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Effect of Modified Fiber from Wheat Bran as Fat Replacer on the Quality Attributes of Beef Sausage

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Abstract: This study was carried out to produce low fat sausages by replacement fat content with fiber gel as fat replacers at levels of 15, 30 and 50% compared with high fat sausage control (20% fat). The effect of substitution ratio on proximate composition, some chemical & physical properties, texture parameters and sensory characteristics of different sausage treatments were studied. The results indicated that fiber gel aimed to reduce T.V.N, TBA and increase the pH value comparison with control sample. Also, there was improvement of WHC, plasticity, cooking yield and reduced cooking loss compared to the control. Moreover, sausages prepared with fiber gel were characterized by significantly higher hardness, Cohesiveness, Gumminess and Springiness than the control sample. Also, results indicated that overall acceptability was good for all prepared sausage treatments the lowest overall acceptability was recorded for sample formulated with 50% fiber gel followed by that prepared with 30% fiber gel with significant differences. Regarding the production of low-fat beef sausages at a commercial scale, it could be recommended to use fiber gel extracted from wheat bran as a fat substitution to prepare healthy sausages to reduce the problems of obesity, atherosclerosis and heart diseases.

Key words: Beef sausage · Wheat bran · Fiber gel · Physico-chemical properties · Sensory properties

INTRODUCTION

Fat is considered important and vital ingredients in meat, as fats are a main source of energy, essential fatty acids and also contains vitamins that melt in fat. It has an influential role in the sensory properties of many food products, as fats interact with other ingredients in food to improve the textures and enhance the flavor [1]. For meat products, fats play an important role in installing emulsions, reducing losses during cooking, increasing the ability to retain water, increasing flavor & juicy and improving the taste in the mouth [2]. Consumers consider meat products to be unhealthy due to their high levels of fat and cholesterol [3]. Therefore, excessive fat intake is related with the hazard of several diseases, including fatness, hypertension, cardiovascular diseases and several forms of cancer [4]. Although fat improves sensory properties, increasing juiciness, tenderness and enhancing flavor, decreasing fat content in meat products is important [5].

Sausages are a highly accepted product by consumers, but their high fat content, especially saturated fatty acids, poses a significant health risk [6]. The preparation and processing of sausages requires the use of minced meat and animal fats in a high proportion of up to 30% (as the use of fat helps to produce a cohesive emulsion), as well as the use of salt, water, spices and other additives, where all these ingredients are mixed together.

Reducing fat in meat products results in products with a tougher, chewier, less juicy crust, darker color, less acceptable to consumers, more expensive to produce and lower cooking yields [7]. Many other technological problems also occur, such as reduced particle binding and

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reduced shelf life with a decreased in fat content [5]. Therefore, researchers have conducted many attempts to compensate for the damage caused by reducing fat levels and these attempts include the use of fat substitutes [8].

Dietary fiber is considered a good replacer for fat in the manufacture of meat products because it's excellent functional and technological characteristics [9]. It also has excellent therapeutic properties such as preventing constipation, decreasing the incidence of cancer, type 2 diabetes and cardiovascular diseases [10]. Dietary fiber is also used in the manufacture of many products, because its high capacity to retain water and fat, improve the texture of food products and reduce production costs. However, replacing fat with fiber is difficult, as it requires maintaining the sensory properties of products and extending the shelf life, as fat improves the taste by releasing, condensing and distributing the compounds responsible for this property [11, 12]. It has also been found that replacing fat with dietary fiber reduces calories [13]. Therefore, consumers have recently become more interested in using dietary fiber in the manufacture of many foods.

Bran is known as a secondary product of the cereal milling process and is utilize in many food and non-food applications [14]. Recently, wheat bran (WB) has been widely utilized in food manufacturing, as the number of food products containing wheat bran superfast from 52 products in 2001 to 800 products in 2011 [15]. Wheat bran has been found to be a rich source of minerals, fiber, B vitamins and biologically active compounds that play an effective role in promoting health and preventing diseases. Consumer awareness of their keenness to eat healthy foods has led to the integration of these healthy ingredients extracted from naturalistic sources in food production [16].

Wheat bran gels have been found to be suitable for the manufacture of healthy meat products, as they form a network by cross-linking carbohydrates or proteins, which act as a matrix to simulate fats. These gels are characterized by their soft texture and high water and fat retention capacity; therefore they are used as a suitable substitute for fats. These emulsified gels are more suitable for transporting and protecting oxidized fats, so they contribute to the preservation of flavor substances and biologically active compounds and they help in the transfer of functional components and thus develop the organoleptic and physical properties of meat products [17]. This gel is prepared by subjecting dietary fibers to chemical and physical treatment until the cellular structures are completely disintegrated. These materials have a high viscosity and therefore are characterized by their high hydration capacity and they can be dried and reshaped easily. It can also be used in the manufacture of many food products and non-food formulations as well, as it is used specifically as a low-calorie fat substitute [18]. It was found that the functional properties of these materials are represented by their ability to form gels or films and thus stabilize emulsions in addition to the ability to retain oil and water [19]. As for the functional properties of meat, they depend on the interaction of protein with other components such as (water, fat and protein), which affects the ability of meat to bind water, stabilize fat and thus produce products with physical and sensory properties acceptable [5].

According to the decision for Nutrition allegations for traditional Foods, food products classified "high fiber" should include minimum 6 g of dietary fiber per 100 g of solid matter. Food products classified "contains dietary fiber" should include minimum 3 g of dietary fiber per 100 g of solid matter [20].

This study was conducted to the development of functional meat products rich in dietary fiber have a value-added and commercial importance. Where, evaluate the proximate, chemical, physical and sensory quality of beef sausages supplemented with 15, 30 and 50% wheat bran fiber gel

MATERIALS AND METHODS

Materials:

- Wheat bran was obtained from North Cairo Flour Mills Company, Egypt.
- Fresh lean beef meat from boneless area and fat tissues were purchased from the private shop in the local market at Giza, Egypt. Other ingredients used in sausage preparation such as rusk, salt and other seasoning were purchased from local store at Giza, 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.
- Methods.

Preparation of Fiber Gels: Fiber gel of wheat bran was prepared according to the method described by (Carriere and Inglett) [21]. At primary treatment one kg of crushed waste was placed into a20L plastic tank and homogenized with 11L of water. The pH was adjusted to 6.8 by 10 g of 50% sodium hydroxide solution. The mixture was heated to 90-94°C, then the 2.4 ml of heat stable α-amylase (55.2 U/mg) was added. The mixture was sheared in autoclave (Vision KMC 1221 made in Korea) at 90-98 °C. The pH is increased to 12 by adding 175 ml of 50% sodium hydroxide solution and continuing the shearing process again. The pH of the solids was adjusted again to 7, then washed twice with distilled water and collected in a 25-µm filter bag. In the second treatment, the pH of the solids was raised to 10 by adding a 50% sodium hydroxide solution. 500 ml of 30% hydrogen peroxide solution was added to the mixture and then the mixture was placed for 45 minutes in a steam sterilizer at 90-98°C. The mixture was stirred for 36 hours and then wet solids (fiber gel) were collected in a filter bag and dried under vacuum, finally ground to obtain the fiber gel powder.

Preparation of Beef Sausage: Four formulas of sausage were manufactured in this research. Control sample was prepared according to the method described by Rocco *et al*. [22] and consists of: lean beef meat (62.0%), sheep fat tail (20.0%), ice water (10.0%), rusk (5.0%), salt (2.0 %) and spices (1.00%). Different sausage samples were prepared by substitution of 15, 30 and 50 % of the fat level by wheat bran fiber gel as shown in Table (1).

All treatments were prepared by blending the minced lean meat with other ingredients by using emulsifier machine (Hobbart Kneading, Italy) specialized for sausage manufacturing. The emulsion was mechanically stuffed into natural casings, then closed and manually chipped into pieces approximately 15 cm length. All treatments were packaged in foam plate, covered with polyethylene film and stored at refrigerator until analysis.

Chemical Analysis: Chemical composition of raw materials and sausage treatments (moisture, crude protein, fat and ash content) were determined according to AOAC [23]. Carbohydrate contents were calculated by difference, all samples were analyzed in duplicate for each component and results were expressed dry basis.

Total dietary fiber (TDF), soluble and insoluble dietary fibers were determined in wheat bran and fiber gel according to the method reported by Prosky *et al.* [24].

Table 1: Product formulation (g kg-1) for different beef sausage samples

		Sausage treatments prepared with fiber gel		
Ingredients	Control	15% replacing	30% replacing	50% replacing
Beef meat	62.0	62.0	62.0	62.0
Fat	20.0	17	14	10
Fiber gel	-	3	6	10
Rusk	5.0	5.0	5.0	5.0
Salt	2.0	2.0	2.0	2.0
Spices	1.0	1.0	1.0	1.0
Ice water	10.0	10.0	10.0	10.0

Water and Oil Holding Capacity: Water and oil holding capacities were determined according to Knuckles and Kohler [25].

Chemical Quality Attributes: Thiobarbituric acid (TBA) and total volatile nitrogen (TVN) were determined in different treatments by the procedure described by Egan *et al*. [26] and Winton & Winton [27], respectively.

pH Value: 10 grams of crushed beef sample homogenized with 90 ml distilled water by using magnetically stirring for 5 min, then the pH of suspension was measured by a ICM 41150 pH meter [28].

Physical Analysis: Water Holding Capacity (WHC) and plasticity of all sausage samples were measured directly after manufacturing according to Soloviev [29]. The cooking loss of sausage formulas were calculated according to AMSA [30]. Cooking yield was measured as given by El-Nemer [31].

% Cooking yield = 100 - % Cooking loss

Texture Profile Analysis: Texture profile analysis (TPA) test was carried out on cooked treatments using a texture profile analyzer (Brookfield, CT3, Middleboro, MA, United States) to measured hardness, cohesiveness, gumminess, chewiness and springiness. Treatments were chipped into (1 × 1 × 1 cm) then held at room temperature (20°C) and covered with plastic film for TPA as the method given by Bourne [32].

Sensory Evaluations: Beef sausage samples were cooked using a Hotplate (Mienta HP41325A Duetto , China) at 120°C for 2–3 minutes until the color transition to golden yellow. Ten members of the Meat and Fish Technology Research Department, Food Technology Research Institute, invite to evaluated sausage samples for odor, color, taste, texture, overall acceptability according to Gelman and Benjamin [33].

Statistical Analysis: Statistical analysis of 3 replicates from obtained data was done by SPSS [34]. Duncan's multiple range tests Duncan [35] at 5% significance level was applied to find out significant differences in mean.

RESULTS AND DISCUSSION

Chemical Composition of Wheat Bran and Fiber Gel: Data illustrated in Table (2), showed that wheat bran and fiber gel contained 13.20 and 2.64% crude protein, 2.13 and 1.87% crude fat, 2.43 and 0.96% total ash, 3.15 and 3.87% crude fiber and 79.09 and 90.66% total carbohydrates, respectively, on a dry weight basis. Also from the same table, it could be observed that fiber gel had higher crude fiber (3.87%) than raw wheat bran (3.15%), with a significant difference. The high fiber content in the fiber gel is necessary to bind more water and fat, the presence of fiber is important for the manufacture of low-fat sausages with less cooking loss, These results are in accordance with those found by Mansour and Khalil [36] who explained that fortifying cooked meat products with fiber reduced cooking loss because its high ability to bind water and fat, thus improving texture as well.

Dietary Fiber of Wheat Bran and Fiber Gel: The dietary fiber content of raw wheat bran and its fiber gel was determined in the form of total dietary fiber (TDF), insoluble dietary fiber (IDF) and soluble dietary fiber (SDF). According to the results in Table (3), the fiber gel had a higher contained of total, insoluble and soluble dietary fiber with a significant difference (45.57, 42.37 and 3.20%) compared with raw wheat bran (38.24, 35.48 and 2.76%), respectively Huang *et al*. [37] Reported that, addition of dietary fiber when prepared Chinese-style sausages led to an increase in their crude fiber content.

Water and Oil Holding Capacity of Wheat Bran and Fiber Gel: Data tabulated in Table (4) show the ability of both raw wheat bran and its fiber gel to bind water and oil. The water holding capacity increased with a significant difference from 6.27 g water/g sample for raw wheat bran to 3.45 g water/g sample for fiber gel. Also, from the same table it can be noticed that, the oil holding capacity increased significantly from 3.78 g oil/g sample for raw wheat bran to 2.14 g oil/g sample for the corresponding gel. These results could be attributed to the content of cellulose and insoluble dietary fiber in all treatments. These results are consistent with the findings of Nyman and Svanberg [38], which cleared that the physiological effects of dietary fiber depend largely on the chemical and physical characteristic of the food substance, such as water binding capacity, viscosity and molecular distribution.

Proximate Chemical Composition of Different Beef Sausage Samples: Gross chemical composition of control and other sausage treatments prepared by replacement adipose tissue with fiber gel at different levels (15, 30 and 50%) are showed in Table (5). From this table, it could be noticed that the moisture content of each samples ranged from 54.30 to 64.88%. Data indicated that all samples formulated with different levels of fiber gel were significantly higher in moisture content than that of control sample. The highest moisture content (64.88%) was recorded for the sausage sample replaced with fiber gel (50%). This might be due to the reduction of fat tissue from (20% in control) to 10% and replaced it with 10% fiber gel. On the other hand, the lowest moisture content (54.30%) was recorded for control sample. Similar results were obtained by Osheba [39], who reported that meat products with a high fat content such as patties, minced beef and sausages, had lower moisture content. Similar results were reported by Troy *et al* [40] and Mansour & Khalil [36] they showed that the moisture content of beef burgers formulated with fat replacer was greater than control sample. Moreover, Choi *et al* [41] reported that the moisture content of low-fat sausages increment significantly as the levels of back fat decreased from 30% to 10%.

From the same table, it can be noticed that protein content in sausage samples formulated with different levels of fiber gel were lower than control sample. In addition that, protein content of samples prepared with fiber gel slightly decreased by increasing substitution ratio, with non-significant difference. The protein content in the control sample was (16.12%), while in the samples prepared using the fiber gel were (15.90, 15.70and 15.69%), respectively. these lower than permissible limit which reported by Egyptian Standards Specifications [42] which sausages should contain protein content not less than 15%.

Table (5) shown the fat contents in the different sausage samples. Fat content was decreased with increasing the level of fiber gel. Also, it could be noticed that, there were significant differences in fat content between all samples which manufactured with fiber gels and the control sample. The lowest fat content (6.67%) was recorded for sausage treatment with 50% fat substitution, followed by the sausage treatment with 30% fat substitution (11.00%) with a significant difference between them. Meanwhile, the fat content increased in the

Table 2: Proximate chemical composition of wheat bran and fiber gel

Ingredients	Raw wheat bran	Fiber gel
Crude protein	13.20^{a}±0.14	2.64^{b}±0.08
Lipids	2.13^{a}±0.02	1.87^{b}±0.11
Ash	2.43^{a}±0.08	0.96^{b}±0.02
Crude fiber	3.15^{b}±0.06	3.87^{a}±0.21
*Total carbohydrates	79.09^{b}±0.28	90.66^{a}±0.43

*Calculated by difference

Values are mean ± SD.

Values within a raw followed by the same letter are non-significantly different (p=0.05)

Table 3: Dietary fiber of wheat bran and Fiber gel

Ingredients	Raw wheat bran	Fiber gel
Total dietary fiber	38.24^{b}±0.84	45.57^{a}±0.75
Insoluble dietary fiber	35.48^{b}±0.37	42.37^{a}±0.48
Soluble dietary fiber	2.76^{b}±0.12	3.20^{a}±0.15

Values are mean ± SD.

Values within a raw followed by the same letter are non-significantly different (p=0.05)

Table 4: Water and oil holding capacity of wheat bran and Fiber gel

	Raw wheat bran	Fiber gel
Water holding capacity (g water ? g fiber)	6.27^{a}±1.06	3.45^{b}±1.24
Oil holding capacity (g oil ? g fiber)	3.78^{a}±0.90	2.14^{b}±0.88

Values are mean ± SD.

Values within a raw followed by the same letter are non-significantly different (p=0.05)

Table 5: Proximate chemical composition of different sausage samples

	Sausage samples			
Chemical composition	Control	15%	30%	50%
Moisture	54.30^{d}±0.47	56.96^{c}±0.70	61.41^{b}±0.61	64.88^{a}±0.77
Crude protein	16.12^{a}±0.12	15.90^{a}±0.66	15.70^{a}±0.72	15.69^{a}±0.13
Lipids	21.95^{a}±0.47	16.98^{b}±0.21	11.00^{c}±0.41	6.67^{d}±0.28
Ash	2.10^{b}±0.27	2.31^{ab}±0.73	2.49^{a}±0.02	2.69^{a}±0.13
Crude fiber	0.89^{b}±0.32	1.18^{ab}±0.42	1.52^{a}±0.07	1.83^{a}±0.02
Total carbohydrates	4.64^{c}±0.04	6.67^{b}±0.51	7.88^{a}±0.16	8.24^{a}±0.07

Values are mean ± SD.

Values within a raw followed by the same letter are non-significantly different (p=0.05)

Table 6: Chemical quality attributes of different beef sausage samples

Sausage samples		T.V.N	T.B.A	pH
Control Sausage sample		12.81^{a}±0.45	0.125^{a}±0.017	6.61^{a}±0.23
Wheat bran fiber gel	15%	12.76^{a}±0.38	0.113^{a}±0.025	6.23^{ab}±0.18
	30%	12.69^{a}±0.42	0.106^{ab}±0.020	5.98^{b}±0.25
	50%	12.64^{a}±0.40	0.084^{b}±0.019	5.74^{b}±0.12

Values are mean ± SD.

Values within a column followed by the same letter are non-significantly different (p=0.05)

T.V.N: Total volatile nitrogen (mg ? 100 mg).

T.B.A: Thiobarbituric acid (mg malonaldehyde ? kg).

control sample (21.95%), followed by the sausage treatment with 15% fat substitution (16.98%) with a significant difference as well. These results are consistent with the trend of Lin and Chao [43] who found that fat content increased in all samples with decreasing of moisture content.

On contrast to the trend of protein and fat content, a gradual increase in ash, crude fiber and total carbohydrates were obtained by increasing levels of fiber gel compared to the control sample with a significant difference in most samples. Also, the percentages of increases were higher with increasing of substitution ratio.

Chemical Quality Attributes of Different Sausage Samples: Data illustrated in Table (6), showed that total volatile nitrogen (TVN) of all sausage samples ranged from 12.64 to 12.81mg/100 g. Moreover, samples formulated with different levels of fiber gel had a lower total volatile nitrogen content compared to control sample with a non-significant difference. Also, total volatile nitrogen (TVN) content of all treatments and control sample was lower than permissible level according to the Egyptian Standards Specifications [42], which stipulated that the total volatile nitrogen content should not exceed 20 mg/100 g.

From Table (6) it could be showed that thiobarbituric acid of all treatmenrs ranged from 0.084 to 0.125 mg malondialdehyde/kg. The greatest TBA value was in control sample compared to other treatments which formulated with fiber gel at different levels with a significant difference and this is might attributed to the high fat content in the control sample which consequently led to higher TBA values. Meanwhile, the TBA values for other samples formulated with fiber gel decreased with increasing fat substitution ratio with a significant difference. This is might be due to the presence of natural antioxidants which could retard lipids oxidation. These results are consistent with the same trend of the results obtained by Qureshi *et al.* [44] which stated that the barley contains tocotrienols and tocopherols, which are natural antioxidants. Generally, the thiobarbituric acid values ??of all samples were within the permissible limited by the Egyptian Standards Specifications [42] which states that the thiobarbituric acid value should not exceed 0.9 mg malondialdehyde/kg for frozen sausages.

Table (6) represents the pH of various sausage samples. Results indicated that the pH values of the different samples ranged from 5.74 to 6.61, with a significant difference b etween the samples ($p>0.05$). Also, the addition of fiber gel to sausage sample decreased pH compared to control sample. These results are conflict with previous studies in research literature García *et al*. [45], reported that dry fermented sausages fortified with dietary fiber don't affect pH values. Meanwhile, Talukder [10] indicated that incorporated dietary fiber into meat products can cause a change in pH.

Physical Analysis of Different Beef Sausage Samples: Water holding capacity (WHC) is defined as the capability of meat to retain its internal or external water when any force is applied (when pressure is applied from outside) and is considered one of the generality important technological characteristic of meat that affects the tenderness of meat products, juiciness, drip loss and cooking yield.

(Table 7) showed the water holding capacity (WHC), plasticity, cooking loss and cooking yield of beef sausage samples as influenced by different levels of fat substitutes (fiber gels). Water holding capacity of all samples ranged from 2.45 to 3.20 cm^2/0.3 g. The highest WHC was noticed for sausage sample prepared with substitute 50% of fiber gel. Whereas, the lowest WHC (as quality) was recorded for control sample with a significant difference. Generally, it can be observed that uses of fiber gel extracted from hydrated wheat bran as fat substitutes increased the water holding capacity of beef sausages. This may be attributed to the ability of wheat bran itself to bind a lot of water. In this regard, Bhat and Bhat [46] reported that fibers have been used in the manufacturing of cooked meat products to increment the cooking yield due to their excellent water holding capacity and fat binding capacity, thus improving the technological properties such as texture.

Finally, the water-Holding capacity of all sausage samples formulated with fiber gel increased significantly with increasing their percentages. This is probably due to the truth that the incorporation of fiber increment the water content of all samples resulting in increased water-holding and fat-binding capacity, Gerardo *et al* [47]. Generally, dietary fibers have excellent water- and fat-binding properties which contribute to the increase in water holding capacity in all treatments Cofrades *et al* [48]. Moreover, Besbes *et al* [49] also found that the incorporation of dietary fibers extracted from peas and wheat during prepared of beef burgers increased the water-holding capacity.

From the same table (7), it was noticed that plasticity values ??took the same direction as the WHC capacity. Plasticity values ??increment with the increasing percentages of fiber gel, the highest value was recorded for the treatment formulated with fiber gel at 50% (4.28 cm^2/0.3 g), while, the lowest value was found for control sample (3.12 cm^2/0.3 g). In general, the addition of fiber gel improved the plasticity of sausages samples. These results are consistent with the trend reached by Mansour and Khalil [36], who reported that wheat bran was an excellent ability to bind water and fat, thus improving plasticity.

From the data presented in Table (7), it can be observed that cooking loss values for all sausage treatments ranged from 17.35 to 22.86%. The highest cooking loss values ??were recorded for control sample (22.86%). This might be due to the fact that addition of hydrogel (fat substitutes) increased cooking yield and thus reduced the cooking loss for all sausage samples. Cooking loss decreased of sausages samples as the percentage of hydrogel increased.

During the cooking process, significant shrinkage of meat and meat products occurs, which is due to deterioration of protein with water evaporation and loss of fat. Cooking loss depends on the capacity of the gel structure to bind water and stabilize fat in minced meat products Varga-Visi and Toxanbayeva [50]. Also, Choi *et al.* [51] found that adding rice bran or vegetable oils to meat paste reduced cooking losses and made the paste emulsion more stable compared to the control sample containing 30% fat. Finally, it can be concluded that adding dietary fiber to meat products decrease cooking loss because its excellent water-fat binding characteristic Cofrades *et al*. [48].

Cooking yield improved significantly with increasing levels of fiber gel (Table 7). This is might be attributed to the moisture-retaining capacity of fiber gel. Control sample had lowest cooking yield (77.14%) while the sample prepared with different ratios of fiber gel had the highest cooking yield which ranged from 79.79 to 82.65%. The decreased cooking yield of control sample might be attributed to fat separation and evaporate water through cooking. Similar trends have been reported by Trius *et al* [52]. They found highly decrease in diameter during cooking for the control sample compared to other samples prepared with different levels of fiber gel, while samples prepared by replacing 50% of the fat with fiber gel had the least diameter reduction. In the same trend, Troy *et al*. [40] found that, the diameter decrease during cooking was small in beef patties containing oat fiber. Also, was observed that adding wheat bran at 5, 10 and 15% during the preparation of chicken meat patties increased the cooking yield and improves the texture Talukder and Sharma [53].

Texture Profile Analysis of Different Beef Sausage Samples: Data obtained in Table (8), explained that texture indices of sausage samples as affected by ratio of fat substitution. From these data, it could be noticed that there were significant differences in all texture indices among each samples. Hardness of sausage samples was significantly increased by increasing fiber gel. The highest hardness value (27.48) was recorded for treatments formulated with 50% fat substitution, followed by sausage prepared with 30% fat substitution and finally samples formulated with 15% fat substitution with a significant differences between them. Meanwhile, the lowest hardness value was recorded for control sample.

Also, from the same table it can be showed that, Cohesiveness values ranged from 0.52 to 0.65 with non-significant differences among each treatment. The highest cohesiveness value was noticed for sample formulated with 50% fat substitution. On the antithesis, the lowest value 0.52 was recorded for control sample.

Data in Tables (8) indicated that, Gumminess of different samples ranged from 11.08 to 18.30g with a significant differences ($p>0.05$). Gumminess of sausage samples was significantly increased by decreasing fat ratios. Sausage sample prepared by fiber gel had higher Gumminess values than control sample at different levels with significant differences between them.

Chewiness values ranged from 7.23 to 14.07 for all samples. Chewiness values significantly increased by fiber gel levels increasing. Also, samples formulated with fiber gel had significantly higher chewiness values than control sample.

On the other hand, springiness value for all samples ranged from 0.70 to 0.76 with non-significant differences between of them. These results supported findings of results reported by some researchers on different cooked sausages Herrero *et al* [54].

Sensory Evaluations of Different Beef Sausage Samples: The important quality characteristics of meat products are flavor, tenderness, color and juiciness, which are considered the most widely recognized quality attributes. Several sensory panels have been held to study the effect of adding fat substitutes on these sensory characteristics of lean meat products. Garcia *et al* [45] evaluated the influence of adding dietary fibers extracted from cereals (wheat and oats) and fruit fibers (apples and oranges) on the sensory properties of low-fat fermented beef sausages. The results revealed that it is possible to obtain sensory acceptable (healthy) sausages enriched with dietary fibers.

Table (9) showed the sensory properties of sausage samples and their effect on different levels of fiber gel. Form these results it can be noticed that there were no significant differences in the sensory properties between treatments. The highest score of odor was recorded for the control sample (8.0). Meanwhile, the lowest score of odor was recorded for the sample prepared by 50% fiber gel (7.3). This explains that the odor degrees decrease with increasing percentages of fiber gel.

Table 7: Physical analysis of different beef sausage samples

Sausage samples		W.H.C (cm2)	Plasticity (cm2)	Cooking loss (%)	Cooking yield (%)
Control Sausage sample		3.20^{a}±0.30	3.12^{b}±0.28	22.86^{a}±1.30	77.14^{b}±2.14
Wheat bran fiber gel	15%	2.98^{ab}±0.45	3.44^{b}±0.30	20.21^{ab}±1.21	79.79^{ab}±1.85
	30%	2.70^{b}±0.50	3.95^{ab}±0.25	18.70^{b}±1.15	81.30^{a}±1.42
	50%	2.45^{b}±0.35	4.28^{a}±0.18	17.35^{b}±0.98	82.65^{a}±1.60

Values are mean ± SD.

Values within a column followed by the same letter are non-significantly different (p=0.05)

W.H.C: Water holding capacity.

Table 8: Texture profile analysis of different beef sausage samples

Sausage samples		Hardness (N)	Cohesiveness (N)	Gumminess (N/mm^2)	Chewiness (N/mm)	Springiness (mm)
Control Sausage sample		22.51^{b}±1.12	0.52^{a}±0.14	11.08^{d}±1.25	7.23^{d}±1.22	0.70^{a}±0.18
Wheat bran fiber gel	15%	23.24^{b}±1.38	0.58^{a}±0.12	13.46^{c}±1.14	9.40^{c}±1.02	0.71^{a}±0.15
	30%	25.17^{ab}±1.27	0.62^{a}±0.11	16.27^{b}±1.37	12.68^{b}±1.43	0.74^{a}±0.20
	50%	27.48^{a}±1.40	0.65^{a}±0.13	18.30^{a}±1.22	14.07^{a}±1.15	0.76^{a}±0.16

Values are mean ± SD.

Values within a column followed by the same letter are non-significantly different (p=0.05)

Table 9: Sensory Evaluations of different beef sausage samples:

Sausage samples		Odor	Color	Taste	Texture	Overall acceptability
Control Sausage sample		8.0^{a}±0.57	7.9^{a}±0.40	8.0^{a}±0.86	7.9^{a}±0.76	7.8^{a}±0.53
Wheat bran fiber gel	15%	7.8^{a}±0.85	7.7^{a}±0.61	7.8^{a}±0.76	7.4^{a}±0.49	7.5^{a}±0.71
	30%	7.5^{a}±0.86	7.4^{ab}±0.66	7.7^{a}±0.41	7.2^{ab}±0.66	7.3^{ab}±0.61
	50%	7.3^{a}±0.70	7.2^{b}±0.67	7.2^{a}±0.66	7.0^{b}±0.29	7.1^{b}±0.53

Values are mean ± SD.

Values within a column followed by the same letter are non-significantly different (p=0.05)

The highest color score (7.9) was recorded for the control sample, followed by the sample formulated with 15% fiber gel (7.7) with insignificant differences between them. While, the sample formulated with 30% fiber gel recorded (7.4). Finally, the lowest color degree (7.2) was recorded for the sample prepared using 50% fiber gel with significant differences between them.

Although, no significant differences were recorded in taste scores between control sample and other treatments. Taste scores decreased for all samples with increment percentages of fiber gel (fat substitution).

From the illustrated data in the same table, it can be observed that there were no significant differences in the texture scores between control sample (7.9) and the sample formulated with 15% fiber gel (7.4). The highest texture score (7.9) was recorded for control sample. Furthermore, the lowest texture score (7.0) was recorded for sample formulated with 50% fiber gel with a significant differences ($P<0.05$).

Overall acceptability was affected by the percentage of fiber gel addition. The highest overall acceptability was recorded for control sample (7.8), followed by sample formulated with 15% fiber gel (7.5) with no significant differences between them, then the sample formulated with 30% fiber gel (7.3). The lowest overall acceptability was recorded for sausages prepared with 50% fiber gel with significant difference.

Finally, it can be observed that fiber gel (fat substitution) improved the sensory properties of sausages. The addition of fiber gel to sausages at 15% gave higher acceptance scores for aroma, color, taste and texture when compared to control sample. Cereal flour can also be successfully used as a fat substitution in duck sausages Yang *et al* [55]. In this concern, Arafa and Al-Akel [56] also found that addition of oat meal gel improved the sensory characteristic of beef patties. Gerardo *et al* [47] found that the sensory evaluation of sausages showed that dietary fibers can be applied as fat substitution and as a source of bioactive components.

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