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The beneficial effects of moderate unsaturated fat diet on reproductive performance of obese rats

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ABSTRACT

Maternal obesity became more prevalence and obese women are suffering from several complications during pregnancy. We investigate the effect of moderate unsaturated fat diet on reproductive performance of obese rats during gestation. The obesity was induced by feeding with high fat diet HF (45%) for 12 weeks with control group LF. The obese rats divided to five subgroups HF-HF (45% tallow), HF-P.d (22.5% peanut), HF-O.d (22.5% olive oil), HF-M.d (22.5% tallow) , HF-LF(10% tallow) before mating and through gestation. The maternal energy intake and body weight were recorded. At gestation day18, dams were sacrificed; blood samples were taken for biochemical and hormonal measurements. The results indicating that feeding with unsaturated fat diet reduced with significantly ($p<0.05$) maternal food intake in HF-P.d and HF-O.d groups that reflected in lowering body weight during pregnancy, their fetal weight were normal as control group, also modulating fasting plasma leptin and insulin concentrations 5.35 ng/ml ,4.52 ng/ml and 1.48 , 2.19 ng/ml compared to the high levels in high and moderate saturated fat diet groups . The higher values of blood lipids and lipoprotein in saturated fat feeding groups were lowered after feeding with peanut or olive oil. Insulin sensitivity was increased in the unsaturated fat groups which reduced glucose and homeostatic index after impaired with saturated fat groups. Therefore the feeding with saturated high fat diet prior and through gestation increased maternal weight and gestational diabetes that influence on fetal growth, these effects can be regulating by feeding with unsaturated fat diet in moderate percentage which improve all these parameters and in spite of lowering saturated fat in the diet, it showed unfavorable effect during gestation indicating the important role of fatty acid types.

Keywords: Obesity, pregnant rats, modified unsaturated fat diet, leptin – insulin sensitivity.

INTRODUCTION

Obesity is one of the important factors causing the impairment of fertility in men and women especially at reproduction age [1], the obese women are more likely than the lean women to suffer from difficult pregnancy outcome with higher incidence of gestinational diabetes and hypertensive disease, endothelial dysfunction [2], prolonged labor and delivery complications [3,4] . Obesity had great role to induce central hypothalamic infertility as the higher leptin levels [5] in leptin resistance is associated with reproductive dysfunction [6, 7]. The high fat diet induced obesity in animal models showed reduction in fertility [8, 9]. The dietary unsaturated fat supplementations play a role in the reproductive functions [10] Linoleic acid (n-6 , cis -9, cis- 12) important in the ovulation, luteolysis and parturition through synthesis precursors for prostaglandins E1 and F1 E2 and F2 alpha production [11, 12].The supplementation with n-3 PUFA [13] or in n-6 PUFA during gestation caused changes in PUFA concentration in the umbilical plasma phospholipids [14]. Because there is no study referred to the effect of unsaturated fat rich diet on reproductive function in obese rats , or using moderate fat diet with unsaturated fats to improve the impairment in

reproduction that result from obesity, therefore we hypothesis that moderate unsaturated fat diet would enhanced the reproductive performance of obese female rats , thus the aim of the study to determine the effect of moderate fat diet with mono or polyunsaturated fatty acids on pregnancy, fetus weight, maternal physiological parameters and gestation diabetes .

MATERIALS AND METHODS

Animals:

Female Wister albino rats (6 weeks aged and 97± 10 g weight) were acclimatizing on low fat diet for one week before introducing to the experimental diets, the animals either feeding on low fat diet (control diet LF:10 % energy from tallow) n=12 or on a high fat diet (HF 45% energy from tallow) n=36 for 12 weeks (table 1) and assigned as experiment one of the study. All animals were kept in constant room temperature (25-30 c) and 12:12 h light: dark cycle with free access to food and water. in the experiment 2 of the study a group of rats n=6 from the control were continued on low fat diet for additional 8 weeks , while the rats from high fat diet group were divided into the following subgroups (n= 6). The first subgroup was continued to feed on HF diet (45%) for additional 8 weeks (HF-HF). The second subgroup was received moderate fat diet (22.5 % fat) in which tallow was replaced by olive oil (HF-O.d) or peanut (HF-P.d) for additional 8 weeks.. The third subgroup was received a low fat diet (10 % tallow) for additional 8 weeks (HF-LF). The forth subgroup was received a moderate fat diet (M.d: 22.5 % tallow) for additional 8 weeks (HF-M.d).

Diet:

Diet induced obesity in rodents (HFd 45 % fat) and it´s control (LFd 10 % fat) was formulated according to the research diet institute USA [15]. Moderate fat diet M.d (HF-M.d , HF-O.d , HF-P.d) was modifying according to the high fat diet of this study. The composition of the experimental diet shows in table1.

Table 1: composition of the experimental diets in the study

Ingredients	Control LF (10 % fat)	HF (45 % fat)	M.d (22.5%) tallow or olive oil	M.d (22.5%) peanut
Casein	200	200	200	158.1
L- cystine	3	3	3	3
Cornstarch	315	72.8	286.55	273.65
sucrose	385	272.8	286.55	273.65
Cellulose powder	50	50	50	36.22
Soy bean oil	25	25	25	25
Beef tallow	20	177.5	76.4*	0
Peanut	0	0	0	183.8
Mineral mixture	10	10	10	10
Dicalicium phosphate	13	13	13	13
Ca^{+2} carbonate	5.5	5.5	5.5	5.5
K citrate	16.5	16.5	16.5	16.5
Vitamin mixture	10	10	10	10
Choline bitartarate	2	2	2	2
Total weight gm	1055	858.1	984.5	984.5
Total Kcal	4057	4057	4057.3	4057.3
Total Kcal/ gm	3.85	4.73	4.078	4.078

** use beef tallow or olive oil in the diet.*

Study the reproductive performance:

To study the reproductive function, virgin female rats from each dietary groups from the experiment 1 and 2 of the study were used : LFd , Hfd , LF-LF , HF-HF , HF-P.d, HF-O.d, HF-LF and HF-M.d (n=6) .The virgin female rats were time mated by monitored ousters cycle in virginal smear before introducing to the male (one male for each female , aged 17 -18 week) .Day one of pregnancy was determined by the present of sperms after vaginal lavage . Pregnant rats were housed in group (n=3 each cage) in standard cage, containing sawdust and maintained on their assigned diet with free access to water. All animals were kept in constant room temperature (25-30 c) and 12:12 h light: dark cycle with free access to food and water. During the gestation period, daily food intake and body weight were recorded for each groups. Pregnant rats from each group either allow to get birth (n=3) or sacrificed (n=3) in the day 18 of gestation, blood samples were collected and plasma stored at -78 c, fetal and placenta weight were recorded. Retroperitoneal adipose tissue and adipose around kidneys, ovaries and uterus were dissected, weighed and frozen at - 78 c.

Hormonal measurements:
Plasma rat leptin and insulin was measured using rat Elisa kit from CRYSTAL CHEM INC (for leptin cat no. 90040, for insulin cat no. 90010, USA).

Biochemical parameters:
Plasma glucose , total cholesterol (T-ch), triglycerides (TG) , high density lipoprotein (HDL), total protein , albumin concentrations were measured by enzymatic method using diagnostic Kit from Randox and Biolabo companies. Low density lipoprotein (LDL) was calculated according to the formula of Friedewal [16]: LDL cholesterol = T.ch - HDL - (TG/5), very low density lipoprotein (VLDL) was measured according to the formula of Tietz [17]: VLDL = TG/5. Phospholipids were measured according to the formula Tietz (1976): Phospholipids = 68 + (T-ch × 0.89).

Insulin resistance:
The homeostatic index of insulin resistance (HOMA-IR) was calculated according to the equation developed by Matthewe [18]:

$$\text{HOMA-IR} = \frac{\text{Glucose (mmol/L)} \times \text{insulin (pmol/L)}}{155}$$

To converting insulin from ng/ml to pmol/L: multiplying by 150.

Statistical analysis:
Data were analyzed by one- way and two- way ANOVA using a general liner models procedure using SPSS version 15.0 statistic program. Comparisons between the data were made using least significant differences (LSD) by genstat3. Differences were considered to be significant at $p<0.05$.

RESULTS

Food consumed and energy intake : Female rats exposure to high fat diet HFd for 12 weeks and then had pregnancy with the same diet showed lower food and energy intake during gestation period 3 weeks (105.34 gm ± 7.56 , 498.258 ± 2.336 kcal /3 weeks),than females exposure to the low fat diet with the same exposure period (139.67 gm ± 6.10, 537.729 ± 2.350 kcal/3weeks) but when the female continued on high fat diet for additional 8 weeks (HF-HF) and then became pregnant ,showed significantly increasing in their food and energy intake (126.67 gm ± 5.74 , 599.149± 4.31 kcal/3 weeks) than the female on low fat diet with the same time (139.32 gm ± 6.32 , 536.382 kcal/3 weeks), Figures 1and 2 .

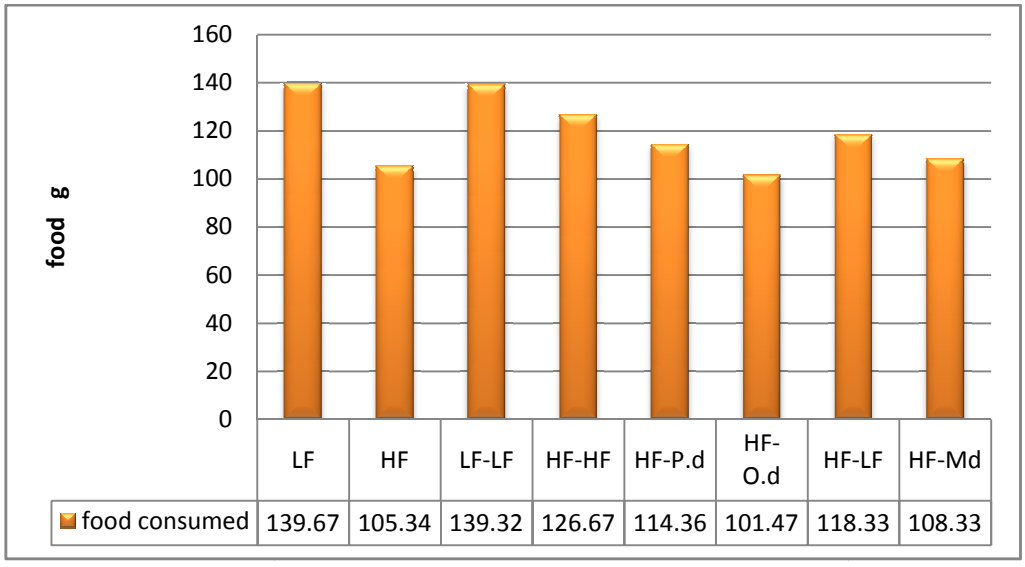

Figure 1: food consumed during gestation period (3 weeks)of pregnant rats fed experimental diets
LF:low fat diet, HF:high fat diet; LF-LF: low fat continue on low fat 10% , HF-HF: high fat continued on high fat(45% tallow), HF-P.d: high fat fed peanut 22.5%, HF-O.d :high fat fed on olive oil 22.5% , HF-LF: high fat fed on low fat 10% , HF-Md : high fat fed on tallow 22.5% . Means ($p< 0.05$) .

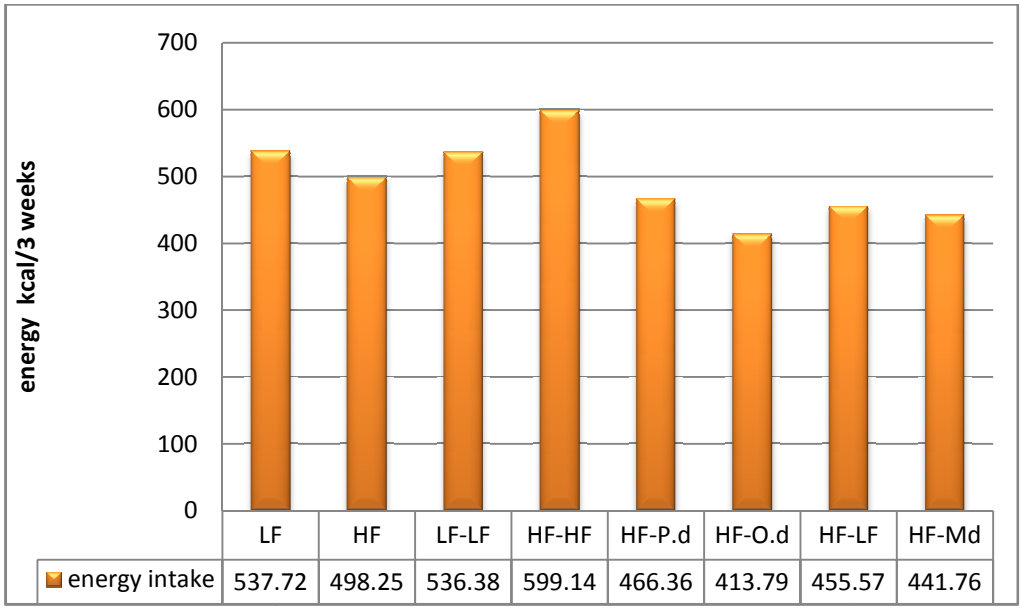

Figure 2 : energy intake during gestation period (3 weeks)of pregnant rats fed experimental diets

LF:low fat diet, HF:high fat diet; LF-LF: low fat continue on low fat 10% , HF-HF: high fat continued on high fat (45% tallow), HF-P.d: high fat fed peanut 22.5%, HF-O.d:high fat fed on olive oil 22.5% , HF-LF: high fat fed on low fat 10% , HF-Md : high fat fed on tallow 22.5% . Means ($p< 0.05$) .

In the experiment 2 of the study, female rats exposure to different experimental diets for additional 8 weeks, and then having pregnancy showed variation in their food and energy intake with the different diets. In the peanut group (HF-P.d) pregnant female consumed high food and energy (114.36 gm ± 6.76 , 466.360 ± 2.157 kcal/3 weeks) followed by females fed HF-LF group (118.33 gm ± 6.76 , 455.570 ± 2.157 kcal/3 weeks) during gestation period, while the females on olive oil (HF-O.d) or in HF-M.d groups seems to have the less food and energy consumed (101.47 gm ± 5.01 , 413.794 ± 1.239 kcal/3 weeks) , (108.33gm ± 4.73 , 441.769 ± 1.293 kcal/3 weeks respectively).

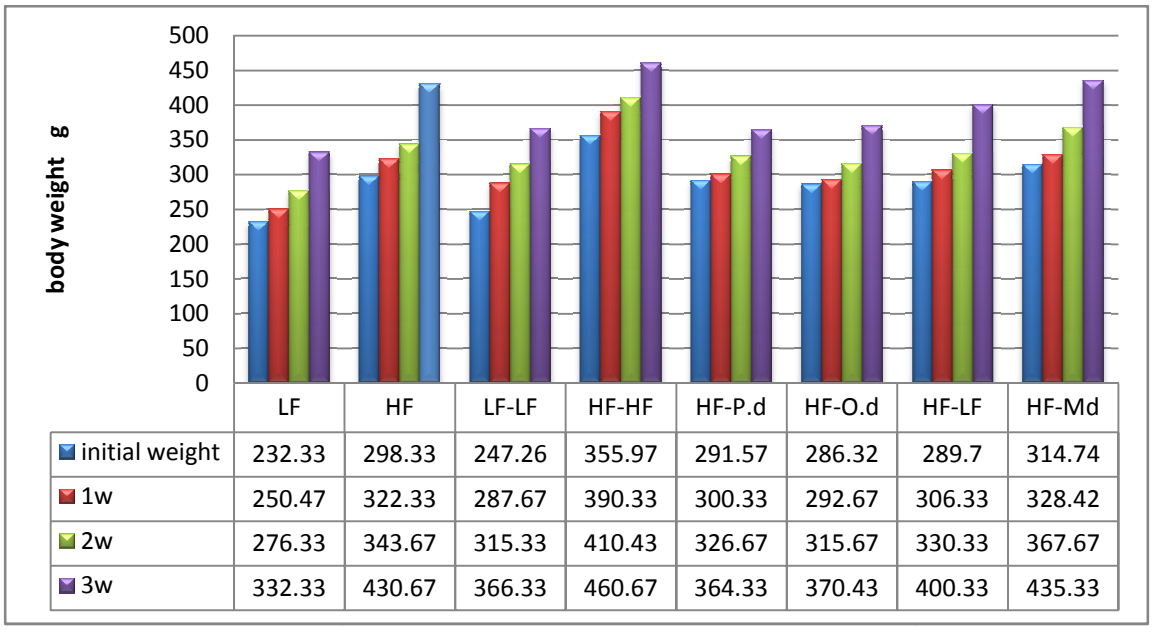

Figure 3 : maternal body weight during gestation period (3 weeks) of rats fed experimental diets

LF:low fat diet, HF:high fat diet ;LF-LF: low fat continued on low fat 10% , HF-HF: high fat continued on high fat(45% tallow), HF-P.d: high fat fed peanut 22.5%, HF-O.d:high fat fed on olive oil 22.5% , HF-LF: high fat fed on low fat 10% , HF-Md : high fat fed on tallow 22.5% . Means ($p< 0.05$) .

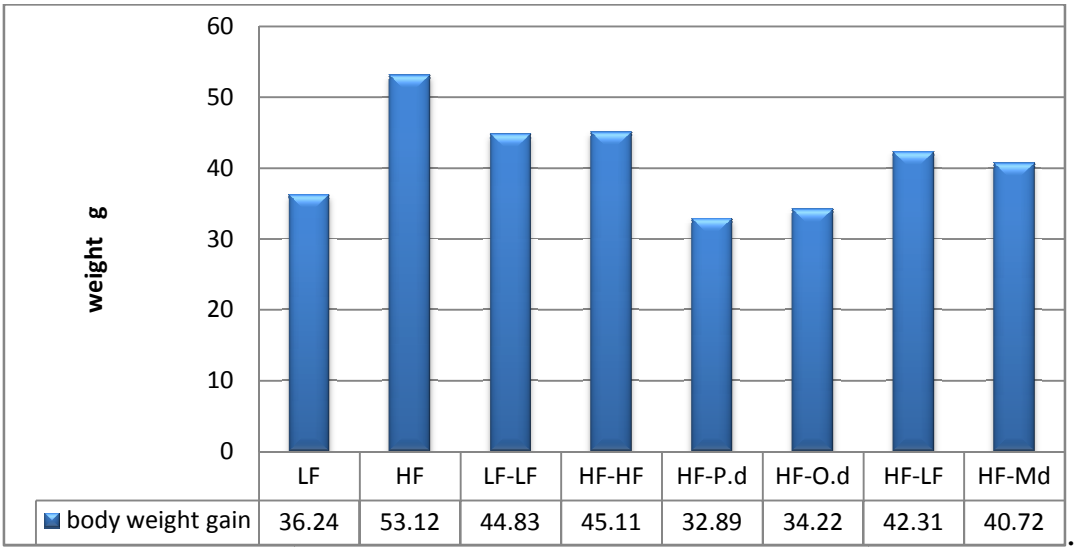

Figure 4 : body weight gain from pregnancy in dams fed experimental diets

LF:low fat diet, HF:high fat diet;LF-LF: low fat continued on low fat 10% , HF-HF: high fat continued on high fat(45% tallow), HF-P.d: high fat fed peanut 22.5%, HF-O.d:high fat fed on olive oil 22.5% , HF-LF: high fat fed on low fat 10% , HF-Md : high fat fed on tallow 22.5% . Means ($p< 0.05$) .

Maternal weight:

Dams consumed high fat diet prior (12 weeks) and during gestation have significantly ($p<0.05$) more body weight (430.67 gm ± 3.80) than females on low fat diet (332.33 gm ± 3.67) (figures 3 and 4). Dams from HF-HF, HF-LF and HF-M.d groups have higher maternal body weight (460.67gm ± 2.32, 400.33 gm ± 2.51 and 435.33 gm ± 2.61 respectively). Females from peanut group (HF-P.d) and from olive oil group (HF-O.d) showed the less maternal body weight at the end of gestation period (364.33 gm ± 3.05 and 370.43 g ± 2.02) .body weight gain from pregnancy shows in figure 4 , dams from high fat diet have more body gain (53.12 gm ± 1.211) than the control dams (36.24 gm ± 1.361) . In spite of higher maternal body weight in high fat group the pregnancy weight gain had no significant differences (45.11gm ± 1.508) than that of control females. The dams of HF-LF and HF-M.d group had higher body weight gain while HF-P.d and HF-O.d showed the less body weight gain (34.22 gm ±1.507 and 32. 89gm + 1.351).

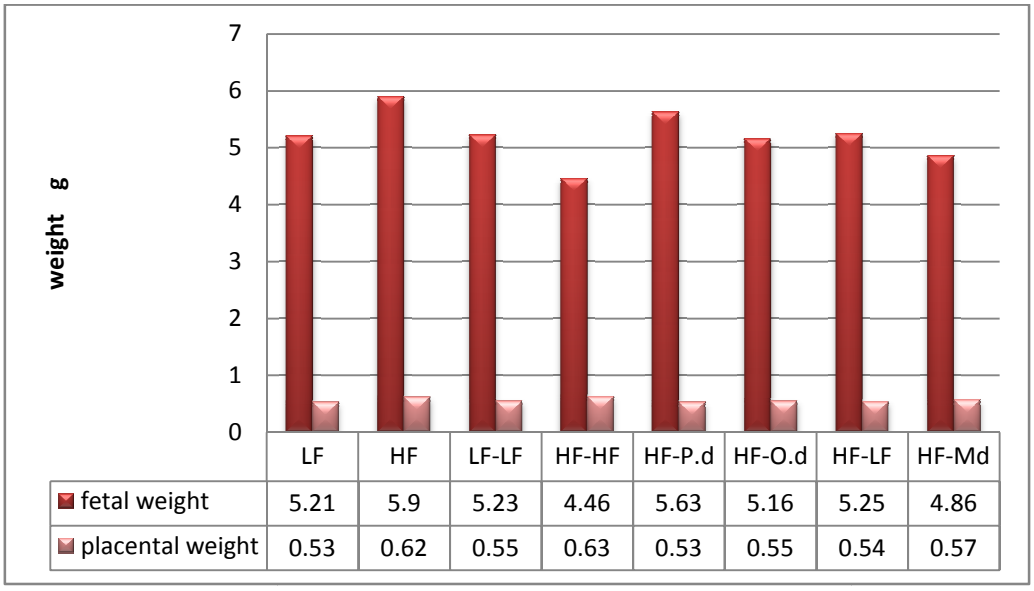

Figure 5 : fetal and placental weight in day 18 of pregnancy in dams of dietary groups

LF-LF: low fat continued on low fat 10% , HF-HF: high fat continued on high fat(45% tallow), HF-P.d: high fat fed peanut 22.5%, HF-O.d:high fat fed on olive oil 22.5% , HF-LF: high fat fed on low fat 10% , HF-Md : high fat fed on tallow 22.5% . Means ($p< 0.05$) .

Fetal and placental weight:
Dams consumed high fat diets (HF group) have significantly ($p<0.05$) more fetal and placental weight (5.90 gm ± 0.25 , 0.62 gm ± 0.2 respectively) compared to dams on low fat diet (LF) (5.21 gm ±0.21 , 0.53 gm ± 0.17 respectively) (figure 5). The increased exposure to high fat diet in dams of HF-HF group, showed decreased in fetal weight (4.467 gm ± 0.251) as compared to the control group (5.233 gm ± 0.208) . There was no significant differences between the control and HF-P.d group in fetal weights (5.633gm ± 0.305) whereas it differed significantly ($p<0.05$) with HF-O.d (5.167 gm ± 0.208) , HF-LF (5.0 gm ± 0.264) and HF-M.d group (4.867 gm ± 0.152) .No significant differences in placental weight was noticed among all dietary groups.

Maternal plasma leptin and insulin : As shown in table 2 , dams from high fat groups (HF,HF-HF) have significantly ($p<0.05$) higher fasting plasma leptin and insulin concentration at the day 18 of gestation (4.210 ng/ml , 11.110 ng/ml for leptin and 3.294 ng /ml , 4.970 ng/ml for insulin) compared to control group (LF) (2.881 ng / ml , 2.942 ng / ml for leptin and 1.390 ng/ml , 1.400 ng / ml for insulin) followed by HF-M.d and HF-LF groups . Dams fed on peanut (HF-P.d) and olive oil diet (HF-O.d) seems to have modest levels of plasma leptin (5.350 ng/ml and 4.520 ng/ml respectively) with significant ($p<0.05$) from the control. The insulin of HF-P.d group had concentration 1.489 ng/ml with significant differences ($p<0.05$) from the control (LF-LF), whereas the HF-O.d and HF-LF groups showed significant differences ($p<0.05$) in insulin concentration (2.191 ng/ml and 2.707 ng/ml) with control group.

Table 2 : plasma leptin and insulin concentration in the day 18 of pregnancy for pregnant rats fed experimental diets
LF:low fat diet, HF:high fat diet;LF-LF: low fat continue on low fat 10% , HF-HF: high fat continued on high fat(45% tallow), HF-P.d: high fat fed peanut butter 22.5%, HF-O.d:high fat fed on olive oil 22.5% , HF-LF: high fat fed on low fat 10% , HF-Md : high fat fed on tallow 22.5% . . Means ±S.D ($p< 0.05$) .

Treatment	Leptin ng/ml	Insulin ng/ml
LF (control)	2.881 ± 0.15 b	1.390 ± 0.300 b
HF	4.210 ± 0.22 a	3.294 ± 0.281 a
LF-LF (control)	2.942 ± 0.388 e	1.400 ± 0.120 f
HF-HF	11.110 ± 0.311 a	4.970 ± 0.252 a
HF-P.d	5.350 ± 0.473 c	1.489 ± 0.140 e
Hf-O.d	4.520 ± 0.155 d	2.191 ± 0.108 d
HF-LF	4.630 ± 0.693 d	2.707 ± 0.212 c
Hf-M.d	9.177 ± 0.406 b	3.278 ± 0.212 b

Glucose and homeostatic index: Fasting plasma glucose levels were significantly ($p<0.05$) higher in dams fed high fat diet (HF, HF-HF groups)(table 3) (15.683mmol/L and 17.205 mmol/L respectively) compared to the control fed dams (12.788 mmol/L and 12.825 mmol/L respectively). The HF-M.d group dams had higher glucose followed by the HF-LF group fed dams, whereas the dams fed on peanut or olive oil had lower plasma glucose concentration 13.530 mmol/L and 13.782 mmol/L respectively compared to the other groups .The HF, HF-HF and HF-M.d fed dams showed a greater level of insulin resistance at the day 18 of gestation. The feeding with HF-LF and HF-O.d diet caused modest decreasing in insulin resistance (HOMI) levels 38.16 and 29.22 respectively compared to the highly reducing in HF-P.d group with concentration 19.50.

Table 3: plasma glucose and homeostatic index concentration in the day 18 of pregnancy for pregnant rats fed experimental diets
LF:low fat diet, HF:high fat diet; LF-LF: low fat continue on low fat 10% , HF-HF: high fat continued on high fat(45% tallow), HF-P.d: high fat fed peanut 22.5%, HF-O.d:high fat fed on olive oil 22.5% , HF-LF: high fat fed on low fat 10% , HF-Md : high fat fed on tallow 22.5% . Means ±S.D ($p< 0.05$) .

Treatment	Glucose mmol/L	HOMI
LF (control)	12.788 ± 1.200 b	17.20 ± 1.380 b
HF	15.683 ± 1.342 a	50.00 ± 1.514 a
LF-LF (control)	12.825 ± 1.251e	17.38 ± 1.312 f
HF-HF	17.205 ± 1.278 a	82.76 ± 1.295 a
HF-P.d	13.530 ± 1.153d	19.50 ± 1.200 e
Hf-O.d	13.782 ± 1.289d	29.22 ± 1.541d
HF-LF	14.561 ± 1.231c	38.16 ± 1.225 c
Hf-M.d	16.571 ± 1.495b	52.59 ± 1.535 b

Maternal biochemical parameters
Fasting plasma total cholesterol (T-Ch) triglycerides (TG) ,low and very low density lipoprotein (LDL,VLDL) and phospholipids (pholip) were significantly ($p<0.05$) higher in dams from HF diet groups :HF and in HF-HF group compared to dams from control diet (low fat diet) (table 4) , following by high concentration in dams from HF-M.d group . No differences were found between HF and LF groups in albumin concentration 2.21 mml/L , Total protein level decreased with significant ($p<0.05$) in HF diet group 74.25 mmol/L . Plasma T-ch , TG , LDL ,VLDL and

phospholipids were significantly ($p<0.05$) decreased in peanut group (HF-P.d) : 1.608 , 0.865, 0.862 , 0.172 , 69.431 mmol/L , following by HF-O.d group 2.377 , 0. 780 , 1.738 , 0.158 , 70.446 mmol/L ,while the HF-LF group had slight decreased in all these parameters 2.526, 1.076 , 1.925 , 0.214 and 70.247mmol/ L respectively. Fasting plasma high density lipoprotein (HDL) were significantly decreased in dams of HF-HF group , HF-M.d and HF-LF group with no significant between them, while the HDL increased in HF-O.d group 0.483 and in HF-P.d group 0.573 mmol/L . No significant differences was found in fasting plasma albumin among the dietary groups, except for HF-HF group which had low concentration 1.872 mmol/L . Plasma total protein was declined in HF-LF 70.50 g/L and in HF-M.d group 71.38 g/Lwith no significance, following by HF-HF group 72.91 g/L and in HF-O.d group 73.90 g/Lwith no differences, while in HF-P.d group , dams had the same concentration of plasma total protein as in the control group 75.58 g/L.

Table 4: Plasma biochemical parameters concentration in the day 18 of pregnancy of pregnant rats fed experimental diets

LF:low fat diet, HF:high fat diet;LF-LF: low fat continue on low fat 10% , HF-HF: high fat continued on high fat(45% tallow), HF-P.d: high fat fed peanut 22.5%, HF-O.d:high fat fed on olive oil 22.5% , HF-LF: high fat fed on low fat 10% , HF-Md : high fat fed on tallow 22.5% . Means ± S.D ($p< 0.05$)

Treatment	T-ch mmol/L	HDL mmol/L	TG mmol/L	LDL mmol/L	VLDL mmol/L	Phoslip mmol/L	Albumin mmol/L	Total protein g/L
LF (control)	0.67± 0.330 b	0.441 ±0.401 a	0.58 ±0.611 b	0.34 ±0.410 b	0.116 ±0.322 b	68.794 ±0.228 b	3.14 ±0.614 a	75.87 ±0.360a a
HF	1.72 ±0.256 a	0.340 ± 0.56 b	1.42 ±0.461 a	0.96 ±0.235 a	0.283 ±0.370 a	69.532 ±0.234 a	2.21 ±0.650 a	74.25 ±0.424 b
LF-LF (control)	0.959 ±0.054 f	0.486 ±0.013 b	0.596 ±0.011 e	0.354 ±0.066 e	0.119 ±0.002 e	68.848 ±0.041 e	3.149 ±0.068 a	75.81 ±0.681 a
HF-HF	4.730 ±0.177 a	0.307 ±0.037 d	2.241 ±0.211 a	3.975 ±0.183 a	0.448 ±0.042 a	72.209 ±0.158 a	1.872 ±0.983 b	72.91 ±0.880 b
HF-P.d	1.608 ±0.155 e	0.573 ±0.006 a	0.865 ±0.075 d	0.862 ±0.175 d	0.172 ±0.015 d	69.431 ±0.138 d	2.757 ±0.07 a	75.58 ±0.519 a
Hf-O.d	2.377 ±0.126 c	0.483 ±0.006 b	0.780 ±0.015 d	1.738 ±0.115 c	0.156 ±0.003 d	70.446 ±0.522 c	2.693 ±0.056 a	73.90 ±0.112 b
HF-LF	2.526 ±0.087 c	0.385 ±0.014 c	1.076 ±0.008 c	1.925 ±0.095 c	0.214 ±0.001 c	70.247 ±0.078 c	2.733 ±0.045 a	70.50 ±0.614 c
Hf-M.d	3.249 ±0.051 b	0.368 ±0.005 c	1.566 ±0.072 b	2.568 ±0.056 b	0.312 ±0.014 b	70.892 ±.045 b	2.453 ±0.056 a	71.38 ±0.398 c

DISCUSSION

Our results showed that female rats consumed high fat diet for 12 weeks and during pregnancy period had less food and energy intake than the females on low fat diet, this Findings were in agreement with findings [19],that dams fed high fat diet (45%) prior (6.5 weeks) and through gestation, consumed less food than dams on the control diet. However the continuous feeding on high fat diet for additional 8 weeks, showed mild increment in feed consumption during gestation period, that subsequently increased in their energy intake more than the dams continuous on low fat diet, this may be related to the high percentage of fat content in high fat diet (4.73 kcal/g) compared to low fat diet (3.86 kcal/g). This was accordance with [20] that consumption of very high fat diet (59.5 %) prior (77days) and through pregnancy, increased caloric consumption in rat dams during the third weeks of gestation more than the control (10.9 %) fed dams. Our study showed the consumption of olive oil or peanut butter prior and during pregnancy, reduced the amount of food and energy intakes in the dams, compared to the pregnant rats on low fat diet, these result was also reported by [21].

In comparison to the control group (low fat diet), the high fat (HF) dams continued to get more body weight during gestation period, these may be related to increased fetal and placental weight as shown from the results, but the body weight gain after birth showed higher increment in high fat group, therefore the weight gain caused by increment in body fat stores as a resulted to higher saturated fat consumption, which that tended to be store in adipose tissue more over oxidized [22]. Our results were agreed with [19] that high fat fed dams were heavier than the control dams and continued to get more weight though gestation period . Also the study of Howie [23] found the dams fed HF though their life including pregnancy and lactation had significantly increased body weight than the control fed dams.

However the dams from HF-HF and HF-M.d dams were heavier than the control dams , but showed a little increment in their body weight gain , this may be illuminate to higher body fat storage (adiposity mass) may effected the status of adipose tissue metabolism , or as a resulted from type 2 diabetes which decreased whole body to insulin sensitivity that indicated from hyperinsulenemia , hyperglycemia and higher homeostatic index during gestation may effected the B-cell function , or the reduction in fetus weight (as shown in gestation day 18) may impaired or interacted with some gestation hormones like progesterone which effected regulating energy homeostasis , this fact was indicated from the difficulty in pregnancy outcome in this group ,which some researchers attributed it either to the obesity lead to energetic inhibition of reproduction [24] or the excessive fuel storage which make it unavailable for reproduction [25] . The pattern of maternal body weight and weight gain in the dietary groups HF-P.d and HF-O.d were differed from that of the control group. Rats fed with unsaturated fats (peanuts or olive oil) reduced gestational weight and maternal body weight gain. These results may attribute to many factors, either the types of unsaturated fat (mono or poly unsaturated) or to the quantity of these fat in the diet or to the period of the experiment had an effect on the results. Our findings agreed with other studies conducted on the using of n-3 poly unsaturated fatty acids (PUFA) such as fish oil [26 , 21] which tend to reduce body weight gain as well as fat accumulation, or using n-6 PUFA [27] That not lead to increase body weight during gestation and lactation.

Dams from HF-HF and HF-M.d groups resulted in hyperleptinemian and hyperinsulinemia in the late gestation period (18 day) , however the consumption of high fat diet (39%) prior and during pregnancy resulted in obesity, hyperinsulinemia , hyperleptinema in female rats compared to control female rats (10.9 % fat) was also reported [20]. Adult rats fed a high fat diet display hyperleptinemia and hyper insulinemia with resistance to their actions at the level of hypothalamus, this related to decreased STAT-3 signaling in response to leptin in mice fed high fat diet pointing to abnormal transport and signal transduction [28]. Also reducing tyrosine phosphorylation of insulin receptor and insulin receptor substrate 2 IRS-2[29] . Dams fed peanut or olive oil reduced their gestational leptin and insulin levels, this related to the activity of USFA to decrease triglycerides levels that enhance leptin transport in the brain and improve their action in hypothalamus, which in turn increased insulin sensitivity and reduced glucose level, this fact was also found in dams fed low fat diet HF-LF group, but their triglycerides levels was more than the previous group as a result of increased carbohydrates ratio in the diet which increased saturated fatty acid synthesis [30] and fat deposition that have positive association with blood lipid [31].

The reduction of insulin sensitivity in HF pregnant rats may explained the hyperglycemia of these groups , in addition to the role of saturated fat to impair receptors of glucose transport (GLUT 1 and 4) in the cell membrane [32] and diabetes association obesity increased glycosylated haemoglobin HbA1C [33]. The greater role of unsaturated fatty acids to improve insulin action and glucose concentration were also occurred in pregnant animals of these group especially in HF-P.d group, the main role may be attributed to the activity of monounsaturated fats (more than the n-6 poly unsaturated in olive oil) to change or modulate cell receptors for glucose transport or for insulin binding and enhanced their biological action. Lowering the ratio of saturated fat to the carbohydrate in HF-M.d and HF-LF diet did not achieve the desire needed especially in HF-M.d group with higher insulin resistance as the contributing of carbohydrates to increased endogenous saturated fat, this adding another evidence that the unsaturated fat was the driving factor .

CONCLUSION

The effect of obesity on maternal weight and gestational diabetes can be regulating by feeding with unsaturated fat diet in moderate percentage which improve all these parameters and in spite of lowering saturated fat in the diet, it showed unfavorable effect during gestation indicating the important role of fatty acid types and composition.

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