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EFFECT OF REDUCING FATS BY FIBER GELS ON THE SENSORYEVALUATION, RHEOLOGICAL PROPERTIES IN BISCUITS AND ITS EFFECTS ON HYPERCHOLESTEROLEMIC RATS

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ABSTRACT

Hypercholesterolemia is a well-known risk factor in the development of atherosclerosis subsequent coronary heart disease and cardiovascular diseases, which represent the primary cause of mortality. Baked products such as biscuits typically contain high amounts of fat, provides important sensory properties. The objective of this present investigation was to evaluate the role of dietary fiber- gels as fatreplacer on the nutritional value, rheological properties and sensory evaluation as well as its effects on blood lipids of hypercholesterolemic rats. Low-fat biscuits were formulated by replacing 20, 40, 60 and 80 % of fat in biscuits formula with rice straw and corn stalks fiber gels. Data of proximate analysis revealed that protein and lipids were gradually decreased with increasing the replacement levels of different fiber gel sources, while ash, fiber and carbohydrates were increased. Physical properties were also affected by replacing fats. Gradual increase in weight, thickness and hardness of prepared biscuits were observed with increasing the level of replacement. On the contrary, the values of volume and diameter were decreased. Results of the sensory evaluation of biscuits revealed no significant changes on taste, appearance, color, and odor as replacing up to 60% of fat with fiber gel. The obtained results of the biological study showed that, low-fat biscuits with using fiber gel as fat replacer are effective for reducing the total cholesterol , triglycerides, LDL-c, VLDL-c , GOT and GPT .

INTRODUCTION

Biscuits are a popular baked food very appreciated by consumers because of their pleasant taste and texture. However, one important problem of such baked goods is their fat and sugar content, which turns them into high-calorie products; at a time whenconsumers are becoming increasingly interested in healthy food products**(Baltsavias *et al*., 1999)**.Fats improve the texture, appearance, lubricity, mouth feel and taste, thus contributing to food palatability **(Zoulias *et al*., 2002a&b)**. In biscuits, higher percentages of fat produce tendered biscuits with less hard texture and more inclined to melt in the mouth **(Lai andLin, 2006)**.

As regards fat, the focus is on low-fat foods, low fat saturated food and the absence oftrans fatty acids; therefore, due to the important functionality of fat in biscuits, achieving a reduction in the fat content without affecting quality properties or consumer acceptability is a challenging task **(Chevallier *et al*., 2000)**.

Fat replacer is an ingredient that can be used to provide some or all of the functions of fat, yielding fewer calories than fat. Fat replacers need to be able to replicate all or some of the functional properties of fat in a fat-modified food. The challenge for food processors is to identify the fat replacer that work best for a given food product **(Jonnalagadda and Jones, 2005)**.For several years, fat substitutes have been used to partially or fully replace fat. There are two main groups of fat replacers including carbohydrate-based fat substitutes and protein-based fat substitutes **(Akoh, 1998)**. Many of the low-fat products introduced contain carbohydrate-based fat substitutes which are derived from cereals, grains and plants that include digestible and non-digestible carbohydrates (starch derivatives and gums). They provide some of the functions of fat by binding water and providing texture, mouth coating and opacity **(Giese, 1996)**.

Among these, fiber has many health benefits besides improving technological properties of the products **(Mansour and Khalil, 1997)**. High-fiber low-fat foods tend to reduce the risk of colon cancer, obesity, cardiovascular diseases and several other disorders **(Tungland and Meyer, 2002)**.

Dietary fiber gels are prepared by chemical and physical treatment of dietary fiber substrates until the cellular structures are almost completely disintegrated. The gels are characterized by high viscosities and high hydration capacities and can easily be dried and reconstituted. The gels can be used in a range of foods and non-food compositions and are particularly useful as reduced calorie fat **(Inglett, 1997)**.

Much evidence suggests that increases in obesity and overweight were related to the increases in fat and caloric intake **(Cutler *et al*., 2003, Neuhouser*et al*., 2004 and Philipson and Posner, 2008)**. Reducing fat in every-day diet has become a public health issue and a concern for most consumers **(Barber *et al*., 2016)**. Moreover, **Akoh, (1998)** and **Zoulias*et al*. (2002a&b)** stated that, high fat intake is associated with increased risk for obesity and some types of cancer, and saturated fat intake is associated with high blood cholesterol and coronary disease.

In bakery products, fats and oils offer various positive functional attributes in baking products. Textural properties of these products are significantly influenced by fats and oils and combined result of their physical, chemical, functional and rheological properties **(Devi and Khatkar, 2016)**. Fat provides the highest energy value of all major food constituents, fat substitution by other ingredients is a great challenge, especially in bakery products, as they can contain high levels of fat **(Felisberto*et al*., 2015)**. Fat, also, interacts with other ingredients to develop and texture, mouth feel, overall sensation of lubricity of the product and it adds a rich quality to cookies **(O'Brien, 2003 and Zahn *et al*., 2010)**.

Biscuits are the most popular bakery items because of their high nutritive value, ready-to-eat nature, and easy availability in different shapes and sizes at an affordable cost. Biscuits and other sweet baked items are rich in sugar (mainly sucrose) and fat **(Zoulias *et al*., 2000)**.

The objectives of this study were to use fiber gel which extracted from rice straw and corn stalks as a functional ingredient in biscuits production and to evaluate the effect of fiber gel as a fat replacer on physical and sensory characteristics of biscuits, in addition to examined the effects of fiber gel on the lipid profile of hypocholesterolemic albino rats fed on these biscuits.

MATERIALS AND METHODS

Materials:

Wheat flour (72% extraction) was obtained from Five Stars Flour Mills Company, Suez, Egypt.

Rice straw and corn stalks were mainly obtained from a farm in Agriculture Research Center, Giza, Egypt.

Sugar (sucrose), butter, corn oil, corn starch, baking powder, vanilla and other ingredients used in this study were purchased from the local market in Cairo, Egypt.

The enzymes employed for the determination of total dietary fiber including heat-stable α-amylase, protease, amyloglucosidase, glucose oxidase, peroxidase and cellulose were obtained from Sigma.All other chemicals used in this study for analysis were of analytical grade.

Male albino rats Winster strain (42 males) with average weigh 150 g were obtained from Experimental Animal House, Food Technology Research Institute, Agricultural Research Center, Giza, Egypt.

Kits for determination of serum Triglycerides (TG), Total Cholesterol (TC), High Density Lipoprotein Cholesterol (HDL-cholesterol), Glutamic-Oxaloacetic Transaminase (GOT), Glutamic-Pyruvic Transaminase (GPT), Alkaline Phosphatase (ALP) and Creatinine were obtained from Biodiagnostic Co. Dokki, Giza, Egypt.

Methods:

Preparation of fiber gels:

Fiber gel of rice straw and corn stalks were prepared according to the method described by **Carriere and Inglett (2003)**. In a 20L plastic tank, one kg of fine ground cereal waste wasmixed with 11L of water for the first stage treatment.Approximately 10 g of a 50% sodium hydroxide solution (sp.gr. 1.52, 13.3%w/v) was added toadjust the pH to 6.8. After heating the mixture to 90-94˚C, 2.4 ml of heat stable α-amylase (55.2 U/mg) was added to themixture.The mixture was sheared in autoclave (Vision KMC 1221 made in Korea) at 90-98 ˚C. After 15 min,175 ml of 50% sodium hydroxide solution was added to adjust thepH to greater than 12 and the shearing was continued for 45 min.The solids were washed with distilled water two times before collecting the solids on a 25-μmfilter bag. The pH of the solids was adjusted to approximately 7. In thesecond stage of treatment, the wet solids (volume amount 6 L), was adjusted to approximately pH 10 using a 50% sodium hydroxidesolution. A 500 ml of 30% hydrogen peroxide solution was added to this mixture and was then autoclaved at 90-98 ˚C for 45 min. The slurry was stirred with mild agitation for 36 hr and the wet solids were collected on a25-μmfilter bag. The resulting fiber gel was than dried under vacuum (50-60 ˚C) to yield a powder of fiber gel.

Analytical methods:

Proximate chemical composition of raw materials and final product (moisture, ash, lipids, crude fibers, total dietary fibers, and nitrogen contents) was determined according to **A.O.A.C (2016)**. Soluble and insoluble dietary fibers were determined according to method described by **Prosky *et al*. (1988)**. Total carbohydrate was calculated by differences.

Cellulose and hemicellulose were determined according to method described by **Myhre and Smith (1960)**. Lignin was determined according to method described by **Martion (1964)**.

Caloric value of final product (biscuit) was calculated according to **Eneche (1999)** by multiplying the proportions of protein, fat and carbohydrate by their respective physiological fuel values of 4, 9 and 4 kcal/g, respectively and taking the sum of the products.

Water and oil holding capacity:

Water and oil holding capacities were determined according to **Knuckles and Kohler (1982)**.

Preparation of biscuit:

Biscuit was prepared according to the method described by **(Wade, 1988)** as follow: The ingredients of biscuits consisted of 100 g flour, 33 g fat (butter), 36 g sugar, 3 g baking powder, 0.25 g vanillin and 18 g water. Fat (butter), sugar and vanillin were mixed in a dough mixer using the flat beater for 1 min. then scraped down and continued to mix for 3 min at high speed. Flour and baking powder were added to the mixture and mixed at low speed. Dough was sheeted to 3.5 mm thickness with the help of an aluminum platform. Circles cut of past pieces were done by using of templates with an outer diameter of 52 mm. The biscuits were baked at 170 - 180˚C for 12 min. The biscuits were allowed to cool for 60 min at room temperature before sealed in metalized oriented polypropylene bags then stored at room temperature. For low fat biscuit formula, fiber gel dispersion was prepared by mixing 10 g of different powder of fiber gel with 90 g of water at room temperature till a smooth gel was formed. Fiber gel dispersion was used to replace 20, 40, 60 and 80% of fat (by weight) and they were mixed together in the creaming step.

Physical properties of biscuit:

According to **Sai-Manohar and Haridas-Rao (1997)**.The diameter (D) and thickness (T) of six biscuits were measured in millimeter by placing them edge to edge and by stacking one above the other, respectively. To obtain the average, measurements were made by rearranging and restacking. Spread factor (SF) was calculated by dividing diameter of the biscuit (mm) by their thickness (mm).

The weight of six biscuits was determined after cooling. The volume was measured by rape seed displaced by six biscuits. Specific volume was calculated by dividing volume (cm3) by biscuit weight (g).

Hardness of biscuit:

Biscuit hardness was determined using a Texture Profile Analyzer (TPA) according to**A.A.C.C (2010)**. Texture was determined by universal testing machine (Conetech, B type, Taiwan) provided with software. Hardness was calculated from TPA graphic in Newton (N).

Sensory evaluation of biscuit:

The biscuit samples wereorganoleptic ally evaluated after baking within one hour according to **Manohar and Rao (1997)**.

Biochemical evaluation:

According to the sensory evaluation of the biscuit samples, the selected products were biologically evaluated.

Experimental design:

Forty-two male albino rats of average weight between 150 ± 5g were obtained and housed in the Experimental Animal House at Food Technology Research Institute, Agricultural Research Centre, Giza, Egypt.

Rats were housed individually in polypropylene cages with screen top in a temperature and humidity controlled room with 12 hr light/dark cycle. Temperature and relative humidity of the animal room were controlled at (25˚ ± 2˚C) and 60-65%, respectively. All animals were kept under normal healthy conditions and fed on a basal diet for seven days as an adaptation period. The basal diet was formulated according to**(AIN, 1993)**as show in Table (1). After adaptation period, the rats were divided randomly into seven groups each group contained six rats (n=6) and named from G1 to G7.

Table (1): Composition of the diets (g/kg diet)

Ingredients	Control (ve-) diet free biscuits	Control (ve+) diet free biscuits	Diets with biscuits				
			Normal biscuits	RS-40%	RS-60%	CS-40%	CS-60%
Sucrose	100	100	100	100	100	100	100
Casein	140	140	130.3	124.1	116.6	124.3	116.6
Corn starch	465.7	453.7	346.4	248.2	126.0	249.4	125.9
Corn oil	40.0	-	-	-	-	-	-
Fiber	50.0	50.0	49.41	40.78	29.45	41.99	33.59
Dextrinized corn starch	155.0	155.0	155.0	155.0	155.0	155.0	155.0
L-Cysteine	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Mineral mix	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Vitamin mix	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Tert-butylhydroquinone	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Choline bitartrate	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Render fat	-	40.0	-	-	-	-	-
Bile salt	-	2.0	-	-	-	-	-
Cholesterol	-	10.0	-	-	-	-	-
Dried biscuits	-	-	169.6	282.7	423.7	280.1	419.7
Total	1000	1000	1000	1000	1000	1000	1000

The group 1 remained eating the basal diet while, the other groups (G2 – G7) fed with hypercholesterolemic diet which prepared by replacing the corn oil and part of starch with15 % tail sheep fat in basal diet with adding 1% pure cholesterol and 0.25% bile salt according to **(Zulet *et al* ., 1999)**.

After two weeks of eating the hypercholesterolemic diet, blood sample were taken from each rat for the determination of serum cholesterol to ensure the occurrence of hypercholestolemic. Animals with serum cholesterol levels of over 250 mg/dL were considered as hypercholesterolemic rats. Then the groups remained individual according to the following scheme until the end of experimental period:

Group 1: Fed on basal diet only throughout the experimental period (Negative control group).

Group 2: Fed on hypercholesterolemic diet only throughout the experimental period (Positive control group).

Group 3: Fed on hypercholesterolemic diet plus control biscuit.

Group 4: Fed on hypercholesterolemic diet plus biscuit prepared by replacing 40% fat with rice straw fiber gel(as a fat replacer).

Group 5: Fed on hypercholesterolemic diet plus biscuit prepared by replacing 60% fat with rice straw fiber gel(as a fat replacer).

Group 6: Fed on hypercholesterolemic diet plus biscuit prepared by replacing 40% fat with corn stalks fiber gel(as a fat replacer).

Group 7: Fed on hypercholesterolemic diet plus biscuit prepared by replacing 60% fat with corn stalks fiber gel(as a fat replacer).

The rats were given free access to experimental diets and water throughout the experimental period.

Blood samples were taken at the end of the experimental period. The blood samples were obtained from orbital plexus venous by means of fine heparinized capillary glass tubes according to the method of **Schermer (1967)**. Each sample was placed into a dry clean centrifuge tubes and centrifuged at 3000 xg for 20 min at 4˚C to obtain serum which subjected to the biochemical analyses.

Serum triglycerides were measured colorimetrically according to the method described by **Fossati and Prencipe(1982).**Serum total cholesterol was colourimetrically determined according to enzymatic method of **Allain*et al*. (1974)**.Serum HDL-Cholesterol was measured colorimetrically according to the method described by **Lopez-virella *et al*. (1977)**. Serum LDL-Cholesterol was calculated according to **Friedewald *et al*. (1972)** by using the following equation.

$$LDL = \text{Total cholesterol} - (HDL + \text{Triglycerides}/5)$$

Serum VLDL-Cholesterol was calculated according to **Lee and Nieman (1996)** by using the following equation.

$$VLDL\text{-}C = \text{Triglycerides}/5$$

Serum aspartateaminotransferase (AST/GOT) and alanine aminotransferase (ALT/GPT) and Alkaline Phosphatase (ALP) activities were determined according to **Retiman and Frankel (1957)**, while creatinine was determined according to the method described by **Bartels *et al*. (1972)**.

Statistical analysis:

Data were analyzed by analysis of variance using General Liner Model (GLM) procedure according to the procedure reported by **Snedecor and Cochran (1997)**. Means were separated using Duncan's test at a degree of significance (P≤ 0.05). Statistical analyses were made using the producer of the SAS software system program **(SAS, 1997)**.

RESULTS AND DISCUSSION

Chemical analysis of wheat flour, rice straw and corn stalks:

Proximate chemical composition of wheat flour, rice straw and corn stalks are presented in Table (2). The obtained results revealed that the highest value of crude protein was recorded for wheat flour (72% ext.) being 9.72%followed by rice straw being 3.86%. Meanwhile, corn stalks had the lowest crude protein value being 2.54%. Also, wheat flour had recorded the highest lipid content followed by corn stalks and rice straw being 1.46, 0.78 and 0.41%, respectively.

On the other hand, rice straw presented higher ash and crude fiber content than corn stalk and wheat flour. Meanwhile, wheat flour had the highest carbohydrates content87.65% followed bycorn stalks 53.96%, and these results were in agreement with **Sosulski and Wu (1988)** and **Yasina *et al*. (2010)**.

Table (2): Proximate chemical composition of wheat flour (72% extraction), rice straw and corn stalks (on dry weight basis)

Raw material	Chemical composition (%)				
	Crude protein	Lipids	Ash	Crude fiber	*Carbohydrates
Wheat flour	9.72	1.46	0.56	0.61	87.65
Rice straw	3.86	0.41	16.38	42.74	36.61
Corn stalks	2.54	0.78	3.70	39.02	53.96

* Calculated by difference.

Chemical analysis and caloric value of rice straw and corn stalks fiber gels:

Results in Table (3) show the effect of preparing of fiber gels from rice straw and corn stalks on their chemical composition and caloric value.The obtained results indicated that the values of crude protein, lipids, ash, crude fiber and carbohydrates are changed after treatment of rice straw and corn stalks to prepare the corresponding fiber gel. This changes are recorded an increase in Crude fiber and carbohydrates content. But, both of crude protein, lipids and ash content are decreased. These results are in agreement with **Houston (1972)** who mentioned that, the major modification in cereal wastes composition after pretreatment with alkaline hydrogen peroxide to produce dietary fiber gel was a decrease in ash, due to removal of high amount of silica reaction with sodium hydroxide in the pretreatment resulted in soluble silicates that were eliminated during the washing procedure. In the same time, the reduction in protein and fat content may be occurred a result to soluble proteins and saponified fatty acids (due to the alkaline pH) that probably lost during washing **(Nawar, 1985).**

Rice straw gel contained higher ash and crude fiber being 6.53 and 52.18%, respectively. While, corn stalks gel contained higher lipids and carbohydrates recorded0.64 and 57.44%, respectively. The relative increase in fiber content could be attributed to the decrease of other components.These results were confirmed by **Inglett and Carriere (2001)**whom found that similar decrease in fat, protein and ash content in corn bran fiber gel as a result of such treatment.

The caloric values for rice straw and corn stalks gel were recorded 167.11 and 237.54 kcal/100 g, respectively.Also, it could be observed that, both of rice straw and corn stalks gels have much lower caloric values than butter and oil (885.1 and 900 kcal/100 g on dry weight basis **(Abd El-Khalek, 2007)**. The low caloric values of such dietary fiber gels provide their capacity to act as fat replacers.

Table (3): Proximate chemical composition and caloric value of rice straw fiber gel and corn stalks fiber gel (on dry weight basis)

Fiber gel samples	Chemical composition (%)					Caloric value (kcal/100g)
	Crudeprotein	Lipids	Ash	Crude fiber	*Carbohydrates	
Rice straw	0.86	0.39	6.53	52.18	40.04	167.11
Corn stalks	0.52	0.64	0.71	40.69	57.44	237.54

*** Calculated by difference.**

Dietary fiber fractions:

Polysaccharides were divided into three fractions depending on their solubility in water and alkali. These fractions were pectin substances (soluble in water), hemicellulose (insoluble in water but soluble in dilute alkali) and cellulose (insoluble in a strong alkali). The major polysaccharide was cellulose which is a linear beta-linked glucan of high molecular weight, ranging between 500.000 and 1 million Dalton **(Candido and Campos, 1996)**.

Dietary fiber fractions of rice straw and corn stalks and their fiber gels were carried for total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). The latter including cellulose, hemicellulose and lignin are show in Table (4).

Results in Table (4) indicated that the values of TDF, SDF, IDF, cellulose, hemicellulose and lignin are changed after treatment of rice straw and corn stalks to prepare the corresponding fiber gel. This changes were recorded an increase in TDF, SDF, IDF, Cellulose and hemicellulose and a decrease in lignin content.

Table (4): Dietary fiber fractions of wheat flour, rice straw and corn stalks and their fiber gel (on dry weight basis)

Components (%)	Wheat flour (72% extraction)	Rice straw	Corn stalks
Raw material			
Total dietary fiber (TDF)	2.85	70.35	67.95
Soluble dietary fiber (SDF)	0.93	14.58	16.48
Insoluble dietary fiber (IDF)	1.92	55.77	51.47
Cellulose	ND	42.20	34.37
Hemicellulose	ND	14.58	24.18
Lignin	ND	5.57	7.32
Fiber gel			
Total dietary fiber (TDF)	ND	80.11	80.99
Soluble dietary fiber (SDF)	ND	17.81	19.76
Insoluble dietary fiber (IDF)	ND	62.30	61.23
Cellulose	ND	48.58	42.90
Hemicellulose	ND	17.62	28.03
Lignin	ND	4.35	6.07

ND: Not determined.

These means that preparation process of fiber gel from fiber samples were led to an increase in the IDF and decrease in lignin. For example, IDF values of rice straw and corn stalks were 55.77 and 51.47%, respectively and they increased to 62.30 and 61.23% for the corresponding gels.

On the other hand, lignin reduced from 5.57 and 7.32% for rice straw and corn stalks to 4.35 and 6.07% for their gels, respectively and these results are in agreement with results obtained by **Inglett and Crriere (2001)** and **Sandak (2004)**.

Water and oil holding capacity:

Data presented in Figures (1 and 2) show water and oil holding capacity of both rice straw and corn stalks and their fiber gel. It could be noticed that the water holding capacity increased from 4.38 and 3.86 g water/ g sample for rice straw and corn stalks to 7.43 and 6.25 g water/ g sample for the corresponding gels, respectively. These increases in WHC values may be attributed to the result of removal of ash and lignin solublization and elimination as show in (Tables 3 and 4). These results are in agreement with **Sosulski and Cadden (1982)** whom found that WHC was increased by increasing the contents of cellulose. Also, cellulose has the ability to stabilize large quantities of water by the formation of gel with lubricant and flow properties similar to that happened by the lipids and cellulose gel which was used a fat replacer **(Candido and Campos, 1996)**.

Figure (2) show that the oil holding capacity was increased from 3.95 and 2.76 g oil/ g sample for rice straw and corn stalks to 5.72 and 4.98 g oil/ g sample for the corresponding gels, respectively. These results are in agreement with **Sosulski and Cadden (1982)**whom found that OHC was increased by increasing the contents of cellulose.

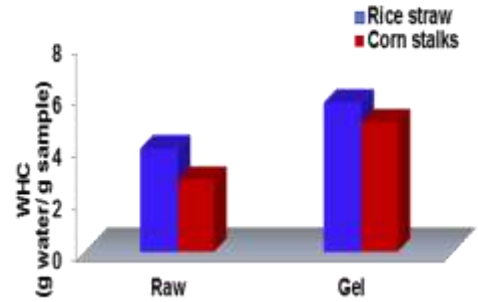


Figure (1): Water holding capacity of rice straw and corn stalks and their fiber gel (g water/ g sample)

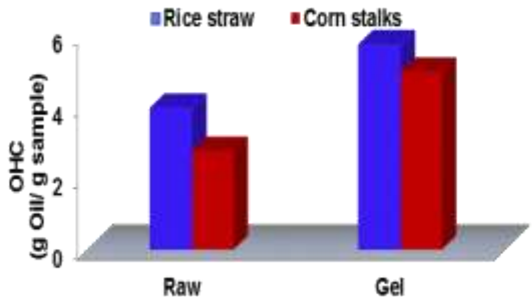


Figure (2): Oil holding capacity of rice straw and corn stalks and their fiber gel (g oil/ g sample)

Chemical analysis of produced biscuit:

The effect of replacing 20, 40, 60 and 80% of fat in biscuits formula with rice straw and corn stalks fiber gels on the chemical composition and caloric value of biscuits are shown in Table (5).

From the obtained results, it could be shown that, the control biscuit sample containing 3.62% moisture, 5.71% crude protein, 23.59% lipids, 1.23% ash, 0.35% crude fiber and 69.12% carbohydrates. Also, it could be observed that, moisture contents of fat-replaced biscuits were gradually increased as the level of replacing with rice straw or corn stalks fiber gels increased. This result was supported by **Sanchez *et al*. (1995)** who reported that, the increase in moisture content associated with using of carbohydrate-based fat substitutes. Also, they concluded that it was a consequence of the higher water requirement with higher levels of fat substitution.

Gradual decreased in crude protein content of the resulted biscuit samples were observed when increasing the replacement levels of different fiber gel sources and these results may be related to the progressive increase in carbohydrates content with increase the replacement levels of fiber gel. Biscuit prepared with replacement of 80% of fat with rice straw and corn stalks fiber gels had protein content of 5.48 and 5.53% respectively compared to 5.71% for control sample.

Table (5): Proximate chemical composition and caloric values of biscuit containing different concentration of rice straw fiber gel and corn stalks fiber gel as a fat replacer (on dry weight basis)

Biscuit samples	Gel Concentration (%)	Chemical composition (%)						Caloric value (kcal/100g)
		Moisture	Crude protein	Lipids	Ash	Crude fiber	*Carbohydrates	
Control sample		3.62	5.71	23.59	1.23	0.35	69.12	511.63
Rice straw	20	4.43	5.68	18.87	2.00	1.81	71.64	479.11
	40	5.24	5.64	14.15	2.76	3.26	74.19	446.67
	60	6.02	5.52	9.44	3.54	4.85	76.65	413.64
	80	6.85	5.48	4.72	4.31	6.30	79.19	381.16
Corn stalks	20	4.12	5.66	18.94	1.78	1.60	72.02	481.18
	40	4.87	5.61	14.28	2.32	2.86	74.93	450.68
	60	5.36	5.58	9.53	3.18	3.91	77.80	419.29
	80	5.97	5.53	4.88	3.73	5.17	80.69	388.80

*** Calculated by difference.**

Fat content was also decreased as the fat replacer level increased. The decrease in fat content was equal to 4.72 and 4.88% respectively for biscuit prepared with replacement of 80% of fat with rice straw and corn stalks fiber gels compared to 23.59% for control sample. This is due to the low fat content of rice straw and corn stalks fiber gels as shown in Table (3).

On contrast to the trend of fat content, a gradual increase in ash, crude fiber and total carbohydrates were obtained by increasing fat replacement level with different fiber gel sources in biscuits. The ash, crude fiber and total carbohydrates of biscuit samples were increased from 1.23, 0.35 and 69.12% for control biscuit sample to 4.31, 6.30, 79.19% and 3.73, 5.17, 80.69% as a result to replacement of 80% of fat with rice straw and corn stalks fiber gels, respectively.

At the same time, caloric value of fat-replaced biscuit was gradually decreased by increasing fat replacement level with different fiber gel sources in biscuits. These results agreed with those obtained by **Drewnowski *et al*. (1998)**who reported that reducing the fat content in cookiesprinciple would reduce total calories.

Physical properties of produced biscuit:

Fat is one of the principle ingredients that affect biscuit texture. Substitution of fat with other ingredients had a greater impact on textural attributes of biscuit than the replacement of sugar or flour as reported by **Campbell *et al*. (1994).**

Data in the Table (6) showed the physical properties of low-fat biscuits prepared by replacing fat with 20, 40, 60 and 80% of rice straw and corn stalks fiber gels as a fat replacer. From the obtained results it could be observed that, the replacement of fat with different levels of different fiber gel sources caused gradual increase in the weight of prepared biscuit parallel with increasing the level of replacement. The increase in biscuit weight may be due to the increase in biscuit fiber content which characterized by higher water holding capacity **(Chen *et al*., 1988)**.

On the other side, replacement of fat with different levels of different fiber gel sources caused gradual decrease in biscuit volume by increasing level of fiber gel in compared to control sample.As expected, the values of specific volume recorded the similar trend as that of volume.

Also, the obtained results showed that, the values of diameter in all biscuit samples had a slight decrease with increasing the amount of different fiber gels as a fat replacer. On the contrary, the values of thickness in all biscuit samples had a slight increase with increasing the amount of different fiber gels. The changes in diameter and thickness were reflected, also, in the spread ratio of biscuits. The spread ratio was a slight decrease with increasing fiber gels ratio as a fat replacer. Similar results were observed by **Sudha *et al*., (2007), Pareyt and Delcour(2008) and Pareyt *et al*., (2009)** found that an increase in fat level in biscuits was generally associated with higher spread rate due to the increased mobility in the system when fat melts and lubrication of the structure by coating the matrix during baking and gave soft structure dough's.

Table (6): Physical measurements of biscuit containing different concentration of rice straw fiber gel and corn stalks fiber gel as a fat replacer

Biscuit samples	Gel Concentration (%)	Weight (g)	Volume (cm3)	Specific volume (cm3/g)	Diameter "D" (cm)	Thickness "T" (cm)	Spread ratio (D/T)	Hardness (N)
Control sample		12.32	22.71	1.84	5.82	0.68	8.56	22.30
Rice straw	20	12.85	21.69	1.69	5.50	0.73	7.53	25.60
	40	13.47	20.45	1.52	5.24	0.78	6.72	28.57
	60	14.09	19.38	1.38	5.07	0.82	6.18	33.08
	80	14.78	18.62	1.26	4.85	0.86	5.64	37.49
Corn stalks	20	12.76	21.88	1.72	5.60	0.70	8.00	24.38
	40	13.24	21.04	1.59	5.36	0.71	7.55	27.85
	60	13.80	20.15	1.46	5.17	0.73	7.08	31.90
	80	14.25	19.47	1.37	4.92	0.75	6.56	35.17

According to hardness data showed that, the hardness of the biscuits were increased by increasing ratio of rice straw and corn stalks fiber gels asa fat replacer from 20 to 80% compared to the control sample. These results agreed with **Zoulias et al. (2002a&b)** and **Żbikowska and Rutkowska(2008)**mentioned that high values of shear force (which indicated hardness) is an unpleasant attribute for such type of product. The hardness, also, increased as percentage replaced fat increased. It was referred that this increase to the structure was less aerated and had more compact crumb in high fat replacer formula **(Rodríguez-García *et al*., 2013)**.

Sensory evaluation of produced biscuit:

Data in Table (7) and Figure (3) showed that, the appearance and color of biscuits were not significantly affected when replacing up to 40 and 60% of fat with rice straw and corn stalks fiber gelwithout any adverse effect. Texture and taste decreased significantly with increasing the level of replacement of fat with rice straw and corn stalks fiber gel, but there are no significant differences between control biscuit sample and biscuit samples prepared with fat replacement levels up to 40%.

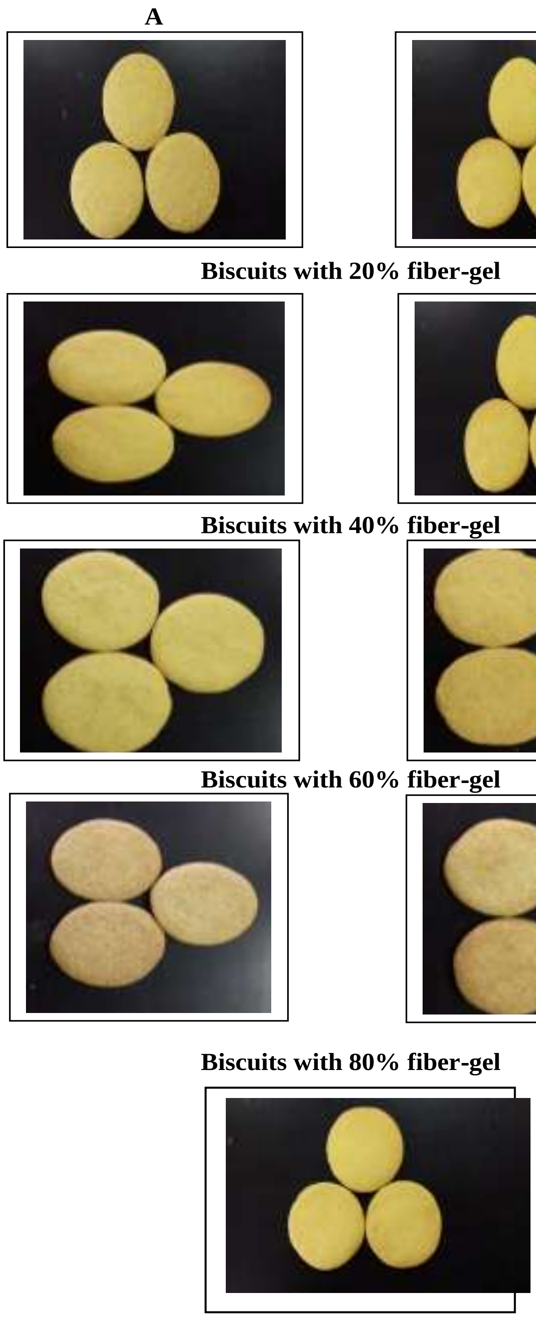
Concerning to the odor no significant difference ($p<0.05$) was recorded between control sample and all other biscuit samples. Finally, the overall acceptability scores are considering a reflection of all the tested quality attributes and acceptability of the studied biscuits. These values were calculated from 100 as a sum of received sensory score. The results demonstrated that, the mean total score values of control biscuit sample was higher than those of other samples and decreased gradually with non-significant differences($p<0.05$) compared with control sample until 60% replacement level with rice straw and corn stalks fiber gel as a fat replacer.

Table (7): Sensory evaluation of biscuit containing different concentration of rice straw fiber gel and corn stalks fiber gel as a fat replacer

Biscuit samples	Gel Concentration (%)	Sensory parameters					
		Appearance (20)	Color (20)	Texture (30)	Odor (15)	Taste (15)	Overall acceptability (100)
Control sample		19.7± 0.03[a]	19.5± 0.02[a]	29.4± 0.01[a]	15.0± 0.00[a]	15.0± 0.00[a]	98.6± 0.02[a]
Rice straw	20	19.4± 0.02[a]	19.5± 0.02[a]	29.0± 0.05[a]	15.0± 0.00[a]	15.0± 0.00[a]	97.9± 0.15[a]
	40	19.2± 0.04[a]	19.2± 0.06[a]	28.3± 0.27[ab]	15.0± 0.00[a]	14.8± 0.02[a]	96.5± 0.47[a]
	60	18.9± 0.11[ab]	18.7± 0.12[ab]	27.6± 0.32[b]	14.9± 0.01[a]	14.2± 0.07[ab]	94.3± 1.19[ab]
	80	17.6± 0.18[b]	18.0± 0.24[b]	24.7± 0.56[c]	14.8± 0.02[a]	13.0± 0.14[b]	88.1± 2.38[b]
Corn stalks	20	19.6± 0.02[a]	19.4± 0.04[a]	28.8± 0.14[a]	15.0± 0.00[a]	15.0± 0.00[a]	97.8± 0.71[a]
	40	19.3± 0.01[a]	19.3± 0.01[a]	27.5± 0.22[b]	15.0± 0.00[a]	14.9± 0.01[a]	96.0± 0.55[a]
	60	19.0± 0.05[ab]	19.0± 0.03[a]	26.9± 1.05[bc]	14.8± 0.02[a]	14.4± 0.05[ab]	94.1± 1.95[ab]
	80	18.1± 0.09[b]	18.5± 0.09[ab]	24.2± 1.64[c]	14.6± 0.03[a]	13.5± 0.08[b]	88.9± 3.11[b]

*** Values were expressed as means ±SE .Means followed by different letters in the same column are significantly different by Duncan's multiple test ($p<0.05$).**

At conclusion, replacing 40 and 60% of fat with fiber gel from rice straw or corn stalks were chosen for production of high quality and low caloric biscuits. These results agree with those obtained by **Swanson *et al*. (1999)** and **Perry *et al*. (2003)**.



Control

Figure (3): Low-fat biscuits with (A: corn stalks-fiber gel, B: rice straw-fiber gel) as fat replacer

Biological evaluation of produced biscuit:

The results presented in Table (8) showed the effect of fat replaced-biscuits using fiber gel on serum lipid profile in hypercholesterolemic rats. Rats fed with cholesterol rich diet developed hypercholesterolemia significantly by increasing total cholesterol and triglycerides as compared with negative control group. On the other hand, feeding hypercholesterolemia rats with different biscuit samples containing 40% or 60% rice straw or corn stalks-fiber gel as fat replacer recorded significant decrease in plasma total cholesterol and triglycerides as compared to normal biscuits and positive control.

Table (8): Effects of biscuit's diets on serum biochemical parameters in rats

Parameters	Control		Treated biscuits				
	(Ve-)	(Ve+)	Normal	RS-fiber gel*		CS-fiber gel**	
				40%	60%	40%	60%
T-CHO (mg/dL)	106.32 ±1.44^{d}	210.94 ±1.77^{a}	176.1 ±3.09^{b}	147.44 ±2.47^{c}	155.24 ±2.98^{bc}	148.24 ±3.24^{c}	160.04 ±2.88^{bc}
TG (mg/dL)	66.10 ±3.48^{d}	123.34 ±2.96^{a}	113.8 ±3.20^{a}	76.36 ±2.92^{cd}	64.50 ±2.43^{d}	89.70 ±2.35^{b}	84.10 ±2.79^{bc}
HDL-CHO (mg/dL)	49.80 ±1.72^{d}	34.50 ±1.56^{f}	40.10 ±2.83^{e}	57.66 ±1.62^{bc}	66.64 ±2.29^{a}	55.22 ±2.32^{c}	60.20 ±2.05^{b}
LDL-c	43.30 ±1.66^{d}	151.81 ±2.20^{a}	113.26 ±4.15^{b}	74.50 ±1.44^{c}	75.30 ±2.85^{c}	75.08 ±3.29^{c}	83.02 ±3.23^{c}
VLDL-c	13.22 ±0.69^{d}	24.66 ±0.59^{a}	22.75 ±0.64^{a}	15.27 ±0.58^{cd}	13.29 ±0.48^{d}	17.94 ±0.47^{b}	16.82 ±0.55^{bc}
LDL/HDL	0.88 ±0.05^{c}	4.41 ±0.25^{a}	2.85 ±0.26^{b}	1.29 ±0.04^{c}	1.13 ±0.07^{c}	1.36 ±0.09^{c}	1.39 ±0.08^{c}
Creatinine (mg/dL)	0.36 ±0.03^{e}	0.56 ±0.04^{a}	0.48 ±0.04^{b}	0.42 ±0.04^{cd}	0.46 ±0.03^{bc}	0.40 ±0.03^{de}	0.42 ±0.04^{cd}
AST/GOT (U/L)	48.0 ±2.86^{e}	78.12 ±1.71^{a}	70.82 ±2.11^{b}	64.2 ±3.70^{c}	51.60 ±3.84^{e}	66.00 ±3.39^{c}	56.00 ±2.82^{d}
ALT/GPT (U/L)	25.20 ±2.38^{e}	43.40 ±2.07^{a}	41.40 ±1.14^{a}	28.00 ±2.91^{de}	32.00 ±2.34^{bc}	30.00 ±2.73^{cd}	35.00 ±2.23^{b}
ALP (U/L)	27.24 ±1.98^{d}	47.70 ±3.04^{a}	47.56 ±3.00^{a}	31.70 ±2.18^{c}	28.12 ±2.83^{d}	36.20 ±1.93^{b}	29.20 ±2.38^{cd}

Values were expressed as means ±SE. Means followed by different letters in the same row are significantly different by Duncan's multiple test ($p<0.05$).

***Rice straw fiber gel**

****Corn stalks fiber gel**

The more pronounced lowering effect of biscuit diets was observed in the groups of rats fed on biscuits with rice straw-fiber gel as compared to other examined groups. The effect of feeding different biscuit samples to the hypercholesterolemic rats on high density lipoproteins cholesterol (HDL-c), low density lipoproteins cholesterol (LDL-c) and very low density lipoproteins cholesterol (VLDL-c) were also shown in Table (8). The group fed the biscuits with 60% rice straw-fiber gel had significantly higher ($p<0.05$) plasma HDL-c level than other biscuits supplemented groups and positive control (+ve). Higher level of HDL-c was associated with reduced risk of atherosclerosis, since high density lipoprotein in serum is thought to facilitate the translocation of excess cholesterol from the peripheral tissue to liver for further catabolism **(Makni *et al*., 2008)**.HDL-c ratio is one of the most important criteria of anti-hypercholesterolemic agent **(Barakat, 2011)**. Hypercholesterolemic rats which were fed biscuits with fiber gel had significantly lower mean values of LDL-c compared to normal biscuits and positive control groups. By increase of fiber gel levels in the biscuits diets is able to reduce VLDL-c comparing to positive control and normal biscuits as shown in Table (8). Also, VLDL-c values were similar ($p<0.05$) for biscuits with 60% rice straw-fiber gel group and the negative control.

This significant decrease in level in LDL-c and VLDL-c according to biscuits with rice straw or corn stalks-fiber gel in diets is due to in soluble dietary fiber in fiber gels **(Zhou *et al*., 2015)**. **Gupta *et al*. (1994)** reported that higher LDL-c level is related with greater deposition of cholesterol in artery and aorta thereby increasing risk for coronary artery disease, whereas low HDL-c is the prevalent lipoprotein abnormality. Low density lipoproteins-cholesterol / High density lipoproteins-cholesterol (LDL/HDL) is predictor of coronary risk **(Hassan *et al*., 2012)**.The results present in Table (8) also indicated that the rats groups fed on biscuit diets using RS- or CS- fiber gel as fat replacer had a significant lower ratio of LDL/HDL-c when compared with normal biscuits and high fat cholesterol diet groups. It could be seen from the obtained results that using rice straw or corn stalks-fiber gel with biscuits to the diet could produce significant reduction in LDL/HDL-c ratios and thus improve beneficial lipoprotein ratios to reduce the risk of heart disease in hypercholesterolemic individuals. Results in Table (8) also indicated that feeding on basal diet containing 1% cholesterol has shown a significant increase $p<0.05$ in serum AST and ALT, as compared to healthy rats group (78.12 and 43.40 vs. 48.0 and 27.24 U/L), respectively. The high levels of AST and ALT in serum are indicators for liver dysfunction **(Kwo *et al*., 2017)**. These findings are in agreement with **Al- Dosari (2011)** and **Halaby *et al*. (2013)** who revealed that the rats feeding on high cholesterol diet showed significant increase in serum liver marker enzymes (GOT, GPT, GGT and ALP) and bilirubin levels. Results indicated also, that, feeding on biscuits with fiber gel resulted in significant decrease $p<0.05$ in serum AST and ALT as compared to positive control group. The best results of liver function recorded for hypercholesterolemic rats fed on biscuits diet with 40% rice straw-fiber gel. It could be concluded from the present study that low- fat biscuits with using fiber gel as fat replacer is more effective to reduce the total triglycerides, LDL-c, VLDL-c and liver enzymes in serum, which could be to reduce the risk of cardiovascular disease who will consumed this biscuits.

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تأثير تقليل الدهون في البسكويت عن طريق استخدام مواد هلامية الألياف على التقييم الحسي، والخصائص الريولوجية وتأثيرهاعلى الفئران المصابة بالكوليسترول

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ارتفاع الكولسترول في الدم هو أحد عوامل الخطر المعروفة في تطور تصلب الشرايين وأمراض القلب والأوعية الدموية ، والتي تمثل السبب الرئيسي للوفيات. تحتوي المنتجات المخبوزة مثل البسكويت عادة على كميات كبيرة من الدهون ، فهي توفر خصائص حسية مهمة. كان الهدف من هذا البحث الحالي هو تقييم دور الألياف الغذائية كبديل للدهن على القيمة الغذائية ، والخصائص الريولوجية والتقييم الحسي ، وكذلك آثاره لخفض نسبة الدهون في الدم على الفئران المصابة بإرتفاع الكوليسترول. تمت صناعة البسكويت قليل الدسم عن طريق استبدال 20 و 40 و 60 و 80 ٪ من الدهون في صناعة البسكويت مع هلامالأليافلقش الأرز و سيقان الذرة. أوضحت التحاليل أن البروتين والدهون انخفضت تدريجياً مع زيادة مستويات الاستبدال لمصادر هلام الألياف المختلفة ، في حين تم زيادة الرماد والألياف والكربوهيدرات. كما تأثرت الخصائص الفيزيائية باستبدال الدهون حيث لوحظت زيادة تدريجية في وزن وسمك وصلابة البسكويت المحضر مع زيادة مستوى الاستبدال. على العكس من ذلك ، انخفضت قيم الحجم والقطر. و بالنسبة للتقييم الحسي للبسكويت فقد أظهرت النتائج أنه لا يوجد تأثير كبير على المظهر واللون والرائحة والطعم و ذلك عند نسبة استبدال أقصاها 60 ٪ من الدهون مع هلام الألياف. بالنسبة للدراسة البيولوجية فقد أظهرت النتائج التي تم الحصول عليها أن البسكويت قليل الدسم باستخدام جل الألياف كبديل الدهون له تأثير مخفض للكوليستيرول الكلى و الجلسريدات الثلاثية و الدهون منخفضة الكثافة بينما زادت الدهون مرتفعة الكثافة و إنخفضت إنزيمات الكبد .