Stress of beef steers transported at a commercial space allowance

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Abstract

The objective of this study was to compare the physiological responses of beef steers transported under the general commercial space allowance of 0.7 m²/head with those of steers transported under a higher space allowance of 1.6 m²/head. Two repeated commercial transport routes with 28 cattle each were studied using a heavy truck (maximum loading weight: 13,700 kg) (0.7 m²/head) in the summer. We compared data from these steers to data from 5 steers transported under a higher space allowance (1.6 m²/head) by a medium-sized truck (maximum loading weight: 4,000 kg). Blood glucose concentration (mg/dL) was higher in the commercially transported steers (33.8±12.0) than in those transported under the higher-space allowance (24.4±7.8) (P < 0.01). Blood lactic acid concentration (mmol/L) was higher under the commercial conditions (1.84±1.51) than under the higher-space allowance (0.81±0.19) (P < 0.05). Serum alanine aminotransferase (ALT) activity (IU/L) was also higher under the commercial conditions (22.8±7.8) than under the higher-space allowance (15.1±3.0) (P < 0.01). Serum triiodothyronine concentration just after commercial transport was higher than 1 wk after transport in both space allowances (both P < 0.05). Serum aspartate aminotransferase (AST) activity just after commercial transport was higher than just after transport under the higher-space allowance and 1 wk after transport in both space allowances (all P < 0.01). In conclusion, some physiological reactions, at least during the summer, indicated that the extent of stress in steers transported under the commercial space allowance, even if it fits the welfare standard, might be slightly stronger than that of steers transported under the higher space allowance.

Key Words: beef cattle, transport, space allowance, stress

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INTRODUCTION

The various effects of transportation on cattle behavior and physiology have recently been studied in Europe and the United States. In Japan, the beef industry needs to transport cattle over long distances due to the geographic separation of breeding and fattening regions. In many cases, young steers and heifers are sold by auction at livestock markets and then transported for several hours or even a few days to the fattening farm. However, there have been few studies on the effects of such commercial cattle transport in Japan. Previously, we investigated the thermal and physical conditions of a truck, and the behavioral and physiological reactions of steers to long distance transport. In these previous studies, long distance transport did not seem to cause severe stress in steers. One of the main reasons for this might be that the space allowance of 1.6 m²/head was much larger than that standard in general commercial transport. The RSPCA welfare standards require that a space allowance of 0.7 – 0.95 m²/head must be provided during transportation of heavy calves weighing about 200 kg. Most Japanese commercial vehicles complied with this requirement. So, in this study, the space allowance of 0.7 m²/head was used as the general space allowance for commercial transportation, and the physiological responses of beef steers to long distance transport were compared with those of steers experimentally transported under a higher space allowance of 1.6 m²/head.

MATERIALS AND METHODS

Animals and transport conditions

Under commercial conditions, 56 steers of the Japanese Black × Holstein breed were transported by truck from a livestock market in Otofuke-cho, Hokkaido (42°N, 143°E) to a fattening farm in Sano-shi, Tochigi prefecture (39°N, 139°E). The physiological reactions of 6 out of 28 steers were measured during two different journeys conducted in the summer (12.2–28.1°C and 17.8–37.2°C). That is to say, the physiological reactions of 12 different steers were measured under commercial conditions. The steers were about 8 months old and weighed 281–356 kg when sold by auction at the market. The steers were transported from several rearing farms to the market. A heavy truck with a single rear axle was used in the commercial transport. The loading space of the truck was covered with a rag-roof measuring 9.3 m in length and 2.2 m in width. The maximum loading weight of the truck was 13,700 kg. The space allowance of the truck was 0.7 m²/head. This space allowance of 0.7 m²/head was found to be common in our related field investigation.

We compared data from steers transported under these commercial conditions to data from 5 steers of the Japanese Black × Holstein breed experimentally transported by truck over the same route from the market to the farm under higher space allowance conditions. The physiological reactions of all 5 of the steers were
measured. These steers, also transported in the summer (21.4\text{ }-\text{ }34.0\text{ }\circ\text{C}), were about 8 months old and weighed 327\text{ }-\text{ }352\text{ kg when sold by auction at the market. They were transported from two rearing farms to the market using a medium-sized truck with a single rear axle. The loading space of the truck was covered with a rag-roof measuring 3.80 m in length and 2.05 m in width. The maximum loading weight of the truck was 4,000 kg. The space allowance of the truck was 1.6 m$^2$/head. The metal floors in the loading spaces of both trucks were covered in sawdust.

Under both space allowance conditions, transportation consisted of driving on expressesways and arterial roads, and parking and boarding a ferry. The total transport distances (time) was 1,020.6 km (25 h): 615.4 km (6.4 h) on expressesways, 163.2 km (3.7 h) on arterial roads and 242.0 km (10.5 h) on a ferry. The cattle had lairage periods with food and water of about 1 h each before boarding the ferry and on the expressesways. More specifically, after the steers were loaded onto a truck at the market in the afternoon, they were transported to the ferry embarkation port for about 3 h. After the first lairage, the truck holding the steers drove onto a ferry and was transported to the mainland for about 10.5 h. After arrival at the ferry disembarkation port in the morning, the truck holding the steers drove for about 7 h, with a second lairage for 1 h on the expressway. The truck arrived at the fattening farm in the evening without any problems or delays. During transport, the cattle in the truck loading space were allowed to move about freely. After being transported under both conditions, the steers were kept in a pen containing about 28 steers in total. They were provided a commercial concentrate diet twice daily at the feeding alley. They were also allowed free access to water troughs and a feeding alley with timothy hay.

**Measurement of the physiological reactions of steers**

We sampled blood from the jugular vein and measured heart rate, rectal temperature and body weight both just after arriving at the fattening farm and 1 wk after transport to the farm. Blood samples were centrifuged at 4,000 rev min$^{-1}$ for 15 min to separate them into serum and plasma. The centrifuged samples were stored at $-80\text{ }\circ\text{C}$ in a freezer, and were analyzed using a cortisol immunoassay kit (COSMO BIO CO., LTD, RSD #DE2700) and were analyzed in a subcontract laboratory (SRL, INC., Tokyo, Japan). Serum was analyzed for total protein concentration, pH, triiodothyronine (T$_3$), triglyceride (TG), non-esterified fatty acids (NEFA), total cholesterol, aspartate aminotransferase (AST), and alanine aminotransferase (ALT). T$_3$ was analyzed using an electro chemiluminescence immunoassay. TG, NEFA and total cholesterol were analyzed using an enzyme method. AST and ALT were analyzed using the Japan Society of Clinical Chemistry (JSCC) consensus method. Plasma was analyzed for cortisol. Lactic acid (ARKRAY INC., LACTATE PRO) and glucose (TERUMO CORPORATION, GR-102) concentrations were determined from whole blood just after sampling. Serum total protein was measured using a refractometer (ATAGO CO., LTD., CAT. No. 2732) and serum pH was measured using a pH meter (HORIBA, LTD., B-212) after centrifugation. After blood sampling, the heart rate of the steers was measured using an electrocardiograph recorder (PARAMA-TECH CO., EP-202) for 24 s. The variation coefficient of the R-R interval ($CV_{R-R}$) was derived from 20 s records of the electrocardiogram. Finally, rectal temperature was measured using a digital thermometer (TERUMO CORPORATION, ET-C203P; accuracy 0.1\text{ }\circ\text{C}).

**Statistical analyses**

The effects of transport conditions (commercial transport vs. experimental transport with a higher-space allowance) and blood sample timing (just after transport vs. 1 wk after transport) on the physiological measurements and liveweight of the steers were analyzed using the two-way repeated measures of ANOVA test. If the effect was significant, a post-hoc test was performed with Tukey's studentized range test. In case the interaction between the effects was significant, two effects were combined and analyzed using one-factor factorial ANOVA and post-hoc tests with the Tukey's studentized range test.

**RESULTS AND DISCUSSION**

Results of all physiological measurements obtained in this study are shown in Table 1. There were significant differences between some of the physiological measurements of the steers transported under standard commercial conditions and those of the steers transported under the higher space allowance, and higher concentrations of those physiological measurements were shown in the commercially transported animals. More specifically, blood glucose concentration (mg/dl) was higher in the commercially transported animals (33.8\text{ }\pm\text{ }12.0) than in those transported under the higher-space allowance (24.4\text{ }\pm\text{ }7.8) (P < 0.01). Blood lactic acid concentration (mmol/L) was higher under commercial conditions (1.84\text{ }\pm\text{ }1.51) than under the higher-space allowance (0.81\text{ }\pm\text{ }0.19) (P < 0.05). Serum ALT activity (IU/L) was also higher under the commercial conditions (22.8\text{ }\pm\text{ }7.8) than under the higher-space allowance (15.1\text{ }\pm\text{ }3.0) (P < 0.01). It has previously been reported that space allowance in a transport vehicle affects glucose concentration and that glucose content in cattle increases with stocking density $^\text{5, 14}$. It is known that transport stress and fatigue cause an increase in the concentrations of glucose $^\text{9, 18}$ and lactate $^\text{17, 19}$. In our previous study $^\text{6}$, long distance transportation led to increases in concentrations of serum AST and ALT. It is known that AST and ALT activities are elevated in cattle with hepatic damage $^\text{20}$. These results indicate that the extent of stress under commercial conditions might be slightly higher than that under the higher space allowance. However, the stress level might not be so high, since we found no differences between the transport conditions in the concentrations of plasma cortisol, serum total protein, total cholesterol, NEFA and TG. There have been some reports that cortisol concentration $^\text{7, 13, 14}$, lactate $^\text{5, 13, 14}$ and heart rate $^\text{3, 14}$ were affected by space allowance in a
Stress of cattle in commercial transport

It has been reported that cortisol concentration and creatine kinase activity increase with stocking density, suggesting increased stress and fatigue with higher stocking density \(^7\), \(^8\). It is likely that these physiological reactions to stress in the initial stage of transportation recovered as the journey proceeded. However, this does not necessarily mean that high level of reaction is shown by all physiological parameters under high stocking densities. For example, Grigor et al. \(^3\) reported that the high space allowance provided an increased opportunity for the calves to move around and to mount each other during transport, which led to higher heart rates. It follows from these facts that the animals' welfare can become poor when their stocking density is either too high or too low \(^7\). The higher space allowance in this study did not cause any negative physiological effects in any of the steers, but further research is needed, especially regarding the initial stage of transport.

In this study, some physiological measurements were significantly higher just after transport than 1 wk after transport. Heart rate was higher just after transport (92.5 ± 15.5 bpm) than 1 wk after transport (72.1 ± 17.0 bpm) (P < 0.01). Blood glucose concentration (37.9 ± 11.6 mg/dL just after transport and 24.2 ± 6.9 mg/dL 1 wk after transport, P < 0.01), serum total protein concentration (8.97 ± 0.46 g/100 mL just after transport and 8.49 ± 0.57 g/100 mL 1 wk after transport, P < 0.05), serum TG concentration (22.2 ± 6.7 mg/dL just after transport and 16.5 ± 2.7 mg/dL 1 wk after transport, P < 0.01), serum total cholesterol concentration (164.8 ± 25.5 mg/dL just after transport and 114.1 ± 29.0 mg/dL 1 wk after transport, P < 0.01) and serum ALT activity (25.3 ± 7.8 IU/L just after transport and 15.8 ± 3.4 IU/L 1 wk after transport, P < 0.01) were higher just after transport than 1 wk after transport. These results indicate that long distance transport, regardless of the transport conditions, caused an increase in some physiological measurements. Then it could be assessed that steers had recovered from these physiological reactions within 1 wk after transport.

The interaction between the effects of transport conditions and blood sample timing was significant for serum T3 concentration (P < 0.05) and serum AST activity (P < 0.01). The interaction between the effects was not significant for the other physiological measurements and liveweight. Serum T3 concentration was higher just after commercial transport than 1 wk after the transport under both space allowance conditions (both P < 0.05) (Table 1). Mitchell et al. \(^8\) have found that handling and transport produce an increase in T3 concentration. Serum AST activity was higher just after commercial transport than both just after transport under the higher-space allowance and 1 wk after transport under both space allowance conditions (all P < 0.01) (Table 1). These results also indicate that there were greater physiological changes in steers transported under the commercial conditions. We reconfirmed that one of the main reasons long distance transport did not cause severe stress on the steers was the higher space allowance, as shown in our previous studies \(^5\), \(^6\).

In our previous studies \(^5\), \(^6\), a higher space allowance that was the same as the one in this study was provided so that all steers had enough space to lie down and could move freely in any direction they wished. The results of the previous studies indicated that the high space allowance could modify the physiological damage to the steers. Under the commercial conditions used in this study, it is likely that the steers could not move freely. Tarrant et al. \(^9\) have found that changes in position decreased as loading density increased. Many studies have also suggested that space allowance or stocking density is important for animal welfare during transport and becomes especially critical at high stocking densities \(^1\), \(^21\). The possible existence of an interaction between stocking density, group size and pen size \(^7\) was suggested as well. In this study, both the number of cattle loaded and the size of the truck’s loading space were different (20.5 m\(^2\) for 28 cattle under the commercial conditions and 7.8 m\(^2\) for 5 steers under the experimental higher space allowance conditions).

In conclusion, comparing some physiological reactions to transportation, at least in the summer, indicated that steers transported under commercial conditions, even if their space allowance was acceptable for welfare standards, might experience slightly stronger stress than those transported under a higher space allowance.

### Table 1 Physiological reactions and liveweight (mean ± SD) of steers just after and 1 wk after transport

<table>
<thead>
<tr>
<th>Measurements</th>
<th>0.7 m(^2)/head</th>
<th>1.6 m(^2)/head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Just after transport</td>
<td>1 wk after transport</td>
<td>Just after transport</td>
</tr>
<tr>
<td>Blood lactate (mmol/L)</td>
<td>1.49 ± 1.08</td>
<td>2.18 ± 1.82</td>
</tr>
<tr>
<td>Blood glucose (mg/dL)</td>
<td>41.3 ± 11.4</td>
<td>26.4 ± 7.2</td>
</tr>
<tr>
<td>Serum pH</td>
<td>7.18 ± 0.79</td>
<td>7.50 ± 0.19</td>
</tr>
<tr>
<td>Serum total protein (g/100 mL)</td>
<td>8.93 ± 0.40</td>
<td>8.41 ± 0.59</td>
</tr>
<tr>
<td>Serum T3 (mg/mL)</td>
<td>2.52 ± 0.28( ^a )</td>
<td>1.68 ± 0.52( ^a )</td>
</tr>
<tr>
<td>Serum TG (mg/dL)</td>
<td>22.9 ± 7.8</td>
<td>16.7 ± 2.9</td>
</tr>
<tr>
<td>Serum NEFA (μEq/L)</td>
<td>793.4 ± 158.2</td>
<td>747.9 ± 546.0</td>
</tr>
<tr>
<td>Serum total cholesterol (mg/dL)</td>
<td>165.5 ± 24.4</td>
<td>115.8 ± 28.6</td>
</tr>
<tr>
<td>Serum AST (IU/L)</td>
<td>104.8 ± 12.6( ^a )</td>
<td>58.9 ± 18.5( ^c )</td>
</tr>
<tr>
<td>Serum ALT (IU/L)</td>
<td>28.5 ± 7.0</td>
<td>17.2 ± 3.1</td>
</tr>
<tr>
<td>Plasma cortisol (ng/mL)</td>
<td>21.6 ± 18.5</td>
<td>33.5 ± 29.9</td>
</tr>
<tr>
<td>Body temperature (°C)</td>
<td>39.3 ± 0.5</td>
<td>39.2 ± 0.4</td>
</tr>
<tr>
<td>Heart rate (BPM)</td>
<td>99.6 ± 15.3</td>
<td>76.1 ± 18.8</td>
</tr>
<tr>
<td>CVPH (%)</td>
<td>6.64 ± 5.24</td>
<td>8.67 ± 10.85</td>
</tr>
<tr>
<td>Liveweight (kg)</td>
<td>293.7 ± 23.7</td>
<td>295.5 ± 18.3</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences (A–B: P < 0.01; a–b: P < 0.05).
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ACKNOWLEDGEMENTS

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REFERENCES

商業的な収容面積で輸送された肥育素牛のストレス

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要 約

本研究の目的は、我が国における商業的に一般的な収容面積（0.7 m²/頭）での輸送における肥育素牛の生理反応を、実験的に設定したより広い収容面積（1.6 m²/頭）での輸送における生理反応と比較することであった。大型の家畜運搬車（最大積載重量13,700 kg）による商業的な2回の輸送において各28頭を夏季に使用し、このうち各6頭、合計12頭について調査した。より広い収容面積での実験的な輸送では、中型の家畜運搬車（4,000 kg）を用いて5頭を調査した。血中グルコース濃度（mg/dL）は、より広い収容面積での輸送（24.4±7.8）に比べて、商業的な輸送（33.8±12.0）において高くなった（P<0.01）。

血中乳酸濃度（mmol/L）も、より広い収容面積での輸送（0.81±0.19）に比べ、商業的な輸送（1.84±1.51）で高くなった（P<0.05）。血清アラニンアミノトランスフェラーゼ（ALT）活性（IU/L）も同様に、より広い収容面積での輸送（15.1±3.0）より、商業的な輸送（22.8±7.8）において高くなった（P<0.01）。商業的に輸送された直後に測定された血清トリヨードサイロニン濃度は、両方の収容面積で輸送された1週間後に測定された値と比べ有意に高かった（ともにP<0.05）。また、商業的輸送の直後に測定された血清アスパラギン酸アミノトランスフェラーゼ（AST）活性は、より広い収容面積で輸送された直後や両方の収容面積で輸送された1週間後に比べて有意に高かった（すべてP<0.01）。以上のことから、我が国の商業的輸送で一般的な収容面積では、たとえそれが福祉基準を満たしていたとしても、夏季においてはより広い収容面積での輸送に比べて、牛に負荷されているストレスが幾分強くなっていることが示唆された。

キーワード：肉牛、輸送、収容面積、ストレス

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