Insulin has been well known to be involved in the regulation of nutrient metabolism in non-ruminants and ruminants. The ability of insulin to stimulate glucose uptake and protein anabolism in the tissues may influence feed efficiency in fattening steers. Concentrations of insulin in blood are known to increase with increasing age in cattle and high insulin secreting ability was associated with age-related fatness. Several studies also showed the age-related decrease in the insulin-stimulated glucose uptake in muscle from rat in vitro. These results suggest that insulin action and secretion in fattening steers might change with age and the progress of fattening. However, the available information on this matter is limited in fattening steers.

The present study was designed to evaluate glucose-induced insulin secretion and insulin-induced glucose uptake at various fattening stages in steers using the glucose clamp techniques.

Materials and Methods

Animal: Three crossbred steers at the first stage of fattening (7±0 mo. weighing 235-260 kg), 3 at the middle stage (15±0.5 mo. weighing 354-394 kg) and 4 at the final stage (25±3 mo. weighing 604-685 kg) were used in the present experiment. The animals were kept in the free barn during the whole experimental period. They were fed the diet consisted of corn and brewer’s grain according to their body weights and grass hay ad libitum.

Glucose clamp techniques: The hyperglycemic and euglycemic clamp techniques were used to evaluate insulin secretion and glucose uptake on fattening steers. The aim of the glucose clamp experiment was to maintain plasma glucose levels in a hyperglycemic and euglycemic steady state for 120 min. Two catheters were inserted into bilateral jugular veins: one was used for blood sampling, the other was for glucose and insulin infusion. The hyperglycemic clamp technique was carried out 3 hrs after inserting catheters. Then one day later, the euglycemic clamp technique was conducted. In the hyperglycemic clamp experiment, blood glucose levels were raised to the desired hyperglycemia (50 mg/100 ml higher...
than the basal blood glucose) and were main- 
tained at that plateau by infusing 34.8% 
(W/V) glucose solution. In the euglycemic 
clamp experiment, crystalline porcine insulin 
(Insulin Novo Actrapid MC, Novo Industri 
Denmark) was diluted with isotonic saline. 
Simultaneously with the continuous infusion of 
insulin at the rate of 6 mU/kg/min, glucose 
was infused to maintain the euglycemic plateau 
(basal levels). Blood glucose levels were 
measured at 5 min intervals throughout the 
experiment, and the glucose infusion rate was 
empirically determined. Glucose and insulin 
were infused with multichannel peristaltic 
pump (Perista Biominipump AC-2120, Atto 
Co. Ltd., Japan). The steady state glucose 
infusion rate (SSGIR) was estimated by mean 
values of glucose infused in 60 min that the 
hyperglycemia and the euglycemia were main- 
tained at the latter half (60-120 min) of the 
2 h-glucose clamp experiments.

Analytical methods: Blood samples (5 ml) 
were taken in heparinized tubes. Samples were 
centrifuged at 3,000 rpm for 10 min. Blood 
and plasma glucose were measured by the 
glucose analyzer (Glucose Analyzer GLU-1, 
Erma Optical Works Ltd., Japan) using the 
glucose oxidase method. The insulin level of 
plasma was measured by double binding radi- 
immuneassay (Radioimmuneassay Kit, Eiken 
Chemical Co. Ltd., Japan) of the plasma sam- 
ples. All parameters were expressed as a mean 
value ± standard error. The significant dif- 
f erences among fattening stages were analyzed 
by one-way analysis of variance and Tukey’s 
multiple range test.

Results and Discussion

Hyperglycemic clamp technique experiment

The mean basal plasma glucose concentra- 
tions before the glucose clamp experiment were 
90.6, 88.4 and 78.2 mg/100 ml for the first, 
middle and final fattening stage, respectively 
(Table 1). The mean basal insulin levels were 
54.3, 42.8 and 40.4 µU/ml, respectively.

In every fattening stage a stable hypergly- 
cemic condition could be achieved 50 min after 
the beginning of the experiment, and was main- 

Table 1. Plasma glucose and insulin concentrations, and steady state glucose infusion rate 
(SSGIR) and mean plasma insulin increment (MPII) during hyperglycemic and euglycemic clamp experiment

<table>
<thead>
<tr>
<th>Fattening stage</th>
<th>First</th>
<th>Middle</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hyperglycemic clamp experiment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basal plasma glucose (mg/dl)</td>
<td>90.6 ± 3.7a</td>
<td>88.4 ± 2.9a</td>
<td>78.2 ± 2.1b</td>
</tr>
<tr>
<td>Basal plasma insulin (µU/ml)</td>
<td>54.3±10.7</td>
<td>42.8±9.6</td>
<td>40.4±3.3</td>
</tr>
<tr>
<td>SSGIR (mg/kg · min)-1</td>
<td>2.67 ± 0.45</td>
<td>2.30 ± 0.58</td>
<td>2.17 ± 0.32</td>
</tr>
<tr>
<td>MPII (µU/ml)</td>
<td>217.6±69.3a</td>
<td>112.8±23.4b</td>
<td>155.2±39.4b</td>
</tr>
<tr>
<td>Secretory insulin response (MPII/SSGIR)-1</td>
<td>98.8±38.2</td>
<td>66.6±27.8</td>
<td>77.6±19.7</td>
</tr>
<tr>
<td><strong>Euglycemic clamp experiment:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basal plasma glucose (mg/dl)</td>
<td>84.8±1.4</td>
<td>84.8±4.0</td>
<td>84.3±4.5</td>
</tr>
<tr>
<td>Basal plasma insulin (µU/ml)</td>
<td>14.4±1.2</td>
<td>30.4±9.1</td>
<td>31.8±5.1</td>
</tr>
<tr>
<td>SSGIR (mg/kg · min)-1</td>
<td>3.08±0.19ab</td>
<td>3.44±0.19a</td>
<td>2.61±0.08b</td>
</tr>
<tr>
<td>MPII (µU/ml)</td>
<td>815±42c</td>
<td>1059±122b</td>
<td>1952±86a</td>
</tr>
<tr>
<td>Insulin sensitivity (SSGIR/1MPII·100)-1</td>
<td>0.38±0.04a</td>
<td>0.32±0.06b</td>
<td>0.18±0.03b</td>
</tr>
</tbody>
</table>

1) See text
2) Result at 60 to 120 minutes after the beginning of the glucose clamp experiment.

a, b, c: Significant difference was observed between different letters (P<0.05).
Insulin Secretion and Glucose
tained during the latter experimental period. The mean plasma glucose concentrations in the steady-state during the period of 60 to 120 min after the beginning of experiment were 150.1, 153.9 and 139.6 mg/100 ml for the first, middle and final fattening stage respectively. The steady state glucose infusion rates were 2.67, 2.30 and 2.17 mg/kg.min, respectively. Though there were no significant differences in SSGIR among fattening stages, the values tended to decrease with the progress of fattening. The mean plasma insulin increment (MPII) deducted the basal level of plasma insulin from its mean level in the steady state was lower (P<0.05) at the middle and final fattening stage than the first fattening stage. The secretary insulin response (MPII/SSGIR) was apt to be high values at the first fattening stage, though there was no significant difference among fattening stages.

These results suggest that glucose-induced insulin secretion tended to be depressed with the progress of fattening in steers.

Euglycemic clamp technique experiment

While insulin was continuously infused at the rate of 6 mU/kg . min, glucose was also infused in order to maintain the desired basal blood glucose level. A stable euglycemic condition could be achieved 50 min after the beginning of experiment and was maintained throughout the latter experiment period. The steady state glucose infusion rate during the period of 60 to 120 min in the experiment was lower (P<0.05) in the final fattening stage than the middle fattening stage (Table 1). The mean plasma insulin levels in the steady state were 815, 1059 and 1552 µU/ml for the first, middle and final fattening stages, respectively. Insulin sensitivity (SSGIR/MPII × 100) at the final fattening stage was significantly lower (P<0.05) than those of the other stages.

The insulin infusion rate in this experiment was determined based on the animal's body weight as described above. Consequently, the heavier body weight of cattle was, the more insulin was infused. In spite of that, the glucose infusion rate to maintain the basal glucose levels was decreasing at the final fattening stage. This result indicates that insulin-induced glucose uptake was markedly depressed with progress of fattening stage.

References