The effect of glucagon-like peptide 2 injection on performance, small intestinal morphology, and nutrient transporter expression of stressed broiler chickens


*The State Key Laboratory of Animal Nutrition, College of Animal Science and Technology, China Agricultural University, Beijing 100193, P. R. China; †Henan Key Laboratory for Animal Immunology, Henan Academy of Agricultural Science, Zhengzhou 450002, P. R. China

ABSTRACT An experiment was conducted to determine the effect of injecting glucagon-like peptide 2 (GLP-2) on the small intestinal weight, morphology, and nutrient transporter expression in pharmacologically stressed broiler chickens. A total of 144 seven-day-old birds were fed either a basal diet (CTRL) or a basal diet plus 30 mg of corticosterone (CORT)/kg of diet for a total of 14 d. Half of the birds from each group were injected daily with GLP-2 (6.7 nmol/kg of BW) or saline for 14 d. The average final BW, ADG, ADFI, and the ratio of feed intake to weight gain (F:G) was recorded over 21 d for the 4 groups of 36 birds, namely CTRL + saline, CTRL + GLP-2, CORT + saline, and CORT + GLP-2. In addition, the absolute and relative small intestinal weight, villus height (VH), and crypt depth (CD) of the duodenum and jejunum, as well as the abundance of sodium and glucose co-transporter 1 (SGLT-1), vitamin D-dependent calcium-binding protein-28,000 molecular weight (CaBP-D28k), peptide transporter 1 (PepT-1) mRNA in the duodenum and of liver fatty acid-binding protein (L-FABP) mRNA, RNA, and total protein content in small intestine were also determined. The results showed that CORT administration significantly lowered average final BW, ADG, ADFI, absolute small intestinal weight, VH, and CD of duodenum and jejunum (P < 0.05) while increasing the relative small intestinal weight, F:G, relative abundance of SGLT-1, CaBP-D28k, PepT-1, and L-FABP mRNA (P < 0.05). Glucagon-like peptide 2 injection increased the average final BW, ADG, VH, and CD in duodenum and jejunum and relative abundance of SGLT-1, CaBP-D28k, and PepT1 mRNA of broiler chickens, respectively (P < 0.05), and decreased F:G (P < 0.05). In birds fed basal diet plus CORT, injecting GLP-2 decreased F:G (P < 0.05); increased VH and CD of duodenum and CD of jejunum; and increased relative abundance of SGLT-1, CaBP-D28k, PepT-1, and L-FABP mRNA, RNA, and total protein content in small intestine compared with the injection of saline (P < 0.05). In birds fed the basal diet, GLP-2 injection decreased F:G (P < 0.05) and increased final BW, ADG, small bowel weight, CD of jejunum, and relative abundance of CaBP-D28k and PepT-1 mRNA compared with injecting saline (P < 0.05). In conclusion, GLP-2 injection reversed the negative effect of stress on the weight and morphology and the absorptive function of small bowel of broiler chickens. Glucagon-like peptide 2 injection also had a positive effect on the growth performance of healthy broiler chickens.

Key word: broiler chicken, corticosterone, stress, glucagon-like peptide 2, performance

INTRODUCTION

The small intestine, a metabolically active tissue (Spratt et al., 1990), is critical for animal development and growth (Ziegler et al., 2003) and in chickens is responsible for the growth potential after hatching (Uni et al., 1998). However, many factors can affect intestinal development (Dibner et al., 1996; Gal-Garber et al., 2000; Yamauchi and Tarachai, 2000; Howard et al., 2004; Pinheiro et al., 2004; Thompson and Applegate, 2006; Hu and Guo, 2008). Several reports indicated that stress delayed intestinal growth and impaired intestinal morphology and function (Mitchell and Carlisle, 1992; Hansen et al., 2004). Our previous investigations in broiler chickens found that pharmacological stress in-
duced by corticosterone exposure decreased the proliferation of small intestinal epithelial cells and resulted in a decline of villus height (VH) and crypt depth (CD), which in turn decreased the small intestinal absorptive function (Hu and Guo, 2008).

Glucagon-like peptide 2 (GLP-2) is a member of a family of peptides derived from the expression of a pro-glucagon gene and is secreted into circulation by enteroendocrine L cells in the small and large intestine (Burrin et al., 2003). This peptide exerts multiple effects on the gastrointestinal tract to regulate digestion and absorption and to modulate food intake by providing a feedback signal to the brain (Brubaker, 2006). Studies have shown that GLP-2 had specific tropic effects on the intestine of humans and rodents and other mammals (Burrin et al., 2001), especially after surgical resection (Martin et al., 2005; Sigalet et al., 2006) or injury from chemotherapy (Tavakkolizadeh et al., 2000). Glucagon-like peptide 2 exposure also has positive effects on the intestine during total parenteral nutrition (TPN; Burrin et al., 2005; Liu et al., 2006).

There is little documentation on the effects of GLP-2 exposure in avian species. Shousha and coworkers reported that neither i.p. nor intracerebroventricular administration of GLP-2 had any effect on food intake, body temperature, and gross locomotor activity of Japanese quail (Shousha et al., 2007). However, there are no reports about the effects of GLP-2 on the small bowel weight, morphology, nor on the expression of nutrient transporter genes in the intestine of broiler chickens. According to the reported effects of GLP-2 on intestinal morphology and function of other species, we hypothesize that GLP-2 injection may improve the small intestinal weight and morphology and change the expression of the nutrient transporter gene in the small intestine of stressed broiler chickens. To test our hypothesis, the effect of GLP-2 injection on the small intestinal weight, morphology, and expression of nutrient transporter mRNA in chickens exposed to corticosteroid has been evaluated.

**MATeRIAls AND METHODS**

**Birds, Housing, and Experimental Design**

One hundred forty-four 7-d-old Arbor Acres chickens, in 24 equal pens (6 birds/pen), were divided into 4 equal groups of 6 pens and pen as a replicate unit. The basal diet was based on corn-soybean meal, containing the following: ME, 2.90 Mcal/kg; CP, 21.5%; calcium, 1.00%; and available P, 0.45%. All chickens had free access to feed and water during the experiment. Twenty-four hours of artificial light was supplied. The experimental period was 14 d, from 8 to 21 d of age.

Our experimental design was as a 2 × 2 factorial with 2 between-subject factors. The birds were fed 1 of 2 diets, namely basal diet (CTRL) or basal diet plus 30 mg of corticosterone (CORT)/kg. At the same time, human GLP-2 trifluoroacetate salt (G8166, Sigma, St. Louis, MO) was given by i.p. injection at 0800 h to half of the birds of CTRL and CORT, and 0.9% saline was similarly injected as a vehicle control to the other half. The GLP-2 dosage was 6.7 nmol/kg of BW (about 26.3 µg/kg of BW) dissolved in 200 µL of 0.9% saline. Thus, there were 4 groups, namely CTRL + saline, CTRL + GLP-2, CORT + saline, and CORT + GLP-2.

**Sampling and Analysis**

The production parameters, including average initial BW, average final BW, ADFI, ADG, and the ratio of feed intake to weight gain (F:G) of each group were calculated by pen continuously during the 14 d. At 21 d of age, 6 birds per group (1 bird per pen) were killed and the entire small intestine was removed, flushed with ice-cold normal saline, and after blotting with filter paper the absolute weight was recorded. The relative small intestinal weight was expressed as the absolute small intestine weight multiplied by 100, then divided by the BW.

A further 6 birds from each group (1 bird per pen) were slaughtered and about 1 cm of duodenum and jejunum were removed, washed with 0.1% diethylpyrocarbonate water, packed with sterile and RNase-free silver paper, and after rapid freezing in liquid nitrogen stored at −80°C for the later analyses of sodium and glucose co-transporter 1 (SGLT-1), vitamin D-dependent calcium-binding protein-28,000 molecular weight (CaBP-D28k), peptide transporter 1 (PepT-1) mRNA from the duodenum, and liver fatty acid-binding protein (L-FABP) mRNA from the jejunum. About 5 g of jejunum was prepared for the determination of the total DNA and RNA content. The DNA and RNA were extracted and quantified using a kit (Tiangen, Beijing, China; Nicolaides and Stoeckert, 1990; Raha et al., 1990) and concentrations were expressed as milligrams per gram of mucosa. One gram of jejunum was homogenized with 9 mL of distilled water, and the supernatant obtained after centrifugation at 12,000 × g for 10 min at 4°C was taken for the estimation of total protein employing a kit (Jiancheng, Nanjing, China; Bradford, 1976); total protein concentration is given as milligrams of protein per gram of mucosa. Samples of about 1 cm of duodenum and jejunum were removed and kept in 4% formalin-buffered saline solution before processing for paraffin embedding. Histological examination was carried out according to the method described by Uni et al. (2001).

The relative abundance of transporter mRNA was assayed by quantitative real-time PCR. The primer sequences for the different nutrient transporter genes and the housekeeping gene β-actin are shown in Table 1. The frozen duodenum and jejunum were ground in sterile mortars, and the powders were used for total RNA extraction employing a kit (Gibco, Grand Island, NY; Chomczynski and Sacchi, 1987; Ausubel et al., 1990; Chomczynski, 1993; Simms et al., 1993; Willfinger et al., 1997; Fox, 1998). The integrity of the RNA was
verified and real-time PCR was carried out as previously described (Hu et al., 2010).

**Statistical Analysis**

Data were analyzed by ANOVA with GLP-2 injection and CORT diet as main effects and for interactions using the GLM procedure (SPSS13.0 software for Windows, SPSS Inc., Chicago, IL). One-way ANOVA was also employed for analyzing the differences between the 4 groups. Differences between means were considered to be statistically significant at \( P < 0.05 \).

**RESULTS**

The average initial BW, average final BW, ADG, and ADFI of broiler chickens are shown in Table 2. The average initial BW did not differ significantly between the 4 groups. Broiler chickens fed on the CORT diet had a lower final BW, ADG, and ADFI but an increased F:G than those on the CTRL diet (\( P < 0.05 \)). Birds injected with GLP-2 had increased final BW, ADG, and decreased F:G than those injected with saline (\( P < 0.05 \)). Injection of GLP-2 significantly increased the final BW, ADG, and feed conversion ratio in birds on the control diet (\( P < 0.05 \)), although changes in the ADFI were slight and insignificant. The birds on the CORT diet showed similar trends when injected with GLP-2, but the average changes were not significant, apart from F:G, which did show a significant decrease (\( P < 0.05 \)).

As shown in Table 3, duodenal and jejunal VH and CD of birds fed the CORT diet were lower than those of the CTRL group (\( P < 0.05 \)). Duodenal and jejunal VH and CD of birds injected with GLP-2 were higher than those injected with saline (\( P < 0.05 \)). In birds on the control diet, injection of GLP-2 increased VH and CD in both the duodenum and jejunum and the same effect was seen in the birds on the CORT diet.

Both the inclusion of corticosterone in the diet and the injection of GLP-2 increased the relative abundance of the mRNA for SGLT-1, CaBP-D28k, PepT-1, and L-FABP (Table 4). The effects appeared to be additive, and thus the birds on the CORT diet and receiving GLP-2 gave the highest abundance for all of these mRNA.

As shown in Table 5, broiler chickens fed on the CORT diet had a lower absolute small intestinal weight but...
an increased relative small intestinal weight and RNA content than those on the CTRL diet ($P < 0.05$). Birds also showed an increased trend of DNA content when treated with CORT. Birds injected with GLP-2 had increased absolute small bowel weight ($P = 0.111$), RNA content ($P = 0.074$), and protein content ($P = 0.102$) than those injected with saline. Injection of GLP-2 significantly increased the absolute small bowel weight in birds on the control diet, whereas increases in the DNA and RNA content were slight and insignificant. The birds on the CORT diet had increased RNA and protein content in jejunum when injected with GLP-2 ($P < 0.05$) and also showed similar trends of the absolute small bowel weight and the DNA content, whereas the relative small bowel weight showed contrary trends.

**DISCUSSION**

In the present study, corticosterone administration in the diet was found to decrease the daily weight gain and the feed conversion ratio of growing broiler chickens, and this indicates that the steroid-containing diet induces a stress response, which is in agreement with that of other studies (Eid et al., 2003; Malheiros et al., 2003; Lin et al., 2004; Virden et al., 2007), leading to the lowered final BW. Dietary restriction leads to a decrease in intestinal protein synthesis with concomitant lowering of intestinal weight (Dudley et al., 1998). In the present study, induced stress decreased feed intake and lowered the small intestinal weight of broiler chickens. This result is in accordance with the result of previous research (Mitchell and Carlisle, 1992). The small intestine is metabolically active and uses the nutrients before other tissues (Spratt et al., 1990). Moreover, CORT administration enhances proteolysis for the gluconeogenesis of broiler chickens (Siegel and Van Kampen, 1984; Donker and Beuving, 1989; Lin et al., 2007). The increased small bowel relative weight of CORT-treated birds is likely due to the suppression of muscle and skeletal growth, whereas gut growth was preserved. Sigalet et al. (2006) found that GLP-2 injection enhanced the absorptive function of the small bowel, and this indicates that the steroid-containing diet induces a stress response, which is in agreement with that of other studies (Eid et al., 2003; Malheiros et al., 2003; Lin et al., 2004; Virden et al., 2007), leading to the lowered final BW. Dietary restriction leads to a decrease in intestinal protein synthesis with concomitant lowering of intestinal weight (Dudley et al., 1998).

### Table 3. Effect of glucagon-like peptide 2 (GLP-2) injection on small intestinal mucosal structure of CTRL and CORT-stressed broiler chickens

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Duodenum</th>
<th>Jejunum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Villus height (µm)</td>
<td>Crypt depth (µm)</td>
</tr>
<tr>
<td>CTRL + saline</td>
<td>983.85ab</td>
<td>110.86b</td>
</tr>
<tr>
<td>CTRL + GLP-2</td>
<td>1,078.25b</td>
<td>125.83b</td>
</tr>
<tr>
<td>CORT + saline</td>
<td>879.59a</td>
<td>92.82a</td>
</tr>
<tr>
<td>CORT + GLP-2</td>
<td>1,008.31b</td>
<td>114.54b</td>
</tr>
<tr>
<td>SEM</td>
<td>19.61</td>
<td>2.51</td>
</tr>
</tbody>
</table>

Main effect

| Diet | 0.048 | 0.014 | 0.006 | 0.000 |
| Injection | 0.016 | 0.004 | 0.001 | 0.000 |
| Diet × injection | 0.670 | 0.514 | 0.225 | 0.011 |

**P-value**

$^a$ For within-column comparisons, different superscripts differ significantly ($P < 0.05$).

$n = 6$ per group.

CTRL = basal diet; CORT = basal diet plus 30 mg of corticosterone.

### Table 4. Effect of glucagon-like peptide 2 (GLP-2) injection on the relative abundance of nutrient transporter mRNA and extractable total protein in small intestine of CTRL and CORT-stressed broiler chickens

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Relative abundance of nutrient transporter mRNA</th>
<th>Extractable total protein</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SGLT-1</td>
<td>CaBP-D28k</td>
</tr>
<tr>
<td>CTRL + saline</td>
<td>5.29a</td>
<td>4.11b</td>
</tr>
<tr>
<td>CTRL + GLP-2</td>
<td>9.17a</td>
<td>9.20b</td>
</tr>
<tr>
<td>CORT + saline</td>
<td>8.28a</td>
<td>8.51b</td>
</tr>
<tr>
<td>CORT + GLP-2</td>
<td>19.33b</td>
<td>15.78c</td>
</tr>
<tr>
<td>SEM</td>
<td>0.90</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Main effect

| Diet | 0.004 | 0.002 | 0.000 | 0.001 |
| Injection | 0.002 | 0.001 | 0.000 | 0.011 |
| Diet × injection | 0.072 | 0.440 | 0.738 | 0.518 |

**P-value**

$^a$ For within-column comparisons, different superscripts differ significantly ($P < 0.05$).

$n = 6$ per group.

CTRL = basal diet; CORT = basal diet plus 30 mg of corticosterone.

SGLT-1 = sodium and glucose co-transporter 1; PepT-1 = peptide transporter 1; CaBP-D28k = vitamin D-dependent calcium-binding protein-28.000 m; L-FABP = liver fatty acid-binding protein.
bowl of mice; therefore, in the present study, the fact that chickens injected with GLP-2 had an increased ADG and final BW was expected. In the present study, GLP-2 injection had an insignificant effect on the ADFI of birds fed the basal diet, which was in agreement with a previous study on Japanese quail (Shousha et al., 2007). Furthermore, GLP-2 injection increased feed conversion ratio, which led to increased ADG and subsequently increased final BW of bird fed the basal diet.

The birds treated with CORT and injected with GLP-2 had a lowered F:G, suggesting a more efficient usage of feed intake. Previous researchers also found that GLP-2 injection enhanced the small bowel’s digestive and absorptive functions in stressed animals (Liu et al., 2006; Sigalet et al., 2006). However, CORT administration enhances proteolysis. The slight and insignificant increase in ADG and final BW in birds treated with CORT and GLP-2 injection in the present study may be a compromise between CORT and GLP-2.

When feed intake of chickens declines or is restricted, VH and CD of small intestinal epithelium are found to decrease (Mitchell and Carlisle, 1992; Yamauchi et al., 1996; Hu and Guo, 2008). Because stress delays the intestinal epithelial cell proliferation (Hu and Guo, 2008), decreased duodenal and jejunal VH and CP would be expected. This effect was seen, particularly in the jejunum (Table 3). Glucagon-like peptide 2 injection induced an increase of VH and CD irrespective of the diet, but it was only significant in the jejunum. This result is consistent with previous reports (Hartmann et al., 2000; Ramsanahie et al., 2004). Hartmann et al. (2000) found that, even under normal conditions, GLP-2 administration to rats, alone or with dipeptidyl peptidase IV (1 enzyme hydrolyzes GLP-2) inhibitor, increased the villus area, height, and CD of mucosa of small intestine. Ramsanahie et al. (2004) further showed that normal rats treated with GLP-2 had an increased proliferation index in jejunal epithelial cells, with a subsequent increase in VH and CD. In the present study, birds on the CORT diet showed increased VH and CD after GLP-2 injections compared with saline controls in accord with previous reports (Chance et al., 1997; Tavakkolizadeh et al., 2000; Burrin et al., 2005). Villus surface area is proportional to VH (Mitchell and Carlisle, 1992) and the expansion of surface area that occurs with villus growth has been used to explain the increased absorptive capacity (Yamauchi et al., 1996). Furthermore, the increase of villus surface area is considered a more important factor than the increase of small intestinal digestive and absorptive capacity in influencing the growth of broiler chickens (Uni et al., 1996).

The movement of the nutrient products of digestion into the enterocytes requires numerous transporters, which are critical for their absorption within the intestine. The mRNA abundance of all of the transporters studied increased in the stressed birds. Sodium-glucose co-transporter 1 (SGLT-1) is the key factor affecting glucose absorption by the intestine (Garriga et al., 2000; Kellett, 2001; Wood and Frayhum, 2003). It is expressed mainly in the duodenum (Garriga et al., 2000). Corticosterone administration gave a significant increase of SGLT-1 mRNA abundance in the present study. Gal-Garber et al. (2000) found that the expression of SGLT-1 mRNA was enhanced significantly in the small intestine of starved chickens. Corticosterone administration decreases feed intake (Malheiros et al., 2003; Lin et al., 2004; Hu and Guo, 2008), so the tendency to increase SGLT-1 mRNA may reflect the lowered nutrient level in the small intestine. Glucagon-like peptide 2 injection in such birds produced a significant increase in SGLT-1 mRNA abundance, greater than that seen under the control diet. In unstressed rats, GLP-2 injection did not produce an increase in SGLT-1 in the jejunum (Ramsanahie et al., 2004). Sigalet et al. (2006) reported that GLP-2 injection has no effect on SGLT-1 protein expression in jejunal mucosa of a TPN rat, but GLP-2 infusion upregulates the SGLT-1 abundance in the jejunum mucosa of a normal rat (Cheeseman, 1997).

Calcium is mainly absorbed in the duodenum and jejunum by the transporter calcium-binding protein

**Table 5.** Effect of glucagon-like peptide 2 (GLP-2) injection on the absolute and relative small intestinal weight and total DNA, RNA, and extractable protein (total protein, TP) in jejunum of CTRL and CORT-stressed broiler chickens

<table>
<thead>
<tr>
<th>Treatment2</th>
<th>Small bowel absolute weight (g)</th>
<th>Small bowel relative weight</th>
<th>DNA (mg/g of jejunum)</th>
<th>RNA (mg/g of jejunum)</th>
<th>TP (mg/g of jejunum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTRL + saline</td>
<td>24.41a</td>
<td>4.16a</td>
<td>0.62b</td>
<td>0.20a</td>
<td>27.57ab</td>
</tr>
<tr>
<td>CTRL + GLP-2</td>
<td>27.61b</td>
<td>3.91a</td>
<td>0.67ab</td>
<td>0.32b</td>
<td>22.74b</td>
</tr>
<tr>
<td>CORT + saline</td>
<td>19.94b</td>
<td>5.88b</td>
<td>0.75ab</td>
<td>0.24a</td>
<td>23.70a</td>
</tr>
<tr>
<td>CORT + GLP-2</td>
<td>20.39b</td>
<td>6.10b</td>
<td>0.82b</td>
<td>0.32b</td>
<td>29.74b</td>
</tr>
<tr>
<td>SEM</td>
<td>0.40</td>
<td>0.10</td>
<td>0.04</td>
<td>0.02</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Main effect

| Diet | 0.000 | 0.000 | 0.070 | 0.024 | 0.745 |
| Injection | 0.111 | 0.903 | 0.401 | 0.074 | 0.102 |
| Diet × injection | 0.042 | 0.250 | 0.901 | 0.301 | 0.045 |

P-value

ɑ For within-column comparisons, different superscripts differ significantly (P < 0.05).

1 n = 6 per group.

2CTRL = basal diet; CORT = basal diet plus 30 mg of corticosterone.
Intestinal fatty acid-binding protein (L-FABP) is mainly expressed in the intestinal epithelium (Banaszak et al., 1994), which is believed to participate in the uptake of long-chain fatty acids from the digesta into enterocytes (Prows et al., 1995). Stress increases the abundance of CaBP-D28k and L-FABP mRNA and these increased further under GLP-2 administration in both control and stressed birds. Stress decreased the absorptive area; the increased abundance of CaBP-D28k and L-FABP mRNA may be a compensation for absorption of intestine. Short-bowel patients treated by GLP-2 improved the calcium absorption (Haderslev et al., 2002); therefore, in the present study, the upregulated expression of the CaBP-D28k and L-FABP gene in both control and stressed birds may be related to an improved intestinal absorptive function. However, treatment of rats with GLP-2 had no effect on the small intestinal morphology and uptake of fatty acid (Iordache et al., 2005), which is in disagreement with the present study. The difference may come from the species (broiler chick vs. rat) and GLP-2 dose (26.3 vs. 100 µg/kg of BW).

Peptide transporter 1 (PepT-1) is responsible for the transportation of di- and tripeptides arising from digestion of dietary protein (Daniel, 2004). Stress was found to enhance the expression of PepT-1, consistent with previous reports (Ogihara et al., 1999; Ihara et al., 2000; Naruhishi et al., 2002; Barbot et al., 2003). Ogihara et al. (1999) showed that starvation increased PepT-1 abundance, whereas dietary administration of amino acid reduced it. Thus, the observed increase in PepT-1 mRNA abundance may again reflect the decrease in feed intake. The GLP-2 treatment increased PepT-1 mRNA abundance in stressed and control birds (Table 4). This result is in contrast to that reported by Howard et al. (2004), who found that GLP-2 infusion reversed the increased PepT-1 expression induced by TPN in rats. Glucagon-like peptide 2 has been shown to increase VH and nutrient transporter expression in the small intestine, which could produce an enhanced absorptive function. This explain its effect on improving the growth performance of broiler chickens.

Corticosterone increased the DNA and RNA concentration in small intestinal mucosa of broiler chickens, which is in agreement with the increased abundance of nutrient transporter mRNA caused by CORT administration in the present study. Corticosterone administration impedes protein synthesis and enhances protein degradation (Lin et al., 2007), which may lead to decreased extractable protein in the small intestine and the absolute small bowel weight. In the present study, GLP-2 increased the DNA, RNA, and protein concentration in the small intestine of broiler chickens in CORT treatment as well as in the CTRL treatment. Previous studies indicate that GLP-2 is a key mediator of intestinal adaptive growth in rats, pigs, and humans (Chance et al., 1997; Haderslev et al., 2002; Burrin et al., 2005; Liu et al., 2006; Sigalet et al., 2006). Glucagon-like peptide 2 administration stimulates small intestinal mucosal growth in association with reduced apoptosis and proteolysis and increased intestinal blood flow, protein synthesis, and enterocyte proliferation in TPN-fed piglets (Burrin et al., 2000, 2005).

In conclusion, we suggest that pharmacological stress decreases small intestinal weight, VH, and CD of duodenum and jejunum and increased nutrient transporter mRNA abundance in the small intestine of broiler chickens, but because stress also reduces feed intake, these effects may relate more to the reduction in available nutrients. Glucagon-like peptide 2 injection reversed the negative effect of pharmacological stress, while not influencing feed intake, on the growth performance of stressed broiler chickens and this increased efficiency reflects a positive effect of GLP-2 on small intestinal weight, morphology, and a further increase in nutrient transporter mRNA abundance.

REFERENCES


