Hepatic mitochondrial function in two Holstein genotypes under two feeding strategies

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Abstract

The aim of this work was to study mitochondrial function in two Holstein genotypes under different feeding strategies duringmid-lactation. Multiparous Holstein cows of New Zealand (HNZ) and North American (NA) origin were assigned to two feeding strategies: maximum pasture intake according to its growth in the grazing area plus an energy-protein concentrate (PMAX) or total mixed ration and one third of the diet offered as pasture (P30). Mitochondrial respiration was measured using Complex I and II substrates and hepatic glucose and glycogen were measured in liver biopsies. Respiration linked to ATP synthesis was affected and state 3 respiration tended to be affected by the interaction between genotype and feeding strategy; both parameters were higher for HNZ cows in the PMAX strategy when using Complex II substrates. Liver glycogen was higher in the PMAX than P30 strategy. Glycogen correlated positively with state 3 and ATP-linked respiration for PMAX cows when succinate was used as substrate, suggesting an association between succinate driven respiration and glucose metabolism.

Keywords: dairy cow, grazing, liver biopsy, respiration

Introduction

Lactation is an energy demanding process, especially for high-yielding dairy cows. In ruminants, the liver plays a central role in energy metabolism since it provides glucose and ketone bodies for the rest of the tissues (Drackley *et al*., 2001). Mitochondria are the main site of ATP synthesis (Brand and Nicholls, 2011) hence, the study of hepatic mitochondrial function is essential to understand metabolic adaptations during lactation in dairy cows. With this aim, we assessed mitochondrial respiration and quantified hepatic glucose reserves in two Holstein genotypes under two contrasting feeding strategies.

Materials and methods

The experiment was carried out at the Experimental Station of INIA 'La Estanzuela' in Colonia, Uruguay in October 2017. Multiparous HNZ and HA Holstein cows; 512±19 vs 563±29 kg live weight (LW), 3.1±0.1 body condition score (BCS), autumn calving) were assigned to two feeding strategies: cows grazing a *Medicago sativa* and *Dactylis glomerata* mix (16.4 kg DM/d herbage allowance for HNZ and HA, respectively) in two sessions (18 h/d) and supplemented with 1.9 kg DM/d of corn silage and 6.4 kg DM/d of concentrate (18.6% CP, 1.81 Meal NEL/kg DM) (PMAX; n=10) and cows grazing a herbage allowance of 10.7 kg DM/d of the same pasture (12 h/d) and received a 12.3 kg DM/d of a total mixed ration (50:50 forage:concentrate; 15% CP; 1.71 Meal NEL /kg DM) (P30; n=10). Liver biopsies were collected and cryopreserved at 180±17 days postpartum. Mitochondrial function was assessed measuring oxygen consumption rates using complex I (glutamate/malate) and II (succinate) substrates. Hepatic glucose and glycogen were measured. Data were analysed using a model that included genotype, feeding strategy and their interaction as fixed effects and calving date, initial LW and BCS were used as covariates if $P<0.20$.

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Results and discussion

Although milk yield was higher (28±1 vs 24±1 kg/d, $P<0.05$), percentages of milk solids were lower ($P<0.06$) for HA than HNZ cows (3.61±0.08 vs 3.24±0.05% protein, 4.5±0.2 vs 4.1±0.13% fat, 4.92±0.04 vs 4.82±0.03% lactose, respectively). In addition, BCS was lower for PMAX than P30 (2.55±0.04 vs 2.35±0.04, $P<0.01$). The interaction between genotype and feeding strategy was observed only for succinate supported respiration. For instance, ATP synthesis linked respiration was affected and state 3 and 4 respiration tended to be affected by the interaction, with HNZ in the PMAX strategy having the highest respiration rates (Table 1). Respiratory control ratio (RCR) and coupling efficiency were higher for HNZ than HA cows and for the PMAX than P30 strategy (Table 1). Hepatic glucose concentration was affected by the interaction ($P<0.05$) as it was greater in HA cows in the P30 strategy, whereas glycogen concentration was greater in the PMAX than P30 strategy (1.84 vs 1.29±0.25 m/m%, respectively). Coupling efficiency correlated positively (r=0.34 and $P<0.05$) with milk lactose and glycogen correlated positively (r=0.60, $P<0.05$) with state 3 and ATP-linked respiration only for PMAX cows. Our results show that cows with higher succinate driven respiration had more liver glycogen reserves, pointing out to a relationship between mitochondrial ATP synthesis and glucose metabolism and suggesting succinate dehydrogenase might play a relevant role, especially in HNZ cows with more pasture inclusion (White *et al.*, 2012).

Table 1. Complex I and II dependent respiration for cows of two different Holstein genotypes (G) under two different feeding strategies (FS).[1,2]

Parameters and indexes	Substrates	Feeding strategy				SE	*P*-value		
		P30		PMAX			G	FS	G×FS
		HNZ	HA	HNZ	HA				
State 3	G/M	10^{aby}	7^{by}	15^{ax}	10^{aby}	2	0.08	0.07	0.54
	Succ	10^{b}	12^{b}	33^{a}	18^{b}	5	0.19	0.003	0.06
State 4	G/M	5	4	5	4	1	0.29	0.90	0.87
	Succ	5^{b}	10^{b}	15^{a}	13^{a}	2	0.57	0.0014	0.09
ATP-linked	G/M	5^{a}	3.0^{b}	7^{a}	5^{a}	2	0.18	0.08	0.74
	Succ	3^{b}	4.2^{b}	16^{a}	6^{b}	2	0.08	0.005	0.03
Maximum	G/M	11^{b}	9^{b}	21^{a}	15^{ab}	3	0.15	0.04	0.90
	Succ	15^{b}	16^{c}	55^{a}	30^{ab}	7	0.17	0.018	0.51
RCR	G/M	2.1^{b}	2.0^{b}	3.5^{a}	3.0^{a}	0.4	0.51	0.003	0.97
	Succ	1.96^{a}	1.27^{bc}	2.34^{a}	1.65^{b}	0.17	0.0003	0.02	0.99
Coupling efficiency	G/M	0.39	0.31	0.50	0.44	0.11	0.51	0.21	0.90
	Succ	0.34^{ab}	0.26^{b}	0.54^{a}	0.29^{b}	0.06	0.01	0.04	0.13

[1] Oxygen consumption rates were measured after the sequential addition of 10 mM glutamate and 5 mM malate (G/M) or 20 mM succinate (Succ), 4 µM ADP, 2 µM oligomycin, up to 4 µM FCCP and 0.5 µM rotenone/2.5 µM antimycin.
[2] Data are shown as least square means ± standard error. ^{ab} denote differences between values ($P<0.05$) while ^{xy} denote tendencies ($0.05<P<0.1$). Rates are expressed as pmol O_2/min/mg wet weight.

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