UTILIZATION OF WHEY CHEESE AND OAT WHOLE-GRAIN TO CONTROLLING WEIGHT GAIN IN RATS FED ON HIGH FAT DIET

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ABSTRACT

Nowadays foods are not purposed to only fulfill hunger and to supply vital nutrients for humans but, also to prohibit nutrition-related diseases and improve physical and mental well-being of the consumers. In this respect, functional foods play distinguished role. Therefore, the aim of this study was to examine the effect of addition of whey cheese and oat whole grain powder in biscuits and crackers by different formulae to produce low calorie biscuits and crackers, and to evaluate their effectiveness on weight gain and lipid profiles in rats fed on a high-fat diet. Feeding rats on different biscuits and crackers formulae recorded reduced body weight gain, adipocyte histological alteration. Feeding rats led to a significant reduction in the levels of LDL and total cholesterol and an improvement in the HDL levels.

In conclusion, consumption of whey cheese and oat whole-grain in form of low calorie biscuits and crackers formula reduced the adipocytes histological changes, resulting in reduction of the body weight of the rats.
Keywords: Whey Cheese, Oat, Weight Gain, Lipid Profile, Rats.

INTRODUCTION

Overweight is a condition due to excess energy intake that stored in the form of fat in adipose tissues to store fat in the human body. The adipose tissue increases either in cell size or in cell number that may negatively affect

other organs like the heart, pancreas and liver. Nowadays, overweight is considered as a medical health problem. The risk of becoming overweight or obese is affected by different factors, including genetics, inactive lifestyle، consumption of high fat or carbohydrates diets, certain medications, social and economic issues and lack of sleep. Generally, overweight and obesity are linked to health problems such as cardiovascular disease، hypertension, diabetes and colon cancers (ASN, 1998; Hruby and Hu, 2015; Stenkula and Erlanson-Albertsson, 2018).

Whey cheese is a liquid obtained after the precipitation of milk casein in the cheese making process. The production of whey cheeses is based on the denaturation and coagulation of the water soluble milk proteins present in the whey when it is heated at temperatures above 85°C (Jovanović *et al*., 2005). Coagulation of milk casein by rennet produced the so called sweet whey, while that produced by lactic acid is called acid whey (Panesar *et al*., 2007). Whey constitutes high values of lactose, proteins, vitamins and minerals. The average content of whey dry residue is: 70% lactose, 14% proteins, 9% minerals, 4% fats and 3% lactic acid (Blažić *et al*., 2017). The protein bioactive component glycomacropeptide (a milk-protein-derived peptide) comprises 15–20% of proteins which is a rich source of branched-chain amino acids (leucine, isoleucine, and valine), essential amino acids (cysteine) and peptides as well, which is likely the reason that it is highly effective at promoting protein synthesis (Børsheim *et al*., 2002; Hulmi *et al*. 2010). Cysteine amino acid, a precursor of glutathione, the non-enzymatic thiol

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antioxidant plays key role in reducing oxidative stress, regulating cellular processes, imbalance of which can trigger diseases (Trachootham *et al*., 2008; Forman *et al*., 2009; Seidkhani-Nahal *et al*., 2019).The high nutritional value of whey cheese target towards the generation of value-added products for food industries (Lappa *et al*., 2019).

Oat (Avena sativa L) (common oat) is a cereal grain belongs to the Poaceae family and is the most important among the cultivated oats. It is suitable for human consumption and is a nutrient-rich food contains high amounts of valuable nutrients such as soluble fibers, proteins, unsaturated fatty acids, vitamins, a number of important minerals, β-glucan, a mixed-linkage polysaccharide, which forms an important part of oat dietary fiber, and also contains various other phytoconstituents like flavonoids (Singh *et al*., 2013; Nałęcz *et al*., 2017). The dietary fiber complex showed antioxidant and antiinflammatory activities in vitro and in vivo studies (Chu *et al*., 2013; Yang *et al*., 2014; Marmouzi *et al*., 2017).

Worldwide, for the past few years the demand for bakery products like biscuits and crackers are increasing and such ready-to-eat, inexpensive and convenient processed food products which are widely consumed. Different types of biscuits and crackers contain high contents of fat, sugar and calories, but they are low in fiber, vitamins, and minerals. Thus, they do not correspond to the rules of a healthy diet (Karklina *et al*., 2012; Park *et al*., 2015).

The development of a commercially viable biscuit and crackers attractive to children and adults that will have a significant reduction in fat and sugar, with fewer calories and contain nutrients like whey and cereals designed to reduce the risk of diseases are highly desirable (Boobier *et al*., 2006; Kaur *et al*., 2014; Marques *et al*., 2016).

Therefore the aim of this study was designed to investigate the proximate composition of the Sensory attributes related to cheese whey (food processing wastes) and oat whole grain powder in the form of functional bakery products (biscuit and cracker) formulates as well as evaluation for their best ratio effect on obese rat model induced by high fat diet through the effect on the body weight gain and the lipid profile.

MATERIALS AND METHODS

Materials:

Sweet whey cheese and whole grain oat were obtained in November 2018 from Food and Technology Research Institute, Agriculture Research Center, Giza. Egypt. The whole oat grains were blended in a blender until have turned into a soft powder. While, Corn oil, margarine, sugar, baking powder, salt and yeast were obtained from local market. Whereas, commercial kits used for determining total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C) were purchased from Biodiagnostic Co. Dokki, Egypt.

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Animals: Male Albino Wistar rats with an average weight of 130±10 g were obtained in January 2019 from laboratory Animal Breeding of National Organization of Drug Control and Research (NODCAR), Giza, Egypt.

Preparation of biscuits formulates: Biscuit samples were processed from dough containing 10% whole oat as substituting level for wheat flour and containing whey cheese by blending ratio as shown in Table (1) based on the standard method according to Manley, (2001).

Table (1): Biscuit formulas

Ingredients	Biscuit blends				
	B_0	**B_1**	**B_2**	**B_3**	**B_4**
Wheat flour (g)	200	180	180	180	180
Whole oat (g)	0	20	20	20	20
Margarine (g)	50	45	40	35	30
Sugar (g)	60	60	60	60	60
Baking powder (g)	2.5	2.5	2.5	2.5	2.5
Salt (g)	1.5	1.5	1.5	1.5	1.5
Whey cheese (ml)	0	10	20	30	40
Water (ml)	40	30	20	10	0

B_0: control Biscuits; B_1, B_2, B_3 & B_4: Biscuits formula with 10% Whole Oat of Wheat flour and whey cheese by blending ratio.

Preparation of crackers formulates: The dough of crackers prepared based on the standard method according to Manley, (2001) by mixing wheat flour with 10% whole oat as substituting levels, margarine, yeast, baking powder, salt, water and whey cheese by blending ratio, as shown in Table (2).

Table (2): Crackers formulas

Ingredients	Cracker blends				
	C_0	C_1	C_2	C_3	C_4
Wheat flour (g)	100	90	90	90	90
Whole oat (g)	0	10	10	10	10
Margarine (g)	20	18	16	14	12
Yeast (g)	1	1	1	1	1
Salt (g)	1.5	1.5	1.5	1.5	1.5
Baking powder (g)	1.25	1.25	1.25	1.25	1.25
Whey cheese (ml)	0	32.5	65	97.5	130
Water (ml)	130	97.5	65	32.5	0

C_0: control Crackers; C_1, C_2, C_3 & C_4: Crackers formula with 10% Whole Oat of Wheat flour and Whey cheese by blending ratio

Methods of analysis

Proximate chemical analysis for biscuits and crackers: All the proximate analysis including; moisture, protein, fat, crude fibers, carbohydrates and ash in biscuits and crackers formula were determined according to the methods of AOAC, (2012).

Sensory attributes for biscuits and crackers: The sensory characteristics of the final product of biscuits and crackers were evaluated according to Watts *et al*., (1989). Ten panelists from the staff members of National Organization of Drug Control and Research (NODCAR), were chosen to evaluate the products. The panelists were asked to score appearance, surface color, taste, texture, aroma and overall acceptability each on a scale of 1(extremely poor) to 10 (excellent).

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Biological experiment design: The experiment was conducted on forty eight male Albino Wistar rats; they were housed in special cages under controlled conditions. The animals were fed on basal diet according to AIN-93 guidelines (Reeves *et al*., 1993) and were provided with water ad-libitum during the experimental period.

This study aimed to compare the effect of the eight different types of diets. After feeding on basal diet for 7 days (adaptation period), six rats were kept as a control which fed basal diet during the experiment period G1 (negative control). The other groups (from G2 to G8) were fed with high-fat diet; HFD (basal diet containing 10% animal fat); the compositions of these diets are shown in Table (3). All groups of rats (6 rats each) were fed the experimental diets for 60 days as follows:

- Group (1) rats were fed on a basal diet (negative control).
- Group (2) rats were fed on HFD (positive control).
- Group (3) rats were fed on HFD + control Biscuit.
- Group (4) rats were fed on HFD + low calorie Biscuit formula three.
- Group (5) rats were fed on HFD + low calorie Biscuit formula four.
- Group (6) rats were fed on HFD + control crackers.
- Group (7) rats were fed on HFD + low calorie crackers formula three.
- Group (8) rats were fed on HFD + low calorie crackers formula four.

Table (3): Feed composition of rat groups (%)

Groups Composition %	1	2	3	4	5	6	7	8
Casein	15	15	15	15	15	15	15	15
Corn oil	10	5	5	5	5	5	5	5
Animal Fats	-	10	10	10	10	10	10	10
Cellulose	5	5	5	5	5	5	5	5
Salt mix.	4	4	4	4	4	4	4	4
Vitamin mix.	1	1	1	1	1	1	1	1
Starch	65	60	45	45	45	45	45	45
Biscuits powder	-	-	15	15	15	-	-	-
Crackers powder	-	-	-	-	-	15	15	15

The changes in body weight were recorded weekly, blood samples were also taken from the retro-orbital plexus of the eyes from all rats of each group at the end of the experiment; the abdominal fat was excised immediately after bleeding for histopathological examination. Serum was obtained from blood samples by centrifugation at 1500 rpm for 15 min at an ambient temperature for analysis.

Biochemical investigation: Enzymatic determination of cholesterol was carried out according to Allain *et al*.,(1974). Fully enzymatic determination of total triglycerides in serum was measured colorimetrically at 546 nm, according to Fossati and Prencipe (1982). The HDL was determined according to the method of Lopes- Virella (1977). While, the low-density lipoproteins (LDL-c) were calculated using Friedewald formula (Friedewald *et al*., 1972) as follows:

LDL-cholesterol= Total cholesterol - (HDL-cholesterol) - (Triglycerides/5)

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Histopathological Examination: Autopsy samples were taken from the abdominal fat of the different groups of rats and used for histological examination as described by Banchroft *et al*, (1996).

Statistical analysis: Descriptive values of data were expressed as the Mean± Standard error (SE) and they were analyzed statistically using the one-way analysis of variance (ANOVA) followed by Duncan's test. In all cases $p<0.05$ was used as the criterion of statistical significance by SAS program (SAS, 2003).

RESULTS AND DISCUSSION

Proximate composition of biscuits and crackers:

Chemical Composition of Biscuits: Data given in Table (4) indicated the results of proximate composition of biscuits, where the biscuits formula (B4) had the highest moisture (5.13%), ash (1.76%) and carbohydrates (33.00%) and the lowest fat (16.71%) contents as well as the lowest calories value (314.43) compared with the other studied of biscuits formulae. In addition, the biscuits formulae (B3) recorded significant increase in total carbohydrate (32.10) when compared with formula (B1). While the protein contents showed no significant differences between the biscuit formulae. These findings are in accordance with those reported by Zaki and Hussien, (2018).

Table (4): Influence of oat and whey cheese addition on proximate composition of biscuits formulas (g/100g)

Analysis	Biscuits samples				
	B_0	B_1	B_2	B_3	B_4
Moisture	**$3.56^{cd} \pm 0.06$**	**$3.91^{bc} \pm 0.05$**	**$4.08^{b} \pm 0.08$**	**$3.49^{d} \pm 0.22$**	**$5.13^{a} \pm 0.06$**
Ash	**$0.99^{c} \pm 0.01$**	**$1.49^{b} \pm 0.03$**	**$1.50^{b} \pm 0.01$**	**$1.47^{b} \pm 0.01$**	**$1.76^{a} \pm 0.02$**
Fat	**$21.13^{a} \pm 0.11$**	**$20.1^{b} \pm 0.07$**	**$19.55^{c} \pm 0.04$**	**$19.64^{c} \pm 0.07$**	**$16.71^{d} \pm 0.08$**
Protein	**$8.0^{a} \pm 0.01$**	**$8.0^{a} \pm 0.01$**	**$8.0^{a} \pm 0.01$**	**$8.0^{a} \pm 0.01$**	**$8.0^{a} \pm 0.01$**
Fiber	**$34.63^{b} \pm 0.13$**	**$35.73^{a} \pm 0.44$**	**$35.47^{ab} \pm 0.34$**	**$35.3^{ab} \pm 0.21$**	**$35.4^{ab} \pm 0.15$**
Carbohydrate	**$31.69^{bc} \pm 0.09$**	**$30.78^{c} \pm 0.58$**	**$31.4^{bc} \pm 0.39$**	**$32.1^{ab} \pm 0.11b$**	**$33.0^{a} \pm 0.15$**
Caloric Kcal/100g	**$348.9^{a} \pm 0.86$**	**$335.9^{b} \pm 1.74$**	**$333.6^{b} \pm 1.42$**	**$337.13^{b} \pm 0.53$**	**$314.43^{c} \pm 0.96$**

Data are mean ± SE, n=3, means with the same letter in the same raw are not significantly different at 5%

Chemical Composition of Crackers: As regard to data given in Table (5) indicated the results of proximate composition of crackers, where the crackers formulae (C3 and C4) had the highest moisture (11.52; 10.96 %) and ash (2.40; 2.58 %) respectively. Moreover, the lowest fat (13.89; 13.89 %) contents and the lowest calories value (266.99; 273.69 %), respectively, as compared with the control cracker formula. In addition, the protein contents showed no significant differences ($p \geq 0.05$) between the crackers formulae. These results are in harmony with those obtained by (El-Batawy *et al*., 2018) when utilized cheese whey to improve the quality of Egyptian Baladi bread.

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Table (5): Influence of oat and whey cheese addition on proximate composition of crackers formulas (g/100g)

Analysis	Crackers samples				
	C_0	C_1	C_2	C_3	C_4
Moisture	**$5.35^{c} \pm 0.20$**	**$7.48^{b} \pm 0.02$**	**$10.92^{a} \pm 0.74$**	**$11.52^{a} \pm 0.10$**	**$10.96^{a} \pm 0.32$**
Ash	**$1.81^{c} \pm 0.05$**	**$2.22^{b} \pm 0.03$**	**$2.49^{a} \pm 0.07$**	**$2.40^{ab} \pm 0.06$**	**$2.58^{a} \pm 0.09$**
Fat	**$19.09^{a} \pm 0.11$**	**$17.49^{b} \pm 0.12$**	**$17.56^{b} \pm 0.03$**	**$13.89^{c} \pm 0.22$**	**$13.89^{c} \pm 0.04$**
Protein	**$10.06^{a} \pm 0.00$**	**$10.06^{a} \pm 0.00$**	**$10.06^{a} \pm 0.00$**	**$10.06^{a} \pm 0.00$**	**$10.1^{a} \pm 0.01$**
Fibers	**$37.40^{a} \pm 0.20$**	**$37.33^{a} \pm 0.43$**	**$36.5^{ab} \pm 0.57$**	**$36.7^{ab} \pm 0.26$**	**$35.4^{b} \pm 0.68$**
Carbohydrates	**$26.29^{ab} \pm 0.36$**	**$25.43^{b} \pm 0.38$**	**$22.47^{c} \pm 0.23$**	**$25.43^{b} \pm 0.43$**	**$27.1^{a} \pm 0.48$**
Caloric Kcal/100g	**$317.18^{a} \pm 0.42$**	**$299.33^{b} \pm 2.25$**	**$288.16^{c} \pm 0.66$**	**$266.99^{e} \pm 0.5$**	**$273.69^{d} \pm 1.73$**

Data are mean ± SE, n=3, means with the same letter in the same raw are not significantly different at 5%

Influence of oat and whey cheese addition on the sensory attributes biscuits and crackers: The data presented in Tables (6) and (7) showed the results of sensory evaluation in terms of appearance, surface color, texture, taste, aroma and overall acceptability of biscuits and crackers samples supplied by different concentrations of oat and whey cheese, respectively. Data as regard to biscuits formulae showed that addition of oat and whey cheese improved all of the sensory attributes scores without significant ($p \geq 0.05$) different as compared to the control formula. These findings are supported by the observation of Youssef *et al*., (2016), who reported that highly acceptable biscuits formula could be obtained by incorporating 10%

oat powders in the wheat biscuits formulation and oat flour has nutritional value due to its high levels of dietary fibers.

Table (6): Influence of oat and whey cheese addition on biscuits Sensory attributes

Sensory attributes	Biscuits samples				
	B_0	**B_1**	**B_2**	**B_3**	**B_4**
Appearance	$7.70^a \pm 0.30$	$7.60^a \pm 0.37$	$8.30^a \pm 0.26$	$7.40^a \pm 0.43$	$8.20^a \pm 0.25$
Surface color	$7.30^a \pm 0.37$	$7.80^a \pm 0.29$	$7.90^a \pm 0.23$	$7.70^a \pm 0.40$	$7.50^a \pm 0.56$
texture	$7.30^a \pm 0.37$	$7.90^a \pm 0.28$	$7.50^a \pm 0.31$	$7.50^a \pm 0.56$	$7.50^a \pm 0.40$
Taste	$7.50^a \pm 0.48$	$7.70^a \pm 0.37$	$7.50^a \pm 0.37$	$7.90^a \pm 0.31$	$7.20^a \pm 0.42$
Aroma	$7.50^a \pm 0.48$	$7.70^a \pm 0.40$	$7.60^a \pm 0.43$	$7.60^a \pm 0.50$	$7.60^a \pm 0.40$
Overall	$7.40^a \pm 0.27$	$8.00^a \pm 0.42$	$8.00^a \pm 0.33$	$8.10^a \pm 0.41$	$8.10^a \pm 0.23$

Data are mean ± SE, n=10, Different uppercase superscript letters in the same lines represent statistically significant data at 5%.

While, in crackers samples the appearance, texture, taste and the overall acceptability of crackers in formulae three and four showed significant ($p \geq 0.05$) increase as compared to the results of the control formula of crackers.

The results of the current study are in harmonization with those obtained by a previous study of Swapna and Rao, (2016), who concluded that 25 % of oats replacement of refined wheat flour showed good quality biscuits. Also, muffins incorporated with 10% oat fibers showed more sensory score than the control as reported by (Bhise and Kaur, 2015). In the same manner substitution of water with whey or permeate in baladi bread formula especially 100% could be enhance the sensory properties according to (El-Batawy *et al*., 2018).

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Table (7): Influence of oat and whey cheese addition on crackers Sensory attributes

Sensory attributes	Crackers samples				
	C0	C1	C2	C3	C4
Appearance	7.20b ± 0.36	8.00a ± 0.21	8.20a ± 0.20	8.20a ± 0.20	8.20a ± 0.25
Surface color	7.40a ± 0.37	7.90a ± 0.23	8.10a ± 0.28	8.20a ± 0.20	8.10a ± 0.23
texture	6.50b ± 0.40	7.80a ± 0.36	7.20ab ± 0.36	7.70a ± 0.30	7.60ab ± 0.43
Taste	6.50b ± 0.40	7.70a ± 0.26	7.50a ± 0.43	8.10a ± 0.28	7.90a ± 0.31
Aroma	7.40a ± 0.40	7.70a ± 0.33	7.80a ± 0.39	8.30a ± 0.26	7.80a ± 0.29
Overall	7.20b ± 0.36	7.80ab ± 0.29	7.90ab ± 0.31	8.40a ± 0.27	8.20a ± 0.20

Data are mean ± SE, n=10, Different uppercase superscript letters in the same lines represent statistically significant data at 5%.

Biological evaluation:

Growth rate in rats: The effect of whey cheese and oat whole-grain powder in form of normal or low calorie biscuits and crackers formula treatment groups on some growth parameters in rats fed on high fat diet are presented in (Table 8). As shown, all groups had similar body weight at the beginning of the experiment ($p \geq 0.05$). The lowest final body weight and weight gain was recorded for the groups five and six (13.0 and 7.3 % less than the positive control, $p \geq 0.05$ respectively). Also other treatment groups recorded slight decrease on weight gain observed in groups three and seven. Meanwhile, an increment was noticed increase in weight gain in groups four and eight but not significant with positive control group. These observations are agreed with Bais *et al*., (2014; Hong *et al*., 2015).

The present study provide that feeding on high fat diet for 60 days was in line with Peng *et al*., (2013), who found that oat supplementation with HFD by 7.5% previously showed effective and significant reduction in rats body weight.

Table (8): Growth rate parameters of different experimental rat groups

Parameters Groups	Initial weight (g)	Final weight (g)	weight gain (g)*
1	$140.0^{a} \pm 4.47$	$262.0^{b} \pm 9.70$	122.0 ± 9.70
2	$142.0^{a} \pm 3.74$	$300.0^{a} \pm 11.40$	$158.0^{a} \pm 8.00$
3	$138.0^{a} \pm 3.74$	$288.0^{ab} \pm 8.00$	150.0 ± 8.37
4	$142.0^{a} \pm 3.74$	$310.0^{a} \pm 8.94$	$168.0^{a} \pm 8.60$
5	$138.0^{a} \pm 3.74$	$260.0^{b} \pm 12.65$	$122.0^{bd} \pm 9.70$
6	$140.0^{a} \pm 4.47$	$278.0^{ab} \pm 8.60$	$138.0^{d} \pm 5.83$
7	$134.0^{a} \pm 6.00$	$286.0^{ab} \pm 13.27$	$152.0^{ae} \pm 11.58$
8	$138.0^{a} \pm 5.83$	$310.0^{a} \pm 10.49$	$172.0^{aef} \pm 15.94$

Data are mean ± SE, n=5, Different uppercase letters in the same column represent statistically significant data at 5%. Whereas; 1: Normal control group; 2: HFD group; 3: HFD + control Biscuit group; 4: HFD + low calorie Biscuit formula three group; 5: HFD + low calorie Biscuit formula four group; 6: HFD + control cracker group; 7: HFD + low calorie cracker formula three group; 8: HFD + low calorie cracker formula four group. * Data in weight gain column represented significant data at 5% by superscripts (a) against group (1), (b) against group (2), (c) against group (3), (d) against group (4), (e) against group (5) and (f) against group (8).

Lipid profiles of different groups: Regarding serum lipids, results in Table (9) ascertained that there were significant differences among all treatments in the rats' serum lipid profiles ($p \geq 0.05$). The whey cheese and oat whole-grain

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powder in form of normal or low calorie biscuits and crackers formula treatment groups exhibited significantly decreased serum total cholesterol, triglycerides and LDL-cholesterol levels. While, elevate the HDL-cholesterol levels in comparing the rat group fed on high fat diet only. This trend has also been reported by Wronkowska *et al*, (2018) who demonstrated that acid whey supplementation to rats resulted significant decrease in triglycerides.

Table (9): Lipid profiles of different rat groups at the End of experimental period

Parameters Groups	T. Cholesterol (mg/dl)	Triglycerides (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
1	**$121.53^{cd} \pm 24.67$**	**$126.37^{cd} \pm 32.62$**	**$46.85^{ab} \pm 8.82$**	**$49.40^{c} \pm 13.47$**
2	**$266.38^{a} \pm 10.48$**	**$306.77^{a} \pm 24.31$**	**$21.20^{b} \pm 2.65$**	**$183.83^{a} \pm 8.93$**
3	**$164.77^{c} \pm 25.40$**	**$240.00^{ab} \pm 42.52$**	**$52.44^{a} \pm 4.82$**	**$64.33^{c} \pm 13.82$**
4	**$161.27^{c} \pm 9.61$**	**$44.58^{e} \pm 7.12$**	**$73.53^{a} \pm 9.16$**	**$78.83^{bc} \pm 6.20$**
5	**$105.28^{d} \pm 19.05$**	**$93.14^{de} \pm 14.28$**	**$47.42^{ab} \pm 3.18$**	**$39.23^{c} \pm 16.91$**
6	**$215.32^{b} \pm 16.00$**	**$189.55^{bc} \pm 18.52$**	**$69.31^{a} \pm 16.72$**	**$108.10^{b} \pm 18.59$**
7	**$130.30^{cd} \pm 16.14$**	**$105.49^{de} \pm 9.23$**	**$68.53^{a} \pm 14.10$**	**$40.67^{c} \pm 9.85$**
8	**$151.57^{cd} \pm 6.81$**	**$82.79^{de} \pm 12.81$**	**$61.07^{a} \pm 5.62$**	**$73.95^{bc} \pm 1.96$**

Data are mean ± SE, n=5, Different uppercase letters in the same column represent statistically significant data at 5%. Whereas; 1: Normal control group; 2: HFD group; 3: HFD + control Biscuit group; 4: HFD + low calorie Biscuit formula three group; 5: HFD + low calorie Biscuit formula four group; 6: HFD + control cracker group; 7: HFD + low calorie cracker formula three group; 8: HFD + low calorie cracker formula four group.

Histopathological investigation: Abdominal fat was evaluated by histopathological alterations finding in Micrographs (from A to H). The

normal histological structure of the adipose tissue with hexagonal shaped adipocytes and peripheral flattened nucleus were recorded in the normal control group; (Micrograph, A). There was congestion in the blood vessels between the lobules were noticed in the positive control group fed on high fat diet (HFD); (Micrograph, B). The abdominal fat sections obtained from animals treated with HFD plus control biscuit and low calorie biscuit formula three showed no histopathological alteration as recorded in (Micrograph, C & D). While, the abdominal fat sections obtained from animals treated with HFD plus low calorie biscuit formula four observed congestion in the blood vessels between the cells (Micrograph E). The abdominal fat sections obtained from animals treated with HFD plus all treatment of crackers showed no histopathological alteration as recorded in (Micrograph, F;G&H).

The histopathological changes in treated groups with normal or low calorie formula of biscuits and crackers except for low calorie biscuit formula four as compared to that induced with high fat di*et al*one indicated marked protective effects of whey cheese and oat addition against weight gain. These results were previously supported by Althwab *et al*., (2020), who reported that whey supplementation efficacy in preventing overweight and obesity by lowering weight gain and serum levels of lipids.

CONCLUSION

As appeared from the aforementioned data, treatment fortified with whey cheese and whole-grain oat in form of low calorie biscuits and crackers formula can be used as effective food supplements for reducing overweight

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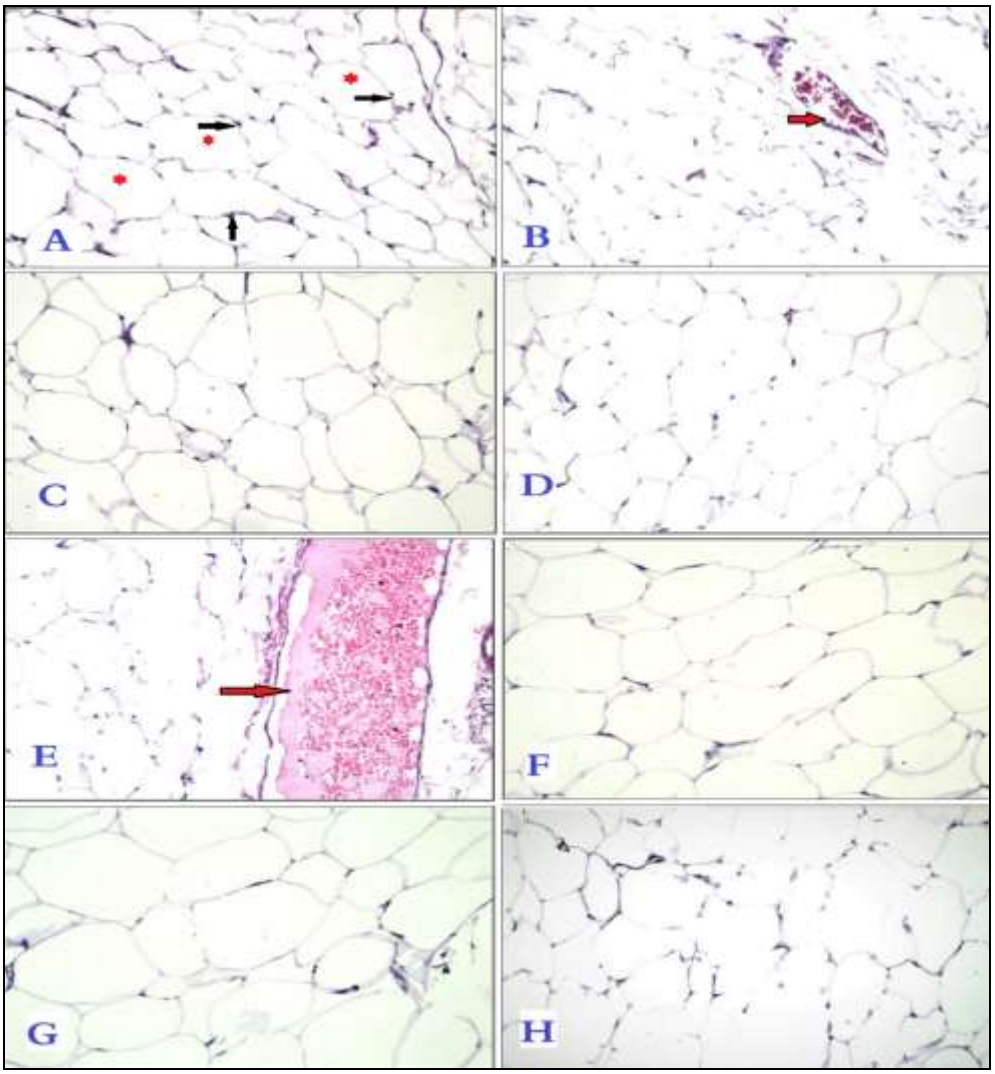
and obesity in rats by lowering weight gain, adipocyte histopathological alteration and serum levels of lipids profile; confirmed protective ability of these treatments.



Figures (A- H): Represent photomicrographs of abdominal fat tissue sections of rat groups. (A), is the micrograph of the negative control rat shows normal histological structure of the adipocytes (red star) with hexagonal shape and peripheral flattened nucleus (black arrow). (B) is the micrograph of the HFD group (positive control) rat shows congestion in the blood vessels between the lobules (red arrow). (C) micrograph represents the HFD + control Biscuit group and (D) represents the HFD + low calorie Biscuit formula three group, both show no histopathological alterations. (E), is the micrograph of the HFD + low calorie Biscuit formula four group shows congestion in the blood vessels between the cells (red arrow). While (F), micrograph of the HFD + control crackers group, (G), micrograph of the HFD + low calorie crackers formula three group and (H) micrograph of the HFD + low calorie crackers formula four group show no histopathological alteration. (H & E, 40×).

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الاستفادة من شرش الجبن وحبوب الشوفان الكاملة في التحكم في زيادة الوزن في الفئران التي يتم تغذيتها على نظام غذائي عالي الدهون

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المستخلص

لا تهدف الأطعمة في الوقت الحاضر إلى إشباع الجوع وتوفير العناصر الغذائية الحيوية للبشر فحسب، بل تهدف أيضًا إلى حظر الأمراض المرتبطة بالتغذية وتحسين الرفاهية الجسدية والعقلية للمستهلكين. في هذا الصدد، تلعب الأطعمة الوظيفية دورًا مميزًا. لذلك إستهدفت الدراسة فحص تأثير إضافة شرش الجبن ومسحوق الشوفان الكامل في البسكويت والمقرمشات بنسب مختلفة لإنتاج بسكويت ومقرمشات منخفضة السعرات الحرارية وتقييم فعاليتها على معدل زيادة الوزن وصورة الدهون في الفئران التي تتغذى على غذاء عالي فى الدهون. بالإضافة إلى ذلك، فإن تغذية الفئران على المعاملات المختلفة قللت من معدل زيادة وزن الجسم، والتغيير النسيجي للخلايا الشحمية. وأدت تغذية الفئران على أنواع مختلفة من البسكويت والمقرمشات إلى انخفاض كبير في مستويات البروتين الدهني منخفض الكثافة والكوليسترول الكلي وتحسين مستويات البروتين الدهني عالي الكثافة.

في الختام، فإن تناول شرش الجبن وحبوب الشوفان الكاملة في شكل بسكويت ومقرمشات منخفض السعرات الحرارية قلل من التغيرات النسيجية للخلايا الدهنية ، مما أدى إلى تقليل وزن الجسم للفئران.

الكلمات الدالة: شرش الجبن، الشوفان، الزيادة فى الوزن، صورة ليبيدات الدم، الفئران.