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Using Barley Beta Glucan, Citrus, and Carrot Fibers as a Meat Substitute in Turkey Meat Sausages and Their Effects on Sensory Characteristics and Properties

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Abstract

This study was aimed to evaluate the effect of addition of two levels (1% and 2%) of Barley Beta Glucan (BBG), citrus (Ceamfibre 7000), and carrot (ID809) fibers on chemical, sensorial properties, oxidation and microbial quality of turkey meat sausage, during 21 days of storage at 4°C. The findings indicated that the addition of the three fibers decreased fat and protein contents but increased moisture content. Color parameters were significantly ($p<0.05$) affected by the fiber type and content. The meat substitution resulted in a tendency toward lighter coloration. A significant progression in the textural hardness, elasticity and chewiness of fiber-added sausages, was observed. The addition of the three fibers, at 1% and 2% level, induced a decrease in hardness when compared to control. Furthermore, color, taste, flavor and overall acceptability attributes were similar to the control when the fibers were incorporated. According to sensorial evaluations, the three polysaccharides remained at 1% to the consumer acceptability of sausage. Besides, the addition of the three polysaccharides had a significant effect on sausage safety because of its reduction of the lipid oxidation degree monitored by TBARS and it had no effect on microbial proliferation. Overall, the results of this study indicate that the three polysaccharides can be applied at 1% in turkey meat sausage to increase their nutritional status whilst maintaining the quality and safety attributes of the product.

Keywords: Fibers; Turkey sausages; Texture; Sensory testing; Lipid oxidation; Microbial proliferation

Introduction

Development of new product is a constant challenge for both applied and scientific research. The design of new food products required the generation of best formulation by ingredients optimization [1]. The present trend of using food for health purposes rather than just for nutrition opens up whole new fields for the meat industry. Thus, meat processors, in particular, continue to search for the ideal fat replacer or substitute, which gives all the fat-related attributes without the accompanying health concerns. It is well documented that high dietary fat intake is related to obesity, hypertension, cardiovascular disease and coronary heart disease, because of the high amounts of saturated fatty acids and cholesterol [2]. However, with fat playing a decisive role in product properties and consumer acceptance, the reduction of fat in meat products poses a challenge to the food industry. Fat stabilizes the meat emulsion, reduces cooking loss, improves water holding capacity and provides juiciness and hardness [3-6]. Besides, fat plays a major role in affecting sensory characteristics (appearance, flavor and texture) and consumer acceptance [7,8]. Furthermore, from a physiological standpoint, fat is a source of vitamins and essential fatty acids. It also constitutes the most concentrated source of energy in the diet (9 kcal/g). Hence, the removal of fat from meat products affects their flavour, juiciness and mouthfeel. In addition to that, it reduces satiety value. In order to produce low fat sausages similar to those of their full-fat counterparts, it is necessary to maintain similar sensory and health profiles. Among the possible options, reformulations by adding or substituting meat ingredients by dietary fiber are being explored [9,10].

Dietary fiber is derived from various plants, fruits, and nuts. It has different functional characteristics depending on processing conditions such as grinding and drying [11]. The addition of dietary fiber to meat products, such as pates, salami and other sausages, has been shown to improve cooking yield, water binding, fat binding, and texture [12]. Several authors have studied the use of dietary fiber as a functional ingredient in dry fermented sausages, with good results. Fernández-López et al. [13] observed that the addition of 1% orange fiber (by-product of juice production) decreases the growth of micrococci and the amount of nitrite required to increase the microbial stability of raw meats. Yalinkiliç et al. [14] observed that the addition of orange fiber (4%) in sucuk (Turkish uncooked cured sausage) has an effect on bacterial growth. On the one hand, it favors the growth of the lactic acid bacteria. On the other hand, the *Micrococcus* and *Staphylococcus* counts decrease, and the Enterobacteriaceae count is below detectable level (<10^2 CFU/g).

Considering the importance of dietary fiber as a frequently used food ingredient in the design of functional foods, the aim of this study was to assess the effect of BBG, Ceamfibre 7000, and ID809 fibers as mechanically separated turkey meat replacers on the quality and safety characteristics of Tunisian turkey meat sausage, including chemical composition, color, texture profile, sensory properties, lipid peroxidation and microbial evaluation.

Materials and Methods

Materials

Mechanically separated turkey (MST) meat was obtained from local processors (Chahia, Tunisia). MST meat was produced from turkey

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carcass after meat cutting. Analytical grade NaCl, $NaNO_2$, ascorbic acid, and sodium tripolyphosphate were used. Modified starch (E1422) was from Sigma Chemical Co. (St. Louis, MD, USA). Cold distilled water (4°C) was used in all formulations.

Origin and appearance of dietary fibers: BBG, Ceamfibre 7000, and ID809 fibers were supplied in powder form by a local meat company (CHAHIA, Sfax, Tunisia). They were initially purchased from F.P.S. GROUPE MANE (Marne La Vallee, France).

BBG is an excellent functional ingredient in a wide range of food and beverage applications. It is one of the richest available sources of concentrated natural beta glucan soluble fiber which is commonly used to make foods and beverages healthier. ID809 is a dietary fiber with strong functional properties. ID809 is manufactured from cooked mashed carrots from which carrot juice has been removed and then the pomace is dehydrated, milled and screened to ensure particle uniformity. The ingredient is GMO free, gluten free and cholesterol free. Ceamfiber 7000 is a natural fiber ingredient purified from citrus peel with high functional properties for a wide variety of applications. It is an all-natural food ingredient. Consequently, no E-number is needed, leading to a clean label. The Ceamfiber 7000 has proved successful in improving cooking yield, drip loss control, reducing fat/meat/solids content, maintaining form stability, preventing jelly formation and fat separation, improving texture of the end-product or replacing other gums and ingredients in the final food formulation. ID809 fibers were dark brown while BBG and Ceamfibre 7000 fibers were of white and yellow appearances, respectively (Figure 1).

Sausage preparation

The standard sausage formulation consisted of: MST meat, cold water, modified starch, NaCl, $NaNO_2$, Sodium tripolyphosphate, and ascorbic acid (Table 1). The three fibers were formulated into turkey meat sausage as described in Table 1. The percentages of spice additives were unchanged compared to the control sample. The main difference consisted in decreasing meat content and increasing fiber content.

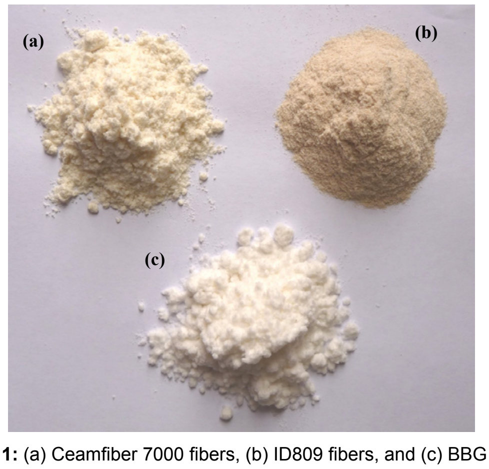

Figure 1: (a) Ceamfiber 7000 fibers, (b) ID809 fibers, and (c) BBG fibers.

Cold water was added to frozen MST meat, which was then ground in a commercial food processor (Moulinex, Paris, France), equipped with a 5 cm blade for 5 min at the highest speed. Salts, sodium tripolyphosphate and other ingredients were slowly added to the ground MST meat while processing. After that, modified starch and fibers were incorporated until completely blended. Stuffing was carried out manually into 27-mm-diameter reconstituted collagen casings and hand-linked to form approximately 8-cm-long links. Then, sausages were heat-processed in a temperature controlled water-bath (Haake, Kalsruhe, Germany) maintained at 90°C until a final internal temperature of 74°C was reached. The temperature was measured using a Type-T (copper–constantan) thermocouple inserted into the center of a link. Afterwards, Sausages were cooled immediately using tap water and stored at 4°C until analysis. The procedure for preparation of turkey meat sausages is given in Figure 2.

Physico-chemical analysis

The moisture and ash contents of turkey meat sausages and fibers were determined according to the standard methods 930.15 and 942.05, respectively. Total nitrogen content was determined by using the Kjeldahl method according to the AOAC method number 984.13 [15]. Crude protein was estimated by multiplying total nitrogen content by the factor of 6.25. Crude fat was determined gravimetrically after Soxhlet extraction of samples with hexane. The pH values of fibers were measured in a homogenate prepared with 1 g of sample and distilled water (25 ml) using a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). Oil binding capacity (OBC) of fibers was measured according to Lin et al. [16]. The three fibers were added to a concentration of 100 mg to 10 ml of corn oil in 50 ml centrifuge tubes. The mixtures were stirred and the tubes were then centrifuged at 2500 g for 30 min. The free oil was decanted and the absorbed oil determined. Water binding capacity (WBC) was measured according to Mac-Connel et al. [17]. Briefly, the three fibers were separately added to a concentration of 100 mg to 10 ml of distilled water in 50 ml centrifuge tubes and stirred overnight at 4°C. After that, the mixtures were centrifuged at 10,000 g for 30 min. The free water was decanted, and the absorbed water determined. All analytical determinations were performed at least in triplicate. Values of different parameters were expressed as the mean ± standard deviation.

Color evaluation of sausages

Color measurements of sausage samples were evaluated at different storage times using a Color Flex spectrocolorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA) and reported as L*, a* and b* values, where L* refers to the measure of lightness, a* to the chromatic scale from green to red, and b* to the chromatic scale from blue to yellow [18]. All determinations were carried out in triplicate.

Ingredients (%)	Control	BBG (1%)	BBG (2%)	ID809 (1%)	ID809 (2%)	Ceamfibre 7000 (1%)	Ceamfibre 7000 (2%)
MST	62.4	52.4	42.4	43.4	24.4	53.4	44.4
Water	30	39	48	48	66	38	46
Modified starch (E1422)	6	6	6	6	6	6	6
NaCl	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Sodium tripolyphosphate	0.28	0.28	0.28	0.28	0.28	0.28	0.28
$NaNO_2$	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Ascorbic acid	0.045	0.045	0.045	0.045	0.045	0.045	0.045

Table 1: Formulations of turkey meat sausages with the three fibers.

Texture properties of sausages

Texture profile analysis (TPA) was done on cooked samples at different storage times using a texturometer (texture analyzer, Lloyd Instruments, Ltd., West Sussex, UK). The center cores of the sausage samples were cut (2 cm in diameter, 2 cm height) and placed between flat plates and a cylindrical probe (12 mm in diameter). Subsequently, samples were compressed to 50% of their original height in a double cycle at a constant rate of 40 mm/min. The texture profile parameters, i.e. hardness (N), elasticity (mm), and chewiness (Nmm) were computed from the resulting force-deformation curves [19].

Sensory evaluation

Five attributes namely taste, flavour, color, texture, and overall acceptability were evaluated on turkey meat sausage samples. Thirty-eight healthy subjects aged between 23 and 48 years old, with no history of taste disorders, were recruited from the staff at Chahia Company and also students at Food Analysis Laboratory of National School of Engineering of Sfax. Subjects were informed on the duration of the testing and gave consent in the same way. The majority of the subjects were familiar with sensory evaluation techniques. Subjects (codes 1 to 38) were asked to avoid drinking coffee and tea, eating, or smoking 1-hour prior testing. Experiments were conducted in an appropriately designed and lighted room. Water was served for the purpose of cleaning the mouth before the test and in-between the samples. Sausage slices of 3-mm thickness were placed in white polystyrene plates with lids coded with 3-digit random numbers. Panelists scored sausage samples ranging from 0 (dislike extremely) to 9 (like extremely).

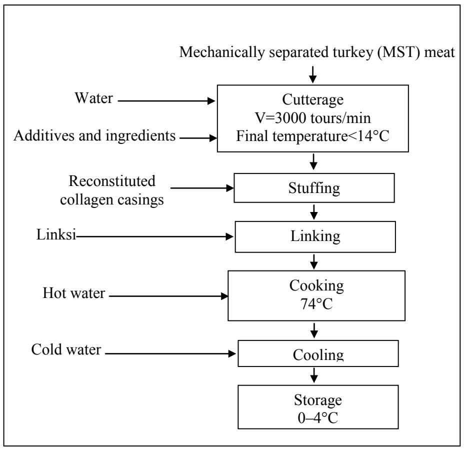

Figure 2: Procedure for preparation of Turkey meat sausage.

	BBG	ID809	Ceamfibre 7000
Protein	2.03% ± 0.04	1.74% ± 0.21	2.92% ± 0.04
Fat	0.88% ± 0.18	0.49% ± 0.13	0.79% ± 0.4
Ash	0.28% ± 0.04	1.59% ± 0.54	1.61% ± 0.1
Total fibers	91.78% ± 1.1	87.57% ± 0.81	86.95% ± 0.64
Moisture	5.4% ± 0.68	8.71% ± 0.5	7.62% ± 0.23
pH	6.07 ± 0.09	5.12 ± 0.17	7.68 ± 0.25
WBC (g/g)	9	18	8
OBC (g/g)	10.5	6.3	7.5

Physico-chemical composition was calculated based on the dry matter. Values are given as mean ± SD from triplicate determinations (n = 3).

Table 2: Physico-chemical compositions of the BBG, Ceamfibre 7000 and ID809 fibers.

Effect of the three dietary fibers on turkey meat sausage lipid oxidation

The extent of lipid oxidation in each turkey meat sausage was determined by the thiobarbituric acid reactive substances (TBARS) assay as described by Hogan et al. [20]. The final TBARS value was expressed as mg of malondialdehyde (MDA) equivalents per kg of sample.

Microbiological profile

Portions of 0.5 g of sausages were removed aseptically using a spoon, transferred to a stomacher bag (Seward Medical, Worthing, West Sussex, UK), containing 4.5 ml of sterile NaCl solution (0.9%), and homogenized using a stomacher (Lab Blender 400, Seward Medical) for 60 seconds at room temperature. For microbial enumeration, 0.1 ml samples of serial dilutions (1:10, NaCl 0.9%) were spread on the surface of agar plates. Total coliforms were determined using Brain Heart Infusion Broth (Pronadise, laboratorios CONDA, Madrid-Spain). Mesophilic germs were determined using Plate Count Agar (Pronadise, laboratorios CONDA, Madrid-Spain) and Yeast was determined using Potato Dextrose Agar (Lab M, United Kingdom). The plates containing 25-250 colonies were selected and counted. All microbial counts were converted to logarithms of colony-forming units per ml of sample (log CFU/ml).

Statistical analysis

All measurements were carried out in triplicate. Data were subjected to analysis of variance (ANOVA) using the General Linear Models procedure of the Statistical Analysis System software of SAS Institute (SAS, 1990). Differences among the mean values of the various treatments were determined by the least significant difference (LSD) test, and the significance was defined at $P<0.05$. The differences equal to or more than the identified LSD values were considered statistically significant.

Results and Discussion

Physico-chemical and techno-functional properties of the three dietary fibers

The physico-chemical and techno-functional properties of BBG, Ceamfibre 7000, and ID809 fibers were presented in Table 2. On a dry weight basis, the fibers containing protein ranged from 1.74% to 2.92%, fat ranged from 0.49% to 0.88%, ash ranged from 0.28% to 1.61% and total fibers ranged from 86.95% to 91.78%. All fibers had relatively low moisture content (5.4%-8.71%). No significant differences ($P>0.05$) in fat and protein were found among the three fibers. A significant difference ($P<0.05$) was observed between the WBC of the three fibers (9 g/g, 18 g/g, and 8 g/g for BBG, ID809, and Ceamfibre 7000, respectively). The high WBC of the three fibers suggests that they could be used as functional ingredients in food formulations to modify texture and viscosity, reduce dehydration during storage, and reduce energetic value.

Chemical properties of turkey sausages formulated with the three fibers

The chemical composition of turkey sausages formulated with the three fibers at two levels (1% and 2%) was determined and compared to that of control Turkey sausage (Table 3). Proximate analysis proved that the control sausage, recorded significantly ($p \leq 0.05$) lower moisture content (76.35%) than fibers added sausages (77.81%-84.05%). The moisture content of formulated sausages increased concomitantly with

Composition (%)	Control	BBG (1%)	BBG (2%)	ID809 (1%)	ID809 (2%)	Ceamfibre 7000 (1%)	Ceamfibre 7000 (2%)
Dry matter	23.65 ± 0.24	22.10 ± 1.52	19.19 ± 0.12	20.8 ± 0.5	15.95 ± 1.08	22.19 ± 0.00	19.7 ± 0.35
Ash	2.62 ± 0.3	2.55 ± 0.12	2 ± 0.68	2.68 ± 0.05	2.84 ± 0.14	2.6 ± 0.08	2.41 ± 0.33
Protein	15.84 ± 0.22	14.11 ± 0.19	12.38 ± 0.53	13.19 ± 0.3	10.01 ± 0.52	14.45 ± 2.26	12.94 ± 0.93
Fat	4.57 ± 0.09	4.33 ± 0.1	3.88 ± 0.15	3.08 ± 0.12	1.94 ± 0.08	3.9 ± 0.15	2.43 ± 0.28

Table 3: Chemical properties of turkey meat sausages formulated with the three fibers.

Storage (days)	Color parameters	Control	BBG (1%)	BBG (2%)	ID809 (1%)	ID809 (2%)	Ceamfibre 7000 (1%)	Ceamfibre 7000 (2%)
0	a*	13.23 ± 0.05	13.05 ± 0.08	13.52 ± 0.09	13.74 ± 0.34	12.89 ± 0.05	14.4 ± 1.74	15.1 ± 0.91
	b*	7.83 ± 0.17	7.64 ± 0.02	7.1 ± 0.03	7.73 ± 0.05	7.91 ± 0.01	7.93 ± 0.21	7.81 ± 0.04
	L*	50.84 ± 1.17	51.84 ± 0.01	52.38 ± 0.22	50.66 ± 0.46	51.49 ± 0.17	52.1 ± 0.2	51.3 ± 1.26
7	a*	14.81 ± 0.03	14.01 ± 0.22	14.89 ± 0.02	14.90 ± 0.05	15.08 ± 0.07	15.13 ± 0.8	14.16 ± 0.13
	b*	7.55 ± 0.08	7.49 ± 0.01	7.30 ± 0.03	7.33 ± 0.02	8.16 ± 0.01	8.02 ± 0.15	8.2 ± 0.11
	L*	50.69 ± 0.36	53.26 ± 0.47	50.48 ± 0.11	51.47 ± 0.09	51.59 ± 0.11	50.61 ± 1.2	51.9 ± 0.52
14	a*	14.39 ± 39	14.47 ± 0.41	14.72 ± 0.05	16.49 ± 0.05	13.89 ± 0.24	14.14 ± 0.18	13.42 ± 0.19
	b*	7.49 ± 0.39	7.14 ± 0.20	6.98 ± 0.08	7.89 ± 0.03	7.75 ± 0.01	8.15 ± 0.03	8.1 ± 0.4
	L*	50.95 ± 0.74	52.9 ± 0.31	51.87 ± 0.03	50.52 ± 0.08	51.92 ± 0.56	51.3 ± 0.28	52.6 ± 0.68
21	a*	15.49 ± 0.01	14.32 ± 0.41	13.90 ± 0.07	14.03 ± 0.05	14.28 ± 0.1	12.15 ± 0.06	11.54 ± 0.04
	b*	7.27 ± 0.05	6.48 ± 0.08	6.61 ± 0.02	7.37 ± 0.3	7.06 ± 0.34	8.2 ± 0.03	8.44 ± 0.15
	L*	50.97 ± 0.10	52.74 ± 0.03	52.02 ± 0.03	52.73 ± 0.01	53.29 ± 0.18	53.9 ± 0.54	53.3 ± 0.12

Table 4: Experimental results relative to instrumental color parameter for turkey sausages formulated with the three fibers during storage at 4°C.

the level of dietary fibers. Among all formulations, sausage formulated with ID809 (2%) recorded significantly the highest ($p \leq 0.05$) moisture retention (84.05%). The increase in moisture percent among sausage formulations with the increasing level of dietary fibers could be due to their high water binding capacity (WBC). This is in accordance with the results obtained by Szczepaniak et al. [21] who found a significantly increased moisture content in finely comminuted thick wiener type sausages with the increasing of potato fiber level. Another study by Choi et al. [22] reported that the moisture content increased in reduced-fat emulsion sausages with added brown rice fiber. Likewise, Fernández-Ginés et al. [23] indicated that lemon albedo as a source of dietary fiber increased the moisture content of bologna sausage. Similar trends in moisture content were observed by García et al. [24] for the moisture content of dry fermented sausage supplemented with wheat, oat and fruit fiber, which were higher than that of the control owing to the high water retention of the fibers.

The protein and fat contents of control sausage were found to be significantly ($p \leq 0.05$) higher than those of sausages formulated with BBG, Ceamfibre 7000, and ID809 fibers. In fact, protein and fat contents decreased significantly ($p \leq 0.05$) with the increasing levels of dietary fibers. This could be due to the replacement of MST meat, the only source of proteins and fats, by dietary fibers. Our findings are in agreement with several other previously reported works. Huda et al. [25] have, for instance, reported that the mean fat and protein values of mutton nuggets formulated with apple pomace at different levels were significantly higher than the control formulated without fiber. Additionally, Sánchez-Zapata et al. [26] have reported that fat percent of dry-cured sausages formulated with tiger nut fiber decreased with the increasing dietary fibers concentrations.

The ash contents of partial meat substituted sausages formulated with BBG and Ceamfibre 7000 fibers were found to decrease with the increasing levels of the two fibers, whereas that of sausage formulated with ID809 fiber was found to increase with the increasing level of the fiber. This may be due to the higher ash content of ID809 fiber. The results presented above are in agreement with several other previously reported findings. Verma et al. [27] showed that the ash content of low fat chicken nuggets decreased with the increasing levels of apple pulp, while Lee et al. [28] indicated that the ash content of sausage supplemented with kimchi fiber was higher than that in the control formulated without fiber. Similar results were previously reported by Turhan et al. [29] and Choi et al. [22] showing that low-fat beef burgers with hazelnut pellicle and reduced-fat emulsion sausages with brown rice fiber have increased ash content compared to that in a control.

Color analysis

The first characteristic which consumers use to evaluate meat product qualities is color [30]. Table 4 presents the development of lightness coordinate (L*), redness coordinate (a*), and yellowness coordinate (b*) during the storage of sausages added with 1% and 2% fibers. L* seems to be the most informative parameter for color changes in meat and meat products [31]. In the control samples, L* values keep constant during the storage. Turkey sausage with added fibers had a similar behaviour, but with higher values. The increase in L* could be attributed to fibers water retention that allows a high light reflection. Similar results were previously reported by Sánchez-Zapata et al. [26], showing that the addition of tiger nut fiber to Spanish dry-cured sausage increase L* value. At the beginning of storage, sausages containing Ceamfiber 7000 (1% and 2%) showed higher redness ($p<0.05$) than control. Thereby, no significant difference was observed in the fiber BBG, ID809 when compared to the control sausage. Redness increased during the storage for all formulation till the 7th day. This increase has been attributed to moisture loss which provokes an increase in pigment concentration [32]. At the end of storage, a* values decreased in all formulations. This decrease could be related to lipid oxidation [33]. There were no differences ($p>0.05$) in b* values between control and samples with fibers added at the beginning (until the 7th day of storage). After that, yellowness was affected slightly during the storage. The observed changes in b*, during the dry-curing process, are probably due to the oxygen consumption by microorganisms during their exponential growth phase. Consequently, the decrease in oxymyoglobin greatly contributes to the value of this color coordinate, because microorganisms produce metabolites that induce the oxidation of meat and fat present in the sausage and, by so doing, contribute to

Storage (days)	Texture parameters	Control	BBG -1%	BBG (2%)	ID809 -1%	ID809 -2%	Ceamfibre 70000 (1%)	Ceamfibre 7000 (2%)
0	Hardness (N)	7.74 ± 0.38	6.42 ± 0.32	4.3 ± 0.01	3.78 ± 0.11	1.91 ± 0.01	6.22 ± 0.18	4.09 ± 0.38
	Elasticity (mm)	12.27 ± 0.12	14.52 ± 0.28	12.44 ± 0.1	12.08 ± 0.21	12.05 ± 0.11	13.52 ± 0.46	11.80 ± 0.32
	Chewiness (Nmm)	29.64 ± 0.8	30.87 ± 0.14	20.22 ± 0.4	19.12 ± 0.31	9.47 ± 0.21	30.29 ± 0.35	16.14 ± 0.29
7	Hardness (N)	7.73 ± 0.3	7.24 ± 0.22	4.61 ± 0.45	5.59 ± 0.32	2.39 ± 0.15	4.62 ± 0.09	4.16 ± 0.22
	Elasticity (mm)	13.07 ± 0.06	12.55 ± 0.13	12.00 ± 0.2	12.32 ± 0.25	13.69 ± 0.25	12.82 ± 0.23	14.07 ± 0.06
	Chewiness (Nmm)	33.91 ± 0.91	32.87 ± 0.23	24.87 ± 0.3	24.59 ± 0.24	12 ± 0.23	22.87 ± 1.63	26.94 ± 1.66
14	Hardness (N)	7.88 ± 0.36	15.77 ± 0.45	11.25 ± 0.2	16.42 ± 0.12	5.14 ± 0.22	5.14 ± 0.24	4.01 ± 0.08
	Elasticity (mm)	14.35 ± 0.09	12.68 ± 0.28	10.62 ± 0.3	10.64 ± 0.11	12.81 ± 0.24	13.87 ± 0.11	11.97 ± 0.06
	Chewiness (Nmm)	53.93 ± 2.68	53.72 ± 0.36	34.17 ± 0.2	53.67 ± 0.41	15.87 ± 0.32	27.41 ± 0.55	24.29 ± 0.4
21	Hardness (N)	4.98 ± 0.03	8.67 ± 0.34	7.0 ± 0.14	7.84 ± 0.11	3.64 ± 0.12	4.66 ± 0.12	2.93 ± 0.14
	Elasticity (mm)	12.22 ± 0.27	11.60 ± 0.36	11.88 ± 0.2	11.39 ± 0.21	12.13 ± 0.11	13.97 ± 0.22	11.30 ± 0.54
	Chewiness (Nmm)	15.92 ± 0.44	38.89 ± 0.26	35.42 ± 0.3	39.98 ± 0.31	15.77 ± 0.31	19.65 ± 1.13	8.41 ± 2.68

Table 5: Experimental results relative to instrumental texture parameter for turkey sausages formulated with the three fibers during storage at 4°C.

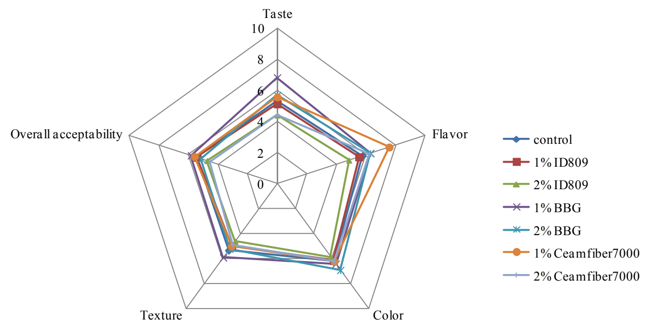

Figure 3: Sensorial analysis of turkey meat sausage formulated with BBG, Ceamfiber 7000, and ID809 fibers.

the decrease of this value [34]. Other authors have explained this color evolution by the presence of yellow compounds in fibers [35].

Textural properties of turkey sausages

The evolution of textural parameters (hardness, elasticity and chewiness) of turkey sausages as a function of the level of dietary added fibers and storage time is shown in Table 5. The findings revealed that the addition of the three fibers, at different levels, to turkey sausage induced a decrease in hardness when compared to control turkey sausage. The significant changes in hardness that were recorded could presumably be attributed to their higher water content and lower fat content. Similar results were obtained by Vural et al. [36] who indicated that the addition of sugar beet fiber decreases the hardness values of meat batters. However, it was observed that the addition of tiger nut fiber to dry-cured sausages increases the hardness [26]. García et al. [24] studied the addition of cereal and fruit fibers in low fat dry fermented sausages, and determined that the addition of cereal fibers (wheat and oat) at 3% to fat reduced sausages produces a significant increase in hardness, while the addition of fruit fibers (peach, apples and orange) decreases the hardness of products. Depending on the amount and type of fibers, the elasticity of formulated sausages was similar to control sausage. However, the chewiness of the new products increases when compared to control sausage. Indeed, it has been reported that owing to their water binding ability and swelling properties, insoluble fibers can influence food texture [23]. Insoluble fiber can increase the consistency of meat products through the formation of an insoluble 3-dimensional network capable of modifying rheological properties of sausages [37].

Sensory evaluation

Sensory analysis of prepared sausages was carried out by checking color, flavor, texture, taste and overall acceptability of the formulated sausages. The scores obtained by each attribute are shown in Figure 3. Attributes such as color and overall acceptability were similar to the control sausage when BBG, Ceamfibre 7000 and ID809 fibers were incorporated at a level of 1%. In addition, the substitution of meat with 1% BBG and 1% Ceamfibre 7000 fibers allows obtaining a product with a better taste and flavor, respectively. Besides, BBG fiber at 2% improves taste, flavor, and color of sausage when compared to control sausage. Unfortunately, the incorporation of Ceamfibre 7000 and ID809 fibers at 2% remarkably decreases the sensory quality of sausages.

Microbial evaluation

The bacterial count of total coliforms, mesophilic germs and yeast in turkey sausage formulated with the three fibers (BBG, ID809 and Ceamfiber 7000) during 21 days of storage at 4°C is shown in Table 6. At the beginning of storage (First week), no microbial germs were observed in all formulated turkey sausages. Initially, the addition of the three types of dietary fiber did not cause microbial change in turkey meat sausages. This outcome is consistent with the findings of the research literature which suggest that the addition of dietary fiber does not influence microbial growth in dry-fermented sausages with reduced fat content [24]. Only during the second week that the samples, with ID809 and Ceamfiber 7000 fibers added, showed the developments of the counts of coliforms, mesophilic germs and yeast. During storage at 4°C, microbial germs increased with time ($p<0.05$) in all sausages, to reach at the end of storage 16.47 log CFU/ml, 15.5 log CFU/ml and 22.29 log CFU/ml in sausages formulated with 2% BBG, ID809 and Ceamfiber 7000 fibers, respectively. Furthermore, none of the microbial groups was affected by fiber concentration during storage.

Effect of the three dietary fibers on lipid peroxidation in turkey meat sausage

Lipid oxidation is a major problem in high-fat food. During storage,

Storage (days)	Microorganism log (cfu/ml)	Control	BBG (1%)	BBG (2%)	ID809 (1%)	ID809 (2%)	Ceamfibre 70000 (1%)	Ceamfibre 7000 (2%)
0	Total coliforms	0	0	0	0	0	0	0
	Mesophilic germs	0	0	0	0	0	0	0
	Yeast	0	0	0	0	0	0	0
7	Total coliforms	0	0	0	0	0	6.68	7.21
	Mesophilic germs	0	0	0	0	0	10.53	10.8
	Yeast	0	0	0	5.24	5.3	12.3	12.81
14	Total coliforms	12.2	14.5	15.45	13.9	12.46	9.77	9.77
	Mesophilic germs	0	12.6	12.7	13.4	11.6	13.04	11.91
	Yeast	14.4	12.2	11	13.7	13.5	17.18	19.55
21	Total coliforms	16.86	17.03	16.5	16.45	17	18.67	18.9
	Mesophilic germs	16.3	16.3	15.13	15.18	15.7	14.58	12.58
	Yeast	16.6	16.48	16.47	15.49	15.5	25.46	22.29

Table 6: Development of total coliforms and mesophilic germs present in turkey sausages formulated with the three fibers during storage at 4°C.

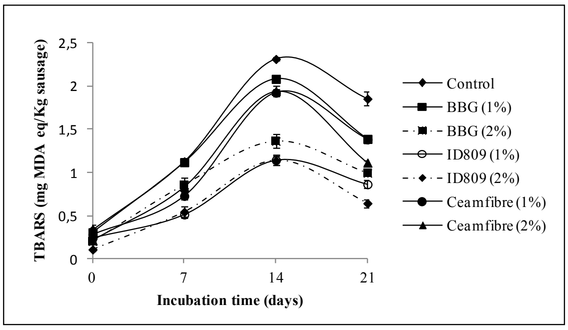

Figure 4: Lipid oxidation of turkey meat sausage formulated with BBG, Ceamfiber 7000, and ID809 fibers. (Bars represent the SD from triplicate determinations).

secondary oxidation products formed may react with nucleic acid, protein, lipid and polysaccharides and exert cytotoxic and genotoxic effects. In the present study, malondialdehydes (MDA) were chosen as markers for lipids oxidative deterioration (Figure 4). MDA reacts with TBA to give the TBA reactive substances (TBARS) detectable by spectrophotometry at 532 nm. As expected, the results showed that TBARS values of the control increased as a function of storage time. The value was 1.13 mg MDA/kg of turkey meat sausage after 7 days of storage. A decrease in TBARS values was observed after 14-days of storage. This was probably due to the loss of oxidation products formed, particularly low molecular weight volatile compounds. Indeed, MDA and other short-chain products of lipid oxidation are not stable for a long period of storage. Oxidation of these products yields alcohols and acids, which are not determined by the TBA test [38].

The incorporation of BBG, ID809 and Ceamfibre 7000 fibers in turkey meat sausage reduced the TBARS formation during storage. Indeed, on storage day 14, ID809 fiber (1% and 2%) reduced the meat lipid oxidation by more than 50% as compared to the control. After 14 days of storage at 4 °C, gradual decreases in TBARS values were observed. This would be due to the replacements of the amount of fat which are the causing agents of oxidation by fibers.

Conclusion

Economic, sensory and health aspects of sausages are the main reasons that processors of formulated foods increase non-meat fibers innovative sausages. The addition of BBG, ID809 and Ceamfibre 7000 fibers at 1% content to Tunisian turkey meat sausage provides a healthier product (lesser percentage of fat) and can help reduce costs associated with these sausages. Furthermore, the substitution of mechanically separated turkey by the three fibers at 1% content does not modify color, taste, flavor and overall acceptability attributes; being sometimes even better. Interestingly, the substitution of meat with 1% BBG fiber allows obtaining a product with a better taste. However, the addition of higher percentages of dietary fibers (2%) resulted in a remarkable decrease in sensory and textural profile. Furthermore, dietary fibers substitutions do not modify microbial growth and improve oxidative stability in formulated sausages. Overall, the dietary fibers described in this work could be a strong candidate for future applications in a wide range of meat products.

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