Pharmacother. 2010;1(2):87-93. doi: 10.4103/0976-500X.72350, PMID 21350616.
16. World Health Organization. Obesity and overweight. World Health Organization; Published 2018. [cited Nov 13, 2018] Available from: http://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
17. Nigro E, Scudiero O, Monaco ML, Palmieri A, Mazzarella G, Costagliola C, *et al.* New insight into adiponectin's role in obesity and obesity-related diseases. BioMed Res Int. 2014;2014(1):658913. doi: 10.1155/2014/658913, PMID 25110685.
18. Kumar N, Ved A, Yadav R, Prakash O. A comprehensive review: phytochemical, nutritional and therapeutic importance of *Musa acuminata*. Int J Curr Res Rev. 2021;13(1):114-24.
19. Oteiza PI, Fraga CG, Mills DA, Taft DH. Flavonoids and the gastrointestinal tract: local and systemic effects. Mol Aspects Med. 2018;61:41-9. doi: 10.1016/j.mam.2018.01.001, PMID 29317252.
20. Singh DB, Suryanarayana MA. Andamans cultivating bananas scientifically. Ind Hortic. 1997;2:30-2.
21. Ratnasiri AW, Lee HC, Lakshminrusimha S. Trends in maternal prepregnancy body mass index (BMI) and its association with birth and maternal outcomes in California, 2007-2016: A retrospective cohort study. Nutrients. 2019;13(1):19-27.

Cite this article: Okafor AC, Favour PA, Uchenna OC, Ferdinand EN, Maduka NL, *et al*. Impact of *Musa acuminata* Sap on Leptin and Adiponectin Concentration in High Fat Diet Induced Obesity on the Offspring of Wistar Rat. Int J Clin Exp Physiol. 2024;11(3):100-6.