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Effect of body condition at calving on milkfat composition of Friesian heifers during the first ten weeks of lactation

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ABSTRACT

The effects of live weight and body condition score (CS) at calving on milksolids production has been well documented. The effects of CS at calving on detailed composition of milk, the physical characteristics, or, product quality are largely unknown. Milkfat yield, fatty acid profile (FAP), solid fat content (SFC) of milkfat during the first 10 weeks of lactation were monitored for Friesian heifers with a pre-calving CS of 4.1 (LCS) or 5.2 (HCS). Once calved, all heifers were grazed as one herd and offered pasture *ad libitum*. Composition and characteristics of milkfat were determined at four, six, and 10 weeks postpartum. At four weeks postpartum the HCS heifers, produced 23% more ($P<0.001$) milkfat, lost 59% more ($P<0.001$) live weight and CS declined 30% more ($P<0.05$) than did LCS heifers. Associated with these changes were compositional changes in milkfat. CS at calving had no effect on milkfat concentration. HCS heifers produced milkfat with lower concentrations ($P<0.01$) of *de novo* synthesised fatty acids (C4:0-C15:1) and higher ($p<0.01$) concentrations of preformed fatty acids. Concentration (mg/100 mg milkfat) of oleic acid ($C_{18:1}$) was higher: 27.4% c.f. 24.8%, s.e.d. 0.94 ($P<0.001$) for HCS compared with LCS heifers. Milkfat from HCS heifers was softer, SFC at 5°C (55% c.f. 59%, s.e.d. 1.2, $P<0.01$) than from LCS heifers. Six weeks postpartum, the differences in FAP persisted but changes in live weight and CS were small compared with the first four weeks of lactation. Ten weeks post calving both groups were gaining live weight, but although differences ($P<0.01$) in live weight, CS, and daily milkfat yield persisted, no differences in FAP or SFC were found. These results show that differences in pre-calving live weight and CS cause differences in the composition and characteristics of milkfat. Milkfat from HCS heifers was more desirable (softer and higher in unsaturated fatty acids) than from LCS heifers. These differences disappeared once the two heifer groups were in positive energy balance by 10 weeks postpartum.

Keywords: calving condition score; early lactation; liveweight change; characteristics of milkfat; composition of milkfat.

INTRODUCTION

Greater condition score (CS) at calving has been shown to increase milkfat production during the subsequent lactation. This increase was attributed to a greater milk yield and milkfat concentration. Grainger & McGowan (1982) reported that an increase in live weight at calving of 35 kg (i.e. 1 CS) was associated during early lactation with an increase in milkfat concentration of 0.4% units and an increase in total milkfat production of 8-10 kg/cow. The effects on milk yield and milkfat concentration occur mainly during the early stages of lactation when cows are in negative energy balance. Cows with high CS at calving obtain a high proportion of the energy required for milk production from the mobilisation of body tissue (Rogers *et al.*, 1979; Grainger & McGowan, 1982). Lower-CS cows strive to meet lactation requirements by consuming more pasture and losing less CS and live weight (Grainger & McGowan, 1982; Thomson *et al.*, 1997). When body reserves were being mobilised, Palmquist *et al.* (1993) reported that the long-chain unsaturated fatty acids in milkfat, particularly oleic acid ($C_{18:1}$), increased and *de novo* synthesis declined, resulting in fewer short- and medium-chain fatty acids. Thus, as cows with different CS at calving compensate for postpartum energy deficits in different ways, suggests that a difference in calving CS will influence milkfat composition. These changes in the fatty acid composition of milkfat may provide an additional tool for interpreting cow metabolism. To determine these effects, milk samples were collected during the first 10 weeks of lactation from heifers that had been managed prepartum to calve at low and high CS.

MATERIALS AND METHOD

Heifers used in this study were obtained from a larger trial described by Chagas *et al.* (2001). Friesian heifers (calving at two years of age) were managed during the last five months of gestation to achieve a low CS (LCS) of 4.0 (n = 15) or high CS (HCS) of 5.0 (n = 13) by six weeks prepartum. Once calved, all heifers grazed as one group and were offered pasture *ad libitum*. Composition and characteristics of milkfat were determined at four, six, and 10 weeks postpartum.

Mating of the heifers was synchronised and the heifers selected for the study all calved within 10 days commencing 18 July 2000. Live weight and CS were recorded weekly throughout the study. For this report, live weight and CS recorded on July 15 were taken as the calving live weight and CS.

At each sampling time, the total milk sample from the in-line milk meters (2.5% of total volume) was collected from each cow at four consecutive milkings. All milk collected from each cow was mixed, sub-sampled and, depending on test, either analysed immediately (fat, protein and lactose) or in the case of milkfat, the cream was extracted and frozen for later fat extraction and analyses. A 200ml aliquot of milk was centrifuged, the cream skimmed off and the fat extracted using a modification of the Rose Gottlieb method (International Dairy Federation, 1987). The fatty acid profiles were

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obtained by gas chromatography according to the method of MacGibbon (1988). Solid fat contents (SFC) of fat samples were measured by pulsed nuclear magnetic resonance as described by MacGibbon & McLennan (1987).

The data for each measurement period was analysed individually as a completely randomised design using ANOVA in GenStat (2000).

RESULTS

The LCS heifers were lighter at calving, lost 55 kg less live weight (P<0.01) during the first six weeks of lactation and gained 12 kg more (P<0.01) live weight from week six to week 10. Live weight and CS differed at calving between LCS and HCS by 100 kg and 1.1 CS units respectively (Table 1). During the first 10 weeks postpartum, all heifers lost CS but the loss was less for LCS than HCS heifers. By week 10, CS was similar for both LCS and HCS heifers. Milkfat concentration (Table 1) was unaffected by calving CS (P>0.05). In LCS compared with HCS heifers milk yield was depressed by 24.9%, 22.2%, and 14.4% respectively at four, six, and 10 weeks postpartum (P<0.001). As a consequence of the lower milk yield and similar milkfat concentration, milkfat yield for the LCS treatment was depressed in a similar manner to milk yield.

CS influenced the fatty acid profile of milkfat at weeks four and six but had little effect by week 10 postpartum (Table 2). The saturated fatty acids synthesised *de novo* (formed fatty acids) with the exception of $C_{4:0}$ decreased, and all mono-unsaturated fatty acids synthesised *de novo* were unaffected by a high condition score at calving. Palmitic acid ($C_{16:0}$) was unaffected by CS at calving and the preformed long-chain saturated fatty acids $C_{17:0}$ and $C_{18:0}$, were greater for the HCS treatment. The preformed unsaturated fatty acids, oleic ($C_{18:1}$) and linoleic acid

TABLE 1: Live weight and condition score (CS) at calving (P1) and live weight, live weight (LWT) change, CS, milk yields and milk composition at four (P2), six (P3), and 10 (P4) weeks postpartum.

	LCS	HCS	s.e.d.
At calving (P1)			
Live weight (kg/c)	356	456	12.6 ***
CS	4.1	5.2	0.1 ***
4 weeks post calving (P2)			
Live weight (kg/c)	324	376	11.5 ***
LWT change (kg/c/d) (P2-P1)	-33	-80	7.8 ***
CS	3.2	4.0	0.1 ***
Milk yield (kg/c/d)	15.1	20.1	1.2 ***
Fat %	4.19	4.29	0.16 NS
Fat yield (kg/c/d)	0.63	0.86	0.06 ***
6 weeks post calving (P3)			
Live weight (kg/c)	327	372	11.7 ***
LWT change (kg/c) (P3-P2)	3	-3	3.2 NS
CS	3.4	4.0	0.2 ***
Milk yield (kg/c/d)	15.1	19.4	1.1 ***
Fat %	4.41	4.54	0.20 NS
Fat yield (kg/c/d)	0.65	0.88	0.06 ***
10 weeks post calving (P4)			
Live weight (kg/c)	372	405	11.3 ***
LWT change (kg/c) (P4-P3)	45	33	4.0 ***
CS	3.8	4.0	0.2 NS
Milk yield (kg/c/d)	14.3	16.7	0.9 **
Fat %	4.50	4.39	0.19 NS
Fat yield (kg/c/d)	0.65	0.72	0.03 *

($C_{18:2}$), increased (P<0.01), linolenic ($C_{18:3}$) was unchanged, and conjugated linoleic acid (CLA; $C_{18:2c}$) decreased (P<0.05) in milkfat from HCS heifers. The SFC profile of milkfat at 0, 5, 10 and 20°C (Table 3), shows that at week four postpartum, a lower proportion of the milkfat from the HCS heifers was solid at 0, 5 and 10°C than from LCS heifers (P<0.05). At week six and week 10, no effect of CS at calving on SFC was apparent.

DISCUSSION

Many reports of the effects of pre-calving nutrition on milkfat production, the last live weight and CS recorded before the cow/heifer calved (live weight and CS at calving) was taken as the basis for comparison (Grainger & McGowan, 1982; Grainger *et al*., 1982; Macmillan & Bryant, 1980; Thomson *et al*., 1991). For comparative purposes the same criteria for determining calving live weight and CS was used in this study.

Penno (1997) recommended a target live weight at calving for Friesian heifers of 400-450 kg. The HCS heifers were in this range, but the LCS were well below target live weight. A difference in live weight at calving for the rising-2-year heifers of 100 kg and a difference in CS of 1.1, differs from published relationships between live weight and CS. Grainger & McGowan (1982) reported a range of 17 to 45 kg live weight/unit CS change and a milkfat response to the extra CS at calving of 10 kg/unit CS. Macmillan & Bryant (1980) and Thomson *et al*. (1991) reported that the loss of milkfat production due to a lower calving CS was greater for heifers (8-10 kg fat/unit CS) than for older cows (4-6 kg fat/unit CS). Mackle *et al*. (1996), however, reported that a 50 kg difference in calving live weight of heifers had no effect on milkfat production. In our study, total milkfat production differed between LCS and HCS by 24.4 kg/heifer suggesting that the pre-calving feeding regime adopted to achieve the difference in calving live weight was more severe than adopted in previous studies.

The effects of calving CS on live weight and CS changes postpartum are consistent with that reported by Grainger *et al.* (1982), Mackle *et al.* (1996) and Thomson *et al.* (1997). Grainger *et al.* (1982) and Thomson *et al.* (1997) reported that immediately postpartum HCS cows consumed less pasture and relied more on mobilisation of body reserves to sustain milk production than did LCS cows. This, however, was not observed in the study undertaken by Mackle *et al*. (1996) in which live weight at calving had no effect on pasture intake.

Cows are in negative energy balance during early lactation and are reliant on the mobilisation of body reserves to partly meet the extra energy demand of lactation. Higher CS at calving provides more energy reserves for mobilisation during early lactation to sustain milk production (Grainger & McGowan 1982). With the metabolism of adipose tissue, fatty acids are mobilised (mainly $C_{18:1}$) and, when incorporated into milkfat, long-chain fatty acids ($C_{18:0}$ and $C_{18:1}$) are increased and the fatty acids synthesised *de novo* ($C_{4:0}$–$C_{15:1}$) decline (Palmquist *et al.,* 1993). Thus, in early lactation when cows are in energy deficit and body tissue is being mobilised (approximately 8-10 weeks), the fatty acid

TABLE 2: The fatty acid profile (% of individual fatty acids in total fat) of milkfat from high (HCS) and low (LCS) condition score heifers at four, six, and 10 weeks postpartum.

	4 weeks			6 weeks			10 weeks		
Fatty acid	**LCS**	**HCS**	**s.e.d.**	**LCS**	**HCS**	**s.e.d.**	**LCS**	**HCS**	**s.e.d.**
Short-chain (C_4–C_8) %	9.94	9.81	0.19 ^{NS}	8.91	8.66	0.12 ^{NS}	8.24	8.11	0.12 ^{NS}
Medium-chain (C_{10}-C_{12}) %	8.09	6.80	0.49 **	7.58	6.24	0.32 ***	8.84	6.30	0.30 ^{NS}
$C_{14:0}$ %	10.73	9.42	0.35 ***	10.49	9.22	0.24 ***	10.61	10.15	0.26 ^{NS}
$C_{14:1}$ %	0.60	0.54	0.04 ^{NS}	0.95	0.82	0.06 *	1.00	1.05	0.06 ^{NS}
$C_{14:1}$: $C_{14:0}$	0.06	0.06	0.01 ^{NS}	0.09	0.09	0.01 ^{NS}	0.1	0.1	0.01 ^{NS}
$C_{15:0}$ %	1.92	1.73	0.10 ^{NS}	2.09	1.76	0.10 ***	2.12	1.96	0.10 ^{NS}
$C_{16:0}$ %	22.82	22.35	0.72 ^{NS}	22.50	22.50	0.67 ^{NS}	24.57	24.57	0.75 ^{NS}
$C_{16:1}$ %	0.86	1.02	0.05 ***	0.86	0.95	0.04 *	0.93	0.97	0.50 ^{NS}
$C_{17:0}$ %	1.35	1.39	0.04 ^{NS}	1.39	1.52	0.05 ***	1.44	1.50	0.04 ^{NS}
$C_{17:1}$ %	0.22	0.27	0.02 ***	0.22	0.28	0.01 ***	0.22	0.26	0.01 *
$C_{18:0}$ %	12.73	13.21	0.57 ^{NS}	13.05	14.03	0.44 *	12.63	12.86	0.45 ^{NS}
$C_{18:1}$ %	24.82	27.43	0.94 **	26.15	28.47	0.76 ***	25.60	26.49	0.66 ^{NS}
$C_{18:2}$ %	1.60	2.03	0.10 ***	1.51	1.62	0.09 ^{NS}	1.39	1.49	0.06 ^{NS}
$C_{18:3}$ %	0.93	0.90	0.06 ^{NS}	0.99	0.89	0.04 *	0.77	0.81	0.04 ^{NS}
$C_{18:2\,c}$ (CLA) %	1.68	1.39	0.14 *	1.89	1.45	0.17 *	1.78	1.49	0.17 ^{NS}
Total unsaturated %	30.76	33.68	1.05 **	32.90	34.83	0.85 *	32.01	32.75	0.78 ^{NS}
Formed ($C_{4:0}$ to $C_{15:1}$) %	43.21	46.56	1.28 **	45.31	48.38	0.99 ***	43.95	45.07	0.95 ^{NS}
Pre formed (>$C_{17:0}$) %	31.63	28.56	1.03 ***	30.34	27.05	0.65 ***	29.12	27.82	0.66 ^{NS}
$C_{18:1}$:$C_{14:0}$	2.36	2.94	0.18 ***	2.51	3.11	0.14 ***	2.45	2.62	0.11 ^{NS}

TABLE 3: The percentage of milkfat solid (solid fat content, % SFC) at 0, 5, 10, 15 and 20°C from high (HCS) and low (LCS) condition score (CS) heifers at four, six, and 10 weeks postpartum.

	4 weeks			6 weeks			10 weeks		
Temperature (°C)	**LCS**	**HCS**	**s.e.d.**	**LCS**	**HCS**	**s.e.d.**	**LCS**	**HCS**	**s.e.d.**
0	62.4	58.5	1.24 **	63.2	61.0	1.15 ^{NS}	65.8	63.8	1.14 ^{NS}
5	58.6	55.1	1.20 **	59.7	57.8	1.20 ^{NS}	62.4	60.5	1.19 ^{NS}
10	51.1	48.1	1.30 *	52.3	50.9	1.36 ^{NS}	55.6	53.9	1.32 ^{NS}
20	18.8	17.5	0.92 ^{NS}	19.9	20.1	1.32 ^{NS}	22.5	21.9	1.56 ^{NS}

composition of milkfat will differ from milkfat produced later in lactation. Thomson & Van der Poel (2000) reported for mature cows and heifers grazing under similar conditions, that the composition and characteristics of milkfat from heifers in early lactation differed from older cows. Spring-calved heifers during early lactation produced milkfat that contained more total unsaturated fatty acids, more $C_{18:1}$, and had a lower SFC at 10°C. The study by Thomson & Van der Poel (2000) also showed that later in lactation, age of cow had no effect on either the composition or the characteristics of milkfat. This suggests that heifers in early lactation were in greater energy deficit and mobilising more body reserves than older cows. Thus, the magnitude of the energy deficit during early lactation and the mass of adipose tissue available for mobilisation may affect the fatty acid composition of milkfat.

As the HCS heifers lost more live weight and produced more milkfat than LCS heifers, the HCS heifers sustained milk yield by mobilising body tissue. Considering the work of Palquist *et al*., (1993) this suggests that the resulting milkfat would have higher concentrations of the $C_{18:0}$ and $C_{18:1}$ fatty acids and lower concentrations of *de novo* synthesised fatty acids. The fatty acid profiles (FAP) of milkfat from heifers calving at different CS presented in Table 2 fully support this hypothesis. The differences were greater at four and six weeks postpartum and by 10 weeks, there was little difference in FAP. Between six and 10 weeks both heifer groups were gaining live-weight, indicating heifers were in positive energy balance and no effect on the milkfat characteristics would be expected. The concentration of $C_{18:1}$ or the ratio of $C_{18:1}$ to $C_{14:0}$ in milkfat may be a useful indicator of the level of mobilisation of body tissue occurring in energy balance studies. As these fatty acids are influenced by the lipid composition of the diet (Palmquist *et al*., 1993), this recommendation would only apply in situations where feed type is constant, e.g. grazed pasture.

The CLA concentration in milkfat from HCS heifers was less than that from LCS heifers. Recently, Griinari *et al*. (2000) reported that CLA predominantly arose from the endogenous synthesis of ruminally produced trans-vacennic fatty acid (TVA) by the Δ^9 desaturase pathway. The effect of calving CS on CLA could have occurred from an increased availability to the mammary gland of TVA or an increased activity of Δ^9 desaturase. As the concentration of $C_{14:1}$ and the ratio of $C_{14:1}$ to $C_{14:0}$ (an indicator of delta-9 desaturase activity, Griinari *et al*. 2000) was unaffected by calving CS, the increased CLA possibly arose from increased availability of TVA. Grainger *et al.* (1982) and Thomson *et al.* (1997) reported that, in early lactation, LCS cows consumed more pasture than HCS cows. In addition, CLA increased with increasing proportions of pasture in the diet (Dhiman *et al.,* 1999). The increased CLA in milkfat likely arose from the LCS heifers consuming more pasture and the resulting increased availability of TVA to the mammary gland.

The physical characteristics of milkfat, such as SFC, are influenced by changes in the FAP. With fewer short- and medium-chain saturated fatty acids, and more unsaturated fatty acids, milkfat becomes softer and more spreadable at cooler temperatures (MacGibbon, 1996). A comparison of results presented in Table 2 (FAP) and Table 3 (SFC), show the HCS heifers produced the lower concentration of formed fatty acids (short- and medium-chain fatty acids) and the higher concentration of unsaturated fatty acids. They also produced the softer milkfat (lower SFC). The effect on SFC was only noted at four weeks postpartum and did not persist. This suggests that calving CS was unlikely to be an important factor influencing the softness or spreadability of butter.

The changes in live weight and CS postpartum were greater for HCS than LCS heifers and were reflected during the first 10-weeks postpartum by changes in the FAP and the characteristics of milkfat. Milkfat from HCS heifers during the initial four and six weeks of lactation, contained more unsaturated fatty acids, less CLA, and was softer than milkfat produced from LCS heifers. Trial results also demonstrated that the fatty acid profile of milkfat, specifically the concentration of $C_{18:1}$ and CLA may provide an aid to interpreting dairy cow metabolism during periods of energy deprivation such as occurs in early lactation.

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