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The use of inulin as fat replacer and its effect on texture and sensory properties of emulsion type sausages

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Summary

The present study aimed to investigate the possibility of reducing energy content in emulsion type sausages by replacing fat with inulin. In the manufactured product, the fat content was reduced to 6%-18% and replaced by inulin and water. The quality of the resulting product was determined by chemical and texture profile analyses (TPA), color measurement and sensory evaluation. The results showed that replacing fat with inulin led to a significant energy content reduction of up to 64% (with 6% inulin and 12% water). In addition, color measurement, sensory evaluation and TPA were comparable to the traditional product in the inulin treated samples. The overall acceptability of all experimental groups was adequate; therefore, inulin is suggested as a good replacement for fat in emulsion type sausages.

Key words: Emulsion type sausage, Functional food, Inulin

Introduction

The relationship between food nutritional values and health is concerning for most consumers as there is an increased demand for health-enhancing functional foods including low-fat meat products (Ruusuen *et al*., 2003a, b; Hahn, 2005; Bigliardi and Galati, 2013). Fat intake is associated with an increased risk of obesity, some types of cancer, high blood cholesterol and coronary heart disease. For these reasons, several health-related organizations have proposed to limit total fat intake to no more than 30% of total calories (Jimenes Colmenero, 1996). However, fat contributes to the flavor, texture, mouth feel and appearance of food and when fat is reduced, the products are firmer, more rubbery and less juicy (Caceres *et al*., 2004; Naga Mallika *et al*., 2009).

Several approaches have been proposed to reduce fat while retaining sensory and textural attributes of foods by replacing it with water, proteins, carbohydrates and fat based substitutes (Jimenes Colmenero, 1996; Sandrou and Arvanitoyannis, 2000). Various dietary fibers such as inulin can be useful for maintaining the organoleptic qualities of fat. In addition, increased fiber in food has various health benefits such as reducing the risks of atherosclerosis and colon cancer and increasing the bioavailability of minerals such as calcium (Roberfroid, 2000; Anderson *et al*., 2009; Scholz-Ahrens *et al*., 2016). Inulin is a soluble dietary fiber (fructooligosaccharide) containing a degree of polymerization of up to sixty monomers of fructose bound. It is not hydrolyzed by human digestive enzymes as it transits intact through the upper gastrointestinal tract to reach the large intestine. As one of the most common probiotics, bifidobacteria, ferment the inulin and produce short chain fatty acids (acetate, propionate, butyrate and lactate). Inulin enhances the growth of these beneficial microorganisms to compete with pathogenic bacteria (Hidaka *et al*., 1986; Gibson *et al*., 1995). Currently, inulin is approved by WHO as a safe food ingredient. It has a unique ability to form discrete highly stable particle gels and contribute to the rheological and textural properties of foods (Boeckner *et al*., 2001; Desmedt *et al*., 2001). Inulin can be used to give meat products a creamier and juicier mouth feel without compromising taste and texture (Franck, 2002; Janvary, 2006).

Nowadays, as high levels of fat in emulsion type sausages is not desirable, both scientists and consumers increasingly demand products with less fat and more fat substitutes (Janvary, 2006; Nitsch, 2006).

The objectives of our study were to determine the effect of inulin on the physicochemical, texture and sensory properties of reduced fat emulsion type sausages.

Materials and Methods

Sausage manufacture

An emulsion type sausage was produced as described by Sham Sham Meat Processing Industry, Shiraz, Iran. The basic formulation consisted of 60% minced cattle meat, 1.50% sodium chloride, 18% vegetable oil, 14% ice flake, 5% wheat flour, 120 ppm sodium nitrate, 1.50% trisodium phosphate, sugar, monosodium glutamate, sodium ascorbate and spices.

In order to replace fat with inulin, the following experimental groups were employed; control, group I (I3 W3): 3% inulin + 3% excess water, group II (I3 W6): 3%

inulin + 6% excess water, group III (I6 W6): 6% inulin + 6% excess water, and group IV (I6 W12): 6% inulin + 12% excess water. A portion of vegetable oil was gradually replaced by long-chain inulin powder (Fibruline XL, Cosucra; Warcoing Industrie S.A., Belgium) and ice flakes (Table 1) which were subsequently chopped in a cutter. The dough was stuffed in a cellulose casing with a 70 mm diameter using an automatic filler and cooked in a steam bath at 85°C for 90 min. The samples were finally stored at 4°C for 24 h. The experiments were repeated three times.

Table 1: Composition of different ingredients in the experimental sausages

Experiments	Ingredients (%)		
	Vegetable oil	Inulin	Ice flakes
Control	18	0	14
I3 W3 [1]	12	3	17
I3 W6 [2]	9	3	20
I6 W6 [3]	6	6	20
I6 W12 [4]	0	6	26

[1] 3% inulin + 3% excess water, [2] 3% inulin + 6% excess water, [3] 6% inulin + 6% excess Water, and [4] 6% inulin + 12% excess water

Physicochemical analysis

Fat content was determined according to the Soxhlet method, and protein (Kjeldhal nitrogen), moisture (oven air-drying method) and ash (muffle furnace method) were analyzed following the AOAC procedure (AOAC, 1997). The amount of carbohydrates were then calculated based on the remaining materials. Water activity (*aw*) was determined using a Decagon CX1 dew point hygrometer at 20°C, and pH was measured in a homogenate prepared with 1.50 g of sausage and 10 ml of distilled water, using a Crison pH-meter.

Energy values

Total calories (kcal) were calculated for 100 g sample using the Atwater values corresponding to fat (9 kcal/g), protein (4.02 kcal/g) and carbohydrates (3.87 kcal/g). Caloric value of inulin was estimated to be 1.50 kcal/g (Cegielka and Tambor, 2012).

Color evaluation

Surface color (L^*, a^* and b^*) of the sample was measured objectively using the Hunter L^*, a^*, b^* system with a simple digital imaging method described by Yam and Papadakis (2004), 30 min after opening the package. A Sony color digital camera (DCR-SR65E/SR85E, Japan) installed at a 30-cm constant distance from the surface of the sliced sample was used for taking digital images. The lamp and camera were placed in a box (50^*50^*60 cm) with interior white color. The angle between the axis of the camera lens and surface of the sample was 90. The angle between the surface of the sample and light source was 45. Illumination was achieved using a 20-W fluorescent light lamp (Natural Day-Light. Cixing, China). The digital images of samples were analyzed in the Lab mode to obtain L^*, a^* and b^* color parameters using photoshop version 8.0. The color was evaluated by obtaining three measurements per sample, which were then averaged to obtain a mean value.

Determination of nitrosomyoglobin (nitrosylheme pigments)

The quantified spectrophotometry of nitrosomyoglobin was performed (read at 540 nm) on the mixture containing 5 g of samples, 20 ml of acetone and 1.5 ml of distilled water, prepared following centrifugation at 1800 rpm for 5 min. Results were exhibited as µg/kg nitrosyl heme pigments (Bozkurt and Erkman, 2004). Hematin (Sigma Aldrich, USA) was used as the standard.

Sensory evaluation

Sensory analysis of the samples performed by a seven member trained panelist, as described by Berizi *et al.* (2016). The attributes studied were color, odor, taste and texture. They were scored using a 5-point scale as follows:

5: Excellent
4: Good
3: Acceptable
2: Fair
1: Unacceptable

The value was reported as the average value of seven determinations per replica.

Texture profile analysis (TPA)

TPA was performed to determine the textural properties of the samples using a texture analyzer (Texture Analyzer, TA Plus, Stable Microsystems, Surrey, England) with a load cell of 30 kg,. Texture profile analysis involves a double compression force test using a cylindrical probe with dimensions greater than the sample dimensions. Sausage samples were removed from their casing, cut into cubes (2.5 cm × 2.5 cm × 2.5 cm) and compressed to 20% of their original height by two consecutive compressions using a cylindrical probe of 100 mm diameter. Pretest speed, test speed and posttest speed were 5, 2, and 10 mm/s, respectively. Waiting time between the two-cycles of the TPA test was 10 s and the trigger force was 5 g. Texture profile parameters such as (hardness, energy required for compressing each specimen, cohesiveness, springiness, gumminess and chewiness) were calculated from the compression force versus time curves using the Texture Exponent Lite developed and supplied by the manufacturer as described by Bourne (1978). All textural measurements were performed at room temperature (22 ± 2°C) on six replicates for each sample.

Statistical analysis

The physicochemical and textural properties were studied using one-way ANOVA independently for each experiment (SPSS 17, 2002; SPSS Inc., Chicago IL). Duncan test was employed to determine the differences between treatment groups ($P<0.05$). Sensory characteristics data were also analyzed using the Kruskal-Wallis test.

Table 2: Proximate composition (mean±SD) of conventional (control) and reduced fat emulsion type sausage treatments

Treatments	Moisture (%)	Aw	pH	Ash (%)	Protein (%)	CHO (%)	Fat (%)	Fat reduction (%)	Energy value (kcal/100 g)
Control	59.90±0.42^{a}	0.97±0.00^{a}	6.50±0.02^{a}	5.40±0.21^{a}	11.20±0.11^{a}	1.30±0.46^{a}	22.20±0.14^{a}	0	250.10±2.62^{a}
I3 W3 [1]	62.90±0.49^{b}	0.97±0.00^{a}	6.50±0.01^{a}	5.50±0.70^{a}	11.20±0.22^{a}	2.10±0.12^{a}	16.30±0.14^{b}	26.57	200.70±0.13^{b}
I3 W6 [2]	65.90±0.84^{c}	0.98±0.00^{b}	6.40±0.14^{a}	5.50±0.70^{a}	11.30±0.08^{a}	2.20±0.01^{a}	13.20±0.07^{c}	40.54	172.70±0.91^{c}
I6 W6 [3]	65.90±0.14^{c}	0.98±0.00^{b}	6.50±0.02^{a}	5.70±0.21^{a}	11.10±0.02^{a}	3.30±0.30^{b}	10.10±0.14^{d}	54.50	149.60±0.17^{d}
I6 W12 [4]	72.20±0.91^{d}	0.99±0.00^{c}	6.60±0.14^{a}	5.50±0.70^{a}	11.20±0.02^{a}	3.60±0.66^{b}	4.10±0.14^{e}	81.53	95.00±1.54^{e}

[1] 3% inulin + 3% excess water, [2] 3% inulin + 6% excess water, [3] 6% inulin + 6% excess water, and [4] 6% inulin + 12% excess water. Means with different superscript letters within the same column are significantly different at P<0.05

Table 3: Instrumental color analyses (mean±SD) of the surface of the conventional (control) and reduced fat emulsion type sausages

Treatments	Nitrosomyoglobin	L^*	a^*	b^*
Control	0.66 ± 0.03^{a}	56.25 ± 0.95^{a}	1.12 ± 0.09^{a}	13.50 ± 1.29^{a}
I3 W3 [1]	0.63 ± 0.02^{a}	56.00 ± 0.81^{a}	1.77 ± 1.04^{ab}	13.75 ± 4.27^{a}
I3 W6 [2]	0.64 ± 0.07^{a}	55.50 ± 0.57^{a}	1.65 ± 0.55^{ab}	14.00 ± 0.81^{a}
I6 W6 [3]	0.66 ± 0.06^{a}	53.50 ± 0.57^{b}	1.80 ± 0.61^{ab}	12.25 ± 1.50^{a}
I6 W12 [4]	0.64 ± 0.01^{a}	51.00 ± 0.81^{c}	2.10 ± 0.21^{b}	12.50 ± 1.29^{a}

[1] 3% inulin + 3% excess water, [2] 3% inulin + 6% excess water, [3] 6% inulin + 6% excess water, and [4] 6% inulin + 12% excess water. L^*: 0 = black and 100 = white, a^*: -60 = green and +60 = red, and b^*: -60 = blue and +60 = yellow. Means with different superscript letters within the same column are significantly different at P<0.05

Table 4: Parameters from instrumental texture profile analysis (mean±SD) of the conventional (control) and reduced fat emulsion type sausage

Treatments	Maximum force (N)	Gradient (N/s)	Cohesiveness (ratio)	Springiness (cm)	Gumminess (N/cm^2)	Chewiness (N/cm)
Control	16.95 ± 0.81^{a}	6.01 ± 0.39^{b}	0.79 ± 0.01^{a}	0.92 ± 0.02^{a}	13.44 ± 0.56^{a}	12.46 ± 0.75^{a}
I3 W3 [1]	17.13 ± 1.24^{a}	5.85 ± 0.54^{ab}	0.77 ± 0.01^{b}	0.91 ± 0.14^{ab}	13.33 ± 0.88^{a}	12.17 ± 0.79^{a}
I3 W6 [2]	16.14 ± 1.82^{a}	5.43 ± 0.38^{a}	0.77 ± 0.01^{b}	0.92 ± 0.03^{a}	12.56 ± 1.33^{a}	11.64 ± 1.39^{a}
I6 W6 [3]	17.91 ± 1.64^{a}	6.51 ± 0.44^{b}	0.74 ± 0.01^{c}	0.89 ± 0.01^{b}	13.40 ± 1.14^{a}	11.98 ± 1.00^{a}
I6 W12 [4]	17.91 ± 1.64^{a}	6.50 ± 0.44^{b}	0.74 ± 0.01^{c}	0.89 ± 0.01^{b}	13.38 ± 1.10^{a}	11.99 ± 1.06^{a}

[1] 3% inulin + 3% excess water, [2] 3% inulin + 6% excess water, [3] 6% inulin + 6% excess water, and [4] 6% inulin + 12% excess water. Means with different superscript letters within the same column are significantly different at P<0.05

Results

Physicochemical analysis

Our results showed that neither fat reduction nor the presence of inulin influenced pH. In addition, water activity in I6 W12, I6 W6 and I3 W6 groups was significantly enhanced (P<0.05) (Table 2).

Sausage composition

The approximate compositions of control and inulin added sausages are shown in Table 2. Fat compositions of the experimental groups reduced with a simultaneous increase of the incorporated inulin. Fat content ranged from 22.20% in the conventional control group to 4.10% in reduced fat sausages with the highest inulin levels. Total fat was reduced by approximately 26.57, 40.76, 54.5 and 81.53% in the groups I3 W3, I3 W6, I6 W6 and I6 W12, respectively. Crude protein content of various groups changed from 11.13% to 11.30%, and carbohydrate content changed from 1.30% to 3.60%.

Caloric values

The energy value of reduced fat sausages decreased from 250.05 kcal/100 g in the control group to 94.98 kcal/100 g in the reduced fat sausages representing an energy reduction close to 62.02% (P<0.05) (Table 2).

Color properties

Changes in CIE L^*, a^* and b^* of the reduced fat sausages and the control are shown in Table 3. Nitro-myoglobin produced by the combination of NO and myoglobin and its amount was not significantly different among treatment groups (P>0.05). All fat-reduced inulin sausages tended to be darker (with lower L^* values) than the controls; this was significant (P<0.05) for batches with 6% inulin.

The redness (a^* value) of the fat-reduced sausages was comparable to the mean value of the control sausages, with a significant brighter redness (P<0.05) in the I6 W12 group. On the other hand, inulin content had no significant (P>0.05) effect on the b^* value (yellowness) of emulsion type sausages.

Textural properties

Textural values of reduced fat sausages are compared with full fat sausages in Table 4. In terms of maximum force, there was no significant difference between the samples; however, the gradient value of the reduced fat sausages of I3 W6 was significantly lower than that of the other samples (P<0.05). In addition, cohesiveness of the reduced fat samples was found to be lower than the control, springiness of all samples was above 0.89, and the chewiness of all four reduced fat sausage samples was similar to the full fat control sample.

Sensory properties

The results for the sensory properties of both control and experimental groups are summarized in Table 5. In general, scores for the different parameters awarded by

Table 5: Sensory characteristics (mean±SD) of the conventional (control) and reduced fat emulsion type sausage

Treatments	Odor	Taste	Color	Texture
Control	4.42 ± 1.13	4.57 ± 0.78	4.71 ± 0.48	4.57 ± 1.13
I3 W3 [1]	4.42 ± 1.13	4.42 ± 1.13	4.71 ± 0.48	4.14 ± 0.69
I3 W6 [2]	4.42 ± 1.13	4.42 ± 1.13	4.71 ± 0.48	4.42 ± 1.13
I6 W6 [3]	4.42 ± 1.13	4.57 ± 0.78	4.71 ± 0.48	4.57 ± 0.53
I6 W12 [4]	4.14 ± 1.21	4.42 ± 1.13	4.00 ± 0.81	3.42 ± 0.78*

[1] 3% inulin + 3% excess water, [2] 3% inulin + 6% excess water, [3] 6% inulin + 6% excess water, and [4] 6% inulin + 12% excess water. * Significantly different at P<0.05

panelists were interestingly similar. No significant differences were found between the ratings for odor in the control and reduced fat sausages (P>0.05). Moreover, there was no significant difference between the groups regarding color or flavor (P>0.05).

Discussion

In our study, we found that fat reduction did not considerably influence the pH, whereas water activity significantly changed in the I6 W12, I6 W6 and I3 W6 groups. The results are supported by several articles regarding dry fermented, cooked and frankfurter sausages (Bloukas and Paneras, 1993; Grigelmo *et al*., 1999; Mendoza *et al*., 2001; Caceres *et al*., 2004). Although the addition of water and inulin to the experimental groups did not significantly change textural properties, they increased water activity levels up to 0.01 in I3 W6 and I6 W6 and also 0.02 to the I6 W12. Hence, the presence of inulin in our study did not modify the physicochemical characteristics of the emulsion type sausages. The carbohydrate content of various groups significantly changed, however, which is similar to previous findings in the literature (Caceres *et al*., 2004; Nowak *et al*., 2007). Levels of protein in the different groups did not significantly change as fat and water content were modified (P>0.05). As the inulin used in this study contributed only to 1.50 kcal/g, its impact on the final energy value was very low. The results obtained by Nowak *et al*. (2007), Flaczyk *et al*. (2009) and Cegielka and Tambor (2012) have shown that the caloric value of meat products may be reduced to a much higher extent if inulin is used as a fat replacer. Color is a very interesting parameter in cooked meat products because consumers associate this product with a bright and characteristic pink color (Caceres *et al*., 2004). The difference in color properties is due to the low brightness described for this type of meat product caused by the lack of fat and an increase in total carbohydrates content (Troutt *et al*., 1992; Grigelmo *et al*., 1999). The inulin itself did not seem to alter the color considerably, since the values obtained were very similar and differences appeared independent of the amount added. Similar results for redness values are shown by Nowak *et al*. (2007), where an increase in dietary fiber and a decrease in fat content resulted in redder emulsion type sausages. Fat reduction, therefore, had a significant impact on the color of emulsion type sausages. In other words, with increased inulin and decreased fat, the products tended to become darker and redder. Researchers have found that the reduction of fat as well as the addition of carrageenan, cellulose gums, or other fibers can influence and darken the color of meat products. (Jimenes Colmenero, 1996; Naga Mallika *et al*., 2009). because it decreases lightness and yellowness (Barbut and Mittali, 1996; Hughes *et al*., 1997). However, it has also been shown that the crucial factor for the darkening of the sausages is the reduced fat but not the added carrageenan (Hughes *et al*., 1997).

Maximum force and gradient parameters both show hardness of the samples. Cohesiveness of the reduced fat samples could be due to the added water as it possibly weakens the three dimensional network of sausage samples. Springiness of the samples shows that in all sausage samples, the elastic component was dominant to the viscous component. Compression energy was stored in the samples so during the relaxation time, they recovered their initial shape. Chewiness shows the energy required to convert solid or semisolid foods to a ready-to-swallow state. Fat reduction in meat formulations normally results in increasing texture hardness and chewiness. However, in the current work, water addition was used as a strategy to overcome texture hardening caused by fat reduction. In addition, inulin can replace fat only when its macromolecules are rehydrated and swollen. This is why extra water was needed.

No significant difference was found between the ratings for odor in the control groups and the reduced fat sausages, indicating that inulin did not change odor, even at higher concentrations (Caceres *et al*., 2004). Moreover, color, specifically an increase in redness, was not different between the groups. This seems to indicate that the color changes detected by the colorimeter did not negatively influence this sensory parameter, since the panelists judged the samples to be of the same level of acceptability. However, changes in texture were not noticeable, except for the reduced fat group with 6% inulin and 12% water. The ratings given to texture did not improve, however, as the amount of added inulin and water increased. Caceres *et al*. (2004) and Cegielka and Tambor (2012) also reported that adding inulin did not influence the general sensory quality of cooked sausages and Polish chicken burgers. Lastly, our findings indicate that inulin is acceptable in terms of the sensory evaluation, even when the amounts are up to 6% of the final product. This level of acceptability is valid for both normal or reduced fat meat products.

Our results suggest that the reduction of the fat content of emulsion type sausages (6% to 18%) leads to a decrease in the energy value of the product by 20% to 64%, respectively. In addition, inulin could be used as a proper replacement for fat in the product without showing any significant changes in overall acceptability and appeal. The main purpose for adding inulin is to provide extra fiber to meat products in order to enhance their digestibility.

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Conflict of interest

No conflict of interest to declare.

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