The impact of long term grain feeding on glycolytic metabolism of cattle

Pighin, D.G. * [2, 3], Warner, R. [1], Jacob, R. [4], Beatty, D. [4], Naththarampatha, A. [5], Ferguson, D. [6]

[1] Food and Nutritional Sciences, CSIRO, 671 Sneydes Road, Werribee, Vic 3030, Australia

[2] Instituto Tecnología de Alimentos, Instituto Nacional de Tecnología - INTA, De Los Reseros y Las Cabañas, Morón, Argentina

[3] Consejo Nacional de Investigaciones Científica y Técnicas - CONICET, Av. Rivadavia 1917, Buenos Aires, Argentina

[4] Murdoch University, South Street, Murdoch, Western Australia, 6150

[5] Livestock Production Sciences, Department of Primary Industries - DPI, 600 Sneydes Road, Werribee, Australia

[6] Livestock Welfare, CSIRO Livestock Industries, Locked Bag 1, Armidale, Australia

[*] Corresponding author (phone: +54-11-4621-0446; fax: +54-11-4621-2012; e-mail: dpighin@cnia.inta.gov.ar)

Abstract— **The aim of the work was to study the effect of long term grain feeding on the glycolytic metabolism of cattle. Eighteen 13-month old *Bos-taurus* Angus steers (369±14kg) were randomly assigned to different diets: grain based feedlot ration during 300 days (300GD); pasture during 150 days and then feedlot grain based ration for 150 days (150GD); and pasture during 300 days (300PD). Blood samples were collected at exsanguination for analysis of glucose, lactic acid and insulin concentrations. Muscle samples were removed from *Psoas-major* (*PM*) at 1, 2, 4 and 24h post-slaughter for glycogen and lactic acid levels assay. The ultimate pH of *PM* was taken at 24h *post-mortem*. All animals presented hyperglycemia at slaughter. High energy-fed animals (300GD and 150GD) showed higher levels of both glucose and lactic acid (p>0.05) in the plasma at slaughter. Plasma insulin was slightly increased in animals fed with high energy diet, for either 300d or 150d. No significant differences could be found in glycogen or in lactate levels between treatments. Animals fed high energy ration (300GD and 150GD) displayed higher rates of anaerobic utilization of glycogen during the first 4h, as evidenced by differences among diets during the first 2h (slopes: -17.3 and -26.0 for 300GD and 150GD *vs.*-10.6 for 300PD).**

Results give evidence of apparent impaired peripheric insulin sensitivity associated with high energy grain-based feeding, either during 300d or 150d. *Post mortem* muscle glycolytic ratio during the first 4h post-slaughter differed due to the energy of diets, suggesting possible meat quality implications.

Keywords—**Diet, Glycogen, Muscle**

I. INTRODUCTION

At present, cattle production systems used to fed high energy grain based diets for extended periods of time. When compared to cattle fed on pasture based roughage diets, cattle raised on high concentrate rations may be exposed to several metabolic modifications including increased heat production and impaired used of glucose [1, 2], with possible implications to both animal welfare and meat quality.

Previous research have focused the attention on the impact of diet and core body temperature upon animal stress and meat quality [1, 3]. Since glycolytic metabolism plays a key role in the conversion of muscle into meat, the impact of prolonged feeding of high energy diets (up to 300 days) on the glucose metabolism and muscle energy storages emerges as an important field of study.

Therefore, the aim of the present work was to study the effect of long term grain feeding on the glycolytic metabolism of cattle.

II. MATERIALS AND METHODS

A. Animals and diets

Eighteen 13 month old Bos taurus Angus steers (369 ± 14 kg; mean ± SEM) were randomly assigned to one of three treatment groups:

- *group 1* (n = 6): steers were fed a grain based feedlot ration (12.6 MJ/kg and 13.2% protein) during 300 days in a commercial feedlot.
- *group 2* (n = 6): steers were fed on pasture (average 9 MJ/kg and 12% protein) during 150 days at a nearby farm and then transferred to the feedlot grain based ration for a further 150 days.
- *group 3* (n = 6): steers were fed on the same pasture during 300 days.

B. Samples and pH measurement

Blood samples were collected from each animal at

exsanguination time into a tube containing heparin as anticoagulant and immediately placed on ice. Samples were centrifuged (3000 x g, 10 min, 4 °C) within 5 h post-slaughter. Plasma was separated and then stored at -20 °C until analysis for glucose, lactic acid and insulin concentrations.

Muscle samples were removed from *Psoas-major* (*PM*) at 1, 2, 4 and 24 h post-slaughter. Samples of *LT* were immediately frozen in liquid nitrogen until processing for glycogen and lactic acid levels. The pH of the *LT* was taken at 24 h *post mortem* using a Micrometer pH Vision Model 6007 (Jenco Instruments, San Diego, CA) with a direct pH probe (Ionode Model No. IJ42).

C. Laboratory Methods

Plasma glucose and lactic acid concentrations were measured using enzymatic commercial kits (Sigma-Aldrich Pty, MO and Randox Labs Ltd., UK, respectively). Insulin concentration was measured by RIA analysis. Muscle glycogen concentration was determined according to Dreiling et al. [4]. Muscle L-lactic acid level was determined as described by Noll [5]. Glycolytic potential was calculated according to Monin and Sellier [6].

D. Statistical and Data Analysis

Statistical analysis was performed using SPSS ® (12.0 Illinois, USA). Results obtained were analyzed by ANOVA and are expressed as mean ± standard deviation. P-values 0.05 were considered statistically different.

III. RESULTS AND DISCUSSION

Plasma levels of glucose, lactic acid and insulin are shown in Table 1. All animals presented hyperglycemia at the slaughter moment, certainly due to the stress of the *ante mortem* handling. Nevertheless, high energy fed animals (300 GD and 150 GD) showed higher levels of both glucose and lactic acid.

Plasma insulin slightly increased in animals fed with high energy diet, either during 300 d or 150 d. Despite the differences were not significant due to increased individual variation, the higher mean insulin levels displayed by both mentioned groups would suggest an impair peripheric effect of insulin, which agree with previus reports [2].

It is noteworthy that grain-fed animals showed the highest inter-animal dispersion of plasma parameters when compared to pasture-fed animals ones. This finding could be possibly related to different adaptation capacity of animal metabolism to the high energy intake, which should be take into account in future studies.

Table 1 Glucose, lactate and insulin concentrations in plasma from cattle fed with grain (300 DGF), grain and pasture (150) or pasture

	300 DGF	150 DGF	300 DPF	P-value
Plasma Glucose (mM)	8.18 ± 1.38	8.15 ± 1.07	6.93 ± 0.65	0.106
Plasma Lactate (mM)	8.89 ± 2.46	8.89 ± 2.03	7.23 ± 0.59	0.242
Plasma Insulin (μU/mL)	35.10 ± 25.81	35.40 ± 13.44	25.68 ± 10.21	0.572

Table 2 shows the levels of glycogen and lactate in *LT* muscle during the anaerobic metabolism after death. Despite no any significant differences neither in glycogen nor in lactate levels were found, high energy-fed animals displayed higher rates of anaerobic utilization of glycogen (Figure 1) during the first 4 h, displaying greater differences among diets during the first 2 h (slopes: -17.3 and -26.0 for 300 DGF and 150 DGF, respectively *vs.*-10.6 for 300 DPF). Recently, an increased body temperature has been found in these high energy-fed animals (unpublished data), suggesting that increased energy intake would lead to an impaired thermoregulation due to insulin resistance mechanism. Therefore, it is possible to think that an increased carcass temperature would lead to an increased activity of the glycolytic enzymes in the first *post mortem* hours, producing the increased utilization of glycogen observed during this period of time.

Table 2 Muscle glycogen and lactate levels in *LT* from cattle fed with grain, grain and pasture or pasture

	300 DGF	150 DGF	300 DPF	P-value
Glycogen 1 h (µmol/g wet tissue)	47.5 ± 10.1	50.7 ± 11.3	38.6 ± 14.6	0.274
Glycogen 24 h (µmol/g wet tissue)	18.7 ± 4.2	19.3 ± 9.8	10.8 ± 5.9	0.111
Lactate 1 h (µmol/g wet tissue)	66.9 ± 14.3	71.5 ± 13.7	72.4 ± 10.0	0.772
Lactate 24 h (µmol/g wet tissue)	87.0 ± 3.1	92.3 ± 5.7	93.5± 5.0	0.097

Since the rate of pH-T decline curve plays a major role in the adequate development of meat quality (i.e. shortening and proteolysis mechanisms), the rate of anaerobic glycolysis is a key issue to study under different feeding conditions, in order to adjust industry processing methodologies.

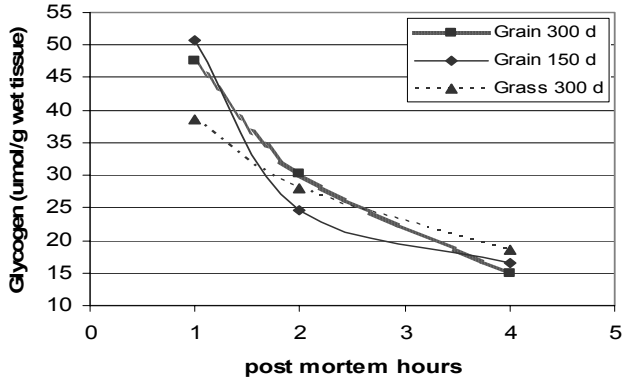

Fig. 1 Rate of muscle glycogen decrease during the first 4 h *post mortem* in *LT* from cattle fed with grain, grain and pasture or pasture.

Regarding glycolytic potential, all animals belonging to the three diets presented comparable muscle energy potential (162.0, 172.8 and 149.6 µmol/g wet tissue for 300 DGD, 150 DGD and 300 DPD, respectively). This finding suggests that the different diets used in the present study would mainly impact more on the use of muscle energy reserves than on its storage.

IV. CONCLUSION

Results obtained give evidence of an apparent impaired peripheric insulin sensitivity associated to feeding of high energy grain-based diets, either during 300 d or 150 d. *Post mortem* muscle glycolytic ratio during the first 4 h differed due to the energy of diets, suggesting the possibility of meat quality implications, apart from the animal welfare ones suggested previously.

Future studies to look further into the impact of diet on the muscle metabolism will be interesting in order to assess the possible effects of current production systems on the meat quality and animal welfare.

ACKNOWLEDGEMENT

The present work was funded by DPI. Financial support from INTA is also acknowledged. The authors would also like to thank Angeles Fischer, Matthew Kerr, Wayne Brown and Mal Boyce for their technical advice and support.

REFERENCES

1. Gaughan JB and Mader TL (2009) Effects of sodium chloride and fat supplementation on finishing steers exposed to hot and cold conditions. J Anim Sci 87: 612-621.
2. Hersom MJ, Wettemann RP, Krehbiel CR, Horn GW, Keisler DH (2004) Effect of live weight gain of steers during winter grazing: III. Blood metabolites and hormones during feedlot finishing. J Anim Sci 82, 2059-68.
3. Ferguson DD, Bruce HL, Thompson JM, Egan AF, Perry D, Shorthose WR (2001) Factors affecting beef palatability: farm gate to chilled carcass. Aust J Exp Agr 41: 879-891.
4. Dreiling CE, Brown DE, Casale L & Kelly L (1987) Muscle glycogen: Comparison of iodine binding and enzyme digestion assays and application to meat samples. Meat Sci 20: 167–177.
5. Noll F (1985) L+ lactate determination. In H. U. Bergmeyer (Ed.), Methods of enzymatic analysis (pp. 583–588). Weinheim, Germany: VCH Verlagsgesellschaft.
6. Monin G and Sellier P (1985) Pork of low technological quality with a normal rate of muscle pH fall in the immediate post-mortem period: the case of the Hampshire breed. Meat Sci 13: 49-63.