



The effect of β -glucan and inulin on the reduction of aflatoxin B₁ level and assessment of textural and sensory properties in chicken sausages

Mohsen Chaharaein^a, Ehsan Sadeghi^{b,*}, Reza Mohammadi^b, Milad Rouhi^b, Mahya Soltani^a

^a Student Research Committee, Department of Food Science and Technology, School of Nutrition Sciences and Food Technology, University of Medical Sciences, Kermanshah, Iran

^b Department of Food Science and Technology, School of Nutrition Sciences and Food Technology, Research Center for Environmental Determinants of Health (RCEDH), Health Institute, Kermanshah University of Medical Sciences, Kermanshah, Iran

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ABSTRACT

In recent years, people have a tendency to consume ready-made foods such as sausages. Therefore, the use of quality raw materials in these products is very important because these compounds may be contaminated with aflatoxin B₁ (AFB₁). Various biological and natural methods have been introduced to reduce aflatoxins in food products. The aim of the present study was to reduce AFB₁ levels. So, β -glucan (β G) and Inulin (IN) were used in different ratios (1: 2%, 2: 1%, 1.5: 1.5%, 0: 3, 3: 0%) in chicken sausages. AFB₁ levels were measured by High Performance Liquid Chromatography (HPLC) in a period of 1–45 days. Then, texture and sensory properties were examined. After 45 days, AFB₁ levels were decreased in all samples, and the highest level of reduction (73.7%) was observed in samples with 5 μ g/kg AFB₁ and 3% β G. Texture analysis showed that all the evaluated features complied with the standard. The hardness of chicken sausage with addition of IN (3%) (3.162N) was close to that of the control (2.99N). None of the products were significantly different from the control sample in terms of sensory properties. Therefore, β G and IN are effective in reducing AFB₁, and the produced sausages can be acceptable for marketing and be offered for consumption.

1. Introduction

Meat is the world's largest protein source due to the presence of essential minerals such as iron, zinc, and a variety of vitamins. More than 50% of the protein consumed comes from meat. According to forecasts, the global meat consumption will reach 72% by 2030 (Boué et al., 2015; González et al., 2020; Lentz et al., 2018; Wang et al., 2019). The more the population increases, the more is protein consumption. Therefore, different meat products such as sausages are marketed with different processing methods because of the excellent taste and reasonable price (Ayyash et al., 2019; Suurs and Barbut, 2020).

Nevertheless, the use of chemical food additives and the risk of using sausage products have always been controversial issues due to causing heart diseases, high cholesterol, and obesity (Felisberto et al., 2015). Moreover, sausages may be contaminated with aflatoxin B₁ (AFB₁), which is produced by *Aspergillus flavus* and *Aspergillus parasiticus*, because ingredients such as meat, flour, and various spices are used in its preparation. Aflatoxins are divided into four categories (B₁, B₂, G₁, G₂), of which type B₁ is one of the most carcinogenic toxins that can be found

in various foods (cereals, spices, meat, eggs, liver, and many other foods) (Pankaj et al., 2018). AFB₁ is very heat resistant and grows well in humid climates. This toxin is very difficult to remove, and the best way to prevent it is proper storage under controlled temperature and humidity. Most countries have set the permitted level of aflatoxin in food at 20 ng/kg. However, there is a stricter standard in some countries (Silva et al., 2019; Xue et al., 2019). Thus, in recent years, the sausage production based on natural compounds such as plant essential oils, microorganisms, various carbohydrates, biogenic amines, alternative probiotics, and prebiotics has increased to detoxify aflatoxins (Bis-Souza et al., 2019; Latorre-Moratalla et al., 2017; Oliveira et al., 2021; Sun et al., 2019). The results of using these compounds include better tissue properties and oral sensation (Esmaili et al., 2020; Franco et al., 2020). Dietary fiber mainly consist of carbohydrates that are indigestible and absorbable and have a positive physiological role in the body. In fact, adding dietary fiber increases the nutritional value, and these compounds are rich in vitamins, micronutrients, antioxidants, and phytochemicals (He et al., 2019). In this context, two beneficial compounds, including β -glucan (β G) and inulin (IN), can be used to detoxify AFB₁ in

* Corresponding author.

E-mail address: ehsan.sadeghi59@yahoo.com (E. Sadeghi).

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the sausage products. β G is a non-starchy, water-soluble compound found in the cell wall of cereals such as barley, oat, wheat, rye, sorghum, rice, yeast, algae, and bacteria. The compound consists of linear chains with β -D-glucopyranose units linked by β -1-3 bonds (Cao et al., 2019). β G has a high viscosity due to its flexible arrangement. From a health point of view, it reduces the time it takes for substances to pass through the intestines, prevents constipation, and reduces the risk of colorectal cancer, and blood sugar. Further, the consumption of 3 gr β G per day has been declared by the Food and Drug Administration (FDA) to be beneficial. It is also used in the food industry as a texture improver, stabilizer, and gel former (Afshari et al., 2015; Han and Bertram, 2017; Mejia et al., 2018). On the other hand, IN is a soluble fiber found in many plants (artichoke, asparagus, chicory, garlic, potatoes, and onion). It is made up of fructose chains with β -1-2 bonds (Shoiab, 2016; Ye et al., 2018). IN is used as a prebiotic and a food source for the beneficial bacteria living in the intestine (Li et al., 2015). This polysaccharide reduces the risk of cancer, diabetes, and cardiovascular diseases (Kumar, 2021). Sausages are widely consumed around the world. On the other hand, the world's population is increasing, and the sources of meat consumption are very small. Therefore, to solve this problem, other protein and polysaccharide compounds can be used in the sausage production. Sausage products are rich in vitamins, minerals, and amino acids due to the presence of meat and other by-products. We introduced a new product using β G and IN to reduce AFB₁. Further, changes in the texture and sensory characteristics were analyzed to examine its marketability. Another goal in this study was to strive for community food security and provide a healthy food product.

2. Materials and methods

2.1. Consumed materials

In this experiment, pure standard AFB₁ with 99.9% purity was used (Sigma Aldridge Company, made in Germany). The materials used in the extraction steps (NaCl and KBr with a purity of 99.9%), all solutions, and mobile phases of HPLC grade (methanol, deionized water, acetonitrile, n-hexane, and chloroform) were purchased from the Merck Company, Germany. The standard quality filter paper used in this study was Whatman No.1)Whatman company, U.K.). The polymers used in the production of sausages included β G (Oat β -Glucan, Neutraceutical Company, Canada) and IN (Beneo Orafit Company, Belgium).

2.2. Sample preparation

The stock solution was made using 1 mg AFB₁ and 10 ml methanol. The standard concentrations (5 and 10 μ g/kg) were prepared in water and methanol (40:60) from the stock solution. Then, they were extended every 14 days and placed in the refrigerator (4 °C). The sausages analyzed in this study were produced according to the commercial formulation of a meat product factory (Meat cutter, Alexanderwerk, USA). They contained chicken (70%), spices (red pepper, cumin, cinnamon, coriander and cardamom, ginger), wheat starch (3%), milk powder (2%), table salt (1.4%), polyphosphate (0.4%), Guar gum (0.4%), L-Ascorbic acid (0.02%), sodium nitrite (0.012%), and ice. The sausage dough was divided into 100 g for each sample. Then, AFB₁ (5, 10 μ g/kg) and different percentages of β G and IN (1: 2%, 2: 1%, 1.5: 1.5%, 0: 3, 3: 0%) were added to the samples. Changes in AFB₁ levels were examined in different times (the first day and the forty-fifth day). Moreover, the factory sausage samples (without the addition of β G, IN, and AFB₁) were analyzed to determine AFB₁ levels (Massarolo et al., 2021; Noroozi et al., 2020; Pintado et al., 2018).

2.3. Sample extraction

The samples were transferred to the laboratory under appropriate and standard conditions (5 °C and sterile). NaCl (1 g), methanol (60 ml),

deionized water (12 ml), and n-hexane (30 ml) were added to 10 g of thoroughly homogenized sausage samples and stirred for 3 min at high speed (Hot plate C-MAG HS10 model). Then, the n-hexane was removed by a separating funnel and passed through the filter paper. In the next step, 40 ml of the filtered solution and 300 μ l chloroform were poured into the falcon tube. Due to the presence of suspended particles, KBr3% (60 ml) was added to the liquid inside the falcon and centrifuged at 6000 g for 4 min (MICRO 185 model, Hettich Company, Switzerland), with a maximum of 13,300 rpm. Finally, 50 μ l of the mobile phase (acetonitrile) was added to 50 μ l of the final extracted solution, which had been dried in the presence of nitrogen gas (Elzupir and Abdulkhair, 2020; Hamad et al., 2021).

2.4. HPLC conditions and standard curves

The HPLC (Knauer AZURA), equipped with a fluorescence detector (RF-20A) and a UV derivative detector (LC-Tech), was used to determine AFB₁. The visible excitation and emission wavelengths were 329 and 460 nm respectively. The HPLC column was C18 and set at 40 °C. Mobile phases were acetonitrile and water (90:10) with a flow rate of 1.5 ml/min. The volume of injection was 100 μ l. In this study, the Limit of Detection (LOD), and Limit of Quantification (LOQ) were 0.005 and 0.015 μ g/kg respectively. Different and consecutive concentrations of the standard AFB₁ (0.087, 0.156, 1.25, 2.5, 5, and 10 μ g/kg) were prepared and injected. The graph slope ($y = 28/39x + 036/19$) and the standard coefficient ($R^2 = 0/5799$) were calculated. Then, the calibration curve was drawn. Percentage recovery was calculated to prove the accuracy of the method by injecting AFB₁ (5 and 10 μ g/kg) into the HPLC (Kortei et al., 2021).

2.5. Texture analysis

Twelve samples with specific ratios of β G and IN (1:2%, 2:1%, 1.5:1.5%, 0:3, 3:0%) along with the control sample were cut into 10 × 10.10 mm sizes. Then, the texture properties (hardness, factorability, energy, and deformation) were measured on the first and forty-fifth days (N350–10CP module, Hons Field Company, U.K.). The speed for cutting the sausage sample was 10 mm/min, and the force peak was 25 kg (Alirezalu et al., 2019; Zhao et al., 2018). A blade with a zero-degree angle was used to measure the texture. The maximum shear force and the amount of energy were measured by calculating the peak point of the curve and the area below it. To measure the texture of the steel rod, it was penetrated into the sausage sample, and the set time was 30s. The final results were performed in triplicate (Lashgari et al., 2020; Mohite, 2020).

2.6. Sensory evaluation

In this research, sensory evaluation was performed by the 5-point (unusable, somewhat acceptable, acceptable, Optimal, Excellent) hedonic method. Therefore, the prepared sausage samples were kept at 4 °C for 45 days to compare their sensory properties (color, odor, softness, chewing, mouthfeel, and total acceptability) with those of the first-day samples. The assessment was done by a panel of nine trained individuals with an age range of 20–28 years. The coded and control samples were randomly provided to the evaluators under appropriate light and temperature conditions (25 °C). After testing each sample, the mouth was rinsed to better understand the sensory characteristics of the product (Jridi et al., 2015; Prescott et al., 2011).

2.7. Data analysis

In this study, SPSS 22 software was used to analyze the variance and compare the means. Factorial Analysis of Variance (ANOVA) was performed in a completely randomized design. Further, the mean levels of AFB₁ in the samples were compared by the LSD test ($P \leq 0.01$).

GraphPad Prism 9 was used to draw the graphs, and Darwin 5 was used to perform grouping in cluster analysis.

3. Results and discussion

3.1. Decreased levels of aflatoxin B₁ by β -glucan and inulin

Due to the presence of AFB₁ in foods that cause cancer and mutagenicity, various methods have been proposed to reduce it in different foods (Gacem & El Hadj-Khelil, 2016). Thus, the use of natural compounds and microorganisms to eliminate AFB₁ can be proposed as a safe method that may lead to the development of a functional food product. In this research, β G and IN (prebiotic) were used as prebiotics to detoxify AFB₁ in sausages because of their anti-cancer, anti-diabetic, and antioxidant properties, low cost, good texture, and immune system boosting (X. Li and Cheung, 2019; van der Beek et al., 2018). The accuracy was determined by calculating the recovery percentage at 5 μ g/kg (92.2%) and 10 μ g/kg (94.3%) concentrations. The marketable sample was evaluated as a control and did not contain AFB₁. The reason could be related to the use of high-quality raw materials and irradiated spices to produce sausages. In addition, the lack of aflatoxin in the market can be due to proper storage and ambient temperature. So far, UV radiation has been used to reduce the levels of aflatoxins B₁ and M₁ in various foods such as peanuts, spices, nuts, wheat, and dairy products (Ghanghro et al., 2016; Khoori et al., 2020). Mao et al. stated that UV radiation can be used as a non-thermal method to reduce aflatoxin. UV has also been shown to significantly reduce AFB₁ (Mao et al., 2016). The results of factorial analysis of variance in a completely randomized design showed that the interaction effect of AFB₁, β G, and IN was significant ($P \leq 0.05$). The other experimental treatments were also significantly different ($P \leq 0.01$). However, the overall interaction between treatments did not show a significant difference. The comparison of means was performed by the LSD test ($P \leq 0.01$) to determine the reduction of AFB₁ level in sausages on the first day and after 45 days. AFB₁ level underwent a decreasing trend at both concentrations (5 and 10 μ g/kg). As shown in Table 1, the highest rate of AFB₁ reduction was observed at 5 μ g/kg (2.993 μ g/kg) concentration, and in total, the average rate reached the lowest level on the forty-fifth day (3.457 μ g/kg). The efficacy of β G (3.449 μ g/kg) in reducing AFB₁ was also higher than that of IN (5.170 μ g/kg), which can be related to the good antioxidant power and structural properties of β G, its good gravity, and hydrogen bond formation ability. Hence, it can trap AFB₁ in its structure (Giese et al., 2015; Waleed et al., 2020). Fig. 1 shows the reduction of AFB₁ level after adding the 5 μ g/kg concentration. The highest and the lowest percentages of removal were related to the sausage samples treated by β G 3% (73.7%) and IN 3% (37.1%). Moreover, the IN1%- β G2% sample showed a significant reduction in the amount of AFB₁ (61/1%). Generally, the AFB₁ level was reduced more by IN in samples with 10 μ g/kg concentration (Fig. 2) than those with 5 μ g/kg concentration (9.4%). Our results were consistent with those of Rajabzadeh Shandiz et al. They extracted β G in a variety of ways and evaluated the ability to absorb

AFB₁. The percentage of reduction was measured by different methods, and AFB₁ uptake was determined. The results also showed that alkaline extraction could absorb 90% of AFB₁ (Rajabzadeh Shandiz, Ziaratnia, Pahlevanloo, & Sarabi Jamab, 2020). In another study, β G and chitosan coatings were used to reduce AFB₁ in peanut. Samples were evaluated for texture and AFB₁ reduction after four months. Finally, the amount of AFB₁ decreased (1%), and this coating could prevent AFB₁ contamination (Kazemian-Bazkiaee et al., 2020). IN is used as a prebiotic in the food industry and may be effective in the elimination of aflatoxins. Sevim et al. used IN as a supplement along with probiotic microorganisms (*L.plantarum*, *B.animalis*, and *B.bifidum*) to remove aflatoxin M₁ (AFM₁) in yogurt. Adding IN supplement to yogurt increased the number of probiotic bacteria and led to an increase in the binding capacity of AFM₁ after ten days of storage. Hence, it turned out that the use of IN is an effective detoxification method to remove AFM₁ (Sevim et al., 2019).

3.2. The effect of β -glucan and inulin on sausage texture

β G and IN have been used as two valuable dietary fibers with unique probiotic properties and as textural reformers in the food industry and pharmacology (Mensink, Frijlink, van der Voort Maarschalk, & Hinrichs, 2015; Zhu, Du, & Xu, 2016). In the present experiment, the effect of β G and IN on the texture changes of the sausage products were compared to introduce the best added ratio of these two crucial dietary fibers to market. Based on the variance analysis, none of the studied characteristics (hardness, fracturability, energy, and deformation) in both times (the 1st day and 45th day) showed a significant difference compared with the control. This results indicated that the use of β G and IN did not damage the texture and emulsion, so it can be used in the production of sausages. The comparison of the means (Table 2) showed that only the hardness of the sausage was significant on the first day, and the sample containing β G (3%) was harder (5.878 N) than the control sample (3.189N). The reason can be due to the formation of a three-dimensional structure among β G, fat, water, and hydrocolloids because it increases the water holding capacity as a vital compound (Álvarez and Barbut, 2013). After 45 days, the hardness of sausages containing β G (3%) was significantly reduced (22.36%). On day 45, unlike the first day, there was no significant difference in the hardness between the control sample and sausage samples containing β G (3%). Hence, it can be an excellent option for introduction into the market. Moreover, gelatinization using IN softened the texture of the product in all samples, and its fracturability index increased after 45 days (Keenan, Resconi, Kerry, & Hamill, 2014). After 45 days, the lowest hardness (3.162N) was related to the IN (3%), which was closer to that of the control (2.999N). Therefore, it can be argued that this combination has a good texture. Similar studies have suggested that β G and IN can improve the texture. So far, β G and IN have been added to various foods to improve tissue properties (Aydinol and Ozcan, 2018; Güler-Akın et al., 2016; Hosseinvand and Sohrabvandi, 2016). Egea et al. used IN and β G to produce sausages. They examined different parameters and compared texture characteristics with the control group. The evaluation of texture properties showed that β G

Table 1

Mean reduction of AFB₁ in sausage samples with different percentages of β G and IN at different concentration and time levels.

Sample	The first day		The forty-fifth day		Mean \pm SD	%Recovery	
	(μ g/kg)5	(μ g/kg)10	(μ g/kg)5	(μ g/kg)10		5(μ g/kg)	10 (μ g/kg)
IN 1%- β G 2%	3.230 \pm 0.16971 ^{gh}	6.320 \pm 0.12021 ^{bc}	1.945 \pm 0.15556 ^{jk}	4.060 \pm 0.07071 ^{ef}	3.889 \pm 1.7061 ^c	92.2%	94.3%
IN 2%- β G1%	3.555 \pm 0.20576 ^{fg}	6.675 \pm 0.15556 ^b	2.330 \pm 0.34648 ^{ij}	4.590 \pm 0.32527 ^e	4.287 \pm 1.7159 ^b		
IN1.5% - β G1.5%	3.965 \pm 0.09192 ^{ef}	7.510 \pm 38891 ^a	2.635 \pm 0.56569 ^{hi}	5.945 \pm 0.12021 ^{cd}	5.014 \pm 2.0074 ^a		
IN3% - β G 0%	4.165 \pm 0.09192 ^{ef}	8.020 \pm 0.13435 ^a	3.145 \pm 0.11314 ^{gh}	5.350 \pm 0.22627 ^d	5.170 \pm 1.9501 ^a		
IN0% - β G 3%	3.050 \pm 0.14142 ^{gh}	6.175 \pm 23335 ^{bc}	1.315 \pm 0.17678 ^k	3.255 \pm 0.12021 ^{gh}	3.449 \pm 1.8702 ^d		
Mean \pm SD	3.593 \pm 0.4588 ^c	6.940 \pm 0.7867 ^a	2.274 \pm 0.6751 ^d	4.640 \pm 1.0066 ^b			

Mean: Mean of decreased AFB₁.

SD: Standard deviation of decreased AFB₁.

AFB₁: Aflatoxin B₁, β G: β -glucans, IN: Inulin.

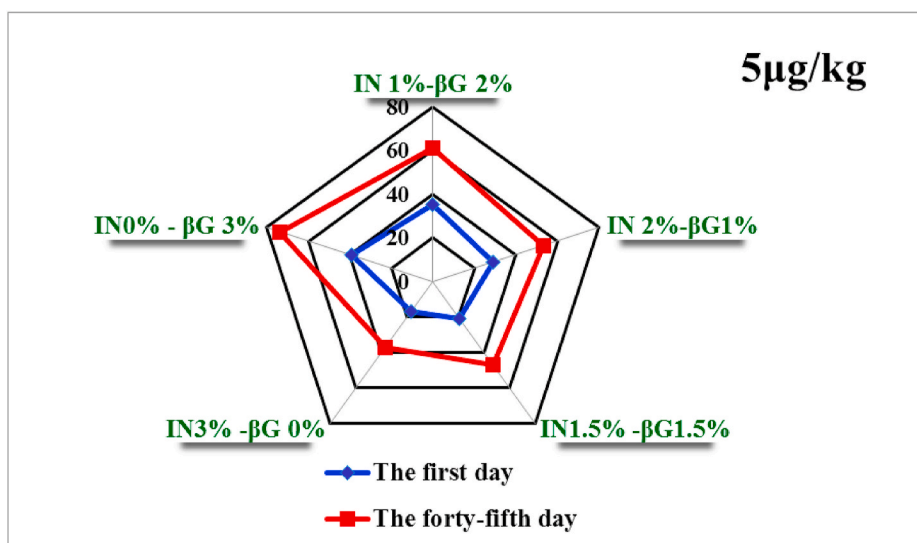


Fig. 1. Percentage reduction of AFB₁ in sausage samples produced using βG and IN at 5 µg/kg and time.

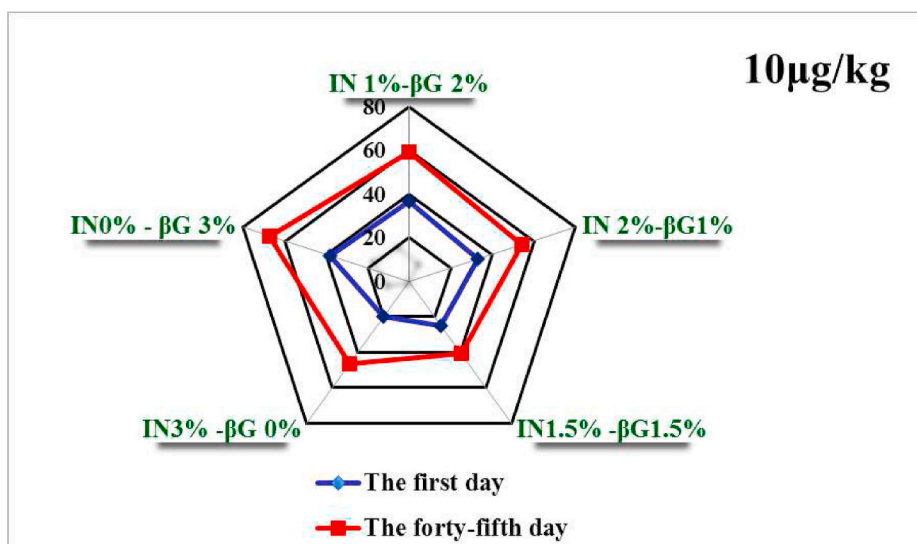


Fig. 2. Percentage reduction of AFB₁ in sausage samples produced using βG and IN at 10 µg/kg and time.

Table 2

Comparison of texture characteristics of sausages produced with different percentages of βG and IN at time levels.

Sample	Texture characteristics at the first day				Texture characteristics at the forty-fifth day			
	Hardness (N)	Fracturability (N)	Energy to Peak (N.m)	Def(mm)	Hardness (N)	Fracturability (N)	Energy to Peak (N.m)	Def(mm)
Control	3.189 ± 0.1831 ^b	0.5546 ± 0.0085 ^a	0.01390 ± 0.0004 ^a	9.837 ± 0.438 ^a	2.999 ± 0.2649 ^a	0.3143 ± 0.0030 ^a	0.0135 ± 0.0006 ^a	9.691 ± 0.3889 ^a
IN 1%-βG 2%	4.4307 ± 0.4217 ^{ab}	0.0628 ± 0.0080 ^a	0.0155 ± 0.0061 ^a	8.2730 ± 1.8866 ^a	4.0125 ± 0.3987 ^a	0.0425 ± 0.0010 ^a	0.0138 ± 0.0026 ^a	8.7340 ± 0.2645 ^{ab}
IN 2%-βG 1%	4.1445 ± 0.5481 ^{ab}	0.1357 ± 0.0042 ^a	0.0161 ± 0.0019 ^a	8.5275 ± 0.2341 ^a	3.4184 ± 0.5852 ^a	0.1089 ± 0.0019 ^a	0.0166 ± 0.0028 ^a	10.125 ± 0.006 ^a
IN 1.5%-βG 1.5%	4.3474 ± 0.3968 ^{ab}	0.0894 ± 0.0021 ^a	0.0150 ± 0.0019 ^a	7.7890 ± 0.3507 ^a	3.6483 ± 0.0766 ^a	0.0699 ± 0.0016 ^a	0.0146 ± 0.0025 ^a	9.5720 ± 0.5148 ^a
IN 3%-βG 0%	3.3213 ± 0.2140 ^b	0.2255 ± 0.038 ^a	0.0098 ± 0.0012 ^a	7.4255 ± 0.2058 ^a	3.1626 ± 0.2475 ^a	0.1790 ± 0.0079 ^a	0.0107 ± 0.0007 ^a	7.3865 ± 0.0361 ^b
IN 0%-βG 3%	5.8785 ± 0.6555 ^a	0.0458 ± 0.0024 ^a	0.0195 ± 0.0056 ^a	8.4250 ± 0.0255 ^a	4.564 ± 0.8340 ^a	0.0269 ± 0.0081 ^a	0.0154 ± 0.0020 ^a	8.819 ± 0.6470 ^{ab}

Mean: Mean of different parameters to compare texture characteristics.

SD: Standard deviation of different parameters.

Def: Deformability.

caused texture hardening. On the other hand, IN was reported as a softener which improves the chewing property. Furthermore, the combination of IN and β G could improve the unacceptable properties. Moreover, the reduction in fat in the emulsified meat product makes the texture firmer (Egea et al., 2020). Silva-Vazquez investigated the effect of IN and pectin on the textural properties and stability of meat batters. Their results showed that adding 15% IN and 15% pectin could be used without changing the texture and affecting the physical properties. Therefore, it was concluded that etholine and pectin could be used to improve the physicochemical properties (Silva-Vazquez et al., 2018). In another study, two probiotics, including β G and IN, were used to make meat burgers. Further, texture characteristics and cooking properties were compared with the control sample. The results showed that the cooking properties and hardness were weak for low-fat burgers. It was also stated that these two probiotic fibers could be used in the production of a healthy product without being much different from the control sample (Kim et al., 2016).

3.3. Sensory properties of sausage samples

Sensory properties are the main factors in accepting many products and gaining satisfaction from their consumption. Therefore, it is necessary to study and identify the factors affecting them and prevent the development of undesirable properties. The sensory characteristics of the sausage samples (color, tenderness, chewiness, mouthfeel, and overall acceptability) were evaluated. The results of ANOVA indicated no significant relationship between different parameters and control samples. Figs. 3 and 4 shows the sensory evaluation of the mean scores of sausage samples on the first and forty-fifth days. Overall, the best sensory properties evaluated were related to the sausage samples prepared with IN 3% - β G 0%. Alaei et al., (2018) used IN as a fat substitute in chicken sausage and examined the sensory properties. Sensory characteristics included taste, color, appearance, texture, mouthfeel, and overall acceptance. Replacement of 100% IN with fat had the highest score. In other words, increasing IN improved the sensory properties, but odor scores were low. Moreover, the results of sensory evaluation were consistent with those of texture characteristics (Alaei et al., 2018). After that, the sausage sample prepared with IN1% - β G 2% was closer to the control, and the lowest acceptability in terms of all evaluated features was observed in the sample prepared with IN 0% - β G 3%. However, the sample prepared with IN 3% - β G 0% reduced AFB₁ to a lesser extent than IN 0% - β G 3%, but it caused a significant reduction in AFB₁ after 45 days (Fig. 2). Therefore, it can be produced and marketed. On the forty-fifth day, the sensory characteristics of all samples were improved,

so that they approached those of the control samples. Moreover, the samples prepared with IN 2% - β G 1% were on the same level with those prepared with IN 3% - β G 0% in terms of color and odor characteristics. Glisic et al., (2019), produced IN-based dry fermented sausages. Sensory evaluation was performed by evaluators after 28 days. The results showed that the lowest scores were related to the appearance, odor, and taste, but overall acceptance was not different from the control sample. Further, cross-section, color, and overall acceptance had the highest scores (Glisic et al., 2019). In another study on sensory evaluation of prepared sausages containing meat and β -glucan, no negative effect on odor and color was observed, but the hardness increased. Overall, the acceptance rate increased with a rise in β -glucan (Slima et al., 2019). Previous studies have evaluated the sensory properties of sausages produced with different natural compounds such as microorganisms, vegetables, plant essential oils, and polysaccharides. Guedes-Oliveira JM et al. used a combination of carboxymethylcellulose and IN to produce low-fat lamb patties. In addition to examining the texture properties, they studied the sensory properties. Their results showed the lower acceptability of carboxymethylcellulose. The combination of carboxymethylcellulose and IN was considered a suitable substitute for fat (Guedes-Oliveira et al., 2019). Another study on the effect of two dietary fibers (barley β G and IN) on the sensory properties of beef sausage showed that these compounds increased the water-oil binding capacity. There were also no adverse changes in the sensory properties. The results showed that beta-glucan affected the sensory properties. With a rise in β G, the acceptance rate was decreased and the scores given to the sensory characteristic were decreased (Souza et al., 2019). Sensory evaluation of turkey sausages by edible cuttlefish gelatin was performed by the hedonic method, which showed no significant effect on taste (Jridi et al., 2015). Finally, cluster analysis was performed based on all sensory parameters, and the similarity of sausage samples with the control was investigated. The sausage samples prepared with IN 3% - β G 0% and the control samples were in the same group on the first and forty-fifth days. The important point was that the samples prepared with IN 0% - β G 3% and IN1% - β G 2% were similar in terms of sensory properties on the first day and were in one group. However, due to the improvement of texture properties, they were separated from this group and approached the control group after 45 days (Fig. 5). So far, cluster analysis has been used in various researches related to food. Neville et al. (2017) performed cluster analysis to identify consumer groups and their preferences in hamburger selection. Consumers were divided into three groups. The first group preferred both meat and meat-free products and the second group accepted the two combinations and the meat sausage. Moreover, the third group liked vegetable (Neville et al., 2017).

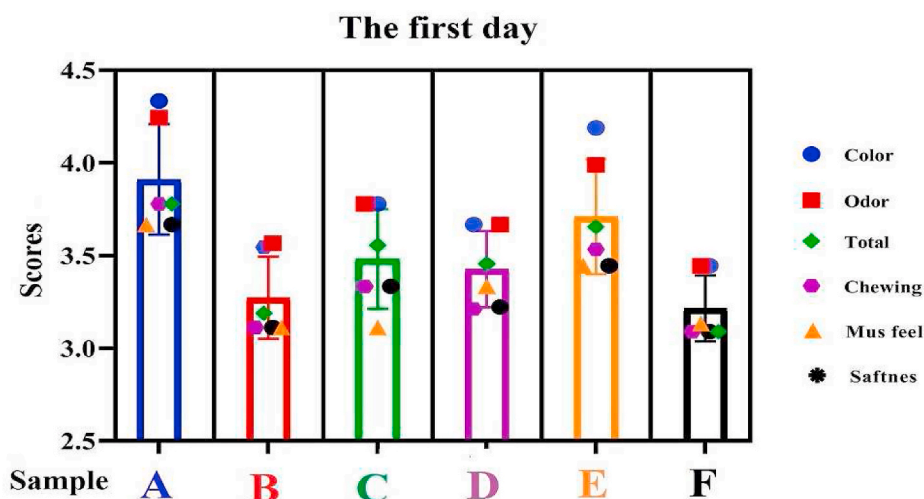


Fig. 3. Mean sensory evaluation of sausage samples produced for different parameters in the first day (color, odore, softness, chewing, mouth feel, and total acceptability). A: Control, B: IN 1% - β G 2%, C: IN 2% - β G 1%, D: IN 1.5% - β G 1.5%, E: IN 3% - β G 0%, F: IN 0% - β G 3%.

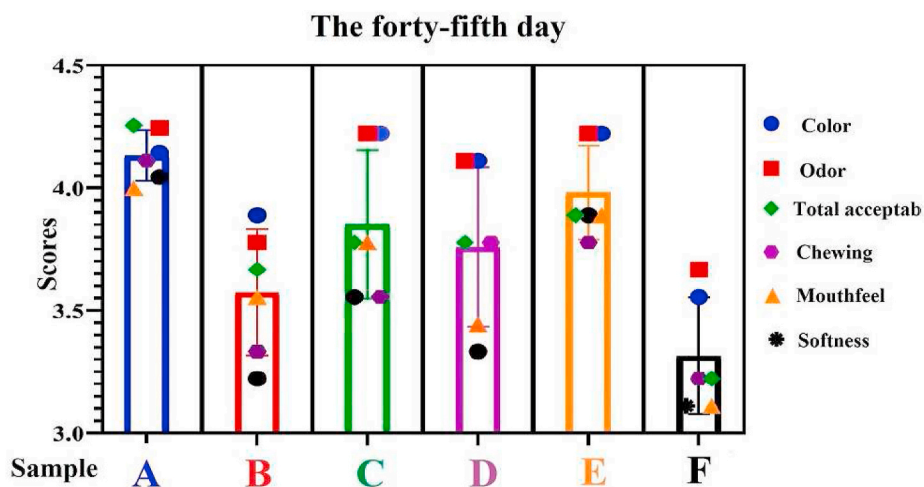


Fig. 4. Mean sensory evaluation of sausage samples produced for different parameters in the forty-fifth day (color, odore, softness, chewing, mouth feel, and total acceptability). A: Control, B: IN 1% - βG 2%, C: IN 2% - βG 1%, D: IN 1.5% - βG 1.5%, E: IN 3% - βG 0%, F: IN 0% - βG 3%.

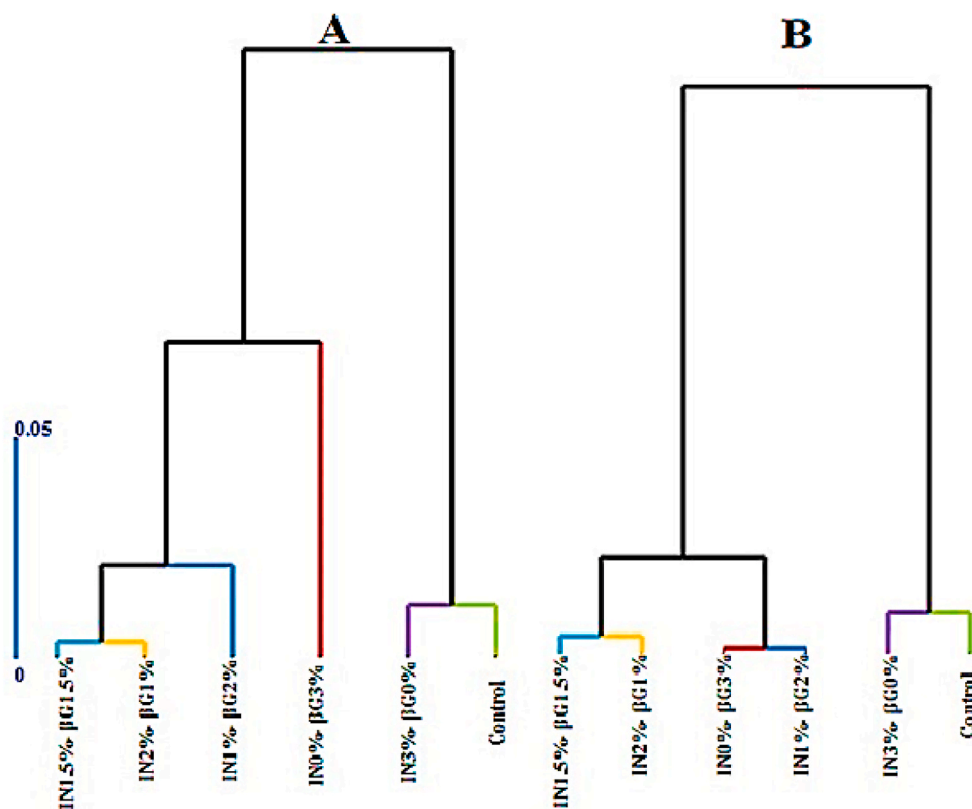


Fig. 5. Grouping of produced sausages to investigate their similarity with the control sample. A: The first day, B: The forty-fifth day.

4. Conclusion

In recent years, the demand for ready-to-eat foods has increased, among which the most important are various meat products such as sausages. Contamination of meat and sausages with aflatoxin has been proven in various studies. Therefore, βG and IN were used to detoxify AFB₁ in sausages in the present study, and the results showed a decrease in AFB₁ level. IN softened the texture, and βG increased the strength and water holding capacity. Acceptance decreased with a rise in βG percentage. The sensory properties of IN were close to those of the control, and all sensory properties were improved on day 45. Therefore,

better color and fragrance were reported by the evaluators. The samples containing βG hardened the tissue, but the hardness was decreased over time. The results indicated that appropriate levels of IN and βG (as a texture improver) can be used in the production of sausages with lower AFB₁ levels and healthy properties.

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CRediT authorship contribution statement

Mohsen Chaharain: Methodology, Software, Writing – original draft. **Ehsan Sadeghi:** Writing – review & editing, Conceptualization, Funding acquisition. **Reza Mohammadi:** Project administration, Funding acquisition, Writing – review & editing. **Mahya Soltani:** Formal analysis, Investigation, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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