Effect of different camel fats on the physicochemical, textural, fatty acid profile and microstructure of camel meat emulsion

Mohamed M. Mashaly, Marwa R. S. Abdallah*, Mohamed M. T. Emara and Mohamed K. Elmossalami

Department of Food Hygiene and Control, Faculty of Veterinary Medicine, Cairo University

*Corresponding author: Current address: Department of Food Hygiene and Control, Faculty of Veterinary Medicine, Cairo University, Giza 12211, Egypt

Tel: 002-011-199-14179; Email: mrwaragab2017@gmail.com

Abstract

Camel meat is a valuable alternative of comparable quality and nutritive value for beef in areas where camels are usually found. Therefore, the objective of the current work was to study the effect of incorporation of different camel fat (hump, mesentery and renal) in the production of a stable and an acceptable camel meat emulsion as well as to study its effect on the chemical composition, physicochemical properties, microstructure, fatty acid profile and sensory quality. Use of different camel fats induced significant differences in the moisture, fat, and collagen contents which affect the water-holding capacity, batter viscosity, and emulsion stability. The mean values of the fatty acids, shear force, instrumental color indices, and the ultrastructure of the luncheon sausage revealed the presence of significant differences between the treatments. The meat batter produced with mesenteric and renal fat exhibited more stable emulsion than the hump.

Keywords: camel fat, luncheon, hump, renal, mesentery, emulsion stability, ultrastructure.

1. Introduction

The dromedary camel plays a crucial role in the human diet in arid and semi-arid areas where the production of other animals is adversely affected **(Kadim et al., 2006)**. Camels represent the main contributor for meat, milk, and fat with a nutritional value comparable to that of beef **(Kadim et al., 2008; Soltanizadeh et al., 2010).** Camel's meat has high levels of both mono-and poly-unsaturated fatty acids as well as considerably lower saturated fats and calories in comparison with other red meat. However, consumers prejudiced against its extreme toughness **(Soltanizadeh et al., 2008)**. Therefore, further processing of camel meat increases its acceptability **(Mansour & Ahmed, 2000; Kadim et al., 2008)**, produces a promising alternative for traditional red meat particularly in countries where camel meat is available and at the same time satisfies the consumer's demand for low calories meat products **(Saparov & Annageldiyev, 2005; Rashed, 2002)**.

Camel meat is a suitable raw material for the processing of different meat products **(Farouk & Bekhit, 2013)** due to its high protein content and water holding capacity **(Babiker & Yousif, 1990)**. However, the main technical problem in the formulation of camel meat emulsion is its poor fat-emulsify ability due to the unacceptably high connective tissue content **(Ulmer et al., 2004; Mohamed et al., 2015)**. Low-fat content of camel meat is an additional problem because animal fat is the main factor that determines the texture and mouthfeel of meat products **(Keeton, 1994)**. Utilization of camel fat from different depots in the processing of camel meat products could be the best solving due to its acceptable nutritional criteria and low cholesterol content as well as ease of emulsification **(Kadim et al., 2013)**.

Meat emulsion is a uniform dispersion of fine fat particles within the viscous protein matrix. The pattern of fat dispersion and its immobilization in the protein matrix before cooking and within a strong gel structure after cooking is responsible for the successful production of meat emulsion. The separation of fat and water during cooking is a serious problem that results in emulsion instability **(Owusu-Apenten, 2004)**. Numerous factors including, the type, the degree of saturation, the level of salt soluble and the connective tissue proteins in the matrix, the level of salt, moisture and the comminution process determine the emulsion stability **(Santhi et al., 2015)**. The technological challenges which face the production of a stable and acceptable camel meat emulsion would make it valuable to investigate the physicochemical, emulsion stability, textural, fatty acid profile and microstructural changes in camel meat emulsion produced with fat from different depots (hump, renal and mesenteric).

2. Materials and Methods

2.1. Experimental design

A three trials-based experiment was designed to study the effect of incorporation of different camel fats on the physicochemical and ultrastructure of the camel meat emulsion. Three batters were prepared using hump, renal, and mesenteric fats with three replicates each in independent time.

2.2. Raw materials

Twenty silver side muscles from 5-years old Arabian male camels (*Camelus dromedarius*) were obtained from El-Bassaten slaughterhouse (Cairo, Egypt) 3h post-slaughter and carcass preparation and stored at 4ºC for the next day. The hump, renal, and mesenteric fats were collected from the same camel carcasses and kept at 4ºC for 24h. Sodium nitrite was purchased from BASF Chemical Company

(Ludwigshafen Rhine, Germany), Sodium tripolyphosphate was obtained from FOODCHEM Company (Shanghai, China), the spice oleoresins were obtained from ‘Nubassa’ (GewürzwerkGmpH, Viernheim, Germany), while the common salt and cornstarch were purchased from local markets.

2.3. Processing of emulsion-type sausages

Three camel meat batters were produced with different types of fat using the Good Manufacturing Practices with 65% camel meat, 16% camel fat, 5% cornstarch, 1.6% common salt, 100 ppm sodium nitrite, 0.3% sodium tripolyphosphate, 12% ice flacks and a quantum sufficient of the spice mix. (oleoresins of coriander, mace, garlic, cardamom, white pepper, and capsicum). Immediately before the preparation of each batter, both lean and fats were ground with Laska meat grinder (K 65, Austria) using a 2mm mincing plate. Minced lean was firstly chopped with the non-meat additives in a K-65 Laska bowl chopper (Germany) at 4000 ×g before the ice was added. At -2ºC, the ground fat was added and chopped for 2ºC, then the starch was added and chopped to 10ºC final batter temperature. Prepared batters were stuffed into 85mm Viskase polyamide casing (Walsroder, GmbH, Germany) and left for 3h at 4ºC before cooking. The sausage batter was cooked using Maurer-Atmos oven (Middleby GmbH Kindlebindstr 100-D78479, Germany) and a complete humid cooking program started with 60ºC for 1h, 75ºC for 1h and finally 85ºC to 72ºC core temperature. After cooking, the sausage was cooled with water under the shower for one hour.

2.4. Investigations

2.4.1. Chemical analysis

Proximate chemical analysis of the raw meat batter and cooked sausage were estimated for three samples from each replicate following the outlines of **AOAC (2013)**. Ten g sample was dried using Heraeus hot air oven (Germany) at 102°C to obtain a constant weight for the determination of moisture content. Half g sample was digested using 'VELP' Scientifica Digester (DK 6, ITALY), distilled in 'VELP' distillation unit (UDK 126 D) to determine the nitrogen content. The total protein content was obtained from the nitrogen content time 6.25. Ether extractable lipids were extracted using six extraction cycles with petroleum ether (40-60°C) and a Soxhlet apparatus. Five g sample was ignited in a muffle furnace at 600°C for 5h to obtain the ash content. The hydroxyproline content was determined following the procedure of **Mahendrakar et al. (1988)** and the equation of **Woessner (1961).** The total collagen (g%), was obtained from hydroxyproline content time 7.25, while the soluble collagen (g%), was calculated by multiplying the soluble hydroxyproline by 7.14.

2.4.2. Water-holding capacity

The centrifugation method described by **Hongsprabhas and Barbut (1999)** was used to determine the WHC of camel meat batters. Twenty grams sample were centrifuged in Beckman Coulter cooling centrifuge (Indianapolis, United States) at 4°C for 20 min. at 20.000xg. The WHC% was calculated from the difference between the weight of the supernatant and that of the initial sample.

2.4.3. Batter viscosity

Viscosity of the meat batters was measured three times for each sample using a Rheostress RS50 rheometer (HAAKE, Germany) with a plate (MP60 steel 18/8) and cone (60 mm Ø/2 angle) and the method described by **Jafarpour and Gorczyca (2009)**. Five g sample was loaded to the rheometer between the cone and the plate and left for five min. at 10ºC. The sample was heated (10-80ºC) with 1ºC/min. heating rate, 100 pa stress, and 0.1 Hz frequency values.

2.4.4. Emulsion stability

Twenty-five grams from each meat batter were centrifuged at 6000 rpm for 15 min using Beckman Coulter cooling centrifuge (Indianapolis, United States) at 4°C, heated at 70ºC for 30 min. and finally centrifuged again for 20 min at 6000 rpm. The pellet was weighed, and the percentage of total fluid released (TFR) to the initial weight was calculated. The loss in the TFR after heating at 105ºC in a hot air oven for 15h is the water released (WR), while the difference between TFR and WR is the percentage of fat released (FR) (**Colmenero et al, 2005)**.

2.4.5. Measurement of pH value

For measurement of pH, five grams from each sample were homogenized with 20 ml distilled water for 15 seconds using a lab blender (Stomacer 400 EVO, England). The pH was measured using Hanna pH meter (H12002-01 edge Dedicated pH/ORP, USA), and the average of three readings was recorded and the mean pH value was calculated **(Kandeepan et al., 2009).**

2.4.6. Measurement of Thiobarbituric Acid Reactive Substances (TBARS)

Five grams from each sample were homogenized with 15 ml deionized distilled water at the highest speed in 400 EVO lab blender for 10 seconds. After filtration, one ml of the homogenate was mixed with 50 µl butylated hydroxyanisole (7.2%), one ml 2-thiobarbituric acid and one ml 15% trichloroacetic acid. After mixing, the aliquot heated in water bath for 15 min., cooled and centrifuged for 15 at 2500 rpm. TBARS content (milligrams malonaldehyde/kg) was obtained by measuring the absorbance of the developed color against the blank and multiplying the reading by 7.8 **(Du and Ahn, 2002).**

2.4.7. Shear force

Twelve cores (1.5 cm diameters) were obtained parallel to the slicing surface from each loaf. Each core was sheared three times by a Warner–Bratzler shear force device, an Instron Universal Testing Machine (Instron Corp., USA) with a 55-kg tension/compression load cell and a cross-head speed of 200 mm min^{-1}. The maximum peaks were recorded and the mean shear force value of each sample was calculated **(Shackelford et al., 2004).**

2.4.8. Instrumental color evaluation

The lightness (L*), redness (a*) and yellowness (b*) of cooked emulsion sausage was measured using Konica Minolta Croma meter (CR 410, Japan) equipped with a white plate and light trap **(Shin et al., 2008)**. The reading of the different color attributes was recorded by CIE standard illuminant D65 light source. Three readings were taken for each sample at each time of examination, and the average score of replicates was recorded and expressed as CIE (L*), (a*), and (b*).

2.4.9. Fatty acid profile

Lipids from each sausage sample were extracted in duplicate using hexane. The fatty acids methyl esters were saponified for 30 min at 60ºC with 40 ml/g 0.5 N NaOH in methanol and then methylated (ISO 12966-2 (2011) method. The resultant fatty acid methyl esters were separated and analyzed by an automated gas-liquid chromatography equipped with a 1.8 m×3.2mm stainless steel column packed in GP 10% sp 2330 on 100/200 Chromosorb WAW at a temperature gradient of 110-210ºC. The fatty acid peaks were determined, and the concentration of each fatty acid was calculated (**Slover and Lanza, 1979)**.

2.4.10. Microscopic examination

2.4.10.1. Light microscopy

A 2x2x2 cm samples from both raw meat batter and cooked sausage samples were fixed in 10% neutral formalin for 24h. Fixed samples were washed overnight in running water. After dehydration in an upgrading concentration of ethyl alcohol, the samples were cleaned in xylene and embedded in paraffin wax. Paraffin blocks were trimmed and sectioned at 4–6μm thickness and stained with Masson's trichrome stain **(Drury and Wallington, 1967).**

2.4.10.2. Scanning electron microscopy

Three 1 × 1 × 1 cm cores from each sample were fixed in 2.5% glutaraldehyde for 2h, trimmed to 2mm thickness, washed three times with phosphate buffer saline (0.1mol L−1), post-fixed in osmium tetraoxide (1%), and dehydrated using upgrading series of ethanol. Dehydrated samples were dried in Sandrari-PV-3D critical point dryer (West Chester, PA, USA) for 15, coated with gold in Edwards

150a vacuum evaporator **(Hayat, 1981 and Dalen et al., 1987)** and examined by QUANTA FEG 250 SEM Hillsboro, Oregon, USA.

2.4.11. Sensory evaluation

Nine staff members (both sex, 30-45 years) from the Department of Food Hygiene at the Faculty of Veterinary Medicine, Cairo University, Egypt received three preparatory sessions to identify the appearance, flavor, juiciness, tenderness and overall acceptability of the emulsion sausage. All the sensory evaluation sessions were carried out under controlled conditions with warm water provided to clean the mouth **(AMSA, 2015).** A 3mm thick slices from each loaf were randomly identified, and the panelists were asked in the main sensory analysis sessions to evaluate each sample in triplicate using a 9-point rating scale.

2.5. Statistical analysis

The data were analyzed by SPSS 23.0 for windows (SPSS Inc., Chicago, IL, USA). The values of the sensory analysis, proximate chemical composition, collagen content, emulsion stability, WHC, TBARS, shear force and color (L*, a* and b*) were recorded as Mean ± SE. One way ANOVA test was used to compare between means and the significance was determined by the least square difference test (LSD) procedure.

3. Results and discussion

The proximate chemical analysis showed that the addition of hump fat significantly increased the moisture ($P<0.05$), and reduced the fat content in final product followed by the samples produced with the mesenteric fat. Cooking camel meat batters induced a very slight effect on its proximate chemical composition (Table 1). The changes in moisture content due to cooking were evident, and the sausage formulated with the hump fat had the highest moisture content. **Soltanizadeh et al. (2010)** reported lower values for the proximate chemical composition of camel cocktail sausage, while, **Alamin (2015)** reported higher moisture, lower fat and higher protein contents for camel sausage. The batters produced with hump fat showed the highest collagen content (P <0.05) while those of the renal fat had the lowest values. The thermal treatment did not affect both collagen content and solubility (Table 1). The obtained data substantiated the previous finding of **Kadim et al. (2008)** that camel connective tissue is heat stable. However, **Mohamed et al. (2015)** reported a slightly higher collagen content for camel meat batter formulated with bio-marinated camel meat.

Both water and fat contents of the meat batters affects the viscosity and textural properties of meat batter **(Choi et al. 2009)**. The data of chemical composition, WHC, and batter viscosity were correlated. The addition of hump fat resulted in the lowest emulsion stability parameters, while the renal fat resulted in the highest stability values. Mean values for both emulsion stability and WHC were correlated with higher WHC of renal fat incorporated batter was associated with the lowest viscosity (Tables 1& 2).

The addition of different types of fat significantly (P<0.05) affected the stability of the camel meat batters. In general, use of hump fat adversely affected the emulsion stability. The mean values for TER, WR and FR were 16.13, 8.52, 7.61 for hump fat, 12.76, 4.64, 8.11 and 13.89, 7.17 & 7.72 for renal and mesenteric fat respectively (Table 2). The emulsion stability is affected by the type and level of fats **(Youssef and Barbut, 2009; Choe et al., 2013)** and the content of different proteins **(Xiong, 2000; Allais, 2010).** The ability of proteins to dissolve and to form an interfacial membrane around the fat and water is the main contribution to the stabilization of meat emulsion. However, the connective tissue proteins have a detrimental impact on emulsion stability due to its inability to dissolve and to form the interfacial membrane around the fats **(Kandeepan et al., 2013)**. The significantly lower emulsion stability of camel meat emulsions especially those produced with hump fat could be due to its high connective tissue content and high thermal stability (Table 2 and Fig 1&2) which affected both water and fat binding.

The level of TBA in the sausage formulated with renal fat was the lowest due to its high saturated fat content. However, the low level of saturated fats resulted in an unacceptable high TBA level in the luncheon prepared with mesenteric fat. The increase in both pH and TBA after cooking is due to the increase in the oxidation process, and the loss of free acid groups during thermal treatment **(Bhattacharyya et al., 2005).**

The texture profile analysis (Table 2) showed that the shear force required to break the luncheon sausage significantly increased from 0.39 and 0.41kg in the product formulated with renal- and mesenteric fat to 0.54kg in case of using hump fat. The results also declared that the high collagen content in the hump fat (1.2 g%) provides greater strength to the luncheon sausage, while (Table 1) the high-fat content in renal and mesenteric formulations provides softness to the product **(Figueiredo et al., 2002)**, which explained the variations in shear force between the different formulations.

The variations in fat content between the three formulations significantly affected the instrumental color indexes (L*, a*, b*) of the cooked emulsion sausages (Tables 1&2). The mean values of both lightness ‘L*’ and redness ‘b*’ increased linearly with the increase in fat content due to the honey color of the camel fat. However, no differences were documented as a result of variations in the protein content. The obtained results were in agreement with **Jin et al. (2016)** who found that the fat content is the principal determinant factor for color indexes of meat products while proteins and moisture play only a minor role.

The fatty acids profile of camel sausage indicated the presence of significant differences between the different formulations. The product formulated with renal fat had the significantly highest saturated fats while that produced with mesenteric fat had the lowest values. The results also revealed that palmitic and stearic acids were the main constituent of saturated fat, while oleic and linoleic acids were the main mono- and poly-unsaturated fats respectively (Table 3). Such fatty acid profile revealed that mesenteric fat is the ideal one for the production of emulsion type products, followed by the hump and finally the renal fat. **Schmidt (1983)** supposed that the general role governing the suitability of fat for emulsification is only its saturated fatty acids content, where the lower the saturated fats, the better shall be its emulsification. On the other hand, the data of emulsion stability (Table 2) proved that renal fat was the ideal choice while the hump was the least suitable for emulsification indicating that connective tissue content was more effective than the fatty acid content in determining the emulsification capacity of fat.

Light Microcopy

The light micrographs of raw camel batter stained with Masson’s Trichrome clearly described the shape and the orientation of both fat globules and the protein matrix. The images of hump fat incorporated batter (Fig. 1 a&b) revealed polymorphic, ovoid, evenly distributed fat globules of variable sizes and shapes. Some fat globules were large and had an irregular non-spheroid shape. The fat globules were impeded in a dense and viscous myofibrillar proteins matrix together with small muscle fiber fragments, and a large amount of collagenous connective tissue (blue color). Higher magnification showed a well-defined interfacial protein film membrane with various tinny pores surrounded each fat globule. The micrographs of renal fat formulated batter (Fig. 1 c&d) showed multiple large size fat globules surrounded by a more dense protein matrix and less dense collagen fibers. In the mesenteric fat incorporated batter, many fat globules coalesce forming a large one surrounded with a protein matrix of moderate density and collagen fibers (Fig. 1 e &f).

The light micrographs of cooked camel emulsion produced with hump fat (Fig. 2 a) revealed coalescence of the small fat globules with the suspension of large ones in a condensed gel structure due to gelation of the myofibrillar proteins and partial degradation of the collagen. **Feiner (2006)** reported that during the thermal treatment of meat emulsion, a viscous protein matrix is formed and consequently stabilized fat and immobilized water. The micrographs also showed lower connective tissue contents in comparison with raw batters due to the effect of heat treatment. Higher magnification indicated that each of the fat globules was coated with an intact protein film (Fig. 2b). The images of both renal- and mesenteric fat formulated emulsion revealed larger fat globules eventually distributed in a more dense protein matrix together with low connective tissue contents (Fig. 2 c-f).

Scanning Electron Microscopy

The scanning electron micrographs of raw camel emulsion formulated with hump showed ovoid or spherical shape fat globules of variable sizes dispersed in a dense protein matrix of salt soluble proteins together with numerous fibrous connective tissue threads. Some longitudinal breaks were evident in the dense protein matrix (Fig. 3a), and the fat globules were both coated with protein films and entrapped in a viscous protein matrix (Fig. 3b). The batter produced with renal fat revealed scattering of small fat globules in a less dense protein matrix (Fig. 3c), with longitudinal breaks in both the matrix and in the film surrounding the fat globules (Fig. 3d). However, the micrographs of mesenteric fat-formulated batter showed fat globules of equal size dispersed close to each other in a less dense protein matrix which showed several deep breaks.

The microstructure of cooked emulsion prepared with the hump fat revealed entrapment of the fat globules in the protein matrix, with some of them adhere to each other indicating loss of its rigidity and compactness. The protein matrix also showed several holes of variable sizes and multiple breaks with aggregation and granulation of the connective tissue (Fig. 4a). Moreover, several breaks and loss of discontinuity of the protein film surrounding the individual fat globules were also found (Fig. 4b). **Barbut (1995)** observed the same ultrastructure after cooking the meat batter to 70°C.

The renal fat incorporated emulsion sausage showed a compact protein matrix with spotty granulated connective tissue scattered all over its surface (Fig. 4c). The fat globules appeared covered with salt soluble proteins with aggregates of connective tissue (Fig. 4d). However, the breaks in the protein matrix were more evident in the case of the emulsion prepared with mesenteric fat (Fig. 4e&f) probably due to the effect of heat on connective tissue.

The formation of a stable meat emulsion is a substantial parameter used to judge the quality of the product. The amount and extractability of the salt soluble proteins are the main factors that control the production of successful emulsion. However, connective tissue content is of greater importance than the extracted myofibrillar proteins. The histological details verified that both the formation of the interfacial protein films around the fat globules and the viscous protein matrix are responsible for the stabilization of camel meat emulsion. The histological findings substantiated the findings of **Lee (1985); Gordon and Barbut (1991) and Barbut (1995).** The results can also explain the variation in the WHC and emulsion stability of the different batters. The high connective tissue content in the case of hump fat resulted in lower WHC and emulsion stability, while the low collagen content of both renal and mesenteric fat resulted in acceptable WHC and emulsion stability despite the high-fat content.

Sensory analysis

Sensory analysis of camel emulsion sausages produced with the hump, renal and mesenteric fat (Table 4) showed significant differences between the three treatments. The assessment of juiciness indicated the presence of a significant correlation with both WHC and emulsion stability. Sausage produced with renal fat had the highest score, highest WHC, lowest TER, and WR (Table 2). The high collagen content of hump fat-induced a detrimental impact on the binding scores, while the low collagen content in the other treatments resulted in more acceptable products. The overall acceptability scores of both renal and mesenteric fat were significantly higher than those of hump samples. However, the flavor was not altered among the different formulations. The differences in the sensory quality may be due to the variations in the WHC and emulsion stability and its correlation with the chemical composition and collagen content.

4. Conclusion

From the data of the proximate chemical analysis, WHC, emulsion stability and sensory quality, it can be concluded that camel fat is a suitable material for the production of an acceptable camel meat emulsion. The addition of both mesentery and renal fats improves the stability, quality, and technological parameter of emulsion sausage than the hump fat. The histological investigation provided a useful tool to explore the changes in the protein matrix, connective tissue, and emulsion stability. For that reason utilization of camel fat in camel meat emulsion products could be a valued alternative for beef meat emulsion products mainly in African and Asian countries. Thus might be share in the growth of meat industry.

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Table (1): Chemical composition* of camel meat batter and sausage produced with different types of camel fat

	Hump	Renal	Mesentery
Raw meat batter (g%)			
Moisture	67.28±1.20^{a}	65.94±1.35^{b}	66.16±1.25^{b}
Protein	13.71±0.58^{ab}	13.77±0.27^{a}	13.78±0.64^{a}
Fat	10.09±0.26^{a}	12.53±0.38^{b}	12.20±0.32^{b}
Ash	2.69±0.09^{a}	2.72±0.08^{a}	2.76±0.07^{a}
Collagen content	1.2±0.05^{a}	0.41±0.09^{b}	0.85±0.06^{a}
Collagen solubility	0.02±0.02^{a}	0.06±0.01^{b}	0.03±0.03^{a}
Emulsion sausage (g%)			
Moisture	67.13±0.26^{a}	65.84±0.15^{b}	65.97±0.17^{b}
Protein	13.83±0.10^{a}	13.70±0.05^{ab}	13.70±0.09^{ab}
Fat	11.13±0.11^{a}	12.66±0.75^{b}	12.29±0.14^{ab}
Ash	2.83±0.09^{a}	2.85±0.08^{a}	2.94±0.07^{a}
Collagen content	1.2±0.05^{a}	0.41±0.09^{b}	0.85±0.06^{c}
Collagen solubility	0.02±0.02^{a}	0.09±0.02^{b}	0.05±0.03^{c}

*Values represent the mean of three independent replicates± standard error
Different letters within the same row indicated that values are significantly different ($P < 0.05$).

Table (2): Physicochemical criteria* of camel meat batter and sausage produced with different types of camel fat

	Hump	Renal	Mesentery
Raw meat batter			
WHC%	94.72±1.05^{a}	97.00±2.10^{b}	95.23±1.90^{a}
Viscosity (cps)	228000±556.35^{a}	161600±305.50^{b}	205600±500.55^{c}
Emulsion stability			
TFR	16.13±0.45^{a}	12.76±0.69^{b}	13.89±0.93^{b}
WR	8.52±0.43^{a}	4.64±0.59^{b}	7.17±0.90^{a}
FR	7.61±0.20^{a}	8.11±0.14^{b}	7.72±0.18^{a}
pH	6.04±0.03^{a}	6.06±0.05^{a}	6.08±0.03^{a}
TBA mg/kg	0.43±0.02^{a}	0.40±0.03^{b}	0.43±0.08^{a}
Emulsion sausage			
pH	6.11±0.05^{a}	6.14±0.05^{a}	6.14±0.09^{a}
TBA mg/kg	0.44±0.07^{a}	0.41±0.05^{b}	0.56±0.08^{c}
Shear force kg	0.54±0.02^{a}	0.39±0.06^{b}	0.41±0.02^{b}
Color			
L*	51.97±0.22^{a}	53.69±0.25^{b}	52.10±0.20^{a}
a*	21.24±0.21^{a}	21.14±0.14^{a}	21.24±0.38^{a}
b*	9.22±0.26^{a}	10.69±0.10^{b}	10.29±0.43^{b}

*Values represent the mean of three independent replicates± standard error
Different letters within the same row indicated that values are significantly different ($P < 0.05$).

Table (3): Fatty acid profile of camel meat sausage produced with different types of camel fat

	Hump	Renal	Mesentery
C14	4.03±0.28^{a}	6.24±0.35^{b}	3.61±0.40^{a}
C14:1	0.24±0.008^{a}	0.37±0.02^{a}	0.24±0.009^{a}
C15	0.75±0.01^{a}	0.86±0.04^{a}	0.42±0.009^{b}
C16	26.65±1.20^{a}	25.40±1.50^{a}	25.62±1.46^{a}
C16:1	1.73±0.07^{a}	1.41±0.04^{ab}	1.69±0.02^{a}
C17	1.68±0.05^{a}	1.12±0.02^{a}	1.34±0.009^{a}
C17:1	0.59±0.02^{a}	0.29±0.002^{bc}	0.46±0.003^{ab}
C18	26.39±2.30^{a}	27.55±1.98^{a}	28.08±2.10^{a}
C18:1	30.48±2.50^{a}	29.17±3.40^{a}	34.37±3.33^{b}
C18:2T	0.75±0.01^{a}	0.73±0.003^{a}	0.60±0.008^{a}
C18:2	2.02±0.03^{a}	2.33±0.09^{a}	1.46±0.02^{a}
C18:3	0.66±0.02^{a}	0.40±0.04^{b}	0.25±0.004^{c}
C18:4	0.35±0.001^{a}	0.74±0.09^{b}	0.37±0.03^{a}
C20	0.39±0.04^{a}	0.25±0.003^{a}	0.27±0.01^{a}
C20:1	0.41±0.009^{a}	0.22±0.004^{b}	0.36±0.01^{ab}
C22	0.09±0.001^{a}	ND^{a}	ND^{a}
C24	0.21±0.002^{ac}	0.10±0.001^{ab}	ND^{b}
Unknown	2.20±0.03^{a}	1.79±0.30^{ab}	0.84±0.032^{b}
Total saturated	60.19±3.79^{a}	62.60±2.99^{b}	59.34±4.45^{a}
Monounsaturated	33.81±1.68^{a}	31.46±1.78^{b}	37.12±3.339^{c}
Polyunsaturated	3.78±0.50^{a}	4.20±0.56^{a}	2.68±0.87^{a}
Total unsaturated	37.59±3.05^{a}	35.66±4.50^{b}	39.80±3.33^{c}
Total trans fat	0.75±0.01^{a}	0.73±0.09^{a}	0.60±0.008^{a}

*Values represent the mean of three independent replicates± standard error

Different letters within the same row indicated that values are significantly different ($P < 0.05$).

Table (4): sensory attributes of camel meat sausage produced with different types of camel fat

sensory attributes of camel meat sausage*						
	Appearance	Flavor	Juiciness	Tenderness	Binding	Overall
Hump	7.00±0.14^{a}	6.54±0.07^{a}	6.75±0.16^{a}	6.56±0.68^{a}	6.00±0.51^{a}	6.59±0.15^{a}
Renal	6.55±0.40^{b}	6.78±0.02^{a}	7.50±0.14^{b}	6.90±0.40^{b}	7.50±0.83^{b}	7.00±0.09^{b}
Mesentery	6.80±0.20^{b}	6.92±0.01^{a}	7.20±0.11^{b}	6.88±0.31^{b}	7.40±0.89^{b}	7.01±0.20^{b}

*Values represent the mean of three independent replicates± standard error

Different letters within the same row indicated that values are significantly different ($P < 0.05$).

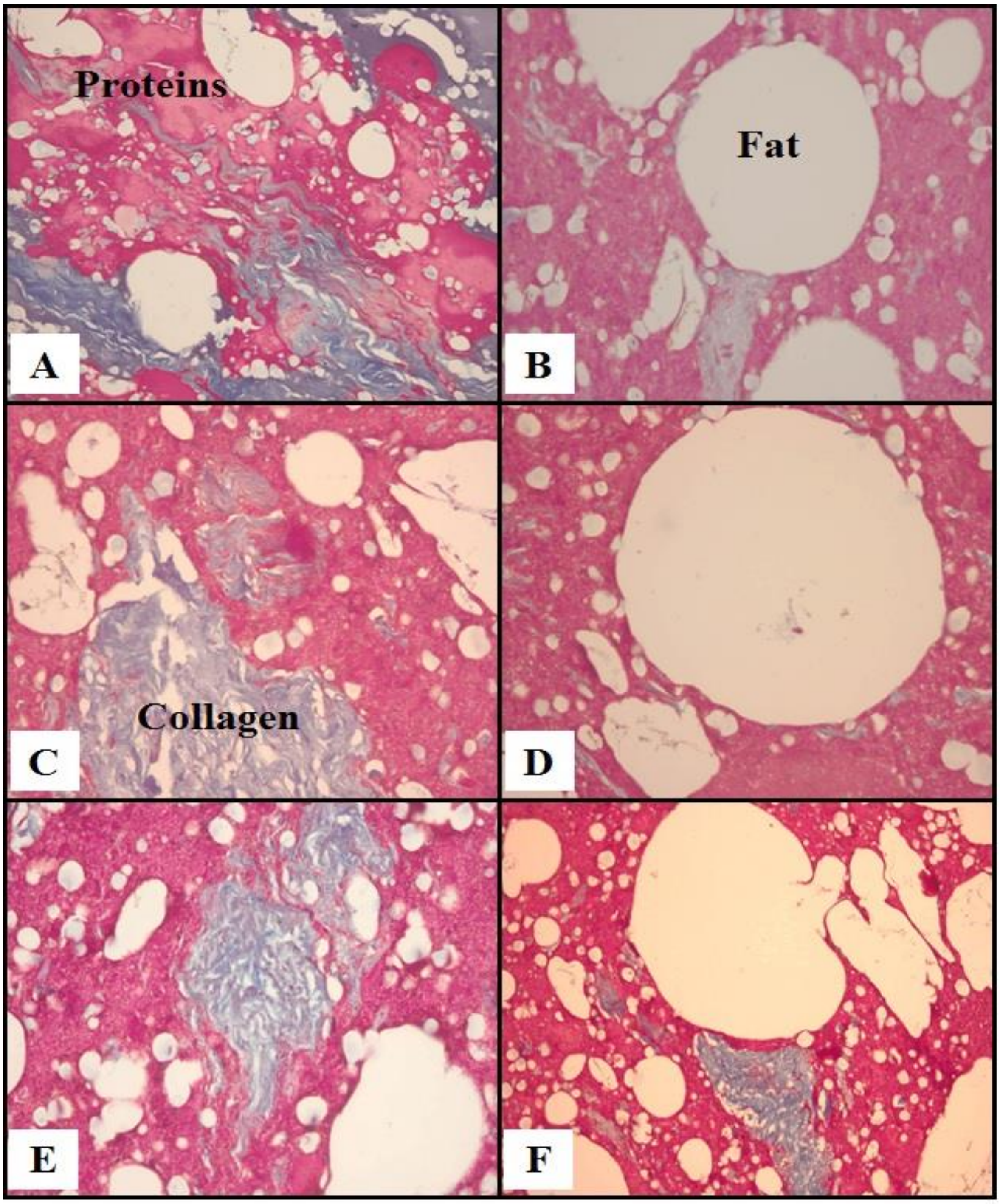

Figure 1. Light micrographs of raw camel meat batter stained with Masson's trichrome stain. A -b batter with hump fat; c-d batter with renal fat; e-f batter with mesenteric fat.

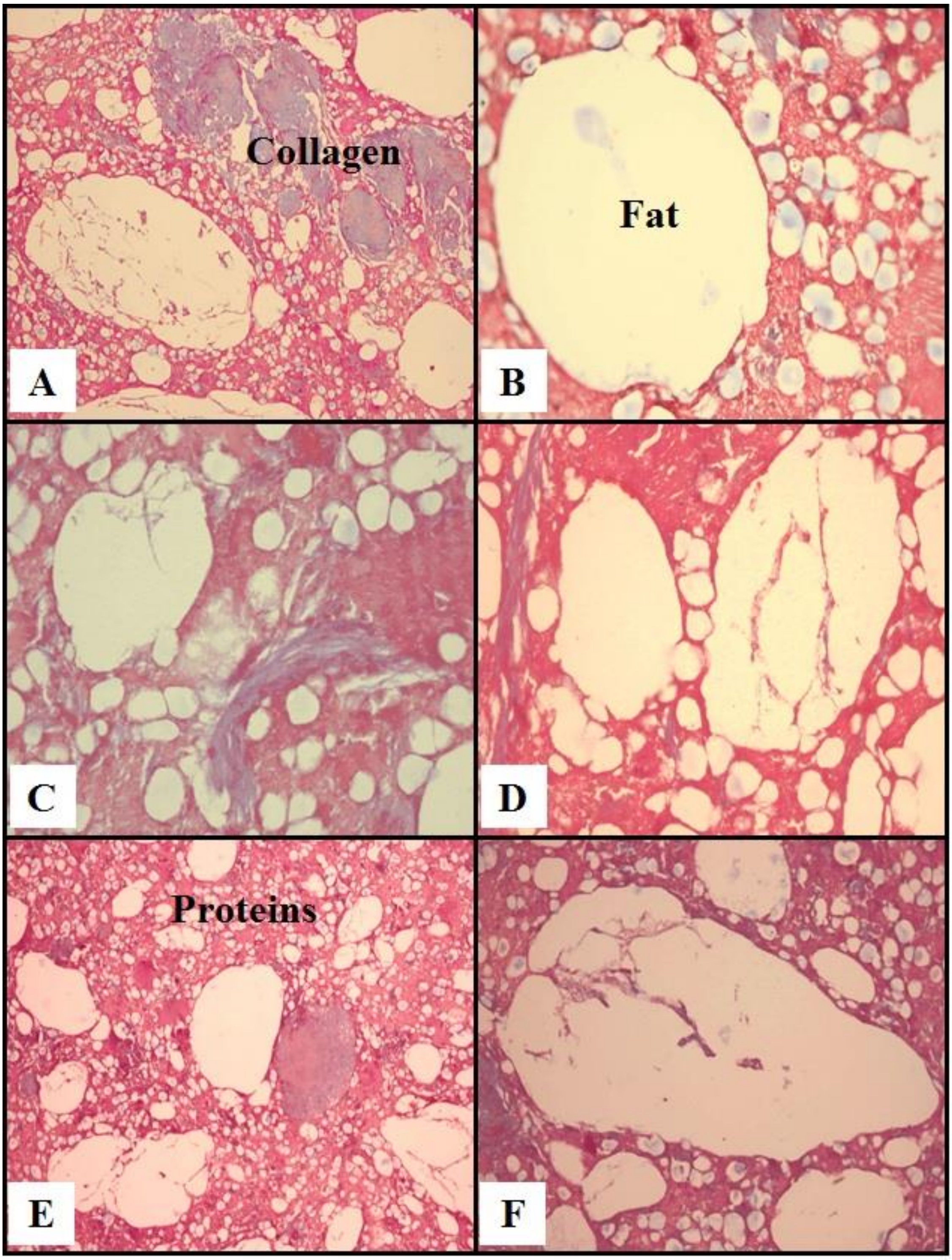

Figure 2. Light micrographs of cooked camel emulsion sausage stained with Masson's trichrome stain. A -b batter with hump fat; c-d batter with renal fat; e-f batter with mesenteric fat.

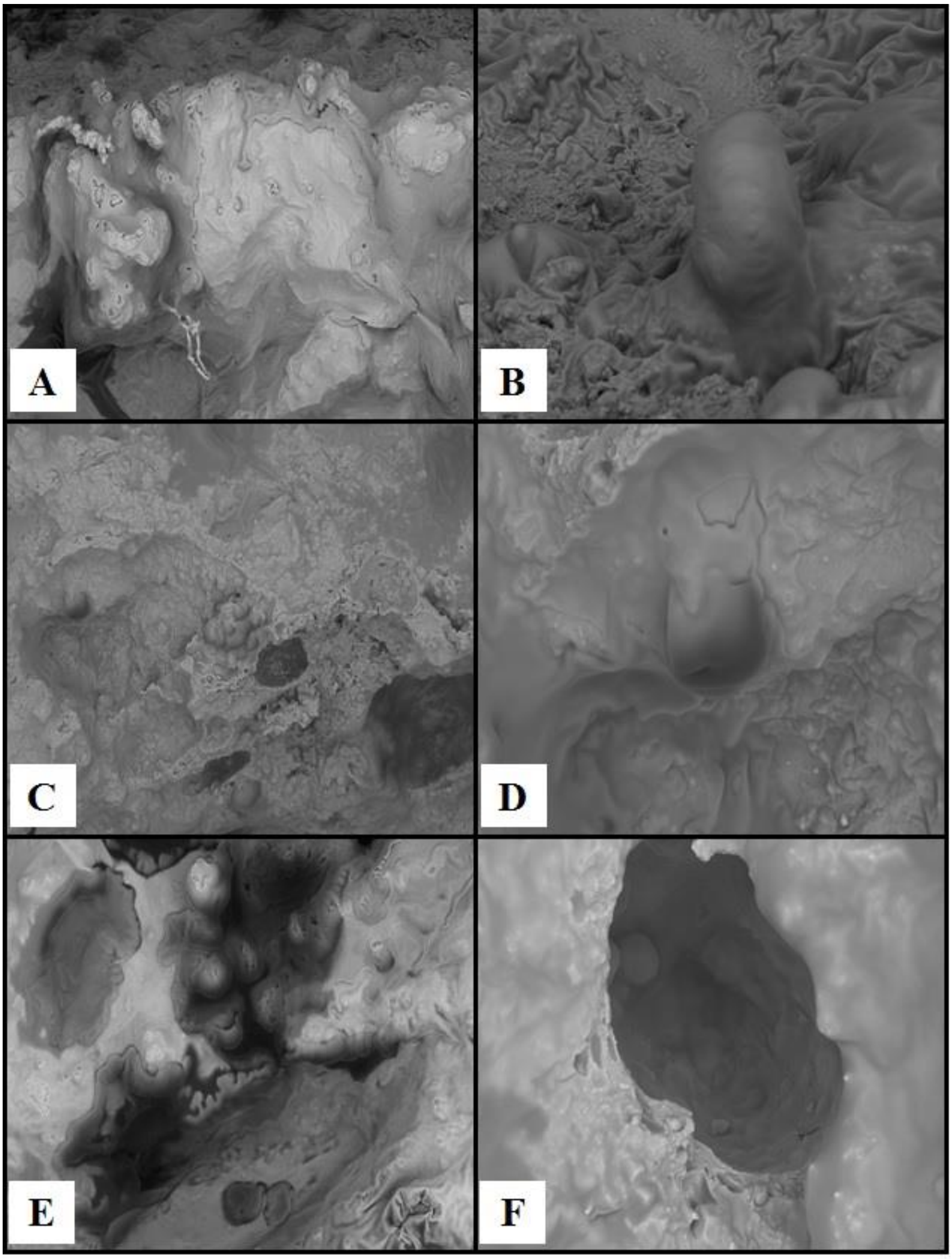

Figure 3. Scanning electron micrographs of raw camel meat batter. A -b batter with hump fat; c-d batter with renal fat; e-f batter with mesenteric fat.

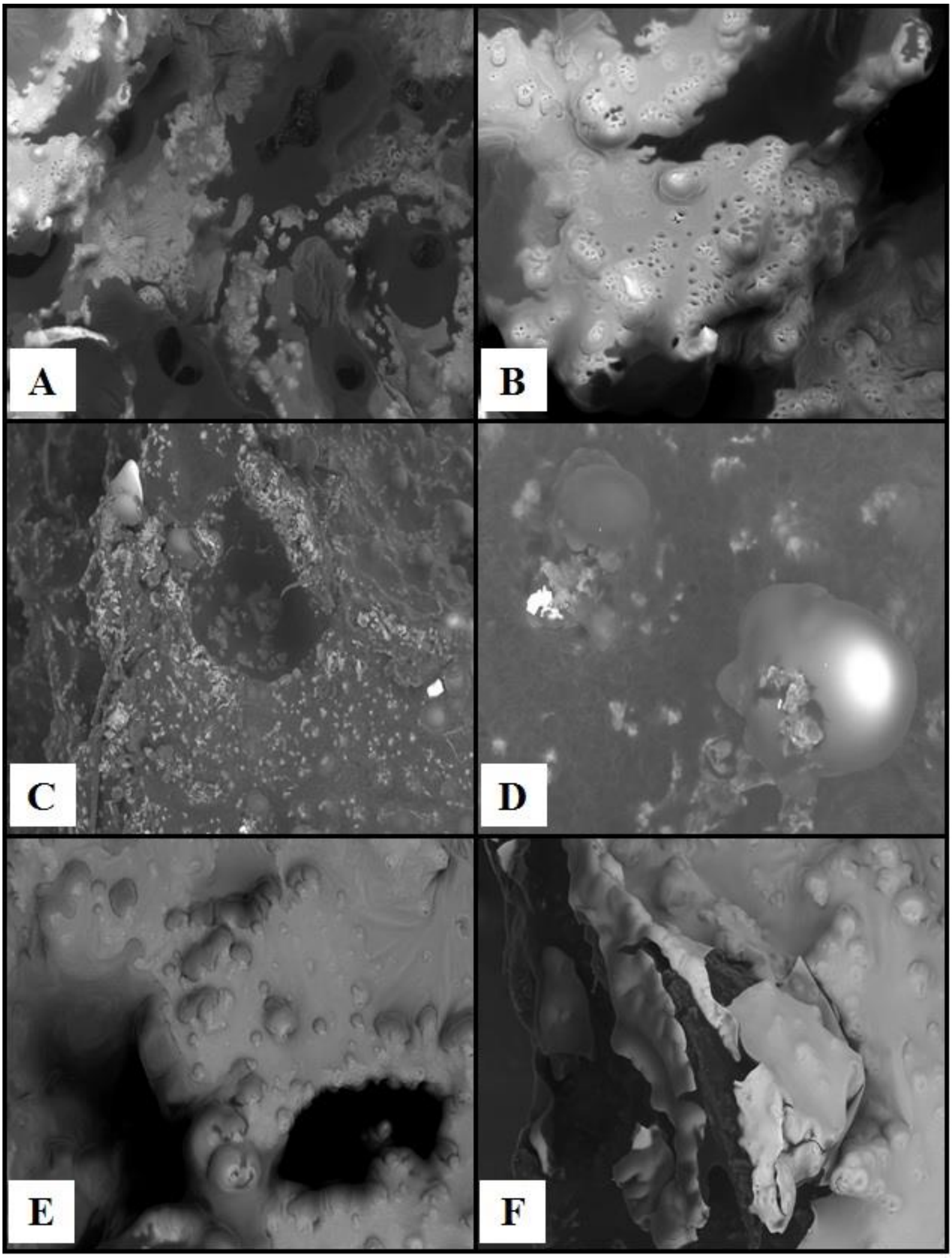

Figure 4. Scanning electron micrographs of cooked emulsion sausage. A -b batter with hump fat; c-d batter with renal fat; e-f batter with mesenteric fat.