SHORT COMMUNICATION

Fibre type characteristics and postmortem glycolysis of bison (*Bison bison bison*) longissimus lumborum

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[1]*Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, Canada T6G 2P5; and* [2]*Meat Research Section, Agriculture and Agri-Food Canada, Lacombe Research Centre, 6000 C & E Trail, Lacombe, Alberta, Canada T4L 1W1.* *Received 23 November 2000, accepted 31 March 2002.*

Janz, J. A. M., Aalhus, J. L. and Price, M. A. 2002. **Fibre type characteristics and postmortem glycolysis of bison (*Bison bison bison*) longissimus lumborum**. Can. J. Anim. Sci. **82**: 259–262. To augment the limited information base, muscle fibre and postmortem glycolytic data from bison longissimus lumborum were compiled. As expected, postmortem glycogen concentration and pH declined while lactate concentration increased. Bison muscle fibres had a greater area, with a greater percentage of fast oxidative glycolytic fibres, and a lesser percentage of fast glycolytic fibres as compared to literature values for beef.

Key words: Bison, muscle fibre type, glycogen, lactate

Janz, J. A. M., Aalhus, J. L. et Price, M. A. 2002. **Propriétés des fibres musculaires et glycolyse post-mortem du *longissimus lumborum* chez le bison (*Bison bison bison*).** Can. J. Anim. Sci. **82**: 259–262. Les auteurs ont rassemblé des données sur les fibres musculaires et la glycolyse post-mortem du *Longissimus lumborum* du bison en vue d'enrichir la base de données existante, par trop restreinte. Comme on le prévoyait, la concentration de glycogène et le pH diminuent après la mort de l'animal, tandis qu'on assiste à une hausse de la concentration de lactate. Les fibres musculaires du bison présentent une plus grande superficie que celle mentionnée pour le bœuf, dans la documentation. La proportion de fibres s'oxydant rapidement à la glycolyse est aussi plus élevée, mais on note un plus faible pourcentage de fibres à glycolyse rapide.

Mots clés: Bison, fibres musculaires, glycogène, lactate

Knowledge of characteristic postmortem biochemical events is essential when designing appropriate carcass handling systems. Little published information on bison is available. Response to typical chilling treatments, as well as to alternative treatments such as carcass electrical stimulation, depends on the proportion of fibre types present in the tissue and on the availability of metabolic substrates. Myofibres are specialized for different types of activity in live muscle (Swatland 1994) and enzymatic and physicochemical events in postmortem tissue are determined, primarily, by the proportion (Brandstetter et al. 1998) and metabolic properties of distinct fibre types. The objective of this study was to provide baseline data on postmortem glycolysis and muscle fibre complement of bison longissimus lumborum (LL) obtained from control carcass sides from two bison meat quality studies (Janz et al. 2000, 2001).

Thirty-nine bison bulls, ranging in age from 24 to 32 m, were transported for 2–6 h from several commercial feeding operations in Alberta to the Agriculture and Agri-Food Canada Lacombe Research Centre for slaughter and processing. Following stunning with a black powder rifle, carcass dressing proceeded under simulated commercial conditions and included chilling at 2°C for 24 h, and periodic sampling as described below. Immediately following exsanguination and at 1, 3, 10, and 24 h postmortem, small (~50 g) LL samples from near the 13th rib were removed using a stainless steel corer, 30 mm in diameter. Core samples were trimmed of subcutaneous fat and obvious connective tissue and immediately flash frozen in liquid nitrogen. Samples were prepared in duplicate following methods previously described by Dalrymple and Hamm (1973) and Yambayamba et al. (1996) with the exception that glycogen (expressed as glucose equivalents) and lactate contents of samples were determined using a YSI 2300 Stat Plus glucose/lactate analyzer (YSI Incorporated, Yellow Springs, OH) and reported as μmol g^{-1} tissue. Following each core removal time, pH was measured adjacent to the sampling site using an Accumet 1002 pH meter (Fisher Scientific, Edmonton, AB) with an Orion Ingold Electrode (Udorf, Switzerland).

At approximately 24 h postmortem, small (~100 g) LL samples were removed from near the 12th rib and immediately prepared for histochemical analysis of muscle fibre types. Fresh LL samples were trimmed into cubes

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Abbreviations: **FG**, fast glycolytic; **FOG**, fast oxidative glycolytic; **LL**, longissimus lumborum; **SO**, slow oxidative

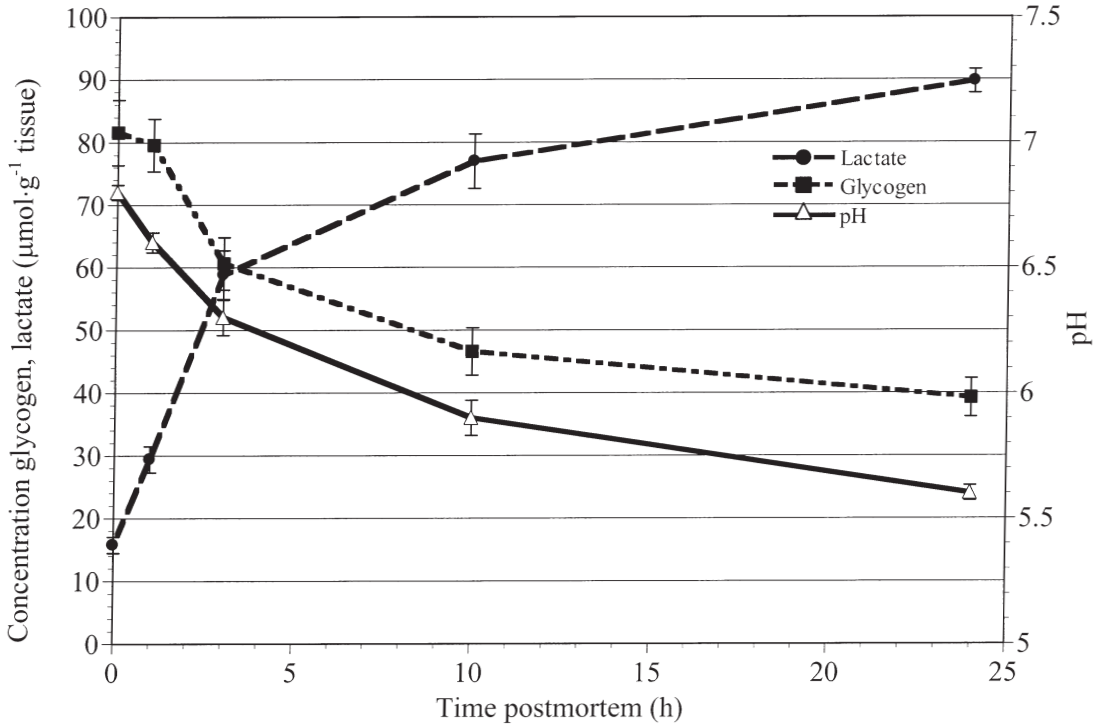

Fig. 1. Trends in glycogen consumption, lactate accumulation, and pH decline in bison longissimus lumborum to 24 h postmortem.

($0.5 \times 0.5 \times 0.75$ cm) with the long axis parallel to the fibre grain. The cubes were then mounted (Tissue-Tek O.C.T. Compound) on cork (tissue grain perpendicular to cork surface) and rapidly frozen in liquid nitrogen. Frozen samples were thinly sectioned (13 μm) using Tissue-Tek Accu-Edge disposable microtome blades in a Tissue-Tek cryostat unit (Miles Inc. Elkhart, IN) maintained at -20°C. Three to four serial sections were placed onto a glass slide at room temperature and allowed to air dry for 1 h prior to differential staining of slow oxidative (SO), fast oxidative glycolytic (FOG), and fast glycolytic (FG) fibre types. The acid preincubation (pH 4.15), combined succinate dehydrogenase (SDH)/ATPase staining procedure followed that described for beef by Solomon and Dunn (1988). Fibres were differentiated on the basis of colour development during the staining procedures with the final result showing brown SO, blue-rimmed FOG, and colourless FG cells. Using image analysis software (Image Pro® Plus Version 3.0, Media Cybernetics, Silver Springs, MD), fibre images were captured under 100× magnification (Zeiss Axioskop, West Germany), counted using an on-screen tagging system and measured using the mouse-controlled measurement function. For each LL sample, all cells in each of four fibre bundles were counted in order to determine the frequency of appearance of each fibre type.

For fibre dimensions, the minimum (d) and maximum (D) diameters of 10 cells of each type in three bundles per sample were recorded. Fibre area was calculated as $(D–d)\pi/4$ (Clancy and Herlihy 1978). The percent of total cross-sectional area occupied by each fibre type was determined as an indicator of the potential contribution of each cell type to overall muscle metabolism (Seideman and Theer 1986).

To isolate any possible effect of age on histological parameters, carcasses were categorized on the basis of dentition score, a well-established indicator of physiological maturity (Graham and Price 1982). Since environmental factors such as nutritional history may affect growth and development, physiological age, rather than chronological, is a more accurate measure of maturity. Bison have eight teeth across the anterior portion of the lower jaw, and a score (maximum possible eight points) was assigned to each carcass on the basis of visual examination of dentition with one "point" given for each permanent incisor present. The difference between deciduous and permanent teeth was evident based on size and degree of erosion on the biting surface. It was assumed that eruption of permanent incisors occurred in pairs. Where only one tooth in a pair had erupted it was assumed that the time interval between eruption of teeth in a pair was minimal and the score was raised accordingly. Scores were run as a class variable in one-way ANOVA analysis using the GLM procedure of SAS (SAS Institute, Inc. 1990) to evaluate the effects of physiological age, as indicated by dentition, on muscle fibre parameters.

Over 24 h postmortem, a curvilinear pattern of pH decline was observed in bison LL (Fig. 1) with ultimate pH reaching 5.54 ± 0.02 (SEM). Glycogen consumption and accompanying lactate accumulation (Fig. 1) also followed patterns expected during the conversion of muscle to meat. Compared to results reported by Bendall (1973), the present bison samples contained more glycogen [78.1±5.2 (SEM, μmol g^{-1}

Table 1. Cross sectional area and proportion (SEM) of muscle fibre types of bison longissimus lumborum

	Dentition score[z,y]				Overall mean value
	0 (*N*=3)	2 (*N*=12)	4 (*N*=3)	*P*	
Fibre area (μm^{2})					
SO[x]	2491.5 (234.7)*a*	2972.8 (117.3)*a*	3959.2 (234.7)*b*	<0.01	3057.0 (139.6)
FOG[w]	2965.4 (361.9)*a*	3479.2 (181.0)*a*	4511.4 (361.9)*b*	0.02	3565.6 (178.5)
FG[v]	5988.4 (855.1)	6465.9 (427.6)	7865.3 (855.1)	0.28	6619.6 (357.2)
Frequency %					
SO	29.3 (2.8)	28.3 (1.4)	28.7 (2.8)	0.95	28.6 (1.1)
FOG	32.3 (3.8)	34.0 (1.9)	31.7 (3.8)	0.83	33.3 (1.5)
FG	38.7 (2.3)	37.8 (1.1)	39.7 (2.3)	0.76	38.3 (0.9)
% of total area[u]					
SO	18.6 (2.6)	19.2 (1.3)	20.2 (2.8)	0.91	19.3 (1.0)
FOG	24.1 (3.4)	26.6 (1.7)	25.1 (3.4)	0.78	26.0 (1.3)
FG	57.2 (2.8)	54.2 (1.4)	54.6 (2.8)	0.62	54.8 (1.1)

[z]Score indicates number of permanent teeth in anterior lower jaw.
[y]Eighteen of the 39 experimental animals were fibre typed.
[x]Slow oxidative.
[w]Fast oxidative glycolytic.
[v]Fast glycolytic.
[u]Calculated as: [(area × frequency)/Σ area × frequency] × 100.
a,b Means in the same row followed by different letters were significantly different.

tissue] than comparable beef cattle (50.0 μmol g^{-1} tissue) and pig muscle (55–65 μmol g^{-1} tissue) muscle at slaughter. Initial lactate concentration in bison LL was similar to beef and greater than that of pig muscle (15.8 ± 1.3 vs. 16.0, 6.0–11.2 μmol g^{-1} tissue, respectively).

The three primary muscle fibre types are SO (slow oxidative, red, βR, Type I), FOG (fast oxidative glycolytic, intermediate, αR, Type IIA), and FG (fast glycolytic, white, αW, Type IIB). Fast glycolytic fibres contain an abundance of glycolytic enzymes for anaerobic metabolism whereas SO fibres contain an abundance of mitochondria for oxidative metabolism. Fast oxidative glycolytic fibres are intermediate in metabolic characteristics (McCormick 1994).

The effect of physiological age on fibre area was significant ($P < 0.05$) only for mean fibre area of SO and FOG fibres, but not FG fibres (Table 1). Within dentition score 4, SO and FOG fibres were significantly larger than fibres within scores 0 and 2. Lawrie (1978) previously reported the increase in fibre area in bovine longissimus with age.

In comparison to beef cattle (Seideman and Theer 1986; Seideman et al. 1987), bison muscle in the present study displayed a greater mean fibre area for all fibre types. Because fibre area increases with age (Lawrie 1978), these data may reflect the greater age of typical slaughter market bison (18–30 m) versus beef animals (12–18 m). This comparison also showed a similar frequency of SO fibres between genera, while bison had a greater percentage of FOG fibres and lower percentage of FG fibres than cattle. Koch et al. (1995) reported the same trend in fibre type frequency amongst bison and beef cattle. Bison and beef samples had similar percentages of calculated total area occupied by SO fibres, while bison displayed a smaller total area devoted to FG fibres.

Because of different contents of glycogen and metabolic enzymes, histochemical fibre types have varying reactions to the conversion of muscle to meat (Swatland 1994). Muscle fibre complement has been demonstrated to impact meat quality traits, although the relationship also depends upon environmental conditions. Rahelic and Puac (1980–1981) reported that "white" fibres (FG) had a comparatively lower water-holding capacity and were tougher than "red" fibres when converted to meat. FG fibres, because of their predisposition to glycolytic metabolism, and also display rapid postmortem lactate accumulation (McCormick 1994). The impact of acidification rate on tenderness/toughness is in itself a controversial issue, with literature supporting both slow (Marsh et al. 1980–1981) and rapid (Martin et al. 1983) pH decline for the development of tender meat. The highly developed sarcotubule system within FG fibres enhances the resistance of this fibre type to cold shortening (McCormick 1994), whereas SO fibres have a greater potential to cold shorten (Lawrie 1978; Pearson and Young 1989) due to a comparatively lower capacity to sequester calcium ions (Buege and Marsh 1975). Lawrie (1978) indicated that a better tenderization response with ageing was realized in muscle of predominantly "white" versus "red" fibres.

Thus, knowledge of fibre type composition can allow for application of appropriate carcass handling techniques. For example, a bison processing system that included a period of elevated temperature conditioning would reduce the risk of cold shortening and enhance the tenderization response with ageing in carcasses that are known to have a comparatively lower FG fibre content. Availability of these baseline data on bison longissimus lumborum may be useful in further study of bison-specific processing systems.

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Bendall, J. R. 1973. Postmortem changes in muscle. Pages 243–309 *in* G. H. Bourne, ed. The structure and function of muscle. 2nd ed. Academic Press, Inc., London, UK.

Brandstetter, A. M., Picard, B. and Geay, Y. 1998. Muscle fibre characteristics in four muscles of growing bulls. I. Postnatal differentiation. Livest. Prod. Sci. **53**: 15–23.

Buege, D. R. and Marsh, B. B. 1975. Mitochondrial calcium and postmortem muscle shortening. Biochem. Biophys. Res. Commun. **65**: 478–482.

Clancy, M. J. and Herlihy, P. D. 1978. Assessment of changes in myofibre size in muscle. Pages 203–218 *in* H. DeBoer and J. Martin, eds. Patterns of growth and development in cattle. Martinus Nijhoff, The Hague, The Netherlands.

Dalrymple, R. H. and Hamm, R. 1973. A method for the extraction of glycogen and metabolites from a single muscle sample. J. Food Technol. **8**: 439–444.

Graham, W. C. and Price, M. A. 1982. Dentition as a measure of physiological age in cows of different breed types. Can. J. Anim. Sci. **62**: 745–750.

Janz, J. A. M., Aalhus, J. L., Price, M. A. and Schaefer, A. L. 2000. The influence of elevated temperature conditioning on bison (*Bison bison bison*) meat quality. Meat Sci. **56**: 279–284.

Janz, J. A. M., Aalhus, J. L. and Price, M. A. 2001. Blast chilling and low voltage electrical stimulation influences on bison (*Bison bison bison*) meat quality. Meat Sci. **57**: 403–411.

Koch, R. M., Jung, H. G., Crouse, J. D., Varel, V. H. and Cundiff, L. V. 1995. Digestive capability, carcass, and meat characteristics of *Bison bison*, *Bos taurus* and *Bos* × *Bison*. J. Anim. Sci. **73**: 1271–1281.

Lawrie, R. A. 1978. Biochemistry of muscle in relation to growth. Pages 57–71 *in* H. DeBoer and J. Martin, eds. Patterns of growth and development in cattle. Martinus Nijhoff, The Hague, The Netherlands.

Marsh, B. B., Lochner, J. V., Takahashi, G. and Kragness, D. D. 1980–1981. Effects of early post-mortem pH and temperature on beef tenderness. Meat Sci. **5**: 479–483.

Martin, A. H., Murray, A. C., Jeremiah, L. E. and Dutson, P. J. 1983. Electrical stimulation and carcass ageing effects on beef carcasses in relation to postmortem glycolytic rates. J. Anim. Sci. **57**: 1456–1462.

McCormick, R. J. 1994. Structure and properties of tissues. Chapter 2 *in* D. M. Kinsman, A. W. Kotula, B. C. Breidenstein, eds. Muscle foods: meat poultry and seafood technology. Chapman and Hall, Inc., New York , NY.

Pearson, A. M. and Young, R. B. 1989. Muscle and meat biochemistry. Academic Press, Inc., San Diego, CA.

Rahelic, S. and Puac, S. 1980–1981. Fibre types in *Longissimus dorsi* from wild and highly selected pig breeds. Meat Sci. **5**: 439–450.

SAS Institute, Inc. 1990. SAS user's guide. Version 6, 4th ed. SAS Institute, Inc., Cary, NC.

Seideman, S. C. and Theer, L. K. 1986. Relationships of instrumental textural properties and muscle fiber types to the sensory properties of beef. J. Food Qual. **9**: 251–261.

Seideman, S. C., Koohmaraie, M. and Crouse, J. D. 1987. Factors associated with tenderness in young beef. Meat Sci. **20**: 281–291.

Solomon, M. B. and Dunn, M. C. 1988. Simultaneous histochemical determination of three fiber types in single sections of ovine, bovine and porcine skeletal muscle. J. Anim. Sci. **66**: 255–264.

Swatland, H. J. 1994. Chapters 6 and 9 *in* Structure and development of meat animals and poultry. Techomic Publishing Company, Inc., Lancaster, PA.

Yambayamba, E. S. K., Aalhus, J. L., Price, M. A. and Jones, S. D. M. 1996. Glycogen metabolites and meat quality in feed-restricted re-fed beef heifers. Can. J. Anim. Sci. **76**: 517–522.