Camel cocktail sausage and its physicochemical and sensory quality

NAFISEH SOLTANIZADEH1, MAHDI KADIVAR1, JAVAD KERAMAT1, HOOSHANG BAHRAMI2 & FATEMEH POORREZA2

1Department of Food Science and Technology, Isfahan University of Technology, Isfahan, Iran, and 2Rak Company, Isfahan, Iran

Abstract
The objective of this study was to compare the nutritional values of camel semitendinosus muscles with those of calves. Then, sausages were made from camel meat, beef and equal proportions of each and stored at 4°C for 45 days. The composition, physicochemical characteristics, sensory properties, and microstructure of the samples were evaluated. The proximate composition of meat from the two species was significantly different. Beef contained a significantly higher amount of vitamin E, whereas camel meat had better profile of fatty acid and higher iron content. Camel meat had a higher pH but similar myofibrillar protein content as beef. Sausages made from 100% camel meat also had higher pH and cooking yield along with higher \textit{a*} (redness) and lower \textit{L*} (lightness) than the others. 2-Thiobarbituric acid values among these treatments were significantly different. Samples containing 50% of each meat had a higher resistance to shear force; however, panelists could not detect any significant difference in tenderness of the samples.

Keywords: Camel meat, beef, fatty acid, iron, caloric value, semitendinosus cocktail sausage, 2-thiobarbituric acid, microstructure, cooking loss

Introduction
Sausages are a type of food consisting of ground meat, animal fat, salt, spices, fillers, extenders and binders that are usually packed in polymeric casing. Sausage-making is a very old food preservation technique and is a logical outcome of efficient butchery. Sausage-makers put to use meat and animal parts that are edible and nutritious, but not particularly appealing, and that allow the preservation of meat that cannot be consumed immediately (Fox 1987). As meat is highly perishable, its storage and marketing requires considerable energy input in the form of chilled or frozen storage. Development of shelf-stable ready-to-eat products would not only save energy, but would also be a valuable contribution to the growth of the meat industry (Ahmad and Srivastava 2007).
Meat and meat products are essential components in the diets of human beings; their consumption is affected by various factors. The most important ones are product characteristics (sensory and nutritional properties, safety, price, convenience, etc.) and consumer and environment-related characteristics (psychological, health, family or educational aspects, general economic situation, climate, legislation, etc.) (Jimenez-Colmenero et al. 2001). The nutritional value of meat products is mainly due to the energy supplied by these products, and also to their high biological value proteins, vitamins and minerals (Muguerza et al. 2004). In addition, meats are most important in supplying iron and other vital substance for human consumption (Rogov et al. 1989). Its importance, however, has also attracted controversy. Meat consumption has been associated with chronic diseases such as cancer and heart disease. These and other concerns, such as safety, have led to a declining level of consumption of some types of red meats. If meat is excluded from the diet without being replaced with sensible alternatives, nutrient deficiencies may occur (Chan 2004). Thus it is necessary to find some source of meat that decreases the probability of occurrence of such diseases.

Although camel meat is not universally consumed, it might be a potential alternative for beef particularly in arid/semi-arid regions where camels are usually bred (Rashed 2002). In recent years the potential of the camel as a meat source has received increased recognition but only few investigations on the chemical composition of this meat have been published (Rawdah et al. 1994). Camel tissue in the form of animal meat is used as an important source of a wide variety of nutrients, proteins, vitamins and minerals by humans in developing countries (Rashed 2002). Camel meat is healthier as they produce carcasses with less fat as well as having less levels of cholesterol than other meat types (Kadim et al. 2006), although measures of cholesterol in comparable samples within the same laboratory are required to confirm this (Kadim et al. 2008). The quality of meat produced by younger animals (5 years old or less) is comparable with beef in taste and texture (Babiker and Yousif 1990). As Kadim et al. (2009) found, camel meat is comparable with cattle meat in nutritive value, meat quality, and composition, when slaughtered at a comparable age range. Camel meat is also relatively high in polyunsaturated fatty acids (PUFA) in comparison with beef (Knoess 1977; Rawdah et al. 1994; Dawood and Alkanhal 1995). This is an important factor in reducing the risk of cardiovascular disease, which is related to saturated fat consumption (Giese 1992). Camel meat is also used for medicinal purposes for diseases such as hyperacidity, hypertension, pneumonia and respiratory disease, as well as for an aphrodisiac (Kurtu 2004). Hence the camel as a meat source seems to present a viable alternative to cattle. This is particularly true in desert regions due to the unique adaptation of camel to the harsh environmental conditions of arid and semi-arid zones, which are very difficult for all other livestock. Human consumption of camel meat should lead to a reduction in total fat intake and an increase in polyunsaturated fat as compared with other conventional meat sources (Rawdah et al. 1994).

There is a paucity of information regarding the use of camel meat in sausage production. The objective of the present study was to investigate the nutritional qualities of camel meat and its physicochemical and sensory quality, along with microstructural characteristics and shelf-life of sausages made from camel meat compared with those sausages made from just beef and from a mixture of both.
Materials and methods

Sample preparation

Semitendinosus muscles were obtained from 20 well-fed bovine and camel carcasses younger than 5 years old. Samples were taken from the muscle immediately after slaughter and were minced (Pars Khazar, Rasht, Iran). These samples were applied for vitamin E content determination. A part of the muscle was lyophilized and applied for lipid and fatty acid profile determination.

Chemical analysis and ultimate pH

Raw camel meat, beef and cocktail sausage samples were first ground and analyzed for moisture, fat and protein content (AOAC 2002). The pH value of meats at 6, 12, 24, 48 and 72 h after slaughtering and in sausages at 0, 15, 30 and 45 days after production were measured, using a pH probe (Eutech Instrument; Thermo Scientific, Kuala Lumpur, Malaysia) directly inserted 2 cm into a section of the sample.

Calorific value

The calorific value of raw meats was determined using a ballistic bomb (GallenKamp, Loughborough, UK).

Vitamin E content

Saponification and extraction. α-Tocopherol was extracted from the lipid fraction by the method of Lopez-Cervantes et al. (2006). Briefly, a subsample of 0.40 g (± 0.001 g) freeze-dried sample was weighed out and 5 ml KOH solution (0.5 M in methanol) were added and vortexed. The tubes were placed in a water bath at 80°C for 15 min. After cooling, 1 ml distilled water and 5 ml hexane was added, and the mixture was vortexed, then centrifuged for 2 min at 425 × g. Three milliliters of the upper phase were transferred to another test tube and dried under nitrogen. The residue was redissolved in 3 ml high-performance liquid chromatography (HPLC) mobile phase (100% methanol), and then membrane-filtered (pore size, 0.50 μm). Finally, an aliquot of 20 μl was injected into the HPLC column.

HPLC conditions. The HPLC-UV system (Shimadzu, Shimadzu, Japan) was equipped with a system controller SCL-6A, a pump LC-6A (Shimadzu), a column oven CTO-6A, a 20 μl injection loop, and a UV–vis detector SPD-6AV. Chromatographic analysis was performed using an analytical scale (250 mm × 4.6 mm I.D.) VP-ODS column with a particle size of 5 μm. HPLC conditions were as follows: mobile phase, 100% methanol; isocratic flow rate, 1 ml/min; column temperature, 36°C. The detection was operated using a UV–vis spectrophotometer, 292 nm for α-tocopherol. The α-tocopherol was identified by retention and spectral data.

Standards and quantification. Stock standard solutions of α-tocopherol (200 ppm) was prepared in 100% methanol and stored at −10°C away from light. Working solutions were prepared from this solution and were diluted with methanol prior to analysis. For determination of α-tocopherol in the lipid fraction, the stock solution was, in all cases,
analyzed together with the samples. Analyte concentrations in samples were estimated on the basis of peak areas.

**Fatty acid profile**

**Lipid extraction.** Meat samples were lyophilized until constant weight using a lyophilizer, maintained desiccated at room temperature, and analyzed within 2 weeks. Lipid of lyophilized meat samples were extracted with 5 vol (v/w) chloroform:methanol (2:1). After evaporating solvents under nitrogen, remains were resolved in hexane and this layer was transferred to another test tube and dried under nitrogen.

**Methylation.** To prepare the methyl ester of total fatty acids, 50 μl sample were methylated by addition of 1 ml of 0.2 M methanolic HCl. This mixture was heated at 60°C for 4 h and then 200 μl distilled water were added. The resulting mixture was extracted with 2 ml hexane (Ortega et al. 2004).

**Gas chromatography conditions.** Analysis for fatty acids was conducted by gas chromatography. One microliter of the methyl ester extract was injected into a ChromPac CP9001 (Chrompack Inc, USA, New Jersey, Raritan, USA) gas chromatography (fitted with 25 m CP-FFAP-CB fused silica wcot column, 0.32 mm inner diameter). The injector and detector temperatures were set at 240°C and 280°C, respectively. The temperature program was as follows: starting at 40°C and heating to 100°C at 25°C/min, followed by heating from 100°C to 240°C at 10°C/min. The final temperature was held for 17 min.

**Total iron**

Total iron was measured according to AOAC (2002).

**Heme iron.** Analysis of heme iron followed the method of Hornsey (1956). Briefly, 0.5 g freeze-dried meat fraction was dissolved in 4 ml deionized water, 0.5 ml concentrated HCl and 20 ml acetone. The solution was centrifuged at 3,000 × g for 20 min, and the absorbance of the supernatant was measured at 640 nm after being filtered through glass filter paper. Total heme was determined by taking the absorbance at 640 nm times 680. Total heme iron was calculated as total pigment × 8.82/100.

**Non-heme iron.** Non-heme iron was analyzed by the Ferrozine method described by Ahn et al. (1993): 0.50 g freeze-dried sample were dissolved in 3 ml of 0.1 M citrate phosphate buffer (pH 5.5) and 1 ml of 2% ascorbic acid in 0.2 m HCl and left to stand at room temperature for 15 min before adding 2 ml of 11.3% tri-chloro acetic acid and centrifuging at 3,000 × g for 10 min. To 2 ml supernatant, 0.8 ml of 10% ammonium acetate and 0.2 ml ferrozine reagent were added and the absorbance was measured at 562 nm against a standard curve. Standards were made by dilution of a 1,000 ± 1 ppm iron standard solution.

**Myofibrillar proteins**

The procedure used to determine myofibrillar proteins was similar to that of Olson et al. (1976).
Preparation of cocktail sausage

Sausages were prepared according to a recipe that is used in the Rak Meat Production Company (Table I). Meat was ground and, along with the other ingredients, was transferred to the cutter. After combining, the mixture was filled in a High density polyethylene (HDPE) case and then heated up to 80°C for 80 min in steam room, and after cooling was stored at 4 ± 1°C for 45 days.

Camel meat and beef were assigned to each of the following treatment groups: 100% camel meat, or 50% camel meat plus 50% beef meat, or 100% beef meat.

Color measurement

The color was instrumentally evaluated using a Texflash instrument (Datacolor International, Zurich, Switzerland). The $L^*$ (lightness), $a^*$ (+/−, redness), and $b^*$ (+/−, yellowness) values of freshly cut sausages were determined. A white ceramic tile was used to standardize the colorimeter. Commission Internationale de l’Eclairage (CIE) $L^*$, $a^*$ and $b^*$ color values were measured at three different point of each sample (Gasperline et al. 2001).

2-thiobarbituric acid value

Twenty grams of meat was blended with 50 ml of 20% trichloroacetic acid (TCA) for 2 min. The blender contents were rinsed with 50 ml water, mixed together, and filtered through a Whatman No. 1 filter. A 5 ml aliquot of the TCA extract was mixed with 5 ml of 0.01 M 2-thiobarbituric acid (TBA) and held for 1 h at 100°C. TBA is reported as milligrams of malonaldehyde per kilogram of samples (Strange et al. 1977).

Texture analysis

The shear force of samples was estimated with a Warner–Bratzeler blade attached to the texture analyzer. These samples were also three cores (1.27 cm diameter) of each cocktail sausage. The crosshead speed was 100 mm/min. Maximum force to cut the samples (shear force) was recorded.

Cooking loss

Cuts of cocktail sausage (about 0.3 cm thick) were individually weighed and heated in a microwave on a power of 100 W for 3 min. The difference in weight of samples before and after cooking was expressed as a percentage of cooking loss.

Table I. Recipe of sausages.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Weight (meat percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>30</td>
</tr>
<tr>
<td>Ice</td>
<td>40</td>
</tr>
<tr>
<td>Garlic paste</td>
<td>2</td>
</tr>
<tr>
<td>Spice mix</td>
<td>2.4</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>4</td>
</tr>
<tr>
<td>Starch</td>
<td>4</td>
</tr>
<tr>
<td>Casein</td>
<td>2.4</td>
</tr>
<tr>
<td>Gluten</td>
<td>3</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>0.016</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Sensory evaluation

Cocktail sausage samples were cooked according to the previous method. Two slices (0.3 cm thick) from each cooked sausage at room temperature were presented as blind studs to panel members. The panelists consisted of 10 graduate students; each had previous sensory evaluation experience. At each evaluation, three samples were coded with random numbers and evaluated for texture, juiciness and overall acceptability on a nine-point hedonic scale (9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). The effect of storage time on sensory attributes of cocktail sausages was not determined in this experiment. Only at day 30, a sensory acceptance panel test was conducted.

Microstructure

Samples were cut from the centers of sausages, pre-fixed in 10 g/100 g formalin for 10 h at 20°C, dehydrated with a series of increasing isopropyl alcohol solutions (70, 95 and 100 g/100 g) and then xylene (100 g/100 g). The samples were later embedded in paraffin, cut with a microtome into sections 4–6 μm thick, allowed to float on water, and transferred onto glass slides. Slides were dried in a 65°C oven for 40 min, deparaffinized in xylene (100 g/100 g) and alcohol (100 and 70 g/100 g), washed in water, and stained with hematoxylin for 10 min. This was followed by a water rinse, acid alcohol dips (six or seven), another water rinse, ammonia water dips (five or six), a water rinse and staining with eosin. The slides were then washed and a cover slip was mounted on top of each slide. Specimens were observed using a light microscope (Olympus Optical BX60, Tokyo, Japan). Photographs were captured by a computerized image analysis system (Image-Pro Plus, Version 4.5-1.29; Media Cybernetics Inc., Silver Spring, MD, USA).

Small pieces of sausages 0.5 cm in diameter and 0.2–0.3 cm thick were used for electron microscopy analysis. After preparation of samples, dehydration and sputter-coating with a layer of gold/palladium in a mettallizer, micrographs of the samples were obtained with scanning electron microscope (SEM 505; Philips, Noord-Brabant, Eindhoven, The Netherlands).

Statistical analysis

The experiment was replicated six times. Data were evaluated using SAS GLM procedures. Treatment means were separated using the least significant differences test (SAS Institute, Inc. 1993). Statistical models included three treatments and four storage times (0, 15, 30 and 45 days) as independent variables. Significance was established at \( P < 0.05 \).

Results and discussion

Chemical composition

The mean and range of chemical composition of the semitendinosus muscle of camel are presented in Table II. The moisture content was significantly higher \( (P < 0.05) \) in camel meat compared with beef. The mean moisture of 76.82% for camel meat was similar to that reported by Babiker and Tibin (1986), El-Faer et al. (1991) and Elgasim...
and Alkanhal (1992) for Saudi camels and by Cristofaneli et al. (2004) for the llama and alpaca, but higher than the value reported by Dawood and Alkanhal (1995) and Kadim et al. (2009). Babiker and Yousif (1990) found a moisture content of 75.81% for semitendinosus muscle of camel. These differences may have resulted from variations in pre-slaughtering and post-slaughtering handling or age of animals. The importance of moisture in meats lies in its pronounced effects on the meat shelf-life, its processing potential and sensory characteristics. Higher moisture content of a meat may affect its juiciness and wetness, being an indication of its water-holding capacity.

There was no significant difference in the fat content of semitendinosus muscles of camel meat and beef. The mean fat of 0.72% for camel’s semitendinosus muscle was similar to those (0.50–1.43%) reported by Babiker and Yousif (1990) and slightly lower than the ranges listed by El-Faer et al. (1991) and Elgasim and Alkanhal (1992). Kadim et al. (2006) reported higher fat content of about 4.4% in the longissimus dorsi muscle of camel meat. This variability is a general trend for camel meat. Meats vary greatly in their fat content according to the animal species, age, diet and part of the carcass used (Valsta et al. 2005). The protein content was affected significantly ($P<0.001$) by species. Elgasim and Alkanhal (1992) reported that the camel has a protein content slightly less than that of beef, lamb, goat or chicken meats. The mean protein of 21.36% for camel is similar to that reported by Dawood and Alkanhal (1995) but higher than the values found by Elgasim and Alkanhal (1992), indicating camel meat is a good source of protein with high quality in harsh-climate arid regions. The amounts of protein decrease in camel meat with increasing age (Kadim et al. 2006). There was not a significant difference in the ash content of camel meat and beef. A significant difference was found in the value of ash between camel meat and other animals (Elgasim and Alkanhal 1992). The ash content was similar to what Kadim et al. (2006) found for camel meat longissimus dorsi muscle. That might be due to different rations, as camels are basically fed by dry teasels. Calorific value was significantly lower ($P<0.001$) in camel meat compared with beef. The difference in caloric content can be attributed to a difference in protein content between two carcasses. Also, a negative correlation was found between moisture content and calorific content (Browning et al. 1990).

The results for chemical composition of sausages are presented in Table III. Differences in composition of the different formulas can be contributed to the type of meat used as it was the only variable. Most of the differences have been found between sausages made with camel meat and beef, in which beef sausages showed the highest fat content and the lowest moisture content.

<table>
<thead>
<tr>
<th></th>
<th>Camel meat</th>
<th>Beef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>76.7 ± 0.93&lt;sup&gt;A&lt;/sup&gt;</td>
<td>75.7 ± 0.97&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>21.4 ± 0.63&lt;sup&gt;B&lt;/sup&gt;</td>
<td>22.6 ± 0.47&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>0.7 ± 0.33&lt;sup&gt;A&lt;/sup&gt;</td>
<td>0.9 ± 0.45&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1.1 ± 0.07&lt;sup&gt;A&lt;/sup&gt;</td>
<td>0.9 ± 0.45&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Calorific value</td>
<td>120.2 ± 1.95&lt;sup&gt;B&lt;/sup&gt;</td>
<td>129.4 ± 0.80&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means in the same row with different uppercase superscript letters are significantly different ($P<0.05$).

<sup>a</sup>Kjeldahl-N × 6.25.
The pH profile for camel and cattle meat is shown in Figure 1. Fresh camel meat indicated a significantly higher pH value than that of beef, while the pH decline was slower in camel meat. However, both meat samples showed a low ultimate pH of 5.5 within 24 h postmortem in beef and 48 h postmortem in camel meat. The pH decline of meat is generally related to glycogen content of the muscle at slaughter time (Immonen and Puolanne 2000), where lower glycogen content may result in a decreased rate of glycolysis; hence, a slower accumulation of lactic acid and a slower rate of post-slaughter pH decline. It is well known that the camel is considered to be a gluconeogenesis animal due to having humps (Wensvoort et al. 2004). The amount of enzymes in its glycolysis pathway is, therefore, less than that of the calf, causing lower glycogen degradation and pH decline. In the study conducted by Kadim et al. (2009) there was no significant difference in the rate of pH decline between camel meat and beef.

The pH values of sausages made from the formulas were significantly different \( (P < 0.05) \). Sausages made from camel meat or camel meat plus beef meat showed higher \( (P < 0.05) \) pH values (5.73 and 5.71, respectively) than that of 100% beef sample (5.59). This could be due to the higher pH values in camel meat (Figure 1).

### pH profile

![Figure 1. pH decline for camel and cattle carcasses.](image)

**Table III. Chemical composition of sausages.**

<table>
<thead>
<tr>
<th>Proximate composition</th>
<th>100% camel meat</th>
<th>50% camel meat + 50% beef</th>
<th>100% beef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>51.3 ± 0.18</td>
<td>50.9A ± 0.06</td>
<td>48.7B ± 0.60</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>15.9 ± 0.78</td>
<td>17.9AB ± 1.22</td>
<td>18.8A ± 0.52</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>13.0B ± 0.95</td>
<td>15.8A ± 0.59</td>
<td>16.8A ± 0.51</td>
</tr>
</tbody>
</table>

Means in the same row with different uppercase superscript letters are significantly different \( (P < 0.05) \).
**Vitamin E**

\(\alpha\)-Tocopherol (vitamin E) is important for muscular and reproductive functions, as well as being an antioxidant (Ching and Mohamed 2001; Ge et al. 2002). In animal studies, vitamin E demonstrated the following abilities: reduction in gastric oxidative stress and mucosal cell membranes from lipid peroxidation; inhibition of nitrosation; and chemical reduction gastric tumors, specifically in combination with other antioxidants (Liu and Russell 2008). The data show a significant difference in the amount of vitamin E between camel meat and beef. As mentioned in Table IV, beef has higher vitamin E in comparison with camel meat and this is caused by different patterns of nutrition between two animals.

**Fatty acid profile**

The fatty acid composition of lean raw meat taken from one-humped camels (*Camelus dromedarius*) and beef are presented in Table IV. Considering fatty acid composition, oleic acid (C18:1cis) was the most represented fatty acid in both meats, followed by palmitic acid (C16:0) and stearic acid (C18:0). The proportion of linoleic acid (C18:2) was approximately 13.0% of the total fatty acids in camel meat and approximately 12.0% in beef, while linolenic acid (C18:3) was found at a lower level of 0.53% in camel meat and 0.46% in beef. The amount of arachidonic acid (C20:4) was up to 1.32% of the total fatty acids in camel meat and 0.26% in beef. In camel meat the saturated chains constitute 41.27% of total fatty acid and this was lower than those found in beef, which are about 46.03%. Among the saturated acids the most abundant

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Camel meat (%)</th>
<th>Beef (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:0</td>
<td>3.65</td>
<td>3.18</td>
</tr>
<tr>
<td>14:0</td>
<td>7.30</td>
<td>3.80</td>
</tr>
<tr>
<td>15:0</td>
<td>0.93</td>
<td>0.27</td>
</tr>
<tr>
<td>16:0</td>
<td>17.81</td>
<td>22.24</td>
</tr>
<tr>
<td>17:0</td>
<td>1.89</td>
<td>3.01</td>
</tr>
<tr>
<td>18:0</td>
<td>9.69</td>
<td>13.42</td>
</tr>
<tr>
<td>20:0</td>
<td>–</td>
<td>0.11</td>
</tr>
<tr>
<td>14:1</td>
<td>1.52</td>
<td>0.28</td>
</tr>
<tr>
<td>16:1</td>
<td>9.32</td>
<td>2.79</td>
</tr>
<tr>
<td>17:1</td>
<td>0.78</td>
<td>0.99</td>
</tr>
<tr>
<td>18:1 cis</td>
<td>28.42</td>
<td>33.27</td>
</tr>
<tr>
<td>18:1 trans</td>
<td>0.77</td>
<td>2.47</td>
</tr>
<tr>
<td>20:1 cis</td>
<td>13.03</td>
<td>11.98</td>
</tr>
<tr>
<td>18:2 cis-9,trans-11 (CLA)</td>
<td>–</td>
<td>0.61</td>
</tr>
<tr>
<td>18:3</td>
<td>0.53</td>
<td>0.46</td>
</tr>
<tr>
<td>20:4</td>
<td>1.32</td>
<td>2.28</td>
</tr>
<tr>
<td>Total saturated fatty acid</td>
<td>41.27</td>
<td>46.03</td>
</tr>
<tr>
<td>Total MUFA</td>
<td>42.81</td>
<td>38.26</td>
</tr>
<tr>
<td>Total PUFA</td>
<td>14.88</td>
<td>13.33</td>
</tr>
<tr>
<td>MUFA/saturated fatty acids</td>
<td>1.022</td>
<td>0.83</td>
</tr>
<tr>
<td>PUFA/saturated fatty acids</td>
<td>0.36</td>
<td>0.29</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>1.03^B ± 0.04</td>
<td>3.42^A ± 0.27</td>
</tr>
</tbody>
</table>

Means in the same row with different uppercase superscript letters are significantly different \((P < 0.05)\).
is palmitic acid. The monounsaturated chains in camel meat account for almost one-third of the total fatty acids. This group of acids is dominated by oleic acid followed by palmitoleic acid. In both ruminant and non-ruminant species, oleic acid is known to be the major monoenoic acid (Rawdah et al. 1994).

Linoleic acid is the major member of PUFA, followed by arachidonic acid. The ratio of polyunsaturated chains to saturated ones in camels is 0.36, compared with 0.29 in beef. Monounsaturated fatty acids (MUFA) are the most common of the fats in all three animal categories mentioned above; specifically, the sum of MUFA is 48.3 g/100 g total fatty acids in beef, 39.5 g/100 g total fatty acids in lamb and 47.9 g/100 g total fatty acids in pork (Chan 2004). In this study, the amount of monounsaturated fatty acids in camel meat (42.81%) was higher than the same fatty acids in beef (38.26%).

Fatty acid composition has a considerable effect on the diet/health relationship, since each fatty acid affects the plasmatic lipids differently. Meat lipids usually contain less than 50% saturated fatty acids (of which only 25–35% have atherogenic properties), and up to 70% (beef, 50–52%; pork, 55–57%; lamb, 50–52%; chicken, 70%; rabbit, 62%) unsaturated fatty acids (monounsaturates, MUFA, and polyunsaturates, PUFA; Jimenez-Colmenero et al. 2001). The presence of MUFA and PUFA in the diet reduces the level of plasma low-density lipoprotein cholesterol, although PUFA also depresses the high-density lipoprotein-cholesterol (Mattson and Grundy 1985). A lower level of saturated fatty acid and a higher amount of MUFA and PUFA in camel meat compared with beef can affect low-density lipoprotein cholesterol of plasma.

Meat from ruminant animals is also a source of other naturally occurring fatty acids, conjugated linoleic acid (CLA). CLA is a collective term used to describe a mixture of positional and geometric isomers of linoleic acid (Williamson et al. 2005). These groups of PUFA appear in dairy products and are thought to have beneficial effects on health, are also found at low milligram levels in meats, especially in beef and lamb (Valsta et al. 2005). The main form present in ruminant products is the cis-9, trans-11 CLA, known as rumenic acid (Padre et al. 2006). In terms of their benefits to human health, products containing CLA (considered nutraceutical or functional) have anti-carcinogens (especially rumenic acid) (Ip et al. 1999) and anti-obesity properties (cis-12,trans-10 isomer). These products also help prevent arteriosclerosis, they are antioxidants due to the conjugated double bonds, and they contribute to prevent non-insulin-dependent diabetes mellitus (Padre et al. 2006). According to Table II, camel meat is empty of CLA but we could find this fatty acid in beef. It seems that the camel hump may be the place for CLA aggregation.

Iron

Beef is well recognized as an important dietary source of iron, and particularly of the more bioavailable heme iron. According to the results found in this study, the amount of iron was significantly \( P < 0.05 \) higher in camel meat, and therefore could be a better source of iron in compared with beef (Table V). Dawood and Alkanhal (1995) measured the iron content of camel meat and reported a value of 3.24 mg/g. Purchas et al. (2003) found that the semitendinosus muscle of beef and lamb had a lower level of iron than the longissimus and triceps brachia muscles. Total iron, estimated by atomic absorption spectroscopy, within the semitendinosus muscle of beef
and camel closely matched the sum of the two fractions of iron as measured by spectrophotometric methods (Table V). The overall correlation between total iron measured in the two ways was 0.93.

Differences between beef and camel meat was significant for heme iron ($P < 0.001$; Table V), with camel meat having a higher percentage of heme iron (83.77% vs. 79.9%). The higher concentration of myoglobin and hemoglobin in camel meat compared with beef (data not shown) accounted for the reported differences.

The ratio of heme to non-heme iron is also important because iron within the heme molecule can be absorbed into enterocyte cells in a wall of the small intestine by the process that is less affected by factors that inhibit the absorption of non-heme iron, thereby often making it more bioavailable (Purchas et al. 2003). The ratio of heme to non-heme iron was higher in camel meat than that of beef, indicating a better absorption of camel meat iron. Heme iron usually enhances the absorption of all dietary non-heme iron (Mulvihill and Morrissey 1998). Species did not significantly affect non-heme iron. It seems that that level of non-heme iron is less affected by species and environmental conditions (Ahn et al. 1993; Purchas et al. 2003).

**Myofibrillar protein**

There was no significant difference between myofibrillar proteins in camel meat and beef (10.89 in camel meat vs. 10.58 in beef). The myofibrillar proteins contribute the most functionality to the processed meat products (Smith 1988). These proteins are important in meat products due to their water and fat binding along with their emulsifying capacity.

**Color**

Sausages made with just beef or camel meat indicate a higher and lower $L^*$ value, respectively ($P < 0.05$) (Table VI). It is reported that lightness in meat and meat products depend on several factors such as water-holding capacity, fat content, free water, and so forth (Fernández-López et al. 2006). Increasing fat content in meat products, such as sausages made from beef, results in lighter products (Littinandana et al. 2005). On the other hand, any increase in water-holding capacity reduces the $L$ value (Fernández-López et al. 2000). Therefore, due to the higher fat content in sausages made from beef and higher cooking loss that is a result of lower water-holding capacity in this, the lighter color is expected.

### Table V. Iron content of camel and beef semitendinosus muscle.

<table>
<thead>
<tr>
<th></th>
<th>Camel meat</th>
<th>Beef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heme iron (ppm)</td>
<td>23.3 ± 5.74A</td>
<td>15.3 ± 5.34B</td>
</tr>
<tr>
<td>Non-heme iron (ppm)</td>
<td>3.2 ± 0.32A</td>
<td>3.1 ± 0.43A</td>
</tr>
<tr>
<td>Total iron (ppm)$^a$</td>
<td>26.5 ± 5.74A</td>
<td>18.4 ± 5.22B</td>
</tr>
<tr>
<td>Total iron (ppm)$^b$</td>
<td>27.8 ± 2.60A</td>
<td>19.2 ± 3.36B</td>
</tr>
<tr>
<td>Heme iron (%)</td>
<td>83.8A</td>
<td>79.9A</td>
</tr>
</tbody>
</table>

Means in the same row with different uppercase superscript letters are significantly different ($P < 0.05$). $^a$Sum of iron levels in the two fractions. $^b$Total by atomic absorption spectroscopy.
Camel meat sausages provide the highest $a^*$ values; however, there was no significant difference ($P < 0.05$) in yellowness ($b^*$) between the three samples. This suggests camel meat provides more pigment in sausage than other formulations. To develop a suitable color in cooked cured meat, the content of myoglobin is important (Aaslyng 2002). In our previous study, it was found that camel meat has a higher myoglobin content than beef (data not shown). This could be the reason why a higher $a^*$ value and darker color were found in cocktail sausages made from camel meat. Several authors have also related meat redness to lipid oxidation in meat products (Fernández-López et al. 2003), in which a higher oxidation rate in meat may provoke a decrease in redness. Sausages made with camel meat showed the highest ($P < 0.05$) redness and the lowest TBA values, which contradicted the corresponding finding in beef sausages. Also, the lowest $a^*$ value ($P < 0.05$) of beef sausages could be due to the higher fat content, which dilutes the myoglobin in the products. Higher chroma (Table III) in camel meat and in mixed samples indicates a more saturated red color than beef samples. Chroma depends directly on the concentration of myoglobin (Mb) in the muscle or anatomical piece, although it has been mentioned that it might be related to the state of the Mb, and would diminish as the proportion of met myoglobin increased (Fernández-López et al. 2000).

**Cooking loss**

A significant loss was found among samples after cooking (Table VI). Camel meat sausage had lower cooking loss than the two other formulations. The difference in cooking loss could be attributed to the denaturation temperature of protein and the difference in mechanical properties of different meats. However, these differences are due to molecular differences or to a variation in the architectural distribution of the connective tissue in different meats (Dawood 1995). Moreover, the yield of cured cooking products depends on the pH of the meat, so that the higher pH, the higher yield. pH specially influences the yield by altering the cooking loss (Aaslyng 2002). Cooking loss depends also on water-holding capacity. A fast pH decline early post mortem has often been shown to result in low water-holding capacity (Henckel et al. 2000). In this study, the pH of camel meat decline was slower than beef; thus, camel meat probably has higher water-holding capacity and lower cooking loss.

### Table VI. Physicochemical and sensory characteristic of sausages.

<table>
<thead>
<tr>
<th></th>
<th>100% camel meat</th>
<th>50% camel meat + 50% beef</th>
<th>100% beef</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>$5.7^A \pm 0.02$</td>
<td>$5.7^A \pm 0.04$</td>
<td>$5.6^B \pm 0.04$</td>
</tr>
<tr>
<td>$L^*$</td>
<td>$66.6^B \pm 1.31$</td>
<td>$67.6^{AB} \pm 0.54$</td>
<td>$68.6^A \pm 0.21$</td>
</tr>
<tr>
<td>$a^*$</td>
<td>$13.9^A \pm 0.10$</td>
<td>$12.9^B \pm 0.11$</td>
<td>$9.2^C \pm 0.09$</td>
</tr>
<tr>
<td>$b^*$</td>
<td>$15.8^A \pm 1.90$</td>
<td>$16.6^A \pm 0.32$</td>
<td>$15.6^A \pm 0.24$</td>
</tr>
<tr>
<td>Chroma</td>
<td>$21.1^A \pm 1.34$</td>
<td>$21.0^A \pm 0.29$</td>
<td>$18.1^B \pm 0.18$</td>
</tr>
<tr>
<td>Cooking loss (%)</td>
<td>$24.2^B \pm 4.20$</td>
<td>$29.1^A \pm 4.15$</td>
<td>$30.2^A \pm 2.73$</td>
</tr>
<tr>
<td>W-B shear force (g F)</td>
<td>$284.8^B \pm 43.20$</td>
<td>$334.7^A \pm 46.02$</td>
<td>$288.4^B \pm 47.78$</td>
</tr>
<tr>
<td>Tenderness</td>
<td>$5.2^A$</td>
<td>$5.2^A$</td>
<td>$6.2^A$</td>
</tr>
<tr>
<td>Juiciness</td>
<td>$6.9^A$</td>
<td>$6.0^A$</td>
<td>$6.7^A$</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>$5.4^A$</td>
<td>$5.3^A$</td>
<td>$5.7^A$</td>
</tr>
</tbody>
</table>

Means in the same row with different uppercase superscript letters are significantly different ($P < 0.05$).
TBA value

Lipid oxidation, expressed as the TBA value, is shown in Figure 2. During storage, the differences in TBA values among these three treatments were significant. The beef sample had higher \((P > 0.05)\) TBA values than the camel and mix sausages. These differences could be easily attributed to the higher fat content of the sausages made with beef, which could speed up lipid oxidation. Shariatmadari and Kadivar (2006) indicated the TBA value was lower for camel meat than that of beef at different aging times. These differences in the TBA values were probably due to higher pH value of camel meat and cocktail sausage made from camels. This result agreed with Yasosky et al. (1984), who studied the relationship between lipid oxidation and pH value of ground pork during 12 days of storage, and concluded that inhibition of oxidation occurred at high pH. The pH oxidation rate may also be affected by heme iron content (Kuo and Chu 2003). However, in our previous study it was found that beef had lower heme iron content than camel meat (data not shown). The increased percentage of TBA values within each treatment was different due to its different lipid oxidation rate. On days 15, 30 and 45, TBA values of all treatments were higher than those at time zero, indicating that lipid oxidation had occurred in the vacuum-packaged sausages. However, TBA values of all products throughout storage time were in the range of 0.24–0.50, which were relatively low and well below the threshold value (1.0 mg malonaldehyde/kg) for detection of warmed-over flavor (Boles and Parrish 1990). Rancid flavor was initially detected between TBA values of 0.5 and 2.0 (Kuo and Chu 2003).

Shear force

The shear force required for cutting of cocktail sausages is presented in Table VI. Sausages made with both meats had significantly higher shear force values than those

![Figure 2. TBA value of sausages as affected by storage time.](image-url)
made from camel meat and beef, whereas there was no significant difference in shear force between the others, and this situation did not change during storage time ($P < 0.05$). Cavestanty et al. (1994) reported that the variation in textural properties of meat products may be influenced by a variety of factors such as differences in formulation, ionic strength, particularly meat protein functionality, concentration and characteristics of fat.

**Sensory evaluation**

The mean value for sensory evaluation of the sausages is presented in Table VI. Panelists were not able to detect significant differences ($P < 0.05$) in terms of tenderness, juiciness and overall acceptability among cocktail sausages; however, the objective measurement of meat tenderness did not support the sensory panel assessment in which higher shear force was found in sausage containing both meats. It seems...
that difference in shear force between treatments has been to an extent that panelists were not able to detect the variation.

Microstructure of sausages

Micrographs of the samples are shown. Different sizes of lipid droplets are observed in sausages (Figure 3c,f,i); the size of fat droplets is smaller than those presented in sausages made from beef (Figure 3a,d,g) and a mixture of the two meats (Figure 3b,e,h), in which larger fat globules have been distributed among smaller ones.

The microstructure of the samples observed by scanning electron microscopy is shown in Figure 4. The microstructure of the meat emulsion exhibited irregular denser formations, giving rise to structures of a spongy (honeycomb-like) appearance (Figure 4)—a matter that has been described by Gordon and Barbut (1990) and Carballo et al. (1995). Sausages containing camel meat with a low level of fat but high moisture content compared with the two other formulations (decrease in protein density) caused the formation of numerous holes of smaller size and similar shape (Figure 4 and Table III). The formation of holes in beef sausages and sausages made with a mixture of two meats may have been related to the high amount of fat that could not spread and accumulated in a point. The three-dimensional microstructure of sausages might be attributed to aggregation of muscle proteins induced by acids.

Gelation is considered to be the cross-linking of randomly dispersed polymer chains to form a three-dimensional network (Riebroy et al. 2005). From the results, the alignment of myofibrillar proteins as well as aggregation induced by acids might be different, depending on the source of myofibrillar proteins and the aggregation pattern. As a result, the gel matrix or developed network in samples varied and water retained in the network might be different. Thus, the arrangements and aggregation of protein

Figure 4. Scanning electron microscopy micrographs of cocktail sausages containing different meats: (a) 100% beef, (b) 100% camel meat, and (c) 50% camel meat +50% beef (magnification ×2,114).
filaments contributed to the different water-holding capacity as well as to the textural properties.

**Conclusion**

Camel meat is not only nutritionally as good as beef but also has some benefits, including a lower calorific value, a lower amount of saturated fatty acid, a higher amount of MUFA and PUFA and a higher amount of iron. Consumption of camel meat therefore may decrease the possibility of obesity and cardiovascular disease. MUFA and PUFA in camel meat have good effects on health. Although some chemical compositions of camel meat are similar to those of beef, the iron content and its bioavailability is much higher in camel meat and may resolve the iron-deficiency problem in poor communities. Based on the results of overall acceptability, it can be concluded that camel meat can be used in the production of cocktail sausages. Such sausages have lower TBA value than beef sausages, which indicate a higher resistance to lipid oxidation, better acceptable sensory characteristics and overall acceptability. Physical properties and the microstructure of sausages differed among formulas but these properties did not directly affect the acceptability of products. Production of this sausage may also be considered economic since it has lower cooking loss and higher water-holding capacity.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

**References**


