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Abstract

Anemia is a public health problem and related to malnutrition, may cause serious complications. Obesity has been related with disordered iron homeostasis and cause anemia. *Moringa oleifera* is rich in iron and can be used as an alternative therapy in iron deficiency. The aim of this study was conducted to investigate the effect of *M. oleifera* leaves powder on obese anemic rats. Thirty five adult female rats were divided into two main groups the first main group (n= 7); were fed on basal diet only and served as negative control group, the second main group (n=28); were fed on high-fat diet with 10% tannic acid with iron-removed from the mineral mixture during all the experimental period to cause obese anemic model, and were divided into 4 subgroups, one of them was fed on high-fat diet only and kept as positive control group, while the other three subgroups were fed on high-fat diet supplemented with dried *M.oleifera* leaves at the concentration of (5,7.5,10%) respectively. The results indicated that, supplementation with *M. oleifera* leaves powder can help overcome iron deficiency anemia and obesity, due to the improvement in mean hematocrit, hemoglobin, red blood cells and platelets of the treated groups as compared to the positive control group. Moreover, significant ($P<0.05$) weight reduction as well as an improvement in liver, kidney functions and lipid profile of the tested rats were observed. So, *M. oleifera* leaves are recommended to obese anemic patients.

Keywords:

Iron deficiency, Anemia, *Moringa oleifera*, Obesity, Hemoglobin.

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مستخلص البحث:

فقر الدم هو مشكلة صحية عامة وترتبط بسوء التغذية وقد تسبب مضاعفات خطيرة. ارتبطت السمنة باضطراب توازن الحديد وارتفاع معدل الإصابة بفقر الدم. المورينجا غنية بالحديد ويمكن استخدامها كعلاج بديل لنقص الحديد. الهدف من هذه الدراسة هو معرفة تأثير مسحوق أوراق المورينجا على الفئران البدينة المصابة بفقر الدم. تم تقسيم خمسة وثلاثين من اناث الفئران البالغة إلى مجموعتين رئيسيتين، المجموعة الرئيسية الأولى (ن= 7) ؛ تم تغذيتها على النظام الغذائي الاساسى فقط كمجموعة ضابطة سالبة، المجموعة الرئيسية الثانية (ن=28)؛ تم تغذيتها على نظام غذائي عالي الدهون ناقص فى الحديد مع 10 ٪ حمض التانيك طوال فترة التجربة لإحداث الانيميا والسمنة ، وتم تقسيمها إلى 4 مجموعات فرعية ، تم تغذية إحداها على نظام غذائي عالي الدهون فقط كمجموعة ضابطة موجبة ، في حين تم تغذية المجموعات الفرعية الثلاثة الأخرى على نظام غذائى عالى الدهون ومدعم بأوراق المورينجا المجففة بتركيز (5، 7.5، 10 ٪) على التوالي. أشارت النتائج إلى أن التدعيم بمسحوق أوراق المورينجا يمكن أن يساعد في التغلب على الانيميا الناتجة عن نقص الحديد والسمنة ،نتيجة التحسن في متوسط الهيماتوكريت والهيموجلوبين وخلايا الدم الحمراء والصفائح الدموية للمجموعات المعالجة مقارنة بالمجموعة الضابطة الموجبة. علاوة على ذلك ، لوحظ انخفاض معنوي فى الوزن بنسبة 0.5 وكذلك تحسن في وظائف الكبد والكلى ومستوى الدهون في الفئران المختبرة. لذلك ، يوصى باستخدام أوراق المورينجا لمرضى فقر الدم الذين يعانون من السمنة المفرطة.

الكلمات المفتاحية:

نقص الحديد، الانيميا، المورينجا، السمنة، الهيموجلوبين.

Introduction

Iron deficiency is accountable for 50% of anemic patients, with 90.000 death cases from different ages **(WHO, 2015 and Simbrunner *et al*., 2020). Iron** deficiency and anemia cause cell death via necrosis and apoptosis. Lipid peroxidation in red blood cells may origin for cell death due to the production of free radicals **(Usman *et al*., 2019).**

Obesity prevalence will reach 50% by 2030 **(Ward *et al*., 2019).** The current prevalence of obesity is 42% and the severe adult obesity (BMI > 40) has increased recently **(Hales *et al*., 2020).** Obesity is related to many chronic complications, as hormonal imbalance, hyperglycemia, dyslipidemia, impaired glucose tolerance **(Ali Redha *et al*., 2021).**

Body weight is increased with Lower levels of iron **(Purdy and Shatzel, 2021),** Consequently, anemia risk may be increased in obese patients **(Sal *et al*., 2018).** Several bodily organs, including the liver, spleen, and bone marrow, are involved in the metabolism of iron are affected with the occurrence with obesity **(Gu *et al*., 2020).**

In developing countries, anemia is worldwide disorders. It is defined as low hemoglobin (Hb) level، which reduces the red blood cells to catchup the oxygen to tissues **(Onyeabo *et al*., 2017 and Soundarya and Suganthi, 2017**). When Hb level lowered under 13 g/dl for men and 12 g/dl in women, anemia can be diagnosed **(Elaby and Ali, 2018).** Nowadays, therapeutic drugs caused many side effects, Therefore, using foods from natural plants could existing a suitable solution for treating anemia **(Onyeabo *et al*., 2017).**

Moring (*Moringa oleifera*) is identified for different healing properties. It has a space with the *Moringaceae* family **(Srivastava *et al*.,2020).** Food industry has been used *Moringa* seed and leaves for therapeutic cases as well as in traditional diets **(Ndabigengesere *et al*., 2021).**

M. oleifera is a excellent dietary source of carbohydrate (fibers); proteins; vitamins (C, B, A, and K); minerals as (Ca, K, Zn and Fe); and water with deficiency of fat **(Lipipun *et al*., 2021).**

Moringa leaves provide 28.29 mg protein **(Kasolo *et al.*, 2012),** dietary folate **(Nikkon *et al.*, 2021),** an excellent source of vitamins and amino acids that improved immunity **(Obioma and Adikwu, 2021).** Therefore, this study was performed to assess the effect of *moringa oleifera* leaves powder on obese anemic female rats.

Materials and Methods

Materials

Chemicals: Casein, minerals, vitamins, and cellulose were purchased from El-Gomhoria Company. Tannic acid was purchased from local distributer of (Sigma Chemical Co). Kits for blood analysis was purchased from Alkan Company for Biodiagnostic Reagents, Dokki, Cairo, Egypt.

Plant: Moringa Fresh leaves were obtained from the National Research Institute.

Rats: Adult female albino rats (Sprague- Dawley strain) (n=35 rat) weighing about (180 ±10 g.) were purchased from Helwan Experimental Animals Farm.

Methods

Chemical composition of moringa leaves: The gross chemical composition and phytochemical screening were carried out at the National Research Center, according to **A.O.A.C, (2020).** Antioxidant activity in *Moringa* leaves was assessed according to **Burda and Oleszek, (2001).**

Preparation of *Moringa leaves* powder: The plant material was shade-dried for 4 days then they were milled into fine powder, then were ground to fine powder then the powder was stored in plastic container.

Induction of obesity: Animals were fed three weeks on basal diet **(Reeves *et al.*, 1993)** with some modification in fat content to induce obesity in rats **(Liu *et al.*, 2004).**

Induction of anemia: Obese rats (n=28) were fed on high fat diet with (10 g tannic acid/kg diet) for three weeks **(Afsana *et al.*, 2004).** Hb concentrations were determined in selected random blood samples after 3 weeks from tail vein **(Borzage *et al.*, 2016).**

Biological study: Thirty-five adult female rats were fed on basal diet for one week for adaptation. Rats then were randomly divided into two main groups as follow: The first main group (n= 7) was fed on basal diet only and served as control negative group. The second main group (n=28) was fed on high-fat diet with 10% tannic acid and iron-removed from the mineral mixture all the period to cause obese anemic rats, then were divided into four subgroups, the first subgroup was fed on a high-fat basal diet with tannic acid and served as positive control group, the other

three subgroups were fed on high-fat basal diet with tannic acid supplemented with dried *Moringa* at the concentration of 5, 7.5 and 10 %.

At the end of the experimental period (6 weeks), rats were fasted over night before sacrificing, two blood samples were collected, and the first sample was collected into a tube containing disodium salt of Ethylene Diamine Tetra Acetic Acid (EDTA) as anticoagulant and used for assessment of the hematological parameters. The second blood samples were collected into a centrifuge tube without any anticoagulant and centrifuged to obtain serum which was stored at - 20°C until used for subsequent analysis.

Biological Evaluation: feed intake (FI), feed efficiency ratio (FER) and body weight gain percent (BWG %) were determined according to **(Chapman *et al*., 1959)** using the following equation:

$$BWG\% = \frac{\text{Final body weight} - \text{Initial body weight}}{\text{Initial body weight}} \times 100$$

FER= Body weight gain (g) / Feed intake (g)

Chemical analysis: Red blood cell counts (RBCs), white blood cell counts (WBCs), platelets, mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), hemoglobin (Hb) and hematocrit (HCT) were determined according to **Ochei and Kolharktar, (2008).** Leptin hormone was determined using enzyme-linked immunosorbent (ELISA) assay **(Xiong *et al*., 2005).**

Serum Aspartate amino transferase (AST) and alanine amino transferase (ALT) **(Bergmeyer *et al*., 1978)** were determined. Serum urea (Kaplan, 1984), uric acid **(Patton and Crouch, 1977)** and creatinine were measured according to **(Murray, 1984).** Serum total cholesterol **(Richmond, 1973),** triglycerides **(Wahlefeld, 1974),** high density lipoprotein **(Albers *et al*., 1983)** were determined. Meanwhile, low density lipoprotein and very low density lipoprotein were calculated according to **(Fridewald *et al*., 1972).**

$$LDL\text{-}c = TC\text{-}[HDL\text{-}c + (TG/5)] \qquad VLDL\text{-}c = TG/5$$

Statistical Analysis: The results were analyzed according to SPSS program. ANOVA test was used to compare results among groups and $P<0.05$ was considered to be significant **(Snedecor and cochron, 1989).**

Results and Discussion

Moisture, protein, total lipids, total carbohydrate, crude fiber, ash, and total antioxidant activity are all present in dried moringa at concentrations of 7.03g, 26.06g, 2.78g, 38.05g, 18.02g, 8.06g, and 16.23g/100 g of the dried leaves, respectively.

These findings support those of **EL-Bushuty and Shanshan (2020) and Rabeh *et al*., (2021),** who discovered that the powder made from Moringa leaves was highly nutrient-dense. Antioxidant activity content especially polyphenolics of Moringa leaves was detected **(Sreelatha and Padma, 2009 and Rabeh *et al*., 2021).** Benzoic acid, caffeine, and polyphenolic chemicals are also present **(Halaby and Emara, 2015).**

Table (1): Chemical composition and total antioxidant activity of *M. Oleifera* leaves powder (g/100g)

Nutrients (g)	***M. Oleifera* leaves**
Moisture	7.03
Crude protein	26.06
Total lipids	2.78
Total carbohydrate	38.05
Crude fiber	18.02
Ash	8.06
Total antioxidant activity (µg)	16.23

Effect of *M. oleifera* leaves powder on BWG, FI, and FER of obese anemic rats.

In Table, the impact of M. oleifera powder on the final body weight of obese anemic rats is shown (2). There were no significant changes in the initial body weight of all groups of rats. The statistical analysis showed that the mean values of the final body weight, BWG%, and FER of positive anemic control group were significantly ($P<0.05$) increased, compared to the negative control group.

Obese anemic rats treated with different concentrations of *M. oleifera* had significant ($P<0.05$) decrease in FBW, BWG% and FER compared to the positive

group (obese anemic rats). There were non-significant ($p<0.05$) changes in FER, between obese anemic rats treated with (5 or 7.5 %) *M. oleifera*. Moreover, obese anemic rats treated with 10% *M. oleifera* caused significant ($P<0.05$) decrease in FBW, BWG% and FER compared to other obese anemic rats treated with 5 or 7.5% *M. oleifera*. The highest decrease in BWG% was observed at the groups given 10% *M. oleifera*.

These result are agreement with **Shamsia *et al*., (2015) and El-Bashshuti and Shanshan, (2020)** revealed that all hypercholesterolemic rat groups which fed on 5%, 10% and 15% moringa leaves powder resulted in decrease in body weight gain. While **Rabeh *et al*., (2021)** found that supplementation with extract of *M. oleifera* at doses of (5, 10 and 15%) compared to anemic rats, increased body weight.

Table (2): Effect of *M. oleifera* leaves on body weight of obese anemic rats.

Parameters / Groups	IBW (g)	FBW (g)	BWG%	FI (g/d/rat)	FER
Control –ve	200.76±1.91^{a}	245.33±0.88^{b}	22.22±1.33^{b}	22.50	0.066±0.03^{b}
Control +ve	200.33±1.74^{a}	268.36±1.32^{a}	33.98±1.54^{a}	24.00	0.094±0.03^{a}
***M. oleifera* (5%)**	201.50±0.86^{a}	243.40±2.08^{b}	20.80±1.55^{b}	22.00	0.063±0.04^{bc}
***M. oleifera* (7.5%)**	201.93±1.73^{a}	235.56±2.84^{c}	16.66±1.22^{c}	21.00	0.053±0.03^{c}
***M. oleifera* (10%)**	201.16±1.42^{a}	222.23±1.03^{d}	10.47±0.38^{d}	20.00	0.035±0.01^{d}

Results are expressed as mean ± SE.
Values in each column which have different letters are significantly different at ($P<0.05$).

Effect of *M. oleifera* leaves on Leptin hormone of obese anemic rats.

The obtained data from table (3) illustrated that, rats fed high fat diet had a significant increase ($P<0.05$) in leptin hormone, as compared with negative group. The results

indicated that, supplementation with *M. oleifera* leaves at the three levels significantly decreased (P<0.05) the level of leptin, as compared with the positive control group. There was significant difference in the level of leptin among the three groups of *M. oleifera* leaves. The highest reduction for leptin hormone was recorded in the group supplemented with 10% of *M. oleifera* leaves. The most recent results are consistent with **El-Shehawi *et al.*, (2021)** showed that feeding HFD significantly increased serum level of leptin level compared to control group. **Metwally *et al.*, (2017)** observed lower leptin during supplementation with *M. oleifera* provided an improvement of adiposity. Also, **El-Shehawi *et al.*, (2021)** showed that Moringa extract significantly decreased serum level of leptin compared to HFD-group.

Table (3): Effect of *M. oleifera* leaves on Leptin hormone of obese anemic rats.

Parameters / Groups	Leptin hormone (µg/l)
Control –ve	1.81 ± 0.05^{e}
Control +ve	5.41 ± 0.18^{a}
***M. oleifera* leaves (5%)**	4.30 ± 0.14^{b}
***M. oleifera* leaves (7.5%)**	3.23 ± 0.17^{c}
***M. oleifera* leaves (10%)**	2.48 ± 0.09^{d}

Results are expressed as mean ± SE.

Values in each column which have different letters are significantly different at (P<0.05).

Effect of *M. oleifera* leaves on Hemoglobin and Hematocrit levels of obese anemic rats.

Table (4) shows how M. oleifera leaves affected the Hemoglobin and Hematocrit levels in obese anemic rats. The obtained results showed that rats fed basal diet deficient of iron and added with tannic acid revealed a significant decrease (p<0.05) in the mean value of Hb and HCT as compared with those of negative control group. Obese anemic rats fed on M. oleifera leaves at the different concentrations had significant (P<0.05) increase in Hb and HCT as compared with that of positive control group. It was observed that, there was significant difference in Hb and HCT among all the experimental groups. *M. oleifera* leaves at (10%) had highly significant increment in Hb and HCT than the other groups.

These findings are consistent with those of **Suzana *et al*. (2017),** who investigated leaf M. oleifera extract at a daily dose of 1400 mg. Adolescent females' Hb levels significantly rose after receiving Moringa leaf extract, according to **Yulianti *et al*., (2016).** Giving M. oleifera leaf extract at a dose of 792 mg/200 g BW per day can raise haemoglobin levels, according to **Abdul Mun'im *et al*.,(2016).**

Table (4): Effect of *M. oleifera leaves* on Hemoglobin (Hb) and Hematocrit (HCT) levels of obese anemic rats.

Parameters / Groups	Hb (g/dl)	HCT (%)
Control –ve	15.10 ±0.17^{a}	55.30±1.07^{a}
Control +ve	3.62 ±0.26^{e}	33.83±1.09^{d}
***M. oleifera* leaves (5%)**	9.89 ±0.31^{d}	38.50±1.57^{c}
***M. oleifera* leaves (7.5%)**	11.23 ±0.67^{c}	41.56±0.84^{c}
***M. oleifera* leaves (10%)**	12.64 ±0.35^{b}	50.27±0.59^{b}

Results are expressed as mean ± SE.

Values in each column which have different letters are significantly different at (P<0.05).

Effect of *M. oleifera* leaves on red blood cells count and white blood cell levels of obese anemic rats.

Table (5) shows how M. oleifera leaves affected the red blood cell parameters in obese anemic female rats. The results showed that RBCs and platelet concentrations were significantly decreased (P<0.05) while WBCs was significantly increased at the positive control group as compared with the negative control group. Treating obese anemic rats with *M. oleifera* leaves at the different tested levels caused a significant decrease (p<0.05) in WBCs and a significant increase in RBCs and platelet concentrations as compared with positive group. There were no significant changes in WBCs between the groups supplemented with *M. oleifera* leaves at the (5 and 7.5%). The highest increase in RBC and platelet as well as the highest reduction in WBCs were observed at the groups supplemented with 10% of *M. oleifera* leaves.

The current findings are consistent with **Suzana *et al*., (2017)** indicated a significant decrease in platelets. In contrast to the normal control group, **Ameh and Alafi,(2018)** discovered a significant (P>0.05) decline in RBCs and a significant rise in WBCs. Feeding *Moringa oleifra* leaf extract increase blood parameters **(Anslem *et***

***al*.,2017). Rabeh *et al*., (2021)** showed that treating anemic rats had a significant moringa extract-induced drop in WBCs and a significant increase in RBC and platelet concentrations.

Table (5): Effect of *M. oleifera leaves* on red blood cells count and white blood cell levels of obese anemic rats.

Parameters / Groups	RBCs (ml/cmm)	WBCs (Th/cmm)	Platelet (Th/cmm)
Control –ve	9.80±0.17^{a}	4.81±0.09^{d}	165.80±3.29^{a}
Control +ve	3.20±0.15^{e}	9.65±0.17^{a}	93.43±1.84^{e}
***M. oleifera* leaves (5%)**	4.85±0.25^{d}	7.26±0.50^{b}	125.10±2.88^{d}
***M. oleifera* leaves (7.5%)**	5.96±0.24^{c}	6.96±0.08^{b}	138.63±1.33^{c}
***M. oleifera* leaves (10%)**	8.46±0.27^{b}	6.05±0.12^{c}	152.18±4.69^{b}

Results are expressed as mean ± SE.
Values in each column which have different letters are significantly different at (P<0.05).

Effect of *M. oleifera* leaves on mean corpuscular volume, corpuscular hemoglobin concentration and lymphocytes of obese anemic rats.

The impact of M. oleifera leaves on the concentration of lymphocytes in the rats' blood, mean corpuscular volume, and mean corpuscular haemoglobin was shown in Table (6). The results showed that positive control group had significant (P<0.05) decrease in MCV, MCHC and lymphocytes compared to the negative control group. Data show that rats supplemented with *M. oleifera* leaves at the (5, 7.5 and 10%) had significant increase in MCV, MCHC and lymphocytes compared with the positive control group. Moreover, there was no significant change in lymphocytes between the two tested levels at the (5 and 7.5%). The highest increase in MCV, MCHC and lymphocytes was observed at the groups supplemented with *M. oleifera* leaves at 10%.

According to **Fatema *et al*., (2020),** *M. oleifera* leaf has a preventive effect against anemia caused by cyclophosphamide. **Rabeh *et al*., (2021)** observed that as compared to anaemic rats, moringa extract significantly increased MCV, MCHC, and lymphocytes. While, these results are in accordance with those of **Hermayanti *et al*., (2020)** reported that total iron binding capacity, MCV, and MCH did not appear to be impacted by moringa leaf extract or vitamin C. Natural antioxidant

compounds such as vitamin E, C, minerals such as iron, calcium, carotenoids, flavonoids and polyphenols present in moringa led to improvement in the level of red blood cells, hemoglobin, MCV and MCHC in both (healthy and anemic) rats **(Rabeh *et al*., 2021).**

Table (6): Effect of *M. oleifera* leaves on mean corpuscular volume, corpuscular hemoglobin concentration and lymphocytes of obese anemic rats.

Parameters / Groups	MCV (mm^3)	MCHC (g/dl)	Lymphocytes (%)
Control –ve	84.23±2.97[a]	49.92±1.16[a]	65.55±1.24[a]
Control +ve	47.02±3.06[d]	23.60±0.95[d]	30.90±3.69[d]
***M. oleifera* leaves (5%)**	59.16±4.81[c]	27.76±2.08[d]	39.00±0.72[c]
***M. oleifera* leaves (7.5%)**	68.79±0.61[b]	36.15±1.97[c]	43.82±0.87[c]
***M. oleifera* leaves (10%)**	79.00±1.69[a]	42.53±1.60[b]	50.64±1.26[b]

Results are expressed as mean ± SE.
Values in each column which have different letters are significantly different at (P<0.05).

Effect of *M. oleifera* leaves on liver functions of obese anemic rats

The impact of M. oleifera leaves on the liver functions of obese, anemic female rats was shown in Table (7). Rats fed basal diet (positive control group) revealed a significant increase (p<0.05) of AST, ALT and ALP as compared with those of negative control group. Supplementation with *M. oleifera* leaves at the tested levels significantly decreased (P<0.05) serum AST, ALT and ALP as compared to the positive control group. There was a significant difference in AST, ALT and ALP among all the groups treated with *M. oleifera* leaves. The highest improvement in AST, ALT and ALP was observed at the group supplemented with *M. oleifera* leaves at 10%.

The results are agreed with the results of **Negm, (2019); Al-Gebily *et al*., (2019); El-Bashshuti and Shanshan, (2020) and Rabeh *et al*., (2021)** observed that M.

oleifera extract had a therapeutic effect on obese rats that is hepato-nephroprotective; this result is also matched with **(Mabrouki *et al*., 2020).** Similarly, *M. oleifera* demonstrated hepatoprotective effect on the liver of obese female rats **(El-Bashshuti and Shanshan, 2020 and Fakurazi *et al*., 2012).**

Table (7): Effect of *M. oleifera* leaves on liver functions of obese anemic rats.

Parameters / Groups	AST	ALT	ALP
	(µ/dl)		
Control –ve	82.66±2.97^{e}	29.80±1.22^{d}	63.76±1.86^{e}
Control +ve	154.94±2.84^{a}	62.63±1.12^{a}	117.45±1.42^{a}
***M. oleifera* leaves (5%)**	129.90±2.17^{b}	47.00±2.00^{b}	102.32±1.07^{b}
***M. oleifera* leaves (7.5%)**	120.63±1.12^{c}	39.76±1.64^{c}	95.69±1.49^{c}
***M. oleifera* leaves (10%)**	111.10±1.78^{d}	32.60±2.27^{d}	83.66±2.54^{d}

Results are expressed as mean ± SE.
Values in each column which have different letters are significantly different at (P<0.05).

Effect of *M. oleifera* leaves on kidney functions of obese anemic rats

The impact of M. oleifera leaves on the kidney functions of obese, anemic rats was shown in Table (8). Rats fed basal diet (positive control group) revealed a significant increase (p<0.05) of urea, uric acid and creatinine as compared with those of negative control group. Supplementation with *M. oleifera* leaves at the tested levels significantly decreased (P<0.05) serum urea, uric acid and creatinine as compared to the positive control group. There were no significant changes in urea, uric acid and creatinine between the two tested levels at the (5 and 7.5%) *M. oleifera* leaves. The highest improvement in urea, uric acid and creatinine was observed at the groups supplemented with *M. oleifera* leaves at 10%. These findings were in line with those of **Metwally *et al*., (2017),** who found that M. oleifera did not differ from the untreated obese group in terms of creatinine and BUN levels (P > 0.05). **Saleh and Sarhat, (2019)** observed that The treatment of M. Oleifera's ethanolic extract had a substantial impact on lowering the diabetic rats' urea and creatinine concentrations to levels comparable to those of control and metformin-treated diabetic animals. *M. oleifera* extract is recommended for kidney patients **(Fakurazi *et al*., 2012).**

Table (8): Effect of *M. oleifera* leaves on kidney functions of obese anemic rats.

Parameters / Groups	Urea	Uric acid	Creatinine
	(mg/dl)		
Control –ve	42.16±1.77^{d}	2.19±0.25^{d}	0.397±0.014^{d}

Control +ve	85.63±2.28[a]	5.44±0.26[a]	1.00±0.008[a]
M. oleifera leaves (5%)	74.03±3.01[b]	4.00±0.11[b]	0.923±0.02[b]
M. oleifera leaves (7.5%)	69.06±0.83[b]	3.70±0.15[b]	0.886±0.01[b]
M. oleifera leaves (10%)	57.17±1.60[c]	2.96±0.08[c]	0.585±0.01[c]

Results are expressed as mean ± SE.
Values in each column which have different letters are significantly different at (P<0.05).

Effect of *M. oleifera* leaves on lipid profile of obese anemic rats

The data from table (9) revealed that, the control positive group has shown a significant increase (P<0.05) in the mean values of serum TC, TG, LDL-c and VLDL-c, while the mean value of HDL-c was significantly decreased compared with the control negative group. Obese anemic rats fed on *M. oleifera* leaves at the three tests levels had significant decrease in serum TC, TG, LDL-c and VLDL-c, while the mean value of HDL-c was significantly increased (P<0.05) in the all treated groups as compared to the positive control group. Moreover, there were significant differences in serum levels of TC, TG, HDL, LDL-c and VLDL-c among the three treated groups. The highest improvement in TC, TG, LDL-c and VLDL-c was observed at the group supplemented with 10% *M. oleifera* leaves. Also, the highest increase in HDL-c was observed at the group supplemented with 10% *M. oleifera* leaves.

These results were consistent with **Metwally *et al*., (2017)** observed that obese females were administered an ethanolic M. oleifera extract, improved obesity and atherogenic dyslipidemia. This was in accordance with **El-Gindy *et al*., (2017)** indicated that moringa leaves significantly improved HDL-c of rabbits under moderate heat stress. Lower levels of TG, TG, LDL, and higher levels of HDL indicate that moringa leaves has a great hypolipidemic activity through control the mechanisms involved in lipids elimination from the body **(Pratik *et al*., 2013 and Negm, 2019).**

Flavonoids and saponins present in moringa led to increase HDL and reduce LDL and VLDL in hypercholesterolemic rats. In this concern, **Othman *et al*., (2019); Negm, (2019) and El-Bashshuti and Shanshan, (2020) and El-Shehawi *et al*., (2021)** revealed that *M. oleifera* decreased BWG% , prevented the increase in LDL-c and TG and increased HDL-c compared to HFD-supplemented rats.

Table (9): Effect of *M. oleifera* leaves on lipid profile of obese anemic rats.

Parameters	TC	TG	HDL-C	LDL-C	VLDL-C

Groups	(mg/dl)				
Control –ve	122.23±1.82^{e}	75.28±2.62^{e}	64.16±0.99^{a}	43.00±1.58^{e}	15.05±0.52^{e}
Control +ve	174.93±1.79^{a}	136.90±2.29^{a}	23.96±1.27^{e}	123.58±2.64^{a}	27.38±0.45^{a}
***M. oleifera* leaves (2.5%)**	155.45±1.10^{b}	120.73±1.01^{b}	40.53 ± 1.12^{d}	90.77±2.04^{b}	24.14±0.20^{b}
***M. oleifera* leaves (5%)**	140.87±1.68^{c}	113.56±3.22^{c}	47.43± 1.78^{c}	70.72±2.76^{c}	22.71±0.64^{c}
***M. oleifera* leaves (7.5%)**	132.15±1.75^{d}	102.64±1.28^{d}	52.03± 1.06^{b}	59.59±1.92^{d}	20.52±0.25^{d}

Results are expressed as mean ± SE.
Values in each column which have different letters are significantly different at ($P<0.05$).

Conclusions: The results of the current research declared that fortification with Moringa leaves powder has positive effects on obese anemic rats. Moringa leaves can be considered a super food due to its high content of nutrients such as protein, minerals، vitamins, phyto nutrients, essential fatty acids and amino acids so it can be used effectively as nutritional supplements to enhance human health and alleviating anemia.

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