Suitability of chemical and physical properties to distinguish between depot fats of cattle fed different fats

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Background and objectives: Several investigations have shown that there is an influence of dietary fats on the composition of milk fat and its physical characteristics, e.g. melting behaviour (Ashes et al., 1997). Findings of previous studies also suggest that the composition of body fat (Scheeder et al., 1997; Scollan et al., 1997) and some of its physical properties (Kreuzer et al., 1995) can be altered in growing cattle by varying the composition of dietary lipid sources. The objective of the present investigation was to evaluate how far diet-induced differences in body fat composition will affect its melting behaviour, solid fat content and textural properties. Furthermore, multivariate statistics were applied to assess the suitability and discriminant power of these variables to distinguish cattle fed different fats.

Methods: 6 x 5 Brown Swiss bulls were fed on 1 out of 6 diets containing different fat supplements. Concentrates either contained no additional fat (control) or quantities equivalent to 3 % fat of coconut oil, rumen-protected fat (partially hydrogenated), crushed rapeseed, sunflower seed and linseed. Experimental details of the feeding procedure were previously described (Scheeder et al., 1997). For analyses, kidney fat was comminuted and 12 g thereof were pressed into cylinders of 20 mm diameter by applying a force of approx. 250 N per cylinder. Instrumental texture characteristics were recorded with a texture analyser (TA-XT2; Stable Micro Systems, Haslemere, Surrey, U.K.). Cylinders were (i) cut with a 1 mm thick rectangular blade (cutting force) or (ii) extruded through a hole of 3 mm diameter (extrusion force). Adhesion force (iii) was measured as the resistance to withdrawal of a flat disk which had been pressed on the sample by a force of approx. 200 N. Differential scanning calorimetry (DSC 2010; TA Instruments, Alzenau, Germany) was used to obtain melting profiles of the extracted and dehydrated kidney fat. 8.5 to 14 mg of fat were heated to 80 °C for 10 min to eliminate any crystal nuclei. Kidney fat was then crystallised by cooling to -50 °C at a rate of 0.8 °C/min and held at this temperature for 10 min. The melting curves were recorded by heating from -50 °C to 80 °C at a rate of 5 °C/min and onset and offset temperatures as well as melting enthalpies were determined from the profiles. Pulsed nuclear magnetic resonance (NMR; Minispec NMS 120; Spectrospin; Bruker Analytical and Medical Instruments, Fällanden, Switzerland) was used for evaluating the solid fat content of the fat at 20 °C. Statistical analyses of data were performed using ANOVA with Scheffé test and correlation procedures of Systat Program (Version 7.01, 1997). The most suitable chemical and physical variables for distinguishing between experimental groups of animals were determined by stepwise discriminant analyses.

Results and Discussion:
Differences between groups: The different dietary lipid sources significantly altered the composition of the depot fat (Table 1, details in Scheeder et al., 1997). NMR and DSC analyses also showed significant differences between experimental groups (Table 1). All DSC thermograms provided two distinct endothermic peaks representing two main melting fractions. The melting profiles differed to the greatest extent between kidney fat from cattle fed with coconut oil (low proportion of unsaturated C18 fatty acids, high proportion of fatty acids ≤ C16 and of total saturated fatty acids) and fat from cattle fed with rapeseed (elevated proportion of unsaturated C18 fatty acids and low level of fatty acids ≤ C16). In the fat of the coconut oil fed animals, melting onset and offset temperatures were lowest. Additionally, the smallest melting enthalpy for the first and the highest for the second peak was observed in the fat of animals fed with coconut oil. The fat of cattle fed with rapeseed showed highest melting enthalpy for the first peak and lowest for the second peak as compared to all other groups. Concerning solid fat content, the fat of the control group with highest proportion of unsaturated C18 and lowest of total saturated fatty acids had the lowest percentage of solid fat at 20 °C. Texture analyses responded to dietary alterations like melting behaviour and solid fat content, although the differences were not significant. Kreuzer et al. (1995) also found certain differences in penetrometer firmness comparing fat of bulls fattened with or without full-fat rapeseed. The fat of the control group in this study was the most spreadable (lowest extrusion force), the most adhesive and the softest one (lowest cutting force). The fat of the group fed with linseed was located on the other side of the scale, in spite of its small but significantly elevated proportion of C18:3. This is probably due to the low proportion of total unsaturated C18 fatty acids and an elevated level of total saturated fatty acids.

Correlations between traits: Significantly negative correlations were found between temperature data of melting profiles and content of fatty acids ≤ C16 (Table 2). Melting enthalpies as well as solid fat content closely correlated with unsaturated C18 and total saturated fatty acids. With an increasing level of unsaturated C18 fatty acids and a decreasing proportion of total saturated fatty acids, kidney fat showed an increasing melting enthalpy for the first and a decreasing one for the second peak, as well as a reduced solid fat content at 20 °C. As for results of texture analyses, the highest positive correlation was found between extrusion force and solid fat content. These two variables were negatively correlated with unsaturated C18 and positively with total saturated fatty acids. Comparable correlations were found in studies investigating the influence of fat supplements on milk fat properties (e.g. Ashes et al., 1997). Ashes et al. (1997) noted a lower solid fat content and a higher spreadability in butter samples with a higher level of unsaturated C18 fatty acids. In our experiment not only unsaturated C18 fatty acids but also fatty acids ≤ C16 and total saturated fatty acids were relevant to characterise depot fat. This is probably due to the considerable variation in all major fatty acids in feed and carcass fat. Furthermore, all texture data correlated significantly with total saturated fatty acids.

Selection of variables by discriminant procedures: Discriminant analyses selected the main variables to attribute individual animals to the respective experimental groups. Fatty acids were the best predictors for distinguishing between treatments. By stepwise discriminant analysis, five fatty acids, such as C12:0, C14:0, C16:0, C18:2 and C18:3 sufficiently specified the kidney fat samples of the six animal groups. The percentage of *a posteriori* correctly classified samples was 100 %, even applying cross-validation. This multivariate statistical analysis demonstrated again that fatty acids ≤ C16, unsaturated C18 and total saturated fatty acids together were most suitable to describe the differences between the investigated kidney fat samples. Concerning NMR and DSC variables, 97 % of the samples could be attributed correctly to the groups in discriminant analysis by combining solid fat content with onset temperatures and melting enthalpies of the two main peaks, and offset temperature. However, only 63 % of the samples could be confirmed by cross-validation. Texture variables accounted for just 43 % of correct identification.

Conclusions: In spite of microbiological biohydrogenation of unsaturated fatty acids in the rumen (Choi et al., 1997), fatty acid composition of depot fat can be altered by nutrition of ruminants. Melting variables and solid fat content differed significantly as well, but only minor differences were found concerning texture properties. Discriminant analyses revealed that fatty acids were the best predictors to classify depot fat of cattle according to the fat used in nutrition, followed by melting variables. Data obtained from texture analyser measurement showed that even in a multivariate approach together with a very wide variety of dietary fats no distinct influence on the texture properties of kidney fat seems to exist.

Pertinent literature:

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This study was supported by the Swiss Cooperative for Fatstock and Meat Supplies and the Hermann Herzer Foundation. The authors are grateful to Prof. Windhab and his group (Swiss Federal Institute of Technology Zurich) for getting access to NMR.

Table 1: Selected chemical and physical variables of kidney fat as affected by dietary fat source (mean ± standard deviation; n = 5)

Group	Control	Protected Fat	Coconut oil	Rapeseed	Sunflower seed	Linseed
Relative proportion of selected fatty acids [g/kg totally analysed fatty acids]						
C12:0 & C14:0	32.7 b ± 6.7	30.4 b ± 3.1	84.1 a ± 10.0	24.7 b ± 2.7	30.3 b ± 3.8	24.5 b ± 4.1
C16:0	263.3 a ± 18.4	261.3 a ± 7.0	277.0 a ± 3.1	199.5 b ± 12.3	212.6 b ± 14.4	203.4 b ± 14.0
Fatty acids ≤ C16	320.2 b ± 26.2	311.9 b ± 11.8	388.8 a ± 11.5	240.1 c ± 16.2	260.2 c ± 19.4	243.4 c ± 19.2
C18:0	296.6 c ± 23.3	329.8 bc ± 22.0	280.0 c ± 11.9	385.7 a ± 27.3	369.6 ba ± 15.2	394.6 a ± 26.2
Total saturated FA	595.9 b ± 14.9	631.1 ab ± 16.6	644.3 a ± 20.3	615.3 ab ± 23.0	616.2 ab ± 5.2	625.8 ab ± 13.2
C18:2	15.4 a ± 1.2	9.3 bc ± 0.8	7.6 c ± 1.0	10.7 b ± 0.8	15.3 a ± 1.2	11.5 b ± 1.8
C18:3	3.6 bc ± 0.3	3.8 b ± 0.4	2.2 c ± 0.3	3.5 bc ± 0.3	2.4 bc ± 0.3	7.8 a ± 1.3
Unsaturated C18 FA	320.8 a ± 14.2	291.9 ab ± 13.6	269.8 b ± 15.8	320.4 a ± 19.8	313.8 a ± 7.7	300.3 ab ± 13.4
Melting variables (DSC)						
Onset temperature [°C]	-25.8 bc ± 2.0	-24.4 abc ± 1.8	-27.6 c ± 1.1	-21.4 a ± 1.6	-23.4 ab ± 0.7	-22.3 a ± 1.1
Offset temperature [°C]	55.3 bc ± 0.9	57.3 ab ± 1.4	54.4 c ± 1.5	57.7 ba ± 1.5	57.4 ba ± 0.8	59.2 a ± 1.5
Enthalpy peak 1 [J/g]	45.8 a ± 2.3	42.8 ab ± 2.6	38.1 b ± 3.1	47.4 a ± 3.6	46.3 a ± 2.1	45.0 a ± 1.7
Enthalpy peak 2 [J/g]	57.9 b ± 3.9	65.5 ab ± 3.5	68.6 a ± 5.0	55.7 b ± 4.8	60.8 ab ± 2.3	64.3 ab ± 5.9
Solid fat content (NMR)						
Solid fat content at 20 °C	59.3 b ± 4.0	68.7 a ± 3.2	68.4 ab ± 4.0	63.6 ab ± 3.5	66.6 ab ± 1.4	69.8 a ± 3.3
Texture variables						
Cutting force [N]	11.4 a ± 2.3	14.5 a ± 1.2	13.1 a ± 1.9	13.9 a ± 2.8	14.0 a ± 1.9	14.2 a ± 1.6
Extrusion force [N]	624.6 a ± 126.7	843.8 a ± 144.0	760.7 a ± 86.0	818.6 a ± 222.8	807.8 a ± 85.7	867.5 a ± 141.8
Adhesion force [kN]	8.6 a ± 1.6	7.4 a ± 0.6	7.9 a ± 0.7	7.5 a ± 1.1	7.4 a ± 0.5	7.0 a ± 1.5

Means within one row lacking a common letter are significantly different (Scheffé, P ≤ 0.05)

Table 2: Correlation coefficients of selected variables measured in kidney fat from bulls fed rations differing in dietary fat source

	FA ≤ C16	Total saturated FA	Unsaturated C18	Cutting force	Extrusion force	Adhesion force
Onset temperature	-0.88 ***	0.08	0.24	0.49 **	0.60 ***	-0.52 **
Offset temperature	-0.78 ***	0.20	0.07	0.47 **	0.62 ***	-0.49 **
Enthalpy for peak 1	-0.71 ***	-0.65 ***	0.78 ***	-0.04	-0.18	-0.05
Enthalpy for peak 2	0.43 *	0.81 ***	-0.88 ***	0.37 *	0.49 **	-0.33
Solid fat content at 20 °C	-0.11	0.74 ***	-0.63 ***	0.55 **	0.76 ***	-0.54 **
Cutting force	-0.23	0.55 ***	-0.36			
Extrusion force	-0.34	0.69 ***	-0.49 **			
Adhesion force	0.35	-0.45 *	0.35			

* significant at P ≤ 0.05
** significant at P ≤ 0.01
*** significant at P ≤ 0.001