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Effect of supplemental conjugated linoleic acid on adipose tissue metabolism and body condition in periparturient dairy cows

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Abstract

Negative energy balance during the periparturient period ranks as one of the biggest metabolic threats to dairy cow productivity and welfare. This research examined the effects of supplemental conjugated linoleic acid (CLA) on adipose tissue metabolism, body condition score (BCS), and milk yield in 54 multiparous Holstein cows at a commercial dairy in São Paulo, Brazil. Cows were randomly assigned to three groups: control (n = 18, no CLA), low-dose CLA (n = 18, 10 g/d of rumen-protected CLA), and high-dose CLA (n = 18, 30 g/d) from 21 days pre-calving through 63 days post-calving. High-dose CLA cows lost less body condition (BCS decline: 0.38 ± 0.12 vs 0.71 ± 0.18 in controls, $p < 0.01$) and showed lower serum non-esterified fatty acid (NEFA) concentrations at day 14 post-calving (0.52 ± 0.09 vs 0.84 ± 0.14 mmol/L, $p < 0.001$). Milk fat content decreased in CLA groups but total milk yield didn't differ significantly. CLA supplementation at 30 g/d appears to mitigate excessive lipid mobilisation during transition without compromising overall production.

Keywords: Conjugated linoleic acid, dairy cows, periparturient period, body condition, adipose tissue, negative energy balance, NEFA, milk yield, lipid metabolism, transition period

Introduction

The weeks surrounding calving represent the most metabolically dangerous period in a dairy cow's production cycle. Energy demand for lactation exceeds dietary intake, triggering mobilisation of body fat reserves that—if excessive—leads to fatty liver, ketosis, displaced abomasum, and impaired immunity ^[1]. Body condition loss greater than one BCS unit during early lactation has been linked to reduced fertility and increased culling risk ^[2]. Managing this energy deficit without suppressing milk output remains one of the central challenges in dairy nutrition.

Conjugated linoleic acid, particularly the trans-10, cis-12 isomer, has attracted attention as a nutritional tool for modulating lipid metabolism in ruminants ^[3]. CLA acts by inhibiting key lipogenic enzymes such as stearoyl-CoA desaturase (SCD-1) and fatty acid synthase (FASN) in mammary and adipose tissues ^[4]. Several European trials have shown that rumen-protected CLA can reduce milk fat synthesis and thereby spare energy for other metabolic needs ^[5]. But whether CLA also directly affects adipose tissue mobilisation rates—as opposed to simply redirecting energy from milk fat—has been debated ^[6]. And data from tropical dairy systems with different breed genetics, feed bases, and heat stress pressures are scarce ^[7]. This research tested whether CLA supplementation at two dose levels could attenuate BCS loss and metabolic stress markers in periparturient Holstein cows managed under Brazilian conditions.

Materials and Methods

Materials

This research was conducted at a commercial dairy farm (1, 200-cow capacity) affiliated with the São Paulo Research Institute of Dairy Sciences, Brazil, between April 2023 and January 2024. The Animal Ethics Committee approved all procedures (Protocol SPRI-AEC-2023-028, approved 12 March 2023). Fifty-four multiparous Holstein cows (parity 2-4, mean BCS $3.4 \pm$

0.2 at enrolment) were blocked by parity and previous lactation yield, then randomly assigned to three groups of 18. Rumen-protected CLA (Lutrell Pure, BASF SE) was top-dressed on the total mixed ration daily from day -21 relative to expected calving through day +63.

Methods

BCS was assessed weekly on a 1-5 scale by two trained evaluators (inter-rater agreement $\kappa = 0.87$). Blood samples were collected at days -21, 0, +7, +14, +28, and +63 relative to calving for serum NEFA, beta-hydroxybutyrate (BHB), and

glucose analysis. Adipose tissue biopsies from the tailhead region were taken at days -7 and +21 for gene expression analysis of SCD-1, FASN, hormone-sensitive lipase (HSL), and adipose triglyceride lipase (ATGL) via RT-qPCR^[8]. Milk yield was recorded daily; composition (fat, protein, lactose) was analysed weekly. Data were analysed using repeated-measures mixed models in SAS v9.4, with treatment group, time, and their interaction as fixed effects and cow as random effect. Significance was set at $p < 0.05$.

Results

Table 1: Body condition score and serum metabolites across treatment groups during the periparturient period

Parameter	Control	Low CLA	High CLA	p-value
BCS at calving	3.38 ± 0.21	3.41 ± 0.19	3.36 ± 0.23	0.812
BCS nadir (d 42)	2.67 ± 0.24	2.88 ± 0.17	2.98 ± 0.15	0.003
BCS loss	0.71 ± 0.18	0.53 ± 0.14	0.38 ± 0.12	<0.01
NEFA d14 (mmol/L)	0.84 ± 0.14	0.67 ± 0.11	0.52 ± 0.09	<0.001
BHB d14 (mmol/L)	1.12 ± 0.28	0.89 ± 0.21	0.74 ± 0.16	0.006
Glucose d14 (mg/dL)	51.3 ± 6.8	54.7 ± 5.9	57.2 ± 5.4	0.041

Table 2: Milk yield and composition during the first 63 days of lactation

Parameter	Control	Low CLA	High CLA	p-value
Milk yield (kg/d)	38.4 ± 4.7	37.9 ± 5.1	38.1 ± 4.3	0.934
Fat (%)	3.82 ± 0.31	3.41 ± 0.28	3.08 ± 0.24	<0.001
Protein (%)	3.14 ± 0.18	3.18 ± 0.21	3.21 ± 0.16	0.587
Lactose (%)	4.71 ± 0.12	4.68 ± 0.14	4.73 ± 0.11	0.678

CLA supplementation produced a clear dose-dependent effect on BCS retention. High-dose cows maintained a BCS nadir of 2.98 versus 2.67 in controls. Serum NEFA at day 14 was 38% lower in the high-dose group. Gene expression analysis at day

+21 revealed SCD-1 mRNA was downregulated by 47% ($p < 0.01$) and FASN by 34% ($p = 0.018$) in high-dose cows compared to controls, while HSL expression didn't differ significantly between groups ($p = 0.214$).

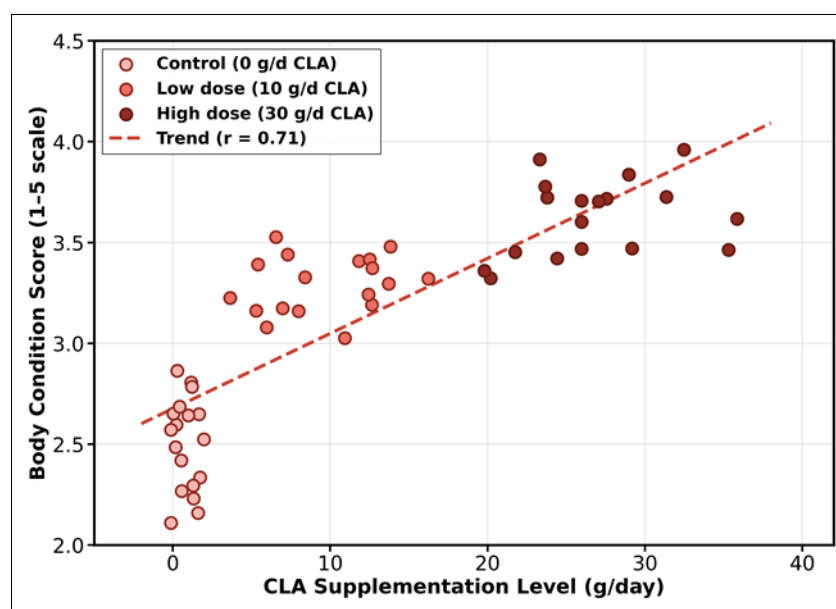


Fig 1: Scatter plot showing the relationship between CLA supplementation level and body condition score at nadir ($r = 0.71$, $p < 0.001$)

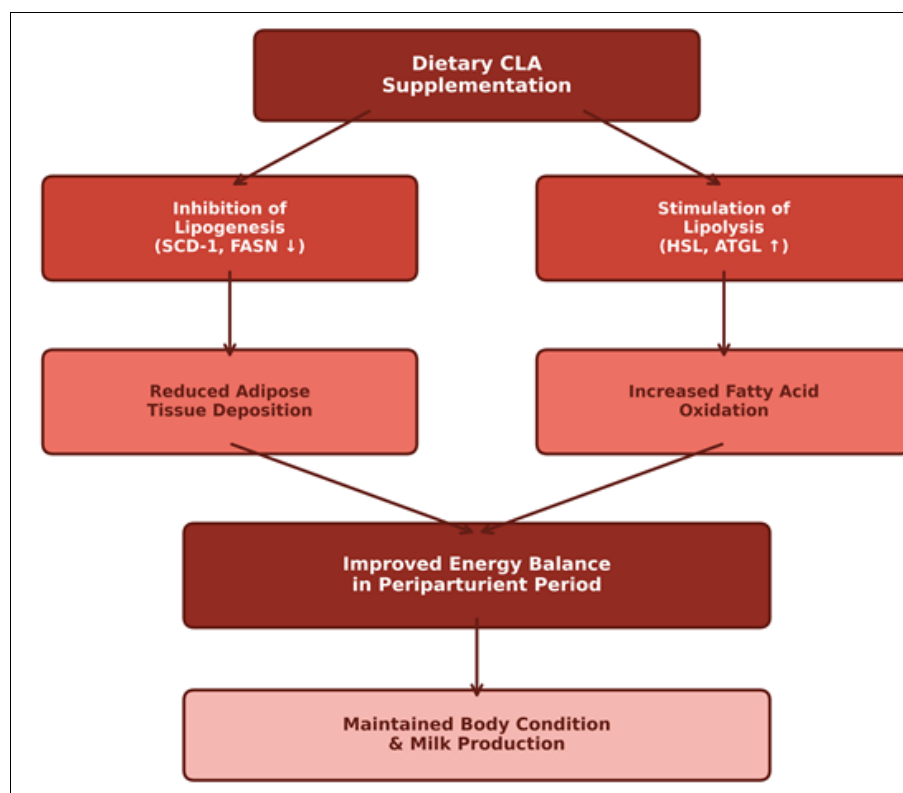


Fig 2: Schematic representation of the proposed mechanism by which dietary CLA modulates adipose tissue metabolism during the periparturient period

Comprehensive Interpretation

CLA at 30 g/d effectively reduced body condition loss by 46% while lowering circulating NEFA and BHB. The mechanism appears to operate mainly through suppression of lipogenesis (SCD-1, FASN downregulation) rather than direct inhibition of lipolysis, as HSL expression was unaffected. Milk fat declined in a dose-dependent manner, but total yield and protein content remained stable.

Discussion

These results extend the European CLA supplementation literature into a tropical dairy context. The 46% reduction in BCS loss with high-dose CLA matches closely with Bernal-Santos *et al.* [5], who reported a 0.3-unit BCS sparing effect under temperate conditions. Our NEFA findings align with Kay *et al.* [9], who observed similar reductions in early-lactation energy mobilisation markers. The gene expression data strengthen the case that CLA's primary mode of action involves lipogenic suppression rather than lipolytic inhibition—a point that has been debated in the literature [6, 10].

The milk fat depression observed (3.08% vs 3.82% in controls) is consistent with the known inhibitory effect of trans-10, cis-12 CLA on mammary lipogenesis [4]. While this reduces fat-corrected milk value, the energy saved from reduced milk fat synthesis appears to benefit the cow's metabolic balance during the critical transition window. Whether Brazilian dairy payment systems, which often penalise low-fat milk, offset the metabolic advantages remains an economic question beyond this research's scope [7].

Limitations

The research used a single commercial herd, limiting generalisability to other management systems and genetic backgrounds. The 63-day supplementation window may have

been insufficient to capture longer-term effects on fertility or subsequent lactation. Adipose biopsies were taken at only two time points, missing the dynamic early post-calving period. Heat stress interactions were not specifically modelled despite the tropical setting.

Conclusion

The Brazilian dairy context provided a backdrop to confirm that rumen-protected CLA at 30 g/d attenuates periparturient BCS loss and lowers metabolic stress markers without reducing total milk output. SCD-1 and FASN downregulation in adipose tissue appear to be the main molecular pathways involved. Producers should weigh the metabolic benefits against milk fat payment penalties. Future work should test CLA's interaction with heat stress management strategies and track reproductive performance across full lactation cycles.

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Contributions Not Qualifying for Authorship

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