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Pattern Recognition Analysis of Fatty Acids. Application to Beef Fat Tissue Classification

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Thirty-six fat samples of hump, kidney, and depot fat of Malagasy zebu (*Bos indicus*), eight samples of kidney and tallow of *Bos taurus*, and two butter samples of *Bos taurus* were analyzed for 36 fatty acids by gas–liquid chromatography (GLC). Repeatability and GLC reproducibility analyses of the main fatty acids were checked. Intercorrelations among the fatty acids and their relations to fat tissue origins were investigated by analyzing the data with pattern recognition techniques. Nineteen fatty acids and four combinations of measurements were used for principal component analysis (PCA) and discriminant analysis (DA). By DA, 36 fat tissue samples of hump (15) and kidney (15) of *B. indicus* and tallow (6) of *B. taurus* were classed in three categories. Supplementary fat tissues were also successfully checked. Misclassifications were observed by DA, when only the main fatty acids were used.

Nutritionists need detailed data on the amounts of fatty acids in foods, in order to evaluate current dietary habits and to execute nutritional research. Such data would require quantitative analysis of a vast number of foods. The use of conventional gas chromatography has allowed the identification of many fatty acids in beef tallows. The latest advances in glass capillary gas chromatography enable even finer separation of fatty acids in complex mixtures such as depot fats and fats from organs of monogastric species, polygastric species, and fishes (Flanzy et al., 1976; Ramananarivo et al., 1981). The use of long (60 and 100 m) and highly efficient glass capillary columns can solve the problems of the separation between peaks, the positional isomers, and the separation of the geometric isomers (cis and trans) for the determination of the amount of trans fatty acids (Slover and Lanza, 1979). However, the analysis is relatively long (1–3 h) with animal fats. The use of short glass capillary columns reduces considerably analysis time, and a comparative study on 100-, 10-, and 2-m glass capillary columns coated with SP 2340 was made by Lanza et al. (1980). The identification of every fatty acid can be time-consuming, and generally the workers limit their studies to fatty acids having concentrations higher than 0.1%.

In this study, the fatty acid composition of various depot fats of French beef lipids (*Bos taurus*) and Malagasy zebu lipids (*Bos indicus*) was investigated. The repeatability and GLC reproducibility will be discussed. Multivariate statistical techniques, including discriminant and cluster analyses, which have been successfully applied in enological research (Kwan and Kowalski, 1980; Noble et al., 1980), were used to distinguish among various animal depot fats. Pattern recognition techniques were applied to 46 samples and proved successful in the distinction of various origin depot fats. The data presented in this investigation show the importance of minor fatty acids for the characterization of beef fat tissues.

EXPERIMENTAL SECTION

Fat Samples. Fifteen samples of hump tissue and fifteen samples of kidney fat, extracted from fifteen male zebu animals (*B. indicus*) were given by Sevima Co. (Antananarivo, Madagascar). Three kidney tissue samples and three external depot fat samples of zebu were collected from a local market in Antananarivo. Six beef tallow samples, two kidney fat samples, and two samples of butter (*B. taurus*) were collected from a local market in Marseilles.

Physicochemical Determinations. Determination of the iodine value (Wijs) and the saponification value were

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carried out according to NFT 60-203 and NFT 60-206 norms, respectively (Afnor, 1981). Refractive indexes were determined at 40 °C. The trans unsaturated fatty acids were determined by using the infrared spectrophotometry method (U.I.C.P.A., 1979) upon three samples of *B. indicus* (hump, kidney, tallow) and two samples of *B. taurus* (kidney, tallow).

Sample Preparation. All fat tissues were extracted with hexane in a Soxhlet apparatus. Fatty acids methyl esters were prepared by saponification of triglycerides (1 g) with KOH–C_2H_5OH, 2 M (25 mL), and acid-catalyzed methylation using BF_3–CH_3OH according to Metcalfe and Schmitz (1961). Purification of the methyl esters was done as described previously (Ramananarivo et al., 1981). For the tentative identification of fatty acid methyl esters, cod liver oil (Ackman et al., 1967) and commercial saturated even-numbered methyl esters (Fluka, Buchs, Switzerland) and unsaturated and polyunsaturated methyl esters (Sigma, St. Louis, MO) were used as standards.

Hydrogenation. Platinum oxide (10% Pt) deposited on charcoal (25 mg) was added to the mixture of fatty acid methyl esters (500 mg) in hexane (6 mL). Hydrogenation was achieved with stirring the mixture for 16 h at ambient temperature under a slight positive pressure of hydrogen.

Nomenclature. The designation used for fatty acid identification was as follows: the number before the colon gives the number of carbon atoms in the fatty acid chain; the number immediately following the colon gives the number of double bonds; the number following the ω is the number of carbon atoms after the double bond farthest from the carboxyl. Iso and anteiso fatty acids are the branched fatty acids having a branched methyl group at the $\omega 2$ and $\omega 3$ carbon atom of the fatty acid.

In cases where some doubt remained about the identification of a fatty acid, the equivalent chain length (ECL) introduced by Miwa et al. (1960) corresponding to this compound was given with the presumed identification followed with a question mark. When no presumption was available, we indicated the ECL value.

Gas–Liquid Chromatography (GLC). A Girdel Model 30 gas chromatograph (Girdel, France), equipped with a flame ionization detector and a glass injector, was used for the analysis. The column employed was a 40 m long (0.30 mm i.d. glass capillary column coated with Carbowax 20M (phase thickness: 0.15 μm). Temperatures used were 190 °C for column and 270 °C for inlet and detector ovens. The inlet pressure of hydrogen used as the carrier gas was 0.8 bar (split: 40 mL·min^{-1}). Peak areas were integrated by an LTT ICAP 5 electronic integrator. All of our results are expressed as uncorrected peak area values. For the expression of the results, we fixed the lower calculated limit of the concentrations at 0.1%. The amounts of fatty acids where the concentration was lower than 0.1% were called traces.

Statistical Analyses. To evaluate the repeatability (difference between data obtained by using the same adipose tissue as the starting material) and GLC reproducibility (difference between results obtained by GLC with the same fatty acid methyl ester mixture sample), coefficients of variation were calculated across 11–13 experiments. Terminologies in pattern recognition used throughout this study were defined as follows. Each individual adipose tissue sample analyzed was an "object" and each fatty acid composition was a "measurement". The measurements were used to generate "features", which might be the simple measurements or some combinations of measurements. Twenty-three features were used in the data set I: 19 fatty acids; the sum of fatty acids < iso-14:0; the sums of saturated and unsaturated fatty acids; the sum of all other fatty acids. Principal component analysis (PCA) was performed using the correlation matrix of the 23 features for 36 objects (15 adipose tissues of hump and 15 adipose tissues of kidney fat of *B. indicus* and 6 tallows of *B. taurus*). Discriminant analysis (DA) was performed to classify the adipose tissues into three adipose tissue categories (hump and kindey fats of *B. indicus* and tallow of *B. taurus*). From these 23 features, some were removed (data Sets II and III) by using stepwise discriminant analysis (SDA) for the determination of the discriminant features of the three adipose tissue categories. Supplementary data (three objects of kidney fat and three objects of external depot fat of *B. indicus*, two objects of kidney fat, and two butter objects of *B. taurus*) were checked for classification. Further descriptions of PCA and DA are provided by Broschat (1979), Lebart et al. (1980), and Romeder (1973). All processing was done on the computer of the Ecole Supérieure de Chimie of Marseilles (France).

Table I. Repeatability and GLC Reproducibility of Analyses for the Main Fatty Acid Methyl Esters in Zebu Lipids

fatty acid	repeatability[a]			GLC reproducibility[b]		
	range	mean	CV	range	mean	CV
14:0	3.2-4.9	4.04	0.34	2.9-3.5	3.21	0.16
iso-16	0.5-2.9	1.36	0.59	2.0-2.8	2.45	0.35
16:0	21.4-24.3	22.3	0.65	25.4-26.1	25.7	0.21
17:0	1.6-2.0	1.82	0.06	0.8-0.9	0.88	0.04
18:0	33.9-37.1	35.6	0.91	9.8-10.8	10.1	0.48
18:1ω9	20.3-21.9	20.7	0.31	32.4-35.9	34.9	1.0
18:1ω7	3.8-5.0	4.1	0.21	3.7-4.9	4.08	0.34

[a] Kidney fat sample (11 replicates). [b] Hump sample (13 replicates).

RESULTS AND DISCUSSION

The lipids investigated were obtained by hexane extraction. The results for iodine values (31–46), saponification values (176–198), and refractive indexes (1.4580–1.4628) were in agreement with those previously published (Wolff, 1968). No simple procedure exists for the accurate determination of trans fatty acid levels in fats and oils (Madison et al., 1982). The trans contents of *B. indicus* samples were in the same order of range (3–5%) as those found in *B. taurus* samples (3–4%).

Fatty acid analyses were performed using a glass capillary column coated with Carbowax 20M. Repeatability and GLC reproducibility of experiments were checked for the most important fatty acids as indicated in Table I. Small coefficients of variation (CV) were obtained for stearic acid in kidney fat and for oleic acid in hump tissues and were less than 1.0, which is comparable to the level of repeatability recommended (Afnor, 1981). The range of the GLC reproducibility was about the same order of the repeatability range, showing therefore that the variation came essentially from GLC analyses.

The fatty acid composition of *Bos* species fats exhibits a greater degree of complexity than do vegetable oils. During the course of this study, we did not mention fatty acids recovered in minute amounts. Furthermore, on the Carbowax 20M column, the separation of cis and trans isomers is generally poor (Flanzy et al., 1976). Table II reports the fatty acid composition of a hump zebu fat before and after hydrogenation. Tentative identification was made by comparison with chromatograms obtained by using cod liver oil (Ackman et al., 1967), standards, and results after hydrogenation and by intrapolation and extrapolation on the lines characteristic of each homologous series of fatty acids. We state that four equivalent chain

Table II. Equivalent Chain Lengths and Fatty Acid Composition[a] of a Hump Zebu Fat Sample before and after Hydrogenation

fatty acid[b]	ECL[c]	before hydrogenation: composition	before hydrogenation: Σ[d]	after hydrogenation, composition
10:0		tr[e]	tr	tr
12:0		0.1	0.1	0.1
iso-14:0	13.50	0.2	0.2	0.2
14:0		3.4	3.8	3.4
14:1ω5?	14.38	0.4		
iso-15:0	14.45	0.8	0.8	0.7
anteiso-15:0	14.65	0.7	0.7	0.6
15:0		0.7	0.7	0.7
iso-16:0	15.50	0.6	0.6	0.5
16:0		25.4	27.0	25.6
16:1ω9	16.22	0.2		
16:1ω7	16.28	1.4		
iso-17:0	16.50	0.9	0.9	0.8
anteiso-17:0	16.65	1.2	1.2	1.2
phytanic[f]	16.92	0.3	0.3	0.3
17:0		1.6	2.1	2.1
17:1ω8?	17.25	0.5		
iso-18:0	17.55	0.3	0.3	0.3
18:0		25.6	58.9	59.9
18:1ω9	18.20	27.0		
18:1ω7	18.28	4.1		
unknown[g]	18.35	0.3		0.1
iso-19:0	18.55	0.3	0.3	0.2
18:2ω6	18.65	0.9		
unknown[h]	18.85	0.4		
19:0		0.5	0.8	0.9
unknown[i]	19.15	0.3		
18:3ω3	19.25	0.3		
unknown[j]	19.50	0.6		
20:0		0.6	0.8	1.5
20:1ω11	20.10	0.2		
20:1ω9	20.20	tr		
21:0		tr	tr	0.1
22:0		0.1	0.1	0.5
23:0		tr	tr	0.1
24:0		tr	tr	0.2

[a] Percent by weight. [b] For the nomenclature, see Experimental Section. [c] Equivalent chain length of fatty acid methyl esters determined on a glass capillary column coated with Carbowax 20M at 190 °C. [d] Sum of amounts of linear or branched (iso and anteiso) fatty acids having a same carbon number. [e] Less than 0.1% in this sample. [f] 3,7,11,15-Tetramethylhexadecanoic acid. [g] Methyloctadecanoic acid (methyl position not determined). [h] Unsaturated fatty acid that was not 18:3ω6. [i] Unsaturated fatty acid. [j] Unsaturated fatty acid that was not 18:4ω3.

lengths (ECL) cannot be imputed to any fatty acid, whereas two ECL give rise to an important presumption of identification, among a total of 36 chromatographical peaks reported in Table II. It can be noticed that we find various positional isomers of even-numbered unsaturated fatty acids. Even- and odd-numbered, iso and anteiso saturated acids are also found. These acids are synthesized by microorganisms from some products of the intermediate metabolism (Horning et al., 1960). Such peculiar fatty acids have been studied by Duncan et al. (1974) in lamb and by Flanzy et al. (1976) in pig and beef depot fats. The occurrence of phytanic acid (3,7,11,15-tetramethylhexadecanoic) is also detected. The peak with ECL = 18.35 corresponds to a methyl-branched saturated fatty acid, and the three other peaks not identified (ECL = 18.85, 19.15, and 19.50) are unsaturated fatty acids that disappear upon hydrogenation. The sum of amounts of linear fatty acids having a same carbon atom number is in agreement with the amount of the corresponding saturated fatty acids after hydrogenation (Table II).

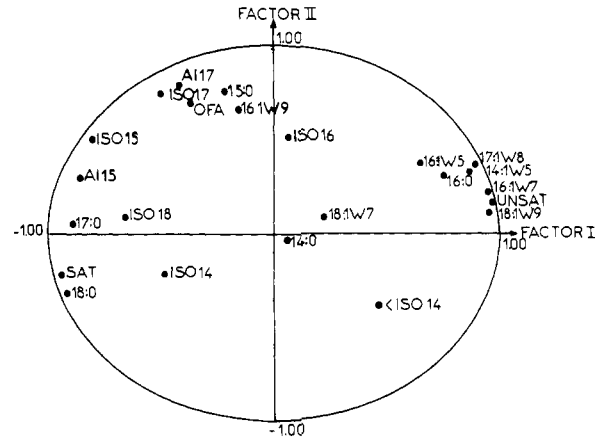

Figure 1. Principal component analysis of 19 fatty acids and 4 other features [fatty acids <iso-14, sum of amounts of other fatty acids (OFA) given in Table II, sum of amounts of saturated fatty acid (SAT), and sum of amounts of unsaturated fatty acids (UNSAT)]. Factor loadings for GLC peaks for principal components I and II.

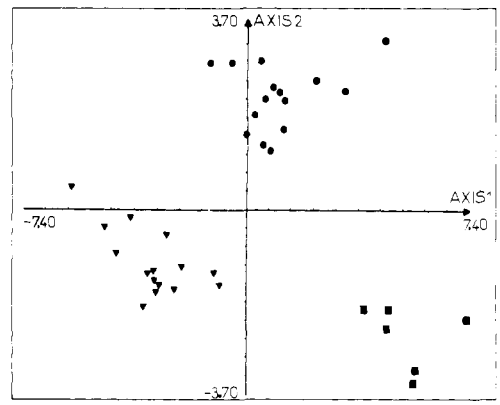

Figure 2. Principal component analysis of 23 features of fat tissue fatty acids (see Figure 1). Fat tissue factor scores for principal components I and II. (●) Hump and (▼) kidney of *B. indicus* and (■) tallow of *B. taurus*.

The mean and range in concentration (percent in weight) for 19 fatty acids within fat categories of *B. indicus* and *B. taurus* are shown in Tables III and IV, respectively. Odd-numbered fatty acids represent 2.2–3.0% in *B. indicus* fat tissues and 1.6–2.5% in *B. taurus*. Iso and anteiso fatty acids are higher in *B. indicus* (2.4–3.0%; 1.5–1.7%) than in *B. taurus* (1.4–2.5%; 0.9–1.3%) (Tables III and IV). Among the total fatty acids quantified, over 90% are produced by six components: myristic (2–4%), palmitic (21–29%), palmitoleic (1–4%), stearic (14–37%), oleic (21–38%), and vaccenic (3–5%) acids for the adipose tissues of the two *Bos* species. The large range of variation in the main fatty acids shows that it is difficult to perform some classifications among the adipose tissue of *B. indicus* and *B. taurus*. The use of statistical analyses is needed to try some differentiation of fat tissues.

In principal component analysis (PCA) the 23 features (data set I) indicated in Table III and IV were used for the classification of hump and kidney fat tissues of *B. indicus* and tallow of *B. taurus* (36 objects). The first principal component (axis 1, 47.02% of the variance) separates the three categories of fat tissues with a slight overlapping between tallow of *B. taurus* and hump of *B. indicus* and between kidney and hump of *B. indicus*. The second principal component (axis 2, 17.83% of the variance) permits the separation of hump tissues from the two other categories. In Figure 1, the factor loadings are

Table III. Fatty Acid Composition (Percent by Weight) of Hump, Kidney, and External Depot Fat of *B. indicus*

	hump[a]				kidney[a]				external depot fat[b]			
fatty acid	min	max	mean	CV	min	max	mean	CV	min	max	mean	CV
∠iso-14[c]	tr	0.4	0.18	0.13	tr	0.3	0.16	0.09	0.1	0.2	0.17	0.05
iso-14:0	tr	0.3	0.22	0.07	0.2	0.4	0.29	0.06	0.2	0.3	0.27	0.05
14:0	2.9	4.7	3.40	0.52	2.7	4.4	3.43	0.47	2.3	2.3	2.30	0.00
14:1ω5?	0.4	1.4	0.70	0.29	tr	0.2	0.13	0.07	0.2	0.3	0.23	0.05
iso-15:0	0.5	0.7	0.65	0.07	0.5	0.9	0.68	0.10	0.5	0.5	0.50	0.00
anteiso-15:0	0.4	0.7	0.56	0.09	0.4	1.0	0.68	0.14	0.5	0.6	0.57	0.05
15:0	0.6	0.9	0.75	0.08	0.4	0.9	0.59	0.14	1.1	1.1	1.07	0.05
iso-16:0	0.5	2.8	0.77	0.62	0.3	0.7	0.48	0.09	0.5	1.8	1.27	0.56
16:0	23.1	28.9	26.06	1.43	18.5	23.8	21.46	1.66	24.1	25.8	24.87	0.70
16:1ω9	tr	0.5	0.32	0.10	0.2	0.3	0.21	0.02	0.3	0.5	0.40	0.08
16:1ω7	1.9	5.6	2.84	0.93	0.4	1.0	0.69	0.18	1.6	1.9	1.77	0.12
16:1ω5	tr	0.4	0.16	0.12	tr	0.1	0.01	0.03	tr	0.3	0.14	0.12
iso-17:0	0.6	0.9	0.77	0.09	0.6	0.8	0.69	0.05	0.7	0.8	0.77	0.05
anteiso-17:0	0.9	1.3	1.12	0.10	0.9	1.1	0.98	0.09	0.9	1.0	0.97	0.05
17:0	0.9	1.7	1.41	0.22	1.3	2.1	1.7	0.21	1.9	2.1	1.97	0.09
17:1ω8?	0.4	0.9	0.69	0.13	0.2	0.3	0.25	0.05	0.6	0.7	0.63	0.05
iso-18:0	0.2	0.3	0.26	0.05	0.2	0.4	0.30	0.04	0.2	0.3	0.23	0.05
18:0	10.4	22.8	17.97	2.91	31.6	43.4	37.35	3.37	21.8	27.2	23.87	2.38
18:1ω9	26.0	35.0	31.60	2.05	13.3	29.0	21.32	3.80	25.7	30.2	28.53	2.01
18:1ω7	3.1	4.6	4.17	0.41	3.0	4.9	3.90	0.47	4.5	4.9	4.77	0.19
others[d]	4.0	6.6	5.37	0.66	3.7	5.9	4.69	0.53	3.4	6.0	4.73	1.06
saturated[e]	47.0	59.4	54.15	2.74	60.7	76.8	68.80	3.84	55.9	63.3	58.80	3.23
unsaturated[f]	34.0	47.2	40.49	2.80	18.1	34.5	26.51	3.94	33.3	38.1	36.47	2.24

[a] Determined from 15 samples. [b] Determined from three samples. [c] Summation of amounts of fatty acids having less than 14 carbon atoms in the chain. [d] Summation of amounts of all other fatty acids given in Table II. [e] Summation of all saturated fatty acids. [f] Summation of all mono- and polyunsaturated fatty acids.

Table IV. Fatty Acid Composition (Percent by Weight) of Tallow, Kidney, and Butter of *B. taurus*.

	tallow[a]				kidney[b]				butter[b]			
fatty acid	min	max	mean	CV	min	max	mean	CV	min	max	mean	CV
∠iso-14[c]	0.3	0.7	0.45	0.13	0.3	0.4	0.35	0.05	6.9	8.7	7.80	0.90
iso-14:0	0.2	0.3	0.23	0.05	0.2	0.3	0.25	0.05	0.1	0.2	0.15	0.05
14:0**[g]	3.0	4.4	3.62	0.42	3.2	3.4	3.30	0.10	14.0	14.0	14.0	0.00
14:1ω5*?	0.5	1.1	0.80	0.19	0.5	0.7	0.60	0.10	1.1	1.1	1.10	0.00
iso-15:0	0.2	0.3	0.23	0.05	0.3	0.3	0.30	0.00	0.4	0.4	0.40	0.00
anteiso-15:0	0.2	0.3	0.23	0.05	0.3	0.3	0.30	0.00	0.6	0.7	0.65	0.05
15:0	0.4	0.6	0.47	0.07	0.4	0.5	0.45	0.05	1.6	1.6	1.60	0.00
iso-16:0	0.2	0.3	0.28	0.04	0.2	0.3	0.25	0.05	1.0	1.5	1.25	0.25
16:0**	24.3	30.8	26.92	2.20	28.5	28.9	28.70	0.20	33.3	33.4	33.35	0.05
16:1ω9*	tr	0.2	0.13	0.09	0.2	0.2	0.20	0.00	0.3	0.3	0.30	0.00
16:1ω7**	3.0	5.5	3.93	0.85	2.3	2.3	2.30	0.00	1.6	1.7	1.65	0.05
16:1ω5	tr	0.3	0.15	0.11	0.4	0.5	0.45	0.05	0.2	0.4	0.30	0.10
iso-17:0	0.3	0.5	0.43	0.07	0.4	0.6	0.50	0.10	0.6	0.7	0.65	0.05
anteiso-17:0	0.6	0.8	0.68	0.07	0.7	0.8	0.75	0.05	0.6	0.7	0.65	0.05
17:0*	0.8	1.2	1.08	0.15	1.1	1.2	1.15	0.05	0.9	0.9	0.90	0.00
17:1ω8*?	0.6	0.9	0.77	0.11	0.5	0.6	0.55	0.05	0.5	0.5	0.50	0.00
iso-18:0	0.1	0.3	0.18	0.07	0.1	0.2	0.15	0.05	tr	0.1	0.05	0.05
18:0**	11.0	16.5	13.60	1.81	21.6	21.7	21.65	0.05	9.8	10.3	10.05	0.25
18:1ω9**	36.0	41.4	38.47	1.60	27.8	30.8	29.30	1.50	16.6	17.9	17.25	0.65
18:1ω7	3.0	5.1	4.43	0.73	3.3	3.3	3.30	0.00	2.4	2.5	2.45	0.05
others[d]	1.2	6.2	2.90	1.59	4.0	6.4	5.20	1.20	4.8	5.1	4.95	0.15
saturated**[e]	45.7	51.7	48.42	2.09	58.0	58.2	58.10	0.10	71.0	72.0	71.50	0.50
unsaturated**[f]	44.7	51.9	48.68	2.59	35.4	38.0	36.70	1.30	22.9	24.2	23.55	0.65

[a] Determined from six samples. [b] Determined from two samples. [c] Summation of amounts of fatty acids having less than 14 carbon atoms in the chain. [d] Summation of amounts of all other fatty acids given in Table II. [e] Summation of all saturated fatty acids. [f] Summation of all mono- and polyunsaturated fatty acids. [g] All the fatty acids were used in data set I, fatty acids labeled with an asterisk (*) were used in data set II, and fatty acids labeled with two asterisks (**) were used in both data sets II and III.

plotted for data set I; in Figure 2, the factor scores are shown for each object for principal components 1 and 2, which together account for 64.85% variation. According to Figure 1, one can notice that fatty acids <iso-14, 14:0, iso-14, iso-16, iso-18, and 18:1ω7 have low factor loadings. For iso- and anteiso-15 and iso- and anteiso-17, higher factor loadings are observed. Strongly negatively loaded (<−0.75) on the first component are the sum of saturated fatty acids, 17:0 and 18:0. Strongly positively loaded (>0.75) on the first component are the sum of the unsaturated fatty acids 14:1ω5, 16:1ω5, 16:1ω7, 17:1ω8, and 18:1ω9. Surprisingly 16:0 is correlated with the unsaturated fatty acids.

A classification in three categories was obtained by using discriminant analysis (DA) for the 36 objects and gives a 100% correct attribution. A plot of the objects is given in Figure 3. Supplementary tissues were used to check this classification. Three samples of external depot fat tissue of *B. indicus* are classed within the hump category; three samples of kidney of *B. indicus* are classed within the kidney category; two kidney samples of *B. taurus* are classed between the hump and kidney of *B. indicus* cate-

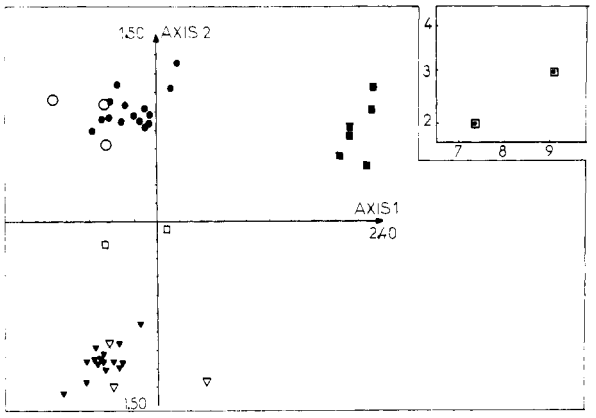

Figure 3. Discriminant analysis of 23 features of fat tissue fatty acids (see Figure 1). Fat tissue factor scores for axes 1 and 2. (●) Hump and (▼) kidney of *B. indicus* and (■) tallow of *B. taurus*. Supplementary objects: (○) external depot fat of *B. indicus*, (▽) kidney of *B. indicus*, and (□) kidney and (▣) butter of *B. taurus*.

gories. These results show the difference between the fat tissues of *B. indicus* and *B. taurus*. The fat of *B. indicus* always contains more saturated fatty acids than *B. taurus* fat tissues. Such result was previously observed by Ramananarivo et al. (1981). Two butter samples of *B. taurus* were also checked for pattern recognition and are classed very far from the barycentre of tallow of the *B. taurus* category as shown in Figure 3.

Stepwise discriminant analysis (SDA) was used for the determination of features giving the best pattern recognition. The use of 11 features (data set II, Table IV) also gives 100% correct classification for the 36 objects used for the three categories of fat classification, but some misclassifications are observed for the supplementary tissues checked: one sample of kidney fat of *B. indicus* is within the tallow category of *B. taurus* and one sample of kidney fat of *B. taurus* is within the hump category of *B. indicus*. When seven features (data set III, Table IV) are used, the separation in three categories using DA is not achieved and the results give 97.2% correct classification, because one tallow sample of *B. taurus* is within the hump category of *B. indicus*.

CONCLUSION

This study demonstrates that pattern recognition techniques enable useful information to be extracted from a massive amount of data. These techniques have been highly successful for the classification of some fat tissues coming from two close animal species such as *B. indicus* and *B. taurus*. The use of the main fatty acids (myristic, palmitic, palmitoleic, stearic, and oleic acids) is not sufficient to obtain a correct classification of the fat tissues. The importance of the minor fatty acids (having a percentage in weight of >0.1%) is demonstrated, suggesting that more should be learned about the interrelationship of fatty acids in foods and their effects investigated by nutritionists.

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