ABSTRACT: Four experiments were conducted to determine the effects of supplemental Trp on meat quality, plasma and salivary cortisol, and plasma lactate. Experiment 1 was a preliminary study to measure plasma cortisol concentrations in 4 barrows (50 kg of BW) that were snared for 30 s at time 0 min. Pigs were bled at −60, −30, −15, 2, 4, 6, 8, 10, 15, 20, 25, 30, 45, 60, 90, and 120 min. Plasma cortisol was near maximum 10 min after the pigs were snared. In Exp. 2, 20 barrows (50 kg of BW) were allotted to a basal corn-soybean meal diet or the basal diet with 0.5% supplemental L-Trp for 5 d. After the 5-d feeding period, pigs were snared for 30 s and bled at −10, 0, 2, 4, 6, 8, 10, 15, 20, 25, 30, 45, 60, 90, and 120 min after snaring. Pigs fed the diet with supplemental Trp had a lower ($P < 0.01$) mean plasma cortisol than pigs fed the basal diet. Plasma lactate also was decreased ($P < 0.07$) by supplemental Trp. In Exp. 3, the same pigs and treatments were used as in Exp. 2, but 5 pigs were snared and 15 pigs adjacent to those being snared were bled to determine if pigs are stressed when they are adjacent to pigs being snared. For pigs adjacent to snared pigs, the area under the curve ($P < 0.01$) and mean for plasma cortisol was lower ($P < 0.01$) in pigs fed Trp relative to those fed the basal diet. In Exp. 4, 90 barrows (initial BW of 106 kg) were allotted to 6 treatments in a $3 \times 2$ factorial arrangement. Three diets with Trp (basal diet, basal supplemented with 0.5% Trp for 5 d, or pigs fed the basal diet with a 0.1 g/kg of BW Trp bolus given 2 h before slaughter) were combined with 2 handling methods (minimal and normal handling). Dressing percent, 24-h pH, and 24-h temperature were reduced in the minimally handled pigs ($P < 0.10$) compared with the normally handled pigs. Pigs fed Trp in the diet relative to those fed the basal diet had increased 45-min temperature, Commission Internationale de l’Eclairage (CIE) redness ($a^*$) and yellowness ($b^*$) values, and drip and total losses ($P < 0.10$). Tryptophan in bolus form decreased 45-min pH in the minimally handled pigs but increased 45-min pH in the normally handled pigs (handling $\times$ Trp bolus interaction, $P = 0.08$). Tryptophan in the diet increased CIE lightness ($L^*$) in minimally handled pigs but decreased CIE $L^*$ in the normally handled pigs (handling $\times$ Trp diet interaction, $P = 0.06$). No other response variables were affected by handling method or Trp. Results indicate that Trp decreases plasma cortisol but has no positive effect on meat quality.

Key words: cortisol, meat quality, swine, tryptophan

INTRODUCTION

Stressing pigs at weaning, mixing, and transport can play an important role in animal well-being, immune function, and growth performance. Meat quality may also be impaired, appearing as PSE pork. In addition to these effects, the stress response of a pig (such as stress-induced vocalization to snaring) may influence other pigs that are in close proximity to the pig being stressed.

Certain neurotransmitters (epinephrine, dopamine, and norepinephrine) are responsible for the animal

1Approved for publication by the director of the Louisiana Agric. Exp. Sta. as manuscript No. 2005-18-0258.

2Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA or the Louisiana State University Agricultural Center and does not imply approval to the exclusion of other products that may be suitable. Amino acids and financial support were provided in part by Nutri-Quest Inc., Chesterfield, MO 63017.

3Corresponding author: kerr@nsric.ars.usda.gov

Received June 2, 2005.

Accepted February 9, 2006.
quickly responding to stress and returning the body to a state of homeostasis (Henry et al., 1992, 1996; Adeola et al., 1993). However, neurotransmitters are often difficult to measure because they are found in various parts of the brain, and animals must often be slaughtered to assess changes in concentration (Piekarczewska et al., 2000). To evaluate stress without slaughtering animals, it may be possible to measure plasma or salivary cortisol (Ruis et al., 1997) because cortisol also responds to stress.

Tryptophan (a precursor of serotonin) has been shown to increase concentrations of serotonin in pigs (Adeola and Ball, 1992; Pethick et al., 1997), rats (Leathwood, 1987), and chickens (Laycock and Ball, 1990). Consequently, supplemental Trp may affect the response an animal has to stress through its ability to increase serotonin. Furthermore, Trp has been used in finishing pigs to improve meat quality by lowering stress at slaughter (Adeola and Ball, 1992; Pethick et al., 1997).

The current experiments were conducted to evaluate effects of Trp on cortisol and lactate concentrations after introduction of an acute stressor and to determine the effect of increased dietary Trp on meat quality of finishing pigs.

MATERIALS AND METHODS

The materials and methods used in these experiments were approved by the Louisiana State University Agricultural Center Animal Care and Use Committee.

General

Four experiments were conducted to evaluate the effect of Trp on plasma and salivary cortisol concentrations and meat quality in finishing pigs. Yorkshire × Landrace, and Yorkshire × Landrace × Duroc barrows from the Louisiana State University Agricultural Center Swine Unit were used in each experiment. Pigs and their environment were monitored daily. Barrows were allotted to treatments on the basis of BW, and ancestry was equalized across treatments in randomized complete block designs.

Experiment 1

A preliminary experiment was conducted to determine the time at which cortisol reached a maximum after introduction of an acute stressor (snaring). Four barrows (50 kg of BW) were housed individually in 0.6 × 1.2 m polyvinyl chloride metabolism crates for the duration of the experiment. Pigs were allowed a 2-d adjustment period before catheters were surgically inserted into the anterior vena cava using the technique described by Amoikon et al. (1995).

After the adjustment period and 2 d after catheter insertion, pigs were bled for 3 h, with blood collection times of −60, −30, −15, 2, 4, 6, 8, 10, 15, 20, 25, 30, 45, 60, 90, and 120 min. At time 0, pigs were snared for 30 s, and blood collection resumed with the 2 min sample. Blood samples were placed in tubes containing 10 mg of sodium fluoride and 8 mg of potassium oxalate. To reduce stress, the same technician was responsible for all blood collections for each pig. Blood samples were placed on ice for 2 h and then centrifuged for 15 min at 1,500 × g at 4°C. Plasma was then frozen (−20°C) until subsequent analyses for cortisol and lactate. This experiment was designed to provide the basis to determine blood collection times and duration of bleeding for subsequent experiments.

Experiment 2

A second experiment was conducted to determine the effects of snaring on plasma cortisol concentrations in pigs fed supplemental Trp. Twenty barrows (initial BW of 50 kg) were allotted to 1) a corn-soybean meal basal diet (Table 1), or 2) the basal diet plus 0.5% supplemental L-Trp (as-fed basis). The basal diet was formulated to meet or exceed 105% of the requirements for all amino acids in growing pigs at 20 to 50 kg of BW (NRC, 1998). Pigs were fed twice daily to approximate ad libitum intake. After catheterization as described in Exp.

Table 1. Composition of basal diets (as-fed basis)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Exp. 1, 2, 3</th>
<th>Exp. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>75.48</td>
<td>85.00</td>
</tr>
<tr>
<td>Soybean meal, 47.5%</td>
<td>19.70</td>
<td>10.98</td>
</tr>
<tr>
<td>Monocalcium phosphate</td>
<td>1.20</td>
<td>0.89</td>
</tr>
<tr>
<td>Limestone</td>
<td>1.13</td>
<td>1.04</td>
</tr>
<tr>
<td>Vitamin mix 1</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>Trace mineral mix 2</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Sodium bentonite 3</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>L-Lys-HCl</td>
<td>0.19</td>
<td>0.07</td>
</tr>
<tr>
<td>L-Thr</td>
<td>0.05</td>
<td>—</td>
</tr>
<tr>
<td>Se premix 4</td>
<td>0.05</td>
<td>0.50</td>
</tr>
<tr>
<td>Cornstarch 5</td>
<td>0.05</td>
<td>0.50</td>
</tr>
<tr>
<td>Calculated composition 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME, kcal/kg</td>
<td>3,265</td>
<td>3,265</td>
</tr>
<tr>
<td>True digestible Lys, %</td>
<td>0.83</td>
<td>0.52</td>
</tr>
<tr>
<td>True digestible TSAA, %</td>
<td>0.52</td>
<td>0.43</td>
</tr>
<tr>
<td>True digestible Thr, %</td>
<td>0.55</td>
<td>0.37</td>
</tr>
<tr>
<td>True digestible Trp, %</td>
<td>0.16</td>
<td>0.011</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.70</td>
<td>0.60</td>
</tr>
<tr>
<td>P, %</td>
<td>0.60</td>
<td>0.50</td>
</tr>
</tbody>
</table>

1Provided the following per kilogram of diet: vitamin A, 11,023 IU; vitamin D₃, 3,307 IU; vitamin E, 88 IU; menadione (menadione pyrimidinol bisulfate) 8.3 mg; riboflavin, 13 mg; pantothenic acid, 50 mg; niacin, 88 mg; vitamin B₁₂, 61 µg; biotin, 441 µg; choline (as choline chloride), 882 mg; folic acid, 3.3 mg; pyridoxine, 4.41 mg; thiamin, 4.41 mg; and vitamin C, 110 µg.
2Provided the following per kilogram of diet: Zn (zinc sulfate), 127 mg; Fe (ferrous sulfate monohydrate), 127 mg; Mn (manganese sulfate), 20 mg; Cu (copper sulfate), 12.7 mg; I (calcium iodate), 0.80 mg.
3Provided 0.3 mg of Se per kilogram of diet.
4In diets containing supplemental Trp, Trp was substituted for cornstarch at 0.5%.
5The digestible amino acid concentrations were estimated by using the true digestibility coefficients in the NRC (1998).
1, pigs were fed the experimental diets for 5 d. The 5-d feeding period was based on the results of Adeola and Ball (1992), who reported increased serotonin production after feeding supplemental Trp for 5 d.

After the 5-d feeding period, pigs were bled over a period of 2 d. At 0800 on d 1, 10 randomly chosen pigs (5 per treatment) were snared for 30 s at time 0. The blood collection times were based on the results of Exp. 1. Blood samples (3 mL) were collected at −10, 0 (during snaring), 2, 4, 6, 8, 10, 15, 30, 45, 60, 90, and 120 min, and were placed in tubes as in Exp. 1. To reduce stress, the same technician was responsible for all blood collections for each pig. On the second day, the remaining 10 pigs were bled in the same manner.

**Experiment 3**

On the third day, using the same pigs as in Exp. 2, another experiment was conducted to determine if a stress response is present in pigs adjacent to those being snared. At 0800, 5 pigs were snared for 30 s. After the pigs were snared, blood collection commenced at 2 min on those pigs adjacent to those that were snared. There were 8 pigs that were previously fed the basal diet and 7 pigs that had been fed the diet containing 0.5% supplemental L-Trp. Collection times were as in Exp. 2.

**Experiment 4**

Ninety barrows (average initial and final BW of 106 ± 2.3 and 111 ± 2.4 kg, respectively) were allotted to 1 of 6 treatments on the basis of BW and ancestry in a randomized complete block design. Four replicates of 3 or 4 pigs per replicate were used. Feed and water were provided on an ad libitum basis, and pigs were housed in an open-sided finishing barn in 1.52 × 4.27 m pens with cement-slatted floors. A 3 × 2 factorial arrangement of treatments was used; there were 3 diets [corn-soybean meal basal diet, the basal diet with 0.5% supplemental L-Trp on an as-fed basis, or pigs fed the basal diet with a bolus of Trp (0.1 g/kg of BW) given 2 h before slaughter] and 2 handling methods at slaughter (normal and minimal).

The diets were fed for 5 d before slaughter. Pigs were weighed at the beginning and end of the 5-d experimental period. To achieve minimal handling before slaughter, pigs were transported to the slaughter facility, were not mixed during transport or at the slaughter facility, and were moved with minimal force to the stunning area. Pigs receiving normal slaughter handling were mixed before transportation and slaughtered within 2 h of mixing, which resulted in fighting among pigs that continued until the time of slaughter (Matthews et al., 2001). Pigs receiving the bolus (0.1 g of L-Trp/kg of BW in 60 mL of H2O) were administered the dose orally 2 h before slaughter. Pigs that did not receive the bolus received 60 mL of H2O orally 2 h before slaughter. On the day of slaughter, after the minimally handled pigs were slaughtered, the other half of the pigs were mixed, transported, and handled at the slaughter facility to induce stress (Matthews et al., 2001). All pigs were held without feed for 16 h before slaughter. In all pigs, blood and saliva were collected at the time of slaughter during exsanguination for cortisol analysis.

**Carcass Evaluation**

Pigs were slaughtered by exsanguination after electrical stunning. Hot carcass weights and rectal temperatures (rectal glass probe) were collected at the time of slaughter, after exsanguination but before entering the scalding tank. Carcass measurements were collected on the left side of the carcass after a 24-h chill at 2°C. Linear measurements included dressing percent, LM muscle area (10th rib), 10th rib backfat, average backfat, and carcass length. Pork quality measurements between the 10th and 11th ribs included 45-min and 24-h pH (hand-held pH meter, Model 2000, VWR Scientific Products Co., South Plainfield, NJ), 45-min and 24-h temperature, and Commission Internationale de l’Eclairage (CIE) lightness (L*), redness (a*), and yellowness (b*) values (determined using the CIELAB color space with a D65 illuminant and a Minolta spectrophotometer, Model CM-508d, Minolta, Ramsey, NJ). After collection of carcass data, two 2.54-cm chops were collected between the ninth and 10th ribs for pork quality (color and marbling; NPPC, 1991), drip and 48-h cook loss, and Warner Bratzler shear force (Instron Model 4501 Universal Testing Instrument, Canton, MA). Drip loss, cook loss, and shear force were conducted as described by Matthews et al. (2001).

**Salivary Cortisol**

The relationship between plasma and salivary cortisol was of interest for practical purposes of collecting samples without stressing (i.e., snaring) the pigs. On the day of slaughter (after electrical stunning), saliva was collected by inserting a cotton-tip applicator into the mouth until the cotton was fully moistened. The sample was placed in a tube, centrifuged, and saliva was removed, frozen, and stored for later cortisol analysis. The technique followed that previously used in other studies (Ruis et al., 1997; Gaverink et al., 1998).

**Plasma Cortisol and Lactate**

Cortisol concentrations (μg/dL) were determined by using an ImmunoChem coated tube (Cat No. 07-221102, ICN Biochemicals, Costa Mesa, CA). The intraassay CV for cortisol determined with a porcine plasma pool was 6.0%. Lactate concentrations (μg/dL) were determined using a commercial kit (Sigma Tech. Bulletin #826-UV, Sigma, St. Louis, MO).

**Statistical Analysis**

Data were analyzed by ANOVA procedures (Steel and Torrie, 1980) appropriate for randomized complete
block designs using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). In Exp. 2 and 3, all hormone data were analyzed with the individual pig representing the experimental unit. Area under the response curve for cortisol was determined using trapezoidal geometry (0 to 120 min), and the −10- and 0-min samples were used to establish a baseline. In Exp. 4, treatment differences were determined using orthogonal contrast statements for a 3 × 2 factorial arrangement of treatments, with the pen of pigs serving as the experimental unit.

RESULTS

Experiments 1 and 2

In Exp. 1, plasma cortisol was 3.6-fold greater at 8 to 15 min after snaring than the average of the 4 samples before and immediately after (−30, −15, 2, and 4 min) the pigs were snared (Figure 1). In Exp. 2 as in Exp. 1, plasma cortisol was greatest approximately 10 min after snaring. The mean cortisol concentration for pigs fed Trp was lower (P < 0.01) than those fed the basal diet, indicating that Trp decreased the cortisol response to snaring stress (Figure 2). Plasma lactate was at its greatest concentration 2 min after snaring. Plasma lactate also was decreased (P < 0.07) in pigs fed Trp relative to those fed the basal diet (Figure 3). Both of these metabolites suggest that dietary Trp affected the stress response and that Trp may be beneficial for reducing stress.

Experiment 3

At the time of snaring, pigs adjacent to those that were snared did not seem to physically react based on visual observation (no change in movement or noise) in a way that indicated they were stressed. Although pigs on either treatment did not seem stressed (visual assessment), the results of this experiment were unexpected; plasma cortisol followed the same trend as in Exp. 1 and 2. The area under the curve for cortisol was decreased (P < 0.06) in pigs fed Trp relative to the pigs fed the basal diet (Figure 4). The overall cortisol concentration also was decreased (P < 0.01) by Trp.

Experiment 4

Pigs averaged 106 kg at the initiation of the experiment, with a final BW of 111 kg at the end of the 5-d study. Feed intake averaged 3.105 kg/d and was not affected by Trp supplementation. Plasma cortisol concentration at the time of slaughter was lower in pigs fed the basal diet compared with pigs given the Trp bolus (P = 0.05), and salivary cortisol was lower in pigs fed the basal diet compared with pigs given Trp in the diet (P = 0.07; Table 2).

There were very few significant effects of Trp or handling method on carcass traits of pigs. Dressing percent (P = 0.08), 24-h pH (P = 0.04), and 24-h temperature (P = 0.01) were reduced in the minimally handled pigs compared with the normally handled pigs (Table 3). Pigs fed Trp in the diet relative to those fed the basal diet had increased 45-min temperature (P = 0.10), CIE a* (P = 0.08) and b* (P = 0.06) values, and drip (P = 0.06) and total (P = 0.08) losses. Tryptophan in bolus form decreased 45-min pH in the minimally handled pigs but increased 45-min pH in the normally handled pigs (handling × Trp bolus interaction, P = 0.08). Tryptophan in the diet increased CIE L* in minimally handled pigs but decreased CIE L* in the normally handled pigs (handling × Trp diet interaction, P = 0.06), with pork color affected in an opposite manner (handling × Trp diet interaction, P = 0.03). No other response variables were affected by handling method or Trp.
DISCUSSION

There are many factors that affect homeostasis of an animal as well as having the potential to affect its wellbeing. There is reason to believe that through dietary manipulation, the incidence of stress can be lowered. Many researchers have evaluated Trp and its impact on the response to a stressor (McGlone et al., 1985; Meunier-Salatun et al., 1991; Shea et al., 1991; Denbow et al., 1993; DeNapoli et al., 2000; Geesink et al., 2004; Peeters et al., 2004). Results from our experiments suggest that feeding supplemental Trp reduces the cortisol and lactate response when an acute stressor, such as snaring, is introduced. This response indicates that there is potential to manipulate the response of the body through dietary supplements such as amino acids, which serve as precursors for various hormones that affect metabolism during times of stress. The amino acids that are most important when neurotransmitters are involved are Phe, Tyr, and Trp (Heine et al., 1995; Sainio et al., 1996). All of these amino acids may play a role in the response we observed in our experiments. If Trp is increased in the diet, it is proposed that Tyr and Phe are not able to cross the same blood brain barrier that Trp occupies and their products, dopamine and epinephrine, are not synthesized in high amounts (Lee and Britton, 1982). This response may have the potential to lower the stress response by not allowing epinephrine to be released, resulting in a lower incidence of anaerobic metabolism, and therefore lactate

Figure 2. Plasma cortisol concentrations of pigs fed a basal diet or the basal diet with 0.5% supplemental Trp for 5 d (Exp. 2). Data are means of 10 pigs each (Trp, \( P < 0.01 \), SEM = 0.22).

Figure 3. Plasma lactate concentrations of pigs fed a basal diet or the basal diet with 0.5% supplemental Trp for 5 d (Exp. 2). Data are means of 10 pigs each (Trp, \( P < 0.07 \), SEM = 1.18).
release, in the muscles (Hedrick et al., 1989). Inher-
ently, the decrease in cortisol may be the result of in-
creased serotonin (by increasing Trp) production, which
has been shown to lower the stress response in pigs
(Shea et al., 1990; Meunier-Salaün et al., 1991; Sève
et al., 1991). Research has indicated that Trp in relation
to the large neutral amino acids (Val, Phe, Tyr, Leu,
and Ile) plays an important role in serotonin production
and may be responsible for the response we observed
in Exp. 2 and 3 (Sainio et al., 1996; Sève, 1999). In
contrast, Peeters et al. (2004) indicated that Trp supple-
mentation in the water did not affect salivary cortisol
or plasma lactate in 24-kg pigs. However, it is unknown
how much additional Trp was consumed by these pigs
because water intake was not measured. Because Trp-
supplemented water has been shown to decrease water
intake (Kerr et al., 2005), this could have prevented
Trp from altering metabolites that were evaluated.
Peeters et al. (2004), however, showed that Trp in the
water increased the time spent lying down during a
transport simulation (vibration stimulus).

Tryptophan also has been shown to increase protein
synthesis in livers of pigs (Cortamira et al., 1991), but
feeding crystalline Trp to pigs above their perceived
nutritional requirement has not been shown to have a
beneficial effect on growth performance or meat quality
(Sève et al., 1991; Adeola and Ball, 1992; Page et al.,
1993; Geesink et al., 2004). Results of Exp. 4 agree with
results from previous experiments indicating that the
use of dietary Trp is not beneficial for improving meat
quality. In our results, a greater CIE L* value and lower
color score were observed, which both indicate a poorer
meat quality in pigs fed Trp that were subjected to
minimal handling. Lower CIE a* and CIE b* values
were obtained and are also indicators of meat color but
are less conclusive. With the increase in both salivary
and plasma cortisol and the negative effects on meat
quality, these results may indicate that, in this experi-

Table 2. Plasma and salivary cortisol concentrations of finishing pigs fed Trp in feed or bolus form before slaughter, Exp. 41

<table>
<thead>
<tr>
<th>Item</th>
<th>Minimal handling</th>
<th>Normal handling</th>
<th>Source of variation, P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basal Trp</td>
<td>Basal Trp</td>
<td>Handling4 Diet Bolus5 Diet Bolus6</td>
</tr>
<tr>
<td>Cortisol, μg/dL</td>
<td>Trp2 Bolus3</td>
<td>Trp2 Bolus3</td>
<td>SEM</td>
</tr>
<tr>
<td>Plasma</td>
<td>10.61 12.19 15.61</td>
<td>10.56 10.55 14.10</td>
<td>1.986</td>
</tr>
<tr>
<td>Saliva</td>
<td>2.05 2.55 2.47</td>
<td>2.00 2.25 2.20</td>
<td>0.191</td>
</tr>
</tbody>
</table>

1Data are means of 4 replicates of 3 or 4 pigs per replicate. Average initial and final BW were 106 and 111 kg, respectively.
2Basal diet plus 0.5% supplemental Trp fed 5 d before slaughter.
3Bolus (0.1 g of l-Trp/kg in 60 mL of H2O) was administered orally 2 h before slaughter.
4Minimal vs. normal handling.
5Tryptophan effect relative to basal diet.
6Handling interaction with dietary or bolus Trp.
Table 3. Carcass and pork quality measurements from the LM of finishing pigs fed tryptophan in feed- or bolus-form before slaughter, Exp. 4

<table>
<thead>
<tr>
<th>Item</th>
<th>Minimal handling</th>
<th>Normal handling</th>
<th>Source of variation, $P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basal</td>
<td>Trp$^2$</td>
<td>Bolus$^3$</td>
</tr>
<tr>
<td>Carcass trait</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DP, %</td>
<td>72.86</td>
<td>72.74</td>
<td>73.42</td>
</tr>
<tr>
<td>CL, cm</td>
<td>81.31</td>
<td>82.02</td>
<td>80.51</td>
</tr>
<tr>
<td>LM, cm$^2$</td>
<td>42.87</td>
<td>45.57</td>
<td>41.54</td>
</tr>
<tr>
<td>BF, cm</td>
<td>2.12</td>
<td>2.14</td>
<td>2.05</td>
</tr>
<tr>
<td>10th rib, cm</td>
<td>2.34</td>
<td>2.25</td>
<td>2.39</td>
</tr>
<tr>
<td>pH and temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45-min pH</td>
<td>6.10</td>
<td>6.10</td>
<td>6.03</td>
</tr>
<tr>
<td>45-min temp, °C</td>
<td>38.14</td>
<td>38.69</td>
<td>38.29</td>
</tr>
<tr>
<td>24-h pH</td>
<td>5.65</td>
<td>5.63</td>
<td>5.59</td>
</tr>
<tr>
<td>24-h temp, °C</td>
<td>1.11</td>
<td>1.03</td>
<td>0.94</td>
</tr>
<tr>
<td>Rectal temp, °C</td>
<td>39.73</td>
<td>39.83</td>
<td>39.89</td>
</tr>
<tr>
<td>Pork quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color$^7$</td>
<td>2.41</td>
<td>1.99</td>
<td>2.10</td>
</tr>
<tr>
<td>Marbling$^8$</td>
<td>1.67</td>
<td>1.47</td>
<td>2.02</td>
</tr>
<tr>
<td>CIE L*9</td>
<td>52.45</td>
<td>54.39</td>
<td>52.69</td>
</tr>
<tr>
<td>CIE a*10</td>
<td>4.77</td>
<td>5.35</td>
<td>5.68</td>
</tr>
<tr>
<td>CIE b*11</td>
<td>9.92</td>
<td>11.08</td>
<td>10.71</td>
</tr>
<tr>
<td>Muscle scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drip loss, %</td>
<td>5.17</td>
<td>5.73</td>
<td>5.09</td>
</tr>
<tr>
<td>Cook loss, %</td>
<td>17.94</td>
<td>20.32</td>
<td>20.23</td>
</tr>
<tr>
<td>Total loss, %</td>
<td>23.12</td>
<td>26.06</td>
<td>25.33</td>
</tr>
<tr>
<td>Shear force, kg</td>
<td>3.69</td>
<td>3.82</td>
<td>3.69</td>
</tr>
</tbody>
</table>

1Data are means of 4 replicates of 3 or 4 pigs per replicate. Average initial and final BW were 106 and 111 kg, respectively. Abbreviations: DP = dressing percent; CL = carcass length; BF = average backfat; temp = temperature.

2Basal diet plus 0.5% supplemental Trp fed 5 d before slaughter.

3Bolus (0.1 g of L-Trp/kg in 60 mL of H$_2$O) was administered orally 2 h before slaughter.

4Minimal vs. normal handling.

5Tryptophan effect relative to basal diet.

6Handling interaction with dietary or bolus Trp.

7Color: 1 = pale and 6 = dark purplish red.

8Marbling: 1 to 10 = 1 to 10% i.m. fat, respectively.

9CIE L* = measurement of lightness to darkness, with a greater value indicating a lighter color.

10a* = measurement of greenness to redness, with a greater value indicating a redder color.

11b* = measurement of blueness to yellowness, with a greater value indicating a more yellow color.

Adeola and Ball (1992) also evaluated the use of supplemental Trp in finishing pigs (92 kg) on stress responses and the reduction of PSE pork. Pigs received a corn-barley-soybean meal diet supplemented with 5 g of Trp/kg in the diet 5 d before slaughter. Tryptophan supplementation had little effect on muscle and fat depth, but there was a lower incidence of PSE pork in pigs fed excess Trp than in pigs fed the control diet (27 vs. 33%, respectively). The pH, color, and structure of the loins and hams were similar regardless of diet fed. Pethick et al. (1997) also reported a lower incidence and severity of PSE pork when 5 g of Trp was supplemented per kilogram of diet.

Perhaps increased concentrations of Trp intake immediately before slaughter may improve meat quality by increasing serotonin and reducing stress, and allowing the glycogen stores to remain high. However, because of the fasting that commonly occurs before slaughter, the diet may not play an important role in affecting the stress response. That hypothesis is the basis for use of the bolus in our experiment. The reason there was not a decrease in cortisol after the administration of the bolus is not understood, but this response may be due to a palatability problem or taste of the bolus that had a negative impact on the pigs. The contradiction in the cortisol response of Exp. 2 and 3 compared with Exp. 4 is not well understood but may be due to the many environmental changes that the finishing pigs had to contend with before slaughter.

Although our results using dietary Trp agree with previous research, handling method did not affect the response variables measured in our study as it has previously. Matthews et al. (2001) evaluated the handling method on carcass traits and observed a decrease in rectal temperature and plasma cortisol in minimally handled pigs. In addition, a lower CIE L* was observed in minimally handled pigs. Cortisol and rectal temperature are valid indicators of stress, and it is not known why we did not see a decrease in either in minimally handled pigs. Differential responses to potential stres-
sors are not uncommon. Warriss et al. (1998) indicated that a 1 to 3 h rest in lairage was optimal for meat quality, whereas Geverink et al. (1996) indicated that lairage time should be kept at a minimum to avoid agonistic behavior.

As previously discussed, Trp may play a role in affecting the stress response through its role in regulation of serotonin. However, the effect of dietary Trp on meat quality may not be beneficial because the pigs are fasted for a long duration before slaughter. On the other hand, increased dietary Trp concentrations may play a role in decreasing stress during the transport to the slaughter facility and thus reduce the incidence of PSE pork. Consequently, greater concentrations of dietary Trp may be necessary to induce the sedative effect that is needed for improved meat quality as reported by Pethick et al. (1997).

Data from the first 3 experiments suggest there is a time lapse between the introduction of the stressor and the response. Therefore, these data indicate that blood samples, if taken quickly, can be analyzed for cortisol without the effect of snaring becoming a factor. This is supported by McGlone et al. (1993), who indicated that plasma cortisol increases after a pen of pigs is aroused. However, because pigs adjacent to those that have been snared exhibit an increase in plasma cortisol, only the number of pigs that can be bled within 2 to 3 min should be bled if plasma cortisol, and perhaps other metabolites, are the intended response variable. In contrast, McGlone et al. (1993) indicated that bleeding one pen of pigs in a room did not cause elevated plasma cortisol among pigs housed in other pens.

**IMPLICATIONS**

Increased dietary tryptophan decreased cortisol after an acute stress, indicating that tryptophan can reduce the stress response. Tryptophan supplementation did not improve meat quality or give any indication of affecting stress at the slaughter facility. Further research is needed to elucidate any beneficial effects of tryptophan on meat quality in finishing pigs before any definite conclusions can be drawn.

**LITERATURE CITED**


in Manipulating Pig Production VI. P. D. Cranwell, ed. Australasian Pig Sci. Assoc., Roseworthy, SA, Australia.