Food Chemistry **31** (1989) 93–103

A Comparative Study on Bone Fats from Different Species of Animals

M. H. Abd-El-Aal & M. S. Mohamed

Food Science and Technology Department, Faculty of Agriculture,
University of Alexandria, Alexandria,
Egypt

(Received 18 November 1987; revised version received and accepted
10 March 1988)

ABSTRACT

Characteristics of fat in bones from two different anatomical locations (rib bone tissue and femur bone marrow) in young and old buffalo, sheep, camel, pig, cow and goat, with a view to utilizing it either for human consumption or industrial purposes, are reported. The fat content of rib bone tissue and long bone marrow ranged from 3·6–11·4% and 84·5–96·9% (fresh weight) respectively. Triglycerides constituted the major class of fat in all cases. The predominant fatty acids were $C_{16:0}$, $C_{18:0}$ and $C_{18:1}$. Some differences in fats in relation to anatomy and species were evident.

INTRODUCTION

At the present time, bones are treated as waste products with little value. They comprise some 16–20% of the carcass (Katz & Ackroyd, 1976). Data on the dry matter, fat, protein ash, amino acid, vitamin A, vitamin E and β-carotene contents of whole bones and bone marrows from several different species are available (Dietz, 1949; Elko & Diluzio, 1959; Field *et al.*, 1974; Belyaev *et al.*, 1985).

Evans & Oppenheimer (1955) published some information on the lipid composition of bone from rabbits. The fatty acid composition of chicken bone fat has also been elucidated (Moerck & Ball, 1973).

Food Chemistry 0308-8146/89/$03·50

Mello *et al.* (1976) reported on the type of lipids present in whole bones from six different anatomical locations of calves, heifers and cow. Recently, Miller *et al.* (1982) stated that cow bone lipids were largely composed of neutral lipids, the predominant fatty acids being $C_{16:0}$, $C_{18:0}$ and $C_{18:1}$.

Since bovine bone is part of the Egyptian diet, via soups and sauces, characterization of the bone fats is important. Hence, the purpose of this study was to characterize bone fats from two different anatomical locations (rib and femur) of six animal species, with a view to utilizing these fats for human consumption and/or industrial purposes.

MATERIALS AND METHODS

Materials

Five ribs and two femurs were removed from one animal of six different species (young and old buffalo, cow, pig, camel, sheep and goat) immediately after slaughter. The bones were physically cleaned of all visible muscle, connective tissue and fat. The ribs were ground twice in a bone cutter, while the femur bones were split and the marrows were removed; both the ground rib bones and femur marrows were stored at $-18°C$ before fat extraction.

Analytical methods

The fat of the ground rib bone tissue and femur bone marrow were extracted with hexane in a Soxhlet apparatus and the mass of fat extracted from femur bone marrows, called white marrow, and that from rib bone tissues, called red marrow, were reported as per cent of their fresh weight.

The extracted fats, after removing hexane, were immediately analyzed for iodine value and saponification value by the standard methods recommended by the AOCS (1973).

Fractionation of lipid classes

This was carried out on a thin-layer of silica gel G with a hexane–diethylether–acetic acid (80:20:1, by volume) solvent system, as described by Mangold & Malins (1960). The separated spots were visualized by charring them with 50% aqueous sulfuric acid (Privett *et al.*, 1973) and identified by comparing with R_F values reported in the literature (Wilson & Rinne, 1974; Abd-El-Aal *et al.*, 1986), then further confirmed by co-chromatography with standard cotton seed lipids (Abd-El-Aal, 1981).

For quantitative determination, the chromatograms were scanned using the charring densitometry technique (Blank *et al.*, 1964). The area under each peak of lipid component was measured by triangulation and the percentage of each fraction was calculated in regard to the total area.

Fatty acid analysis

The methyl esters were prepared according to Chalvardjian (1964), using 1% of sulfuric acid in absolute methyl alcohol. A Perkin-Elmer gas chromatograph (SIGMA 3) with a flame ionization detector was used with nitrogen as carrier gas. A glass column (2·0 × 2·5 mm) packed with 15% DEGS supported on Chromosorb W-HP at a temperature of 180°C was used. The area under each peak was measured and the percentage expressed in regard to the total area.

RESULTS AND DISCUSSION

The mass of fat and the values of the saponification and iodine numbers of the extracted fats are listed in Table 1. On a fresh weight basis, the fat contents of the rib bone tissue and femur bone marrow ranged from 3·6–11·4% and 84·5–96·9%, respectively. Camel bone tissue and bone marrow, had the largest proportions of fat and those of goat, the lowest.

It is remarkable that bone tissue and bone marrow of young buffalo contained less fat than did old buffalo. Other tested species showed considerable variation. These data agree with the limited data available in the literature (Meng *et al.*, 1969; Field *et al.*, 1974).

The chemical constants (Table 1) indicated that iodine and saponification values were always higher in white marrow than in bone tissue (red marrow) fats. Sheep, pig and goat red and white marrow fats, had higher and similar values of iodine and saponification numbers compared to other species and, in this respect, the values reported here were higher than subcutaneous or intramuscular bovine fat as given by Link *et al.* (1970). Because oxidative rancidity is a major cause of flavour deterioration, the higher level of iodine value in bone fats when compared to subcutaneous fat could have a detrimental effect on products containing them.

The qualitative and quantitative data of the individual components of bone tissue and marrow fats are summarized in Fig. 1 and Table 2. Cotton seed lipids contain nine classes which appear on the thin-layer chromatogram in the following sequence from the front to the base line: hydrocarbons + sterolesters, triglycerides, tocopherols, free fatty acids, 1,3-diglycerides, free sterols, 1,2 (2,3)-diglycerides, monoglycerides and polar

TABLE 1
Fat Content and Iodine and Saponification Values of Bone Tissue and Marrow Fats from Different Animal Species

Species	*Fat (%)*[a]	*Iodine value*[a]	*Saponification value*[a]
Young buffalo			
RBT[b]	5·2 ± 0·3	56·7 ± 0·4	210·0 ± 1·0
FBM[c]	89·4 ± 0·5	44·7 ± 0·3	218·8 ± 1·3
Old buffalo			
RBT	8·6 ± 0·6	39·3 ± 0·5	190·3 ± 0·9
FBM	90·3 ± 0·2	39·8 ± 0·2	211·9 ± 0·4
Camel			
RBT	11·4 ± 1·1	45·7 ± 0·4	210·4 ± 0·9
FBM	96·9 ± 0·6	49·9 ± 0·4	218·5 ± 0·6
Cow			
RBT	5·4 ± 0·2	54·7 ± 0·5	189·8 ± 0·2
FBM	89·8 ± 0·5	54·1 ± 0·3	212·8 ± 0·9
Goat			
RBT	3·6 ± 0·4	40·4 ± 0·3	207·8 ± 1·1
FBM	84·5 ± 0·2	76·9 ± 0·3	211·5 ± 0·8
Pig			
RBT	4·3 ± 0·3	65·5 ± 0·1	206·7 ± 0·2
FBM	86·7 ± 0·2	74·9 ± 0·3	210·4 ± 0·7
Sheep			
RBT	6·7 ± 0·6	65·5 ± 0·5	200·7 ± 0·8
FBM	95·4 ± 0·3	74·9 ± 0·9	209·7 ± 0·4

[a] Means of three determination ±SE, on fresh weight basis.
[b] RBT, Rib bone tissue.
[c] FBM, Femur bone marrow.

lipids. Bone tissue and white marrow fats contain at least six of the lipid classes.

Triglycerides were predominant (Table 2) and accounted for 68·5–97·3%. They were found to be low in bone tissue fats of young buffalo, pig and cow, indicating the possibility of quick and extensive enzymatic hydrolysis of triglyceride molecules and/or phospholipid components before extraction of the fat from them, which also accounts for the higher proportions of the free fatty acids (6·0–17·6%). Miller *et al.* (1982) found that cervical and lumbar tissue fats contained high levels of phospholipids which contained significant levels of lysophosphatidyl choline and lysophosphatidyl ethanolamine compared to marrow fat which was devoid of those

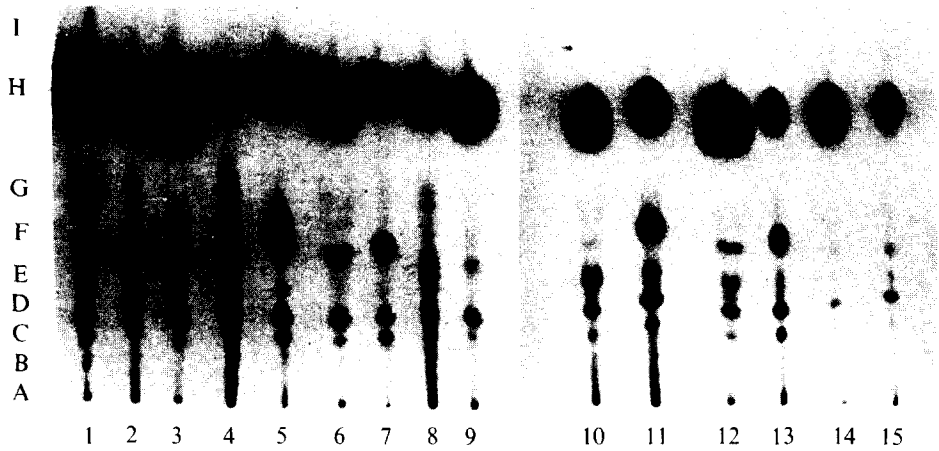

Fig. 1. Thin-layer chromatograms of red and white bone marrow fats from different animal species. Solvent system = Hexane–diethylether–acetic acid (80:20:1, by volume). Detection = Charring with 50% aqueous sulfuric acid. A = Polar lipid, B = Monoglycerides, C = 1,2(2,3)diglycerides, D = Cholesterols, E = 1,3-diglycerides, F = Free fatty acids, G = Tocopherol, H = Triglycerides and I = Cholesterolesters. 1 = Standard cottonseed lipid. 2, 4, 6, 8, 10, 12, 14 = White marrow fats of old and young buffalo, sheep, camel, pig, cow and goat, respectively. 3, 5,7, 9, 11, 13, 15 = Red marrow fats of old and young buffalo, sheep, camel, pig, cow and goat, respectively.

components. During their work on crude palm oil Goh & Timms (1985) found that there was not significant correlation between free fatty acids and mono- or diglycerides.

Rib bone tissue fats contained higher levels of cholosterol and polar lipids than femur marrow fats. Seitz (1969) found that the lipid characteristics of human bone fat varied according to bone source. Field *et al.* (1980) stated that mature femur mainly stored lipid and lumbar vertebra were usually considered to be metabolically rich in cholesterol. Mello *et al.* (1976) found that cholesterol content of marrow fats from cervical vertebra of 2-, 25-, and 230-month old beef animals was 175, 239 and 94 mg per 100 g tissue, respectively. However, the large increase in cholesterol content in the food products containing such red marrow can be considered nutritionally hazardous (Food and Nutrition Board, 1980).

One of the major contributions of bone fat to foods is fatty acid, being a source of energy and/or a dietary essential. The fatty acid composition of the fats extracted from bone tissue and bone marrow is presented in Table 3. As with most ruminant tissue, the predominant acids present in bone marrow fats were $C_{16:0}$, $C_{18:0}$ and $C_{18:1}$. Similar results have been reported in the literature (Lund *et al.*, 1962; Meng *et al.*, 1969; Liberman *et al.*, 1968; Moerck & Ball, 1973; Miller *et al.*, 1982). Palmitic acid represented the major

TABLE 2
Fat Composition of Bone Tissue and Marrow from Different Animal Species

Species[b]	*Polar lipid*	*Fat class per cent*[a]			*Free fatty acids*	*Triglycerides*
		1,2 (2,3) Diglycerides	*Cholesterol*	*1,3 Diglycerides*		
Young buffalo						
RBT[c]	2·1 ± 0·3	2·7 ± 0·1	3·9 ± 0·4	1·0 ± 0·1	6·0 ± 0·6	84·3 ± 0·9
FBM[d]	2·8 ± 0·2	0·9 ± 0·3	3·6 ± 0·3	1·0 ± 0·2	3·3 ± 0·1	88·3 ± 0·9
Old buffalo						
RBT	1·1 ± 0·2	2·2 ± 0·1	3·3 ± 0·3	0·5 ± 0·1	2·5 ± 0·2	90·4 ± 0·9
FBM	2·7 ± 0·3	1·6 ± 0·2	3·8 ± 0·1	0·4 ± 0·1	3·1 ± 0·2	88·4 ± 0·5
Camel						
RBT	1·1 ± 0·3	0·4 ± 0·1	2·9 ± 0·5	0·2 ± 0·1	0·5 ± 0·1	94·9 ± 0·9
FBM	2·2 ± 0·2	0·5 ± 0·1	0·9 ± 0·2	0·3 ± 0·1	1·4 ± 0·3	94·7 ± 0·7

Cow						
RBT	1·9 ± 0·3	3·7 ± 0·3	7·9 ± 0·5	0·4 ± 0·1	17·6 ± 1·0	68·5 ± 1·2
FBM	0·5 ± 0·2	0·3 ± 0·1	2·7 ± 0·2	0·2 ± 0·1	0·7 ± 0·2	95·5 ± 0·5
Goat						
RBT	1·6 ± 0·3	0·6 ± 0·2	6·9 ± 0·4	0·7 ± 0·3	0·3 ± 0·1	89·8 ± 0·6
FBM	0·4 ± 0·1	0·3 ± 0·1	1·5 ± 0·3	0·2 ± 0·1	0·2 ± 0·1	97·3 ± 0·4
Pig						
RBT	3·6 ± 0·4	1·4 ± 0·2	8·2 ± 0·4	0·6 ± 0·1	15·2 ± 0·9	71·4 ± 1·1
FBM	2·0 ± 0·3	0·9 ± 0·2	1·8 ± 0·2	2·1 ± 0·3	0·2 ± 0·1	93·1 ± 0·9
Sheep						
RBT	1·6 ± 0·3	1·1 ± 0·2	4·0 ± 0·3	0·3 ± 0·1	3·0 ± 0·1	90·0 ± 0·9
FBM	0·6 ± 0·2	0·6 ± 0·2	0·4 ± 0·1	0·2 ± 0·1	1·6 ± 0·3	96·6 ± 0·5

[a] Means of three determinations ±SE.
[b] All fats contained cholesterolesters in trace amounts.
[c] BRT, Rib bone tissue.
[d] FBM, Femur bone marrow.

TABLE 3
Fatty Acid Composition of Bone Tissue and Marrow Fats from Different Animal Species

Species	*% Fatty acid Chain length: Number of double bonds*							*Total saturated*	*Total unsaturated*
	14:0	*14:1*	*16:0*	*16:1*	*18:0*	*18:1*	*18:2*		
Young buffalo									
RBT[a]	0·8	0·2	21·1	0·5	26·5	48·2	2·7	48·4	51·6
FBM[b]	7·9	0·3	34·5	0·1	12·2	44·3	0·7	54·6	45·4
Old buffalo									
RBT	3·8	0·5	33·3	0·5	19·9	41·4	0·6	57·0	43·0
FBM	1·9	0·2	30·4	0·1	26·3	40·1	1·0	58·6	41·4
Camel									
RBT	6·8	0·3	26·7	0·7	20·8	44·3	0·4	54·3	45·7
FBM	5·2	0·2	26·3	Trace[c]	18·2	50·0	0·1	49·7	50·3

Cow									
RBT	0·8	Trace	25·5	0·4	22·1	50·8	0·4	48·4	51·6
FBM	4·5	0·2	28·6	Trace	15·7	50·8	0·2	48·8	51·2
Goat									
RBT	1·8	0·2	26·2	0·2	29·4	40·9	1·3	57·4	42·6
FBM	1·4	0·2	20·6	0·9	9·0	67·1	0·8	31·0	69·0
Pig									
RBT	0·9	Trace	26·7	0·1	21·2	44·4	6·7	48·8	51·2
FBM	1·4	0·1	30·1	Trace	3·2	60·3	4·9	34·7	65·3
Sheep									
RBT	1·1	Trace	27·9	0·3	11·1	58·9	0·7	40·1	59·9
FBM	1·7	Trace	22·3	0·2	12·9	61·8	1·1	36·9	63·1

[a] RBT, Rib bone tissue.
[b] FBM, Femur bone marrow.
[c] Trace, Less than 0·05%.

saturated component (20·6–34·5%) followed by stearic acid (9·0–26·5%). Of the total unsaturated fatty acids present in bone fats, oleic acid was the predominant constituent (40·1–67·1%), followed by linoleic acid (0·2–4·9%). The fatty acids of bone fats in this study were more unsaturated than those reported by Imamura *et al.* (1969) for beef and pork adipose tissues. Siegel & Latimer (1971) stated that chicken bone fat contained high levels of unsaturated fatty acids. Variations regarding those acids were noticed between the red and white marrow fats and also within animal species. Both the red and white marrow fats of sheep and pigs as well as the white marrow fat of goat, had higher percentages of total unsaturated fatty acids.

From the standpoint of utilization, the fats of the red and white marrows are rich in palmitic, stearic and oleic acids, which could be characterized as nondrying fat. Such fats could be used for stearin manufacture or in the soap industry. Shmidt & Yusupova (1968) recorded that fresh bone fats are stable during storage and can be recommended for the production of combined fats. Recently, Belyaev *et al.* (1984) concluded that bone marrow is of high nutritional and biological value.

REFERENCES

Abd-El-Aal, M. H. (1981). Changes in lipids and protein composition in developing cottonseeds, PhD Thesis, Faculty of Agriculture, Alexandria University, Alexandria, Egypt.

Abd-El-Aal, M. H., Khalil, M. K. & Rahma, E. H. (1986). Apricot kernel oil: Characterization, Chemical composition and utilization in some baked products. *Food Chem.*, **19**, 287.

AOCS (1973). *Official and Tentative Methods of the American Oil Chemists Society*, Vol. 1 (3rd edn), AOCS, Champaign, IL.

Belyaev, M. I., Cherevko, A. I., Korosteleva, T. P. & Vinokurov, G. A. (1984). Chemical composition of raw bone marrow from beef hollow bones. *Izvestiya Vyschikn Uehebnykh Zavedenii Phishehevaya Tekhnologiya No. 2*, 17–18 (cf. *FSTA* **17**, 4551).

Blank, M. L., Schmidt, J. A. & Privett, O. S. (1964). Quantitative analysis of lipid by thin-layer chromatography. *J. Am. Oil Chem. Soc.*, **41**, 371.

Chalvardjian, A. M. (1964). Fatty acids of brown and yellow fat in rats. *Biochem. J.*, **47**, 1106.

Dietz, A. A. (1949). Chemical composition of normal bone marrow. *Arch. Biochem. Biophys.*, **23**, 211.

Elko, E. E. and Diluzio, N. R. (1959). Effect of x-irradiation on plasma, liver, and bone marrow lipids of the rabbit. *Radiation Res.*, **11**, 1.

Evans, J. D. & Oppenheimer, M. J. (1955). Effect of bleeding on rabbit marrow polyunsaturated fatty acids. *Am. J. Physiol.*, **181**, 509.

Field, R. A., Riley, M. L., Mello, F. C., Corbridge, M. H. & Kotula, A. W. (1974). Bone composition in cattle, pigs, sheep and poultry. *J. Anim. Sci.*, **39**, 493.

Field, R. A., Sanchez, L. R., Kunsman, J. E. & Kruggel, W. C. (1980). Heme pigment content of bovine hemopoietic marrow and muscle. *J. Food Sci.*, **45**, 1109.

Food and Nutrition Board (1980). *Toward Healthful Diets*, Natl. Acad. Sci., Washington, DC.

Goh, E. M. & Timms, R. E. (1985). Determination of mono- and diglycerides in palm oil, olein and stearin. *JAOCS*, **62**, 730.

Imamura, M., Niiya, I., Takagi, K. & Matsumoto, T. (1969). The Bomer Number, VIII. Discrimination of foreign fats in lard by *trans*-acids. *J. of the Japanese Oil Chem. Soc.*, **18**, 72.

Katz, M. & Ackroyd, H. (1976). Separating meat from bone. *Meat Magazine*, April, 1976.

Link, B. A., Brey, R. W., Cassens, R. G. & Kauffman, R. G. (1970). Fatty acid composition of bovine subcutaneous adipose tissue lipids during growth. *J. Anim. Sci.*, **30**, 722.

Liberman, S. G., Faivishevskii, M. L. & Jusunova, I. (1968). Research on the content of fatty acids in fat obtained from different kinds of bone. *Trydyvsesayuznyi Nauchno—Issledovatel'skii Institut My a snoi promyshlennosti*, **21**, 48 (cf. *FSTA* **2**, 65433).

Lund, P. K., Abadi, D. M. & Mathies, J. C. (1962). Lipid composition of normal human bone marrow as determined by column chromatography. *J. Lipid Res.*, **3**, 95.

Mangold, H. K. & Malins, D. C. (1960). Fractionation of fats, oils and waxes on thin-layer of silicic acid. *J. Amer. Oil Chem. Soc.*, **37**, 383.

Mello, F. C. Jr, Field, R. A., Forenza, S. & Kunsman, J. E. (1976). Lipid characterization of bovine bone marrow. *J. Food Sci.*, **41**, 226.

Meng, M. S., West, G. C. & Irving, L. (1969). Fatty acid composition of caribou bone marrow. *Comp. Biochem. Physiol.*, **30**, 187.

Miller, G. J., Frey, M. R., Kunsman, J. E. & Field, R. A. (1982). Bovine bone marrow lipids, *J. Food Sci.*, **47**, 657.

Moerck, K. E. & Ball, H. R. (1973). The lipid autoxidation in mechanically deboned chickenmeat. *J. Food Sci.*, **39**, 876.

Privett, O. S., Dougherty, K. A., Erdahl, W. L. & Stolyhwo, A. (1973). Studies on the lipid composition of developing soybeans. *J. Amer. Oil. Chem. Soc.*, **50**, 516.

Seitz, J. F. (1969). *The Biochemistry of the cells of Blood and Bone Marrow*. Charles C. Thomas Publisher. Springfield, IL.

Shmidt, A. A. & Yusupova, I. U. (1986). Composition of aliphatic acids of fats obtained from various kinds of bones. *Maslozhirovaya Promyshlennost*, **34**, 12. (cf. *FSTA*, **13** (92)).

Siegel, H. S. & Latimer, J. W. (1971). Effect of ACTH, Cortisol and low environmental temperatures on the tibia lipids of growing chickens. *Poultry Sci.*, **50**, 1631.

Wilson, R. F. & Rinne, R. W. (1974). Phospholipids in the developing soybean seed. *Plant Physiol.*, **54**, 744.