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EFFECT OF FRUCTOOLIGOSACCHARIDES IN *CYNARA SCOLYMUS* AND *ALLIUM CEPA* ON CARBOHYDRATE AND LIPID METABOLISM IN RATS

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ABSTRACT

Fructooligosaccharides (FOS) are dietary fibers found naturally at high concentrations in *Cynara scolymus and Allium cepa* used as natural sources of FOS. FOS have a prebiotic effects which stimulate gut microflora, hypoglycemic and hypocholesterolemic effects. Chemical analysis of dry artichoke and onion revealed the presence of different amounts (g/100g DM) of carbohydrates, proteins and lipids (83.4, 90.3% and 7.5, 6.9% and 1.61, 1.74% respectively). Quantitative and qualitative analysis revealed the presence of kestose, nystose and fructosylnystose as major components. Rats were divided into three groups one fed with control (HCD) and two experimental groups fed with dry artichoke (DA) and dry onion (DO) diets supplemented with 10% FOS/kg diet for 8 weeks. The results showed a high, significant decrease in glucose and lipid profile in sera of rats fed with the two supplemented diets (DA and DO) diets compared with control. Another beneficial effect was the lowering of liver lipids and glycogen content. Thus the FOS supplementation in diets has hypoglycemic, hypolipidemic effects and prevention of cardiovascular diseases.

Key words: dietary fibers, kestose, nystose, cardiovascular diseases and diet.

Abbreviations

(CVD) Cardiovascular diseases
(DA) Dry artichoke diet
(DO) Dry onion diet
(DP) Degree of polymerization
(DP3) Kestose
(DP4) Nystose
(DP5) Fructosylnystose
(FOS) Fructooligosaccharides
(HCD) High carbohydrate diet
(HDL-C) High density lipoprotein cholesterol
(LDL-C) Low density lipoprotein cholesterol
(SCFA) Short chain fatty acids
(TG) Triglycerides
(VLDL-C) Very low density lipoprotein cholesterol

1. INTRODUCTION

During the last decades, carbohydrates are the most abundant naturally occurring organic compounds on the earth. The qualitative and quantitative knowledge of carbohydrate distribution is an essential information in food chemistry.

Cardiovascular diseases (CVD) are one of the most significant diet related health problems, representing a major cause of premature death in western countries. CVD comprise most or all of the following: overweight or obesity with atherogenic triglyceride rich lipoproteins, dyslipidemia, hypertriglyceridemia, hypertension, insulin resistance and glucose intolerance [54]. There are a number of epidemiological studies supporting the dietary regulation of each of metabolic risk factors of the cardiovascular syndrome [25, 46]. The incidence of hyperlipidemia as well as its complications is increasing in the world. Moreover, alterations in sera lipid and lipoprotein levels resulted in a variety of chronic diseases such as CVD and atherosclerosis [37]. Fructooligosaccharides (FOS) are widely used in functional foods throughout the world. FOS are used as a food ingredient in various food items and consumed regularly in appreciable amounts in typical Western diets [77]. The physiological effects of FOS, which are indigestible carbohydrates, especially mixtures of different sugar length such as 1-kestose, nystose and fructofuranosyl-nystose in which, they are safe for diabetic and improve the intestinal flora [4, 40].

FOS have been shown to be indigestible by human enzymes in the small intestine, but are extensively fermented in the large bowel into SCFA (lactate, acetate, propionate and butyrate) which can be absorbed and metabolized by the host [51]. These fatty acids may have various health benefits, including antimicrobial, anticancer, hypolipidemic and hypoglycemic effects [4, 9]. FOS like dietary fibers, they have physiological actions on gastrointestinal tract. FOS is a non-viscous, soluble fiber produced from sucrose via an enzymatic process [10]. Much interest has been focused on the role of fermentable FOS and dietary fibers in the treatment of rats fed diet, diabetes mellitus that retards the rate of carbohydrate digestion and absorption [9, 52].

Obtaining and preserving balance in the intestinal microflora may be done by consumption of products containing nutrients that stimulate the growth of microorganisms [71]. FOS, inulin, isomalto-oligosaccharides (IMO), polydextrose, lactulose and resistant starch are considered as the main prebiotic components through their fermentation in the colon to yield SCFAs [35, 10]. The latter products are referred to as prebiotics, improving the health state of humans [68]. The chain length of FOS is with a degree of polymerization (DP) between 2 and 8 [62]. FOS classified as oligosaccharides with a DP between 3 and 10 [14].

Fibers added to diets, including fermentable carbohydrates such as inulin have an effect on lowering cholesterol and triglycerides [81]. One reason for this lowering effect is the viscous nature of fiber that binds the dietary or biliary cholesterol in the intestinal lumen increasing fecal excretion of the bile acids [66]. The regular consumption of fructans has benefits reduction or prevention of cardiovascular disease [19]. The rats were fed a 10% oligosaccharide diet showed a reduction of glycemia and insulinemia by 17% and 26% respectively [12]. Moreover, FOS affected delaying gastric emptying, and/or shortening their transit time through the GI tract [41].

Research found that FOS consumption increased the number of bifidobacteria and lactobacilli in associated with FOS fermentation may provide digestive benefits and improve gut health [31]. FOS-containing diets increase the levels of Ca and Mg absorption in rats this effect was linearly dose-dependent [57].

Dietary intervention is one of the main therapies proposed in the case of type 2 diabetes patients, and hence non-digestible dietary fibers and polysaccharides are gaining importance for the treatment of diabetic subjects [50].

The aim of the present study was done for production of fructooligosaccharides (FOS) from fruit of globe artichoke (*Cynara scolymus)* and red onion bulb *(Allium cepa)* by simple method with a high yield. The biochemical effect of both FOS, produced on carbohydrate and lipid metabolism in rats was also studied.

2. MATERIALS AND METHODS

2.1. Plant material

Onion (*Allium cepa*) and globe artichoke (*Cynara scolymus*) were purchased from the local market in Cairo, Egypt.

2.2. Preparation of samples

Onion bulb and artichoke fruit were weighed, cut into small pieces, and dried till complete dryness at 60°C. Moisture contents were determined [5]. The dried samples were ground to fine powders, sifted through a 16-mesh sieve and packed in well sealed polyethylene bags and stored at room temperature until use.

Pure compounds of kestose and nystose were obtained from Sigma Company and all solvents used in all experiments were HPLC grade and all the chemicals used were highly pure.

2.3. Animals and diets

Eighty four male albino rats (*Rattus norvgicus*), 7 weeks of age and weighed about 110±1.32 g. Rats were obtained from National Research Center breeding unit and fed with a commercial diet and used as experimental animals. The rats were acclimatized for a period of two weeks before the experiments began The rats were then divided into three groups, 28 rats each, on the basis of their body weight and individually housed in wire screen metabolic cages. The animals were maintained on food and water ad libitum. The animal room was controlled (25±1ºC) and had a 12-hour light-dark cycle and humidity at 60±5%. The diet compositions are illustrated in Table (1). Groups of rats fed control (FOS-free diet) and two experimental diets (DA and DO diets) for 8 weeks [52]. Every two weeks, blood samples were drawn, liver and cecum were removed from feeding rats separately (7 rats/each group).

Table 1. Composition of experimental diets [g/kg diet]

Component	Control diet	DA diet*	DO diet**

	(FOS free)		
Starch	360	153.32	165.59
Sucrose	300	300	300
Casein	200	184.39	183.96
Maize oil	80	76.07	76.56
Mineral mix.[a]	40	40	40
vitamin mix.[b]	20	20	20
DAc	–	226.14	–
DOd	–	–	213.9

[a] Minerals mixture prepared according to Johnson and Gee [31].
Mineral mixture (g/kg diet): CaHPO4 (13), CaCO3 (8.2), KCI (7.03), Na2HPO4 (7.4), MgSO4 .H2O (4.0), MnSO4 .H2O (0.18), ZnCO3 (0.03), FeSO4.7H2O (0.144), CuSO4 (0.015), KIO3 (0.001).

[b] Vitamin mixture was prepared as described by Revees et al. [60].
Vitamins mixture (g/kg diet): Nicotinic acid (3.0), Ca pantothenate (1.6), Pyridoxine-HCl (0.7), Thiamin-HCl (0.6), Riboflavin (0.6), Folic acid (0.2), Biotin (0.02), Vitamin B-12 (2.5), Vitamin E (15), Vitamin A (0.8), Vitamin D-3 (cholecalcifero)l (0.25), Vitamin K-1 (phylloquinone) (0.075), Powdered sucrose (974.655).

DA[c]: DryArtichoke containing (100g FOS + 88.44g Carbohydrates + 15.61g Protein + 3.93g Lipids + 18.234 Ash).

DO[d]: Dry Onion containing (100g FOS + 92.94g Carbohydrates + 16.04g Protein + 3.44g Lipids + 1.47g Ash).

2.4. Blood samples
At the end of the experimental period rats were euthanized, blood samples were drawn and collected by cardiac puncture. The samples were centrifuged at 3000 rpm for 10 min at room temperature; the sera was separated and kept in clean stoppered glass vials at -20ºC until used for the determination of glucose, total lipids total cholesterol, HDL-C, LDL-C and VLDL-C.

2.5. Tissue samples
Livers and kidneys were separately quickly removed and weighed, part of them was taken for histopathology in 10% buffered formalin solution and the remaining part of livers was homogenized and used for the determination of total lipids and glycogen contents.

2.6. Dry matter and moisture content
Onion (*Allium cepa*) and globe artichoke (*Cynara scolymus*) were put in an oven at 60°C to constant weight (16 h) according to the association of official agricultural chemists [6]. Duplicate samples were tested and averaged. Samples were removed from the oven and allowed to cool in desiccators.

2.7. Chemical analysis
Moisture content was determined gravimetrically. Ash content of onion and globe artichoke were determined by heating the dry sample in a muffle at 550°C [24]. Extraction of FOS was performed according to method of Yildiz et al. [81]. Total carbohydrate was determined using phenol-sulfuric acid method of Dubois et al. [21], the protein concentration was estimated by Lowry et al. [49]. Total lipid content was determined according to Pantis et al. [58]. Sera glucose levels were also estimated by Trinder [76] using Biodiagnostic Co kits. Total lipid was estimated using Biodiagnostic Co kits, Cairo, Egypt according to Zollner et al. [85]. Triacyglycerol was estimated using Biodiagnostic Co. kit by Fassati and Prencipe [24]. Total cholesterol and LDL-C were determined by by Richmond [61] using Biodiagnostic Co. kits. Glycogen content was estimated according to the method described by Carrol et al. [13].

2.8. Statistical analysis
One-way analysis of variance (ANOVA) was used to assess significant differences among groups Dunnett test (compare all vs. control). The criterion for statistical significance was set at $P< 0.05$ (significant) or $P< 0.01$(high significant) using Instate software [35].

2.9. Histological examination
Histopathological examination of liver and kidney was carried in National Cancer Institute according to Scheuer and Chalk [67].

3. RESULTS

Chemical analysis of dry matter revealed that the levels of carbohydrates and proteins in onion were increased than that of artichoke, while the lipids concentration nearly the same in both samples (Tab. 2). The present results indicated that the extraction procedure gave yield dry matter of FOS about 42.22 and 46.75 g% from artichoke and onion, respectively. The composition of both FOS yields (mg/g DM) by HPLC analysis (Tab. 3).

Table 2. Concentrations of total carbohydrates, proteins and lipids in Globe artichoke and onion [g/100g DM].

Components	Concentration [g/100g DM]	
	For artichoke	For onion

Carbohydrates	83.36±0.17	90.26±1.25
Proteins	6.9±0.64	7.5±0.54
Lipids	1.74±0.19	1.61±0.06
Values represent means of three samples ±SD.		

Table 3. FOS components in artichoke and onion by HPLC.

FOS name (DP)	Artichoke [mg/g DM]	Onion [mg/g DM]
Kestose (DP3)	101.71	294.53
Nystose (DP4)	285.13	41.79
fructosyl-nystose (DP5)	228.62	24.96
(DP6)	24.76	41.14
(DP7)	29.63	0.65
(DP8)	17.69	70.97
(DP9)	1.68	1.53
(DP10)	2.12	0.47

The concentrations of kestose (DP3), (DP6) and (DP8) in artichoke were less than those of onion about 3, 2 and 4 folds, respectively. While the concentrations of nystose (DP4), fructosyl-nystose (DP5), (DP7) and (DP10) in artichoke were more than those in onion about 6, 10, 46 and 5 times, respectively. On the other hand, there was no difference in the concentration of (DP9) of both artichoke and onion.

Results in Figures (1 and 2) showed the chromatograms of the two samples (artichoke and onion).

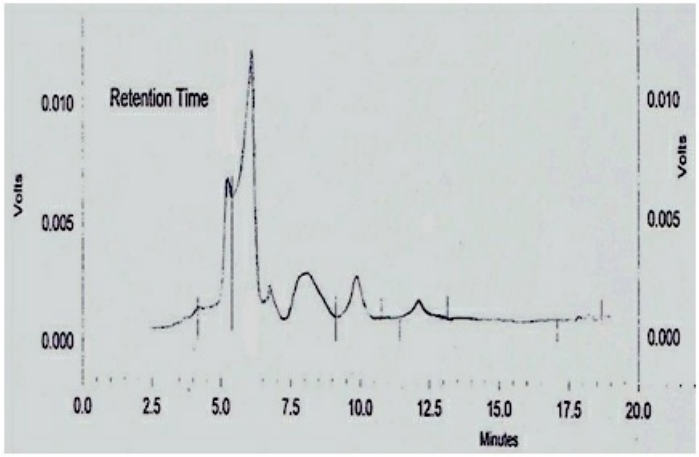

Fig. 1. HPLC chromatogram for artichoke sample after extraction

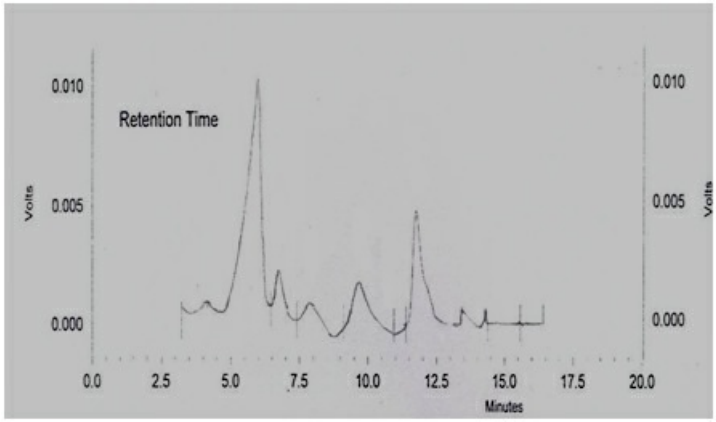

Fig. 2. HPLC chromatogram for onion sample after extraction

3.1. Sera parameters

Table (4) and Figure (3), showed highly significant decrease ($P< 0.01$) in glucose concentration in sera of rats fed both DA and DO diets compared with those fed control diet particularly at 4, 6 and 8 weeks. Highly significant decrease in the concentration of glucose in sera of rats fed DO ($P< 0.01$) and DA ($P< 0.05$) diets respectively at week 2 was observed. Total cholesterol in sera of rats (Fig. 4), showed that rats fed control diet exhibited significant increase in total cholesterol over the experimental period (8 weeks). The result also showed highly significant decrease ($P< 0.01$) in total cholesterol in rats fed with both DA and DO diets compared with the control at 4, 6 and 8 weeks and significant decrease ($P< 0.05$) in total cholesterol after 2 weeks.

Table 4. Glucose, total lipids, total cholesterol, HDL-C, LDL-C, LDL/HDL Ratio, TG levels, VLDL levels in sera, total lipids and glycogen content in liver of rats fed with control and the two experimental diets (DA and DO) [Mean values for 7 rats / group].

Parameters	Diets			
	Time in weeks	Control diet (FOS free)	Experimental diets	
			DA diet group	DO diet group
		Mean ± SD	Mean ± SD	Mean ± SD
Glucose levels	2	126.96±18.78	101.21±9.23*	88.87±13.54**
	4	159.14±12.94	109.05±8.72**	93.49±8.43**
	6	197.08±19.71	104.6±8.41**	93.59±14.49**
	8	201.21±15.5	92.22±3.77**	86.1±13.65**
Total cholesterol [mg/dl]	2	94.79±5.6	87.79±8.72*	87.14±5.96*
	4	105.40±11.08	86.2±5.49**	86.70±6.99**
	6	123.67±9.6	85.12±7.19**	84.61±4.71**
	8	135.65±14.25	84.68±5.79**	83.16±5.74**
HDL-C	2	49.05±2.98	48.18±5.35	54.09±1.9**
	4	50.31±7.37	54.17±3.26	57.53±5.69
	6	53.31±5.42	56.61±5.0	62.23±6.19*
	8	53.93±5.66	61.52±8.63	66.34±5.59**
LDL-C [mg/dl]	2	33.2±4.35	26.50±4.86*	24.28±2.91**
	4	40.07±4.01	22.22±3.6**	18.68±3.92**
	6	53.85±6.99	19.56±4.65**	15.62±2.92**
	8	65.39±7.79	16.66±3.87**	12±1.99**
LDL/HDL Ratio	2	0.68±0.11	0.55±0.11	0.46±0.09*
	4	0.81±0.14	0.41±0.07**	0.33±0.06**
	6	1.01±0.12	0.35±0.10**	0.26±.0.07**
	8	1.21±0.10	0.28±0.09**	0.18±0.03**
Triacylglycerol TG [mg/dl]	2	60.51±8.83	52.02±12.51	48.56±6.9*
	4	59.04±5.9	54.38±5.0	43.58±3.82**
	6	60.84±5.3	49.91±5.65**	45.56±4.63**
	8	65.93±4.82	46.93±4.47**	43.64±5.4**
VLDL-C [mg/dl]	2	12.10±1.76	10.40±2.5	9.70±1.38*
	4	11.81±1.18	10.87±1.0	8.72±0.78**
	6	12.17±1.06	9.98±1.13**	9.11±0.91**
	8	13.19±0.97	9.39±0.90**	8.74±1.08**
Total lipids in sera [mg/dl]	2	546.83±29.05	500.05±23.36*	484.32±20.67**
	4	575.46±32.47	492.79±40.71**	475.85±32.14**
	6	610.95±34.14	463.35±22.78**	448.43±29.13**
	8	643.21±26.20	444±25.34**	435.53±20.66**

Values are Means ±SD
*Significant (P<0.05)
**Higher significant (P<0.01)

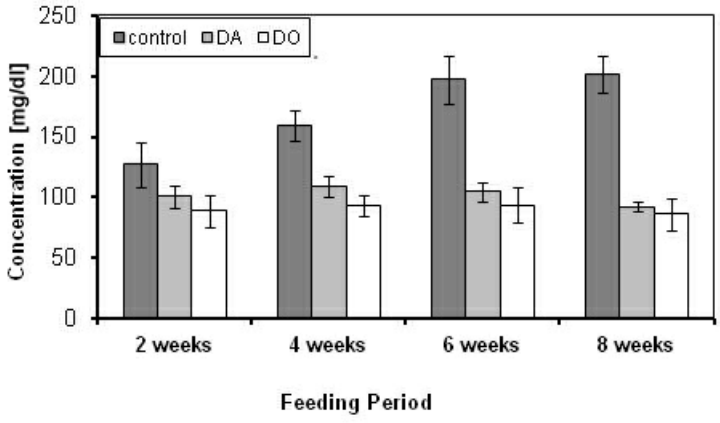

Fig. 3. Glucose levels in sera of rats fed with control and the two experimental diets (DA and DO diets).

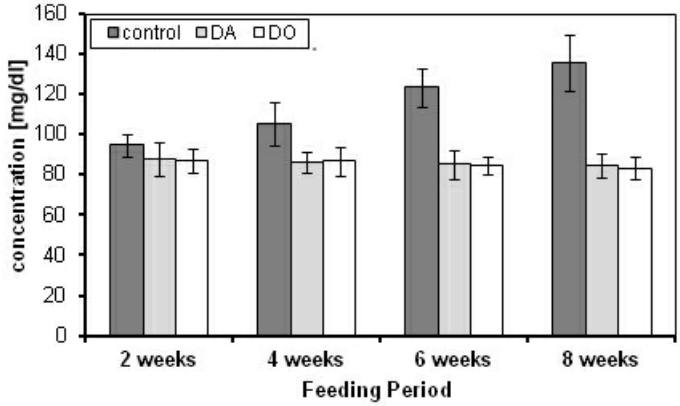

Fig. 4. Total cholesterol in sera of rats fed with control and the two experimental diets (DA and DO diets).

HDL-cholesterol concentration in sera showed highly significant increase (P<0.01) in HDL- C on rats fed with DO diet compared with the control after 2, 6 and 8 weeks. The rats fed with DA diet exhibited insignificant change (P>0.05) in the level of HDL-C compared to these fed with control diet (Fig. 5).

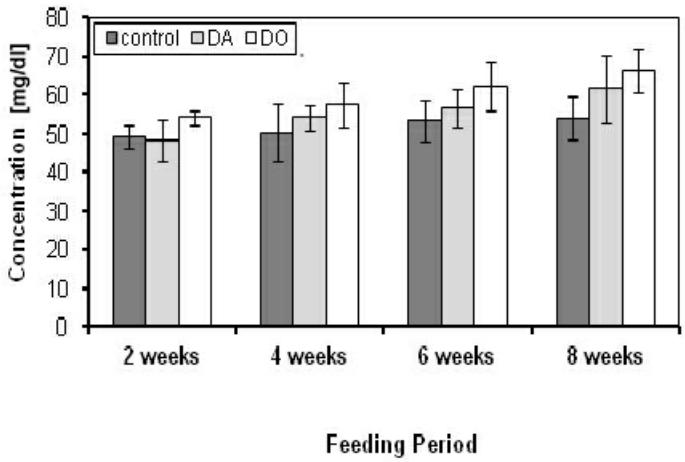

Fig. 5. HDL-C in sera of rats fed with control and the two experimental diets (DA and DO diets).

LDL-cholesterol in sera in Figure (6), showed highly significant decrease (P<0.01) in LDL-C in rats fed DO diet compared with control over the experimental period (8 weeks). Also results showed highly significant decrease (P<0.01) in LDL-C in rats fed with DA diet compared with control in 4, 6, 8 weeks and significant decrease (P<0.05) in week 2. Significant decrease (P<0.01) were observed between rats fed DO diet compared with those fed DA diet at 8 week. LDL-C/HDL-C ratio in figure (7), showed highly significant decrease (P<0.01) in rats fed DO and DA diet compared with control diet over the experimental period (8 weeks).

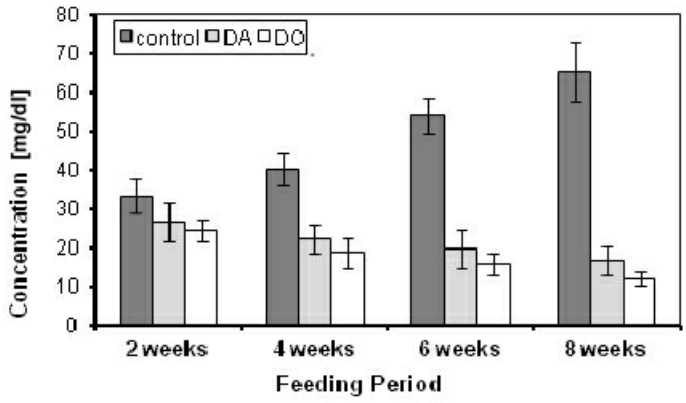

Fig. 6. LDL-C in sera of rats fed with control and the two experimental diets (DA and DO

diets).

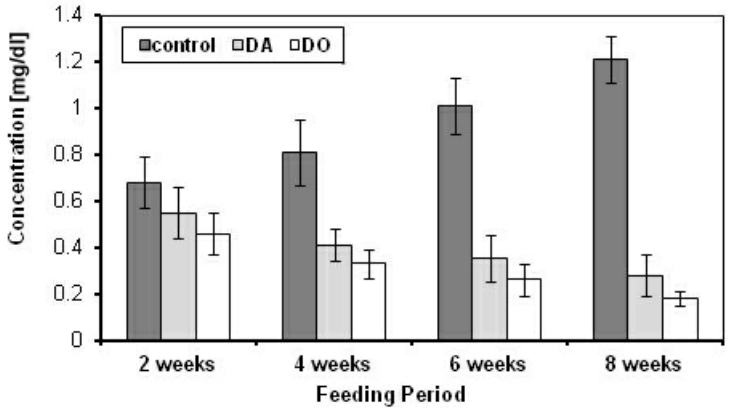

Fig. 7. LDL-C/HDL-C ratio of rats fed with control and the two experimental diets (DA and DO diets)

Triacylglycerol in rat sera (Fig. 8), the results indicated highly significant decrease (P<0.01) in level of TG in sera of rats fed with DA diet compared with the control at 6 and 8 weeks and insignificant change (P>0.05) was observed at 2 and 4 weeks. Also results showed highly significant decrease (P<0.01) in sera of rats fed DO diet compared with control at 4, 6 and 8 weeks and significant decrease (P<0.05) was observed at week 2. High significant decrease (P<0.01) in the level of TG in sera of rats fed with DO diet compared with those fed with DA diet particularly, at week 4.

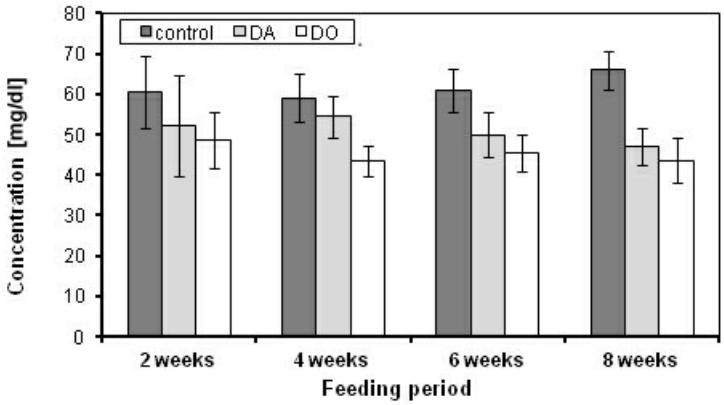

Fig. 8. Triacylglycerol in sera of rats fed with control and two the experimental diets (DA and DO diets).

VLDL-C in sera showed in (Fig. 9) the results indicated highly significant decrease (P<0.01) in VLDL-C in sera of rats fed with DA diet compared with control at 6 and 8 weeks and insignificant change (P>0.05) was observed at 2 and 4 week. Also results showed highly significant decrease (P<0.01) in VLDL-C in sera of rats fed with DO diet compared with control at 4, 6 and 8 weeks. High significant decrease (P<0.01) in VLDL-C in sera of rats fed DO diet compared with those fed with DA diet particularly, at week 4.

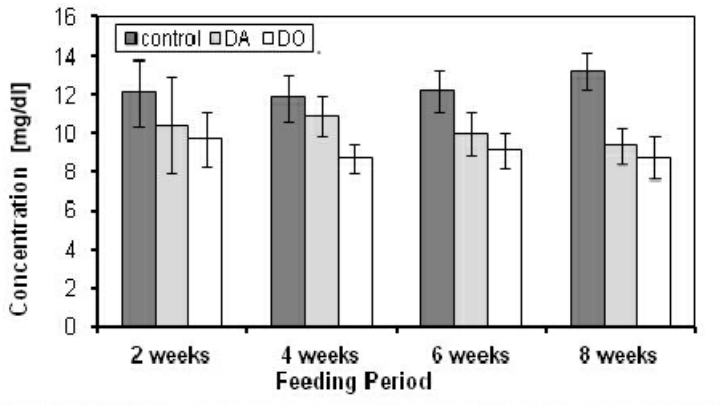

Fig. 9. VLDL-C in sera of rats fed with control and the two experimental diets (DA and DO

diets).

Total lipids in sera showed (Fig. 10), the present results showed highly significant decrease (P<0.01) in the level of total lipids in sera of rats fed both DA and DO diets compared with those fed with control diet particularly at 4, 6 and 8 weeks. Highly significant (P<0.01) and significant decrease (P<0.05) were observed in total lipids in sera of rats fed DO and DA diets respectively after 2 week.

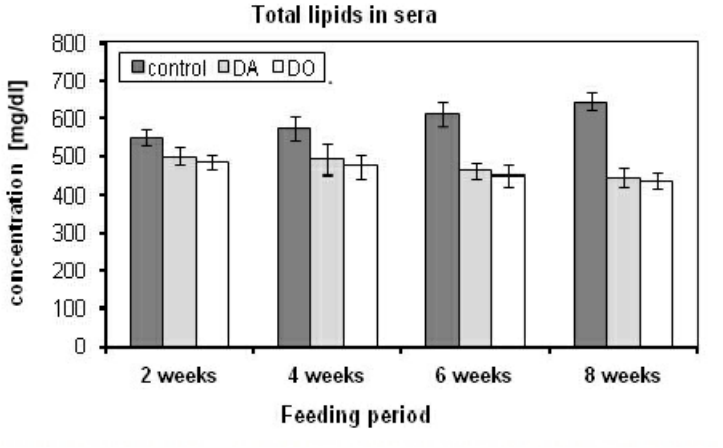

Fig. 10. Total lipids in sera of rats fed with control and the two experimental diets (DA and DO diets).

3.2. Liver tissue parameters

The results in Table (5) and Figure (11), indicated highly significant decrease (P<0.01) in liver total lipids of rats fed both DA and DO diets after 6 and 8 week compared with these fed control diet. Results also showed significant decrease (P<0.05) in liver total lipids of rats fed DO diet after 2 and 4 weeks compared with the control. Insignificant change (P>0.05) was observed at 2 and 4 week of rats fed DA diet. Results also showed insignificant change (P>0.05) between rats fed DA and DO diets over the experimental period (8 weeks).

Table 5. Total lipids and glycogen content in liver of rats fed with control and the two experimental diets (DA and DO diet) [Mean values for 7 rats / group].

Parameters	Diets			
	Time in weeks	Control diet (FOS free)	Experimental diets	
			DA diet group	DO diet group
		Mean ± SE	Mean ± SE	Mean ± SE
Total lipids in liver [mg/g tissue]	2	44.11±6.17	43.29±6.11	40.77±4.95*
	4	49.15±8.6	40.45±6.64	36.84±4.21*
	6	67.97±16.38	37.64±4.86**	33.59±5.42**
	8	75.47±11.49	36.84±6.80**	30.61±5.15**
Glycogen content in liver [mg/g tissue]	2	3.76±0.75	3.26±0.61	2.97±0.57**
	4	6.72±1.8	2.98±1.09**	1.96±0.70**
	6	7.09±1.26	2.48±1.28**	1.39±0.78**
	8	7.20±1.06	1.92±0.85**	1.13±0.40**
Values are Means ± SD *Significant(P<0.05) **Higher significant (P<0.01)				

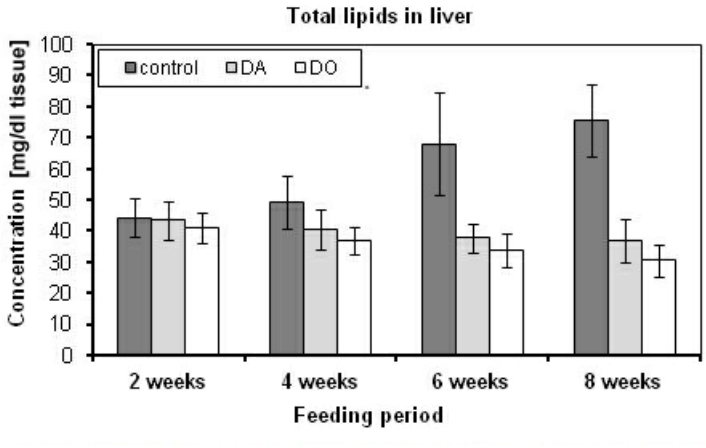

Fig. 11. Total lipids in liver of rats fed with control and the two experimental diets (DA and DO diets).

Results in Table (5) and Figure (12), showed highly significant decrease (P<0.01) in glycogen content in liver of rats fed with DA and DO diets compared with those fed with control diet particularly after 4, 6 and 8 weeks of feeding diets. Highly significant decrease (P<0.01) at week 2 for rats fed DO diet was observed. Significant decrease (P<0.05) was observed in liver glycogen content of rats fed with DO diet and those fed with DA diet after week 8. Insignificant changes were observed between rats fed both DA and DO diet at 4, 6 and 8 weeks.

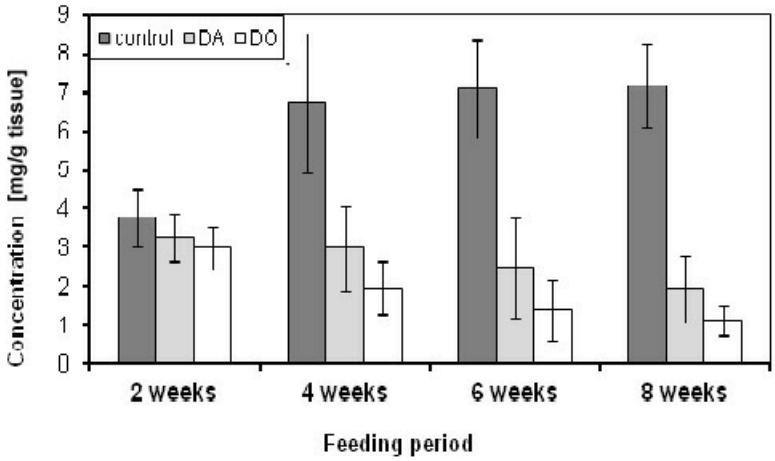

Fig. 12. Glycogen contents in liver of rats fed with control and the two experimental diets (DA and DO diets).

3.2.1. Histological assessment of liver and kidney tissues

Histological pattern of liver and kidney derived from rats after 2 and 8 weeks.

3.2.1.1. Liver

1. Livers of rats fed high carbohydrate diet (control diet) have normal liver lobule with normal sinusoidal pattern and normal parenchymal cells and portal spaces after 2 weeks as in Figure 13 (a). Liver sections of rats fed with control (HCD) diet after 8 weeks, hepatic cells revealed changes shown degeneration and vaculation also, appeared disrupted with considerable numbers of RBCs aggregating intercellular together. Blood vessels were narrowing by thickness it's wall and found fat bodies inside it as in Figure (14a).
2. Livers of rats fed 10% FOS from DA and DO diets appeared almost normal, intercellular spaces appeared slightly larger than control, parenchymal cells had no histological changes with a normal anatomy and no presence of steatosis as shown in Figures 13 (b, c) and Figures 14 (b, c).

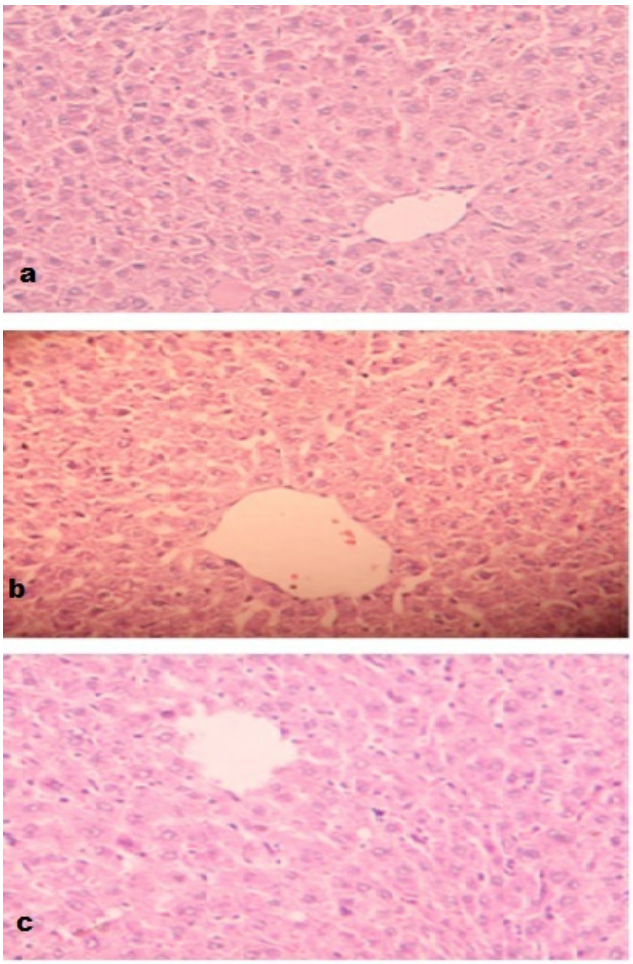

Fig. 13. Histological pattern of liver of rats fed with control (a), DA (b) and DO (c) diets after 2 weeks.

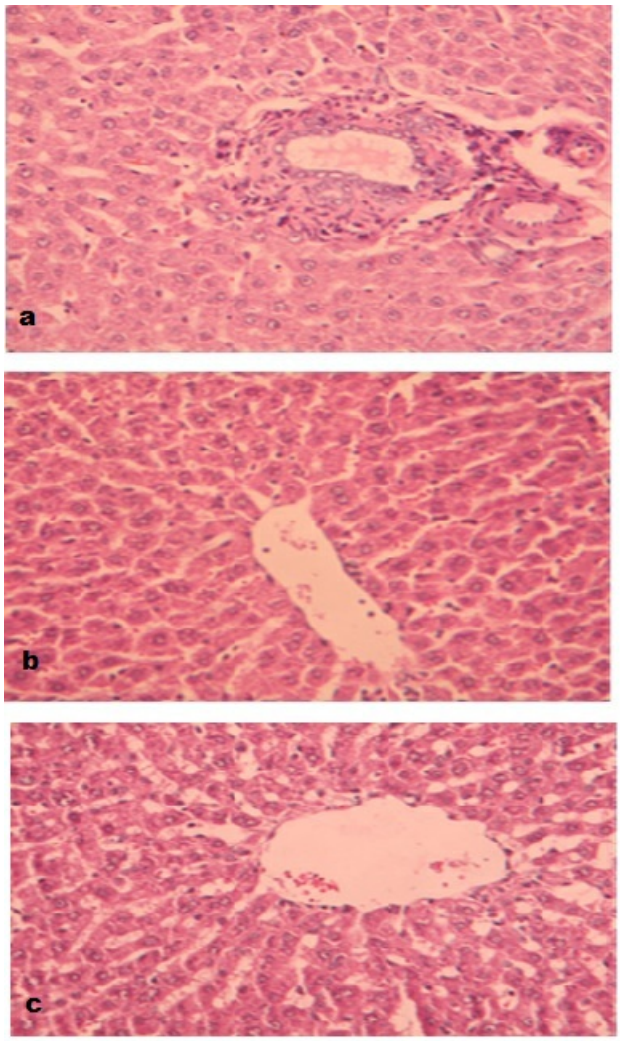

Fig. 14. Histological pattern of liver of rats fed with control (a), DA (b) and DO (c) diets after 8 weeks.

3.2.1.2. Kidney

1. Kidneys of rats fed Control diet showed normal and unaltered structure as shown in Figure 15 (a) after 2 weeks, although the blood vessels were rather enlarged and congested Figure 16 (a) after 8 week.
2. Kidneys of rats fed with 10% FOS from DA and DO diets appeared almost normal and unaltered structures after 2 weeks as in Figures 15 (b, c), After 8 weeks cells appeared almost normal with no histological changes as in Figures 16 (b, c).

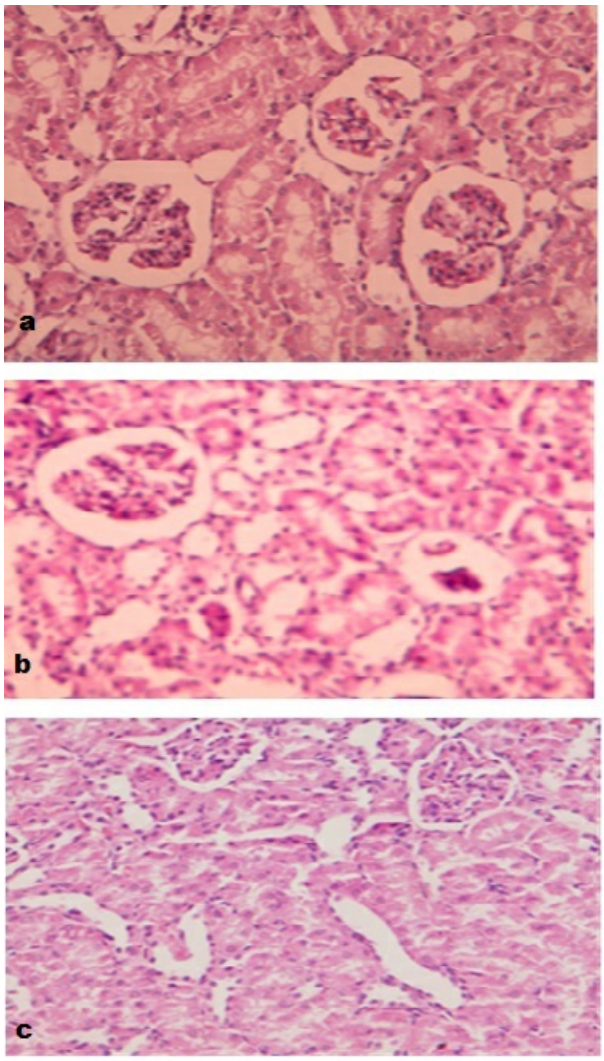

Fig. 15. Histological pattern of kidney of rats fed with control (a), DA (b) and DO (c) diets after 2 weeks

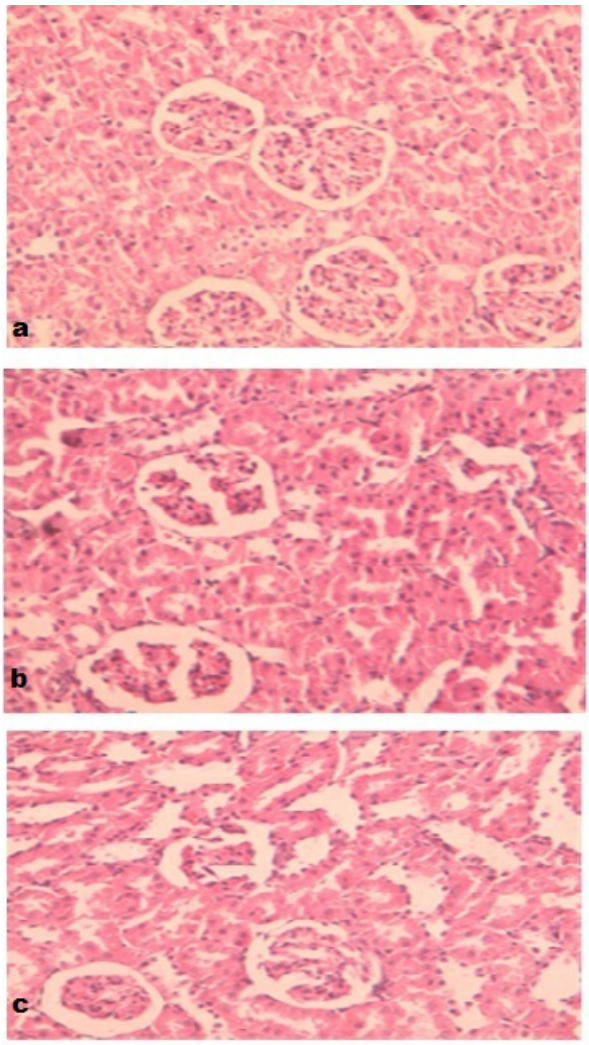

Fig. 16. Histological pattern of kidney of rats fed with control (a), DA (b) and DO (c) diets after 8 weeks.

4. DISCUSSION

The present results showed that water makes up the majority of fresh weight of artichoke ranged from 88–87%. The mean concentration for moisture in onion ranged from 85–95%, which can be considered as a usual range for the moisture of onions [37, 15]. The onions ash content was 0.35±0.03 g/100 g are similar to Ketiku [42] and lower than the results reported by other investigators [2, 74]. The protein content in onion and artichoke was in the range observed by Moreau et al. [53] but lower than that reported by other researchers [2, 36, 63]. However, several fractions related to the carbohydrate content were predominant in onions [65]. The present results showed that the carbohydrate in artichoke and onion accounts the major portions of dry matter contributing as much as 83.36 and 90.26% respectively. Similar results were obtained by Rodríguez-Cabezas et al. [64]. The principle component of these carbohydrates is a series of FOS fructosylpolymer of DP ranged from 3:10. These results are in accordance with results of [15, 65, 20]. The degree of polymerization (DP) of these fructans can vary to a large extent amongst *Allium* species [17]. The present results showed that the dry mater contain 42.22 and 46.75 g% FOS from Artichoke and Onion respectively. FOS are a group of glycosyl-fructosyl polymer with DP (3–5) occur in onion and artichoke, these results are in accordance with those reported by Bornet et al. [9]. The present results are in the range with those reported by Ernst et al. [23], who reported that in onion the fructan DP level is mostly in between 3 and 15. It has been reported that high-solid and sweet onions have specific carbohydrates storage patterns which are strongly related to their DM content [70, 79].

The main FOS in artichoke and onion are kestose (101.71, 294.53 mg/g DM), nystose (285.13, 41.79 mg/g DM) and fructosyl-nystose (228.62, 24.96 mg/g DM), respectively (Tab. 3). These results are in agreement with those reported by other investigators [15, 65]. A few reports have shown that there are differences in fermentability and availability to intestinal bacteria among these FOS in vitro [57].

Onion is generally consumed for its nutritive values, medicinal power and flavor has been appreciated [40]. Among the feeding rats, there was a significant decrease in sera glucose level in rat groups fed DA and DO diets containing 10% FOS g/kg diet.

The results of sera glucose are consistent with the finding of Campos et al. [11] in rats and mice [22]. Previous study has been shown that chicory reduce glucose level uptake in rats [43]. FOS not hydrolyzed by digestive enzyme, it behaves like a soluble fiber and process hypoglycemic effect [59]. The factors involved in this role of indigestible oligosaccharides to influence the glucose and lipid metabolism has been believed to arise by increasing bifidobacterial counts and producing high SCFA

concentrations [33, 48].

Oligosaccharides have also been reported to lower total sera cholesterol (0.226–0.566 mmol/L) in humans [33]. Also, the bacterial fermentation products like SCFA which are absorbed into the portal blood supply might have an inhibitory effect on hepatic cholesterol synthesis [48].

Onion has inhibits rat hepatic cholesterol biosynthesis in vitro [30]. In the present study, experimental diets DA and DO containing 10% FOS g/kg diet caused highly significant decrease in sera total cholesterol and TG. Similar results were obtained by Tang et al. [73] dietary supplementation of FOS can promote the regulation of lipid metabolism.

The onion may be effective as hypocholesterolemic under condition experimentally induced hypercholesterolemia or hyperlipidemia [78].

Total cholesterol in sera was significantly reduced in rats fed on diets supplemented with dry onion and artichoke. Dyslipidemia means elevated plasma levels of TC, LDL-C and TG and a low concentration of HDL-C is one of the most common complications of diabetes mellitus [55]. It plays a significant role in the development of premature atherosclerosis, coronary insufficiency and myocardial infarction [56].

FOS supplementation was a significant factor as increasing HDL-C levels in rats fed experimental diets. Although the level of TC was decreased in sera of rats fed both DA and DO diets, the HDL-C/LDL-C ratio was increased (Table 4). Fiordaliso et al. [27] reported that the decrease in plasma TG levels was mostly due to decrease in level of VLDL-TG. This TG-lowering effect of FOS has also been observed in rats fed a high carbohydrate diet [10] and in rats fed a fiber-free diet [8, 52]. Other studies have shown a decrease in the intra-hepatic concentration of TG with oligofructose [18]. The hypotriglyceridaemic action resulted from a decrease in the hepatic synthesis of TG [10]. Other explanation relates to the mechanism proposed for hypotriglyceridaemic effect by inhibition of hepatic lipogenesis in animals fed diet containing inulin-type fructans [69]. The present results revealed that the DA and DO diets supplemented 10% FOS (g/kg diet) resulting significant decrease in sera TG levels may be due to high content of FOS [44]. At least part of the triglyceride-lowering action of FOS due to reduction of de novo fatty acid synthesis in the liver, through the inhibition of fatty acid synthase activity [27, 44, 45]. Similar results were obtained by other investigators [19, 27, 69]. On the contrary [16, 69], found that FOS and XOS supplementation in animal diets for 8 weeks showed no influence on glucose, TG and TC levels.

The supplementation with FOS in diet revealed less triglyceride level in sera of rats [19]. Oligosaccharides might reduce the expression of the enzymes for fatty acid synthesis [80]. The potential hypolipidemic effect of both experimental diets (DA and DO diets) was observed through reduces sera TC, TG and LDL-C levels and increases HDL-C levels in rats. The HDL level inversely correlates with the risk of atherosclerotic cardiovascular disease [55].

The present results showed that liver total lipids and glycogen levels (Tab. 5) of rats given FOS containing diets were highly significantly decreased compared to those received FOS-free control diet (HCD). Other studies in consistence with the present results [7, 52] found reduction in liver total lipids. The results of the present study were contradicted to Kritchevsky et al. [47] who indicated that dietary fiber supplemented to the diet elevated the level of these hepatic lipid components.

Glycogen synthesis in the rat liver and skeletal muscles was impaired during diabetes [34]. The prevention of glycogen depletion in liver may be attributed to the stimulation of insulin release from beta cells [1]. Previous study demonstrated that glycogen storage was impaired in diabetic animals [82]. In contrast, glycogen content was significantly increased in rat liver was reported by Jung et al. [39]. Histopathological examination clearly indicated no pathological changes in liver and kidney appeared for 8 weeks in rats fed with DA and DO diets containing 10% FOS. The present results are in consistence with rats received low doses of onion (50 mg/kg) which exhibited minimal levels of kidney and liver damage reported the animals were administered low dose of onion had no significant liver damage [75]. The effect of administration of 1 and 2 g/kg of globe artichoke and found no histological change in normal cells [72]. The effect of natural sweeteners fiber on liver histology founds normal liver cells without steatosis [26]. The influence of water soluble polysaccharides on pancreas and liver histology of animal induced by tert-butyl hydroperoxide, they found markedly prevented and minimized liver injury [83]. These results are similar to the present results revealed no histological change in liver of rats fed with DA and DO diets (Fig. 13 and 14).

CONCLUSION

The data concluded that artichoke and onion have high percentage of natural FOS. The data also concluded that FOS supplementation in diet exhibited hypoglycemic and hypolipidemic effects. They also cause lowering effect on sera and liver lipids components, consequently decreasing the incidence of atherosclerosis and coronary heart diseases. The present study recommended by the administration of artichoke and onion as natural source of FOS in the diet will improve health, treatment diabetes and decreasing the incidence of cardiovascular diseases.

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