The influence of creatine and a high glycemic carbohydrate on the growth performance and meat quality of market hogs fed ractopamine hydrochloride

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Abstract

Crossbred barrows (n = 128; 85 ± 0.91 kg) were randomly allotted to one of four dietary treatments. A pelleted corn-soybean diet containing 5 ppm Paylean® (PAY) was tested against a negative control (NCON) diet formulated to meet or exceed the National Research Council’s requirements for the growing pig, a pelleted corn-soybean diet containing 0.92% creatine and 2.75% dextrose (COMBO), and a pelleted corn-soybean diet containing a combination of 5 ppm Paylean®, 0.92% creatine, and 2.75% dextrose (PAYPLUS). No treatment differences were noted when comparing ADG (P = 0.66) and hot carcass weight (P = 0.75). Over the 27 d test, barrows fed PAY and PAYPLUS produced loins with a larger (P < 0.01) loin muscle area (LMA) than those fed NCON or COMBO diets. Barrows fed the NCON diet were fatter at the 10th-rib (P < 0.01) than those animals fed the remaining dietary treatments. Dietary treatment did not affect the ultimate pH (P = 0.87), Japanese color score (P = 0.25) or Minolta L* (P = 0.61) and b* (P = 0.56) values of the loin. Loin chops from NCON, COMBO and PAYPLUS tended (P = 0.07) to contain a higher intramuscular fat content than those from barrows fed PAY. Additionally, loin chops from the NCON and COMBO fed animals were more red (higher a*-value) than those chops coming from animals fed the PAY diet (P < 0.01).

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1. Introduction

Recent advances in genetic selection, coupled with the emergence of growth promoting agents such as ractopamine hydrochloride, have resulted in a dramatic increase in the lean tissue deposition of the US market hog. Ractopamine hydrochloride (Paylean®; Elanco Animal Health, Greenfield, IN) is a United States Food and Drug Administration (FDA) regulated feed supplement that is used by swine producers to improve feed efficiency, average daily gain, carcass dressing percentage, and carcass fat-free lean content, while having little to no effect on pork quality (color, marbling, firmness). This said, Stoller et al. (2003) reported a genetic line × treatment interaction for loin intramuscular fat (marbling) deposition, suggesting that Paylean® may reduce the percentage of marbling found within pork chops of certain genetic lines prone to producing higher quality cuts of meat. These findings are somewhat concerning given the positive relationship between marbling content and improved consumer taste panel scores (Brewer & McKeith, 1999).

Although the mode of action is quite different from that of Paylean®, researchers have attempted to augment the rate of protein deposition in grow-finish swine by including creatine monohydrate (CMH) within the diet (Berg & Allee, 2001; Maddock et al., 2002; O’Quinn et al., 2000; Stahl, Allee, & Berg, 2001). A preliminary study conducted...
by Stahl and Berg (2002) found that feeding creatine in conjunction with a high glycemic carbohydrate tended to increase loin muscle area (LMA) gain when fed 30 d pre-harvest. Moreover, research conducted by Maddock et al. (2002) and Berg and Allee (2001) found that CMH supplementation tended to increase the intramuscular fat content of the loin. Consequently, this experiment was designed to: (1) further explore the growth performance and meat quality of market barrows fed CMH and a high glycemic carbohydrate; (2) compare the growth performance and meat quality of barrows supplemented CMH and a high glycemic carbohydrate to that of barrows receiving 5 ppm rac-topamine hydrochloride (Paylean®); and (3) determine the additive dietary effects of combining CMH and a high glycemic carbohydrate with Paylean®.

2. Materials and methods

2.1. Live animals

All animals used within this study were raised, transported, and harvested in accordance with University of Missouri Animal Care and Use Committee rules and regulations. One hundred and twenty eight crossbred barrows weighing 85 ± 0.91 kg were randomly allotted to one of 16 pens (eight pigs/pen; four replications/treatment). All animals were provided ad libitum access to feed and water via a single two-holed feeder and water nipple, respectively. A 12 d acclimation period was provided prior to the initiation of treatments (Table 1). A pelleted corn-soybean diet containing 5 ppm Paylean® (PAY) was tested against a pelleted negative control (NCON) diet, a pelleted corn-soybean diet containing 0.92% CMH and 2.75% dextrose (COMBO), and a pelleted corn-soybean diet containing a combination of 5 ppm Paylean®, 0.92% creatine, and 2.75% dextrose (PAYPLUS). Test diets (PAY, COMBO and PAYPLUS) were isocaloric and formulated to contain equal amounts of synthetic lysine and a minimum of 16% crude protein (CP) in compliance with the Paylean® label. The NCON was formulated to meet the NRC recommendation (NRC, 1998) for growing pigs (12.71% CP) and was used to determine the value of each feeding strategy relative to the industry standard.

Live weights were recorded at 9 d intervals throughout the 27 d testing period to determine average daily gain. A National Swine Improvement Federation (NSIF) certified ultrasound technician was used to determine 10th-rib fat depth (FD) and LMA on d 1 and d 27. Scanning was conducted using an Aloka SSD 500 (Corometrics Medical Systems, Wallingford, CN) real-time ultrasonic machine fitted with a 12.5 cm, 3.5 MHz linear array transducer. It is important to note that five animals died or were removed from the test due to problems unassociated with treatment.

2.2. Animal harvest and cooler measurements

After 27 d on test, barrows (n = 123) were tattooed on both the right and left shoulder with a four digit individual ID number and delivered (222 km) to a commercial packing plant. Hot carcass weights were recorded and carcasses were identified after hair removal as they moved through the scald polisher. On-line fat and loin depth measurements were obtained between the 3rd and 4th from last thoracic vertebrae using a Hennessy Optical Grading Probe (Hennessy Grading Systems, Auckland, New Zealand). Left side hams, loins, and bellies were marked with the appropriate tattoo number using edible carcass ink. On the day of fabrication, cold carcass weights were obtained as each carcass exited the equalization bay of the chiller. It should be noted that one

Table 1

<table>
<thead>
<tr>
<th>Item (%)</th>
<th>PAY</th>
<th>NCON</th>
<th>COMBO</th>
<th>PAYPLUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground corn</td>
<td>69.01</td>
<td>80.99</td>
<td>65.03</td>
<td>65.00</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>25.82</td>
<td>13.68</td>
<td>26.12</td>
<td>26.13</td>
</tr>
<tr>
<td>Fat</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Di-calcium phosphate</td>
<td>0.54</td>
<td>0.78</td>
<td>0.59</td>
<td>0.59</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.86</td>
<td>0.80</td>
<td>0.83</td>
<td>0.83</td>
</tr>
<tr>
<td>Salt</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>L-Lysine HCl</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Swine vitamin pre-mix</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Swine trace mineral pre-mix</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Cu sulfate</td>
<td>0.05</td>
<td>0.10</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Creatine monohydrate</td>
<td>–</td>
<td>–</td>
<td>0.92</td>
<td>0.92</td>
</tr>
<tr>
<td>Dextrose</td>
<td>–</td>
<td>–</td>
<td>2.75</td>
<td>2.75</td>
</tr>
<tr>
<td>Paylean®</td>
<td>0.0025</td>
<td>–</td>
<td>–</td>
<td>0.025</td>
</tr>
</tbody>
</table>

a Pelletted corn-soybean base containing 4.5 g/ton Paylean®.

b Pelletted corn-soybean base formulated to meet or exceed the NRC requirements for growing pigs.

c Pelletted corn-soybean base containing 0.92% creatine monohydrate and 2.75% dextrose.

d Pelletted corn-soybean base containing 0.92% creatine monohydrate, 2.75% dextrose, and 4.5 g/ton Paylean®.

e Provided the following per kilogram of complete diet: vitamin A, 6600 IU; vitamin D₃, 660 IU; vitamin E, 13.2 IU; vitamin K₂, 2.4 mg; riboflavin, 4.95 mg; niacin, 19.8 mg; p-pantothenic acid, 16.83 mg; and vitamin B₁₂, 18.15 µg.

f Provided the following per kilogram of complete diet (milligrams): Zn, 110; Fe, 110; Mn, 22; Cu, 11; I, 0.2; Se, 0.2.
NCON, three COMBO, one PAY, and four PAYPLUS carcasses \((n = 9)\) were lost during the harvest processes due to indiscernible tattoo numbers.

### 2.3. Hams

Left side bone-in hams (IMPS 401A; NAMP, 1997) were collected from the commercial fabrication line and weighed to the nearest 0.01 kg. After determination of bone-in ham weights, hams were skinned, deboned, and fabricated to obtain a four-muscle ham yield (inside: semimembranosus; outside: biceps femoris and semitendinosus; knuckle: quadriceps; light butt: gluteus medius). Objective light reflectance (Minolta \(L^*, a^*, b^*\)-values) were obtained using a Minolta CR-300 (8 mm aperture and 0° viewing angle) and subjective intramuscular fat content was obtained from the cut lean surface of the biceps femoris. Subjective intramuscular fat content was determined using a four point scale developed by the cooperating packing plant where a score of 1 represented little marbling, 2 represented modest/acceptable marbling, 3 represented abundant/unacceptable marbling, and 4 represented excessive marbling/steatosis (deemed unacceptable).

### 2.4. Loins

Left side rough-cut loins (IMPS 410; NAMP, 1997) were collected from the commercial fabrication line and deboned to obtain a center-cut boneless loin (IMPS 412B; NAMP, 1997). Boneless loins were then weighed (nearest 0.01 kg) to determine the boneless loin yield as a percentage of the total carcass. A single chop (2.54 cm in thickness) was removed from the posterior (sirloin) portion of the boneless loin and provided with an appropriate bloom time. Objective color measurements (Minolta \(L^*, a^*, b^*\)-values), subjective Japanese color scores (Nakai, Saito, Ikeda, Ando, & Komatsu, 1975), and subjective marbling (NPPC, 2000) measurements were obtained from the cut lean surface of each chop. These same chops were then packaged in sterile Whirl-Pack bags (Nasco, Fort Atkinson, WI) for delivery to the University of Missouri Meat Lab for determination of total lipid and moisture content using the CEM SMART Trac Moisture and Fat Analysis System (CEM Corp., Matthews, NC). Two additional chops were removed from the posterior portion of the boneless loin to determine both drip loss (not presented) and Warner Bratzler shear force measurements (WBSF; AMSA, 1995); respectively. Ultimate pH was obtained from the center of the loin (sirloin end) after removing the third chop. Intramuscular pH was acquired using a glass tipped pH Star Probe (SFK Technol., Peosta, IA) calibrated in pH 4.00 and 7.00 buffer solutions.

### 2.5. Statistical analysis

All data were analyzed using the general linear model procedures (PROC GLM) of SAS (SAS Institute Inc., Cary, NC). Least squares means were evaluated for least significant differences \((P < 0.05)\) in a general linear model for all dependent variables associated with production, carcass composition, and pork quality using dietary treatment as the main effect and pig as the experimental unit.

### 3. Results and discussion

#### 3.1. Live animals

#### 3.1.1. Average daily gain

The least squares means and standard errors associated with growth performance are presented in Table 2. The average daily gain of barrows representing the COMBO treatment did not differ \((P > 0.05)\) from PAY or NCON.

<table>
<thead>
<tr>
<th>Dietary treatments</th>
<th>SE</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAY (^a)</td>
<td>1.10</td>
<td>0.66</td>
</tr>
<tr>
<td>NCON (^b)</td>
<td>1.14</td>
<td></td>
</tr>
<tr>
<td>COMBO (^c)</td>
<td>1.07</td>
<td></td>
</tr>
<tr>
<td>PAYPLUS (^d)</td>
<td>1.12</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Pelletted corn-soybean base containing 4.5 g/ton Paylean\(^8\).
\(^b\) Pelletted corn-soybean base formulated to meet or exceed the NRC requirements for growing pigs.
\(^c\) Pelletted corn-soybean base containing 0.92% creatine monohydrate and 2.75% dextrose.
\(^d\) Pelletted corn-soybean base containing 0.92% creatine monohydrate, 2.75% dextrose, and 4.5 g/ton Paylean\(^8\).

\(^{xy}\) Within a row, least squares means not bearing a common superscript differ significantly.

\(^{xy}\) Within a row, least squares means not bearing a common superscript letter differ at \(P < 0.05\).
Additionally, no additive effect ($P = 0.66$) was noted when comparing the growth performance of barrows fed PAYPLUS to that of barrows fed PAY.

Previous research conducted by Stahl et al. (2001), Stahl and Berg (2002) and O’Quinn et al. (2000) suggested that neither creatine, dextrose, or a combination thereof was able to improve the growth performance of market hogs when fed in a commercial environment. This explains why no significant differences in growth performance existed between barrows fed the NCON and COMBO diets. Nevertheless, barrows fed a diet containing Paylean® (PAY and PAYPLUS) were expected to outperform those not fed Paylean® (COMBO and NCON). Given the relatively high ADG of each dietary treatment over the course of the 27 d testing period, it is possible that the specific genotype used within this study was capable of meeting its genetic propensity for growth performance, regardless of feeding strategy. This would subsequently explain the lack of improvement in the growth performance of pigs fed Paylean® within the study.

3.1.2. Fat accretion

Real-time ultrasound comparisons of d 1 and d 27 subcutaneous fat thickness (10th-rib) identified treatment differences ($P < 0.01$) in fat accretion over time (Table 2). Fat accumulations at the 10th-rib were 0.69, 0.36, 0.48, and 0.46 cm for NCON, PAY, COMBO, and PAYPLUS, respectively. As expected, pigs fed PAY, COMBO and PAYPLUS diets deposited less fat ($P < 0.01$) over the 27 d feeding period than NCON, while no differences were observed between PAY, COMBO, and PAYPLUS.

The marginal difference in the subcutaneous fat accretion between pigs fed the PAY, COMBO and PAYPLUS diets was not entirely unexpected. Research with human subjects has found that although creatine monohydrate can increase total body and fat-free mass, it may concomitantly reduce the ability to lose fat mass. Huso, Hamp, Johnston, and Swan (2002) found that creatine supplementation altered substrate (fat, carbohydrate, and protein) utilization at rest, indicating that creatine may significantly increase carbohydrate oxidation, decrease fatty acid oxidation and prohibit fat loss in humans. Creatine’s inability to significantly decrease subcutaneous fat deposition has also been noted when fed to market hogs (Stahl et al., 2001). In addition to creatine, it should also be noted that the inclusion of 5 ppm Paylean® into a complete grow/finish swine diet has been shown to have little to no efficacious impact on 10th-rib backfat thickness (Stites et al., 1991; Watkins, Jones, Mowrey, Anderson, & Veenhuizen, 1990).

3.1.3. Lean tissue accretion

Differences in LMA gain (ultrasoundically measured at the 10th/11th-rib interface) were observed when comparing d 1 and d 27 ultrasound measurements ($P < 0.01$). The LMA gain of pigs fed PAYPLUS was greater ($P < 0.01$) than that of pigs fed the NCON and COMBO diets (Table 2). However, no significant differences in LMA were noted when comparing the data of pigs fed PAY and PAYPLUS. This said, it is important to note that online Hennessy grading probe measurements of loin depth were similar across dietary treatments.

Human research has shown that creatine utilization is 10–33% higher in type II muscle fibers than in type I muscle fibers (Casey & Greenhaff, 2000). Given that pig longissimus muscle contains primarily type IIB muscle fibers (Gerrard & Grant, 2003) and that Paylean® has been shown to shift the proportion of myosin heavy chain isoforms (and fiber types) from types I and IIA to types IIX and IIB fibers (Depreux, Grant, Anderson, & Gerrard, 2002), pigs fed PAYPLUS were expected to present a greater LMA gain on test (10th-rib) than pigs fed PAY, NCON, and COMBO. This said, the findings of this study suggest that the addition of 0.92% creatine and 2.75% dextrose is unable to further enhance the lean tissue accretion of barrows fed diets containing 5 ppm Paylean®.

3.2. Pork quality parameters of the loin muscle

3.2.1. Intramuscular pH

Pork carcasses entered a blast chill approximately 30–40 min post-exsanguination, thus the acquisition of 45-min postmortem pH was not possible. No differences ($P = 0.87$) in ultimate pH (24 h postmortem; Table 3) were observed (5.54, 5.57, 5.55, and 5.54) for NCON, PAY, COMBO, and PAYPLUS, respectively. Human research has demonstrated that creatine monohydrate can significantly blunt the accumulation of lactic acid following exercise (Prevost, Nelson, & Morris, 1997). Nevertheless, researchers attempting to use these findings as justification for supplementing CMH to swine finishing diets have been unsuccessful, particularly when attempting to significantly buffer pH decline early postmortem (Berg & Allee, 2001; O’Quinn et al., 2000; Stahl et al., 2001). Research conducted by Gaitanos, Williams, Boobis, and Brooks (1993) demonstrated that phosphorylcreatine concentrations can be depleted by nearly 85% when humans are subjected to repeated bouts of maximal exercise (10 bouts of maximal exercise, 6 s each). Given the physical rigors of loading, transport, and lairage, it is likely that the total creatine pool (free creatine + phosphorylcreatine) of the pig has been depleted or significantly reduced prior to exsanguination, thereby negating the buffering ability of creatine in early postmortem muscle.

3.2.2. Color

Japanese color scores obtained from the fresh lean surface of the boneless sirloin chop and the ventral (rib) side of the whole-muscle boneless loin section were not different ($P > 0.05$) across treatment groups (Table 3). Additionally, dietary treatment did not affect ($P > 0.05$) the Minolta $L^*$ and $b^*$-values of fresh cut loin chops. These findings are in agreement with previous work involving the use of creatine in conjunction with a high glycemic carbohydrate (Stahl & Berg, 2002) or Paylean® (Ivers et al., 2000).
Table 3
Least squares means and standard errors (SEs) for measurements associated with the loin muscle

<table>
<thead>
<tr>
<th>Measurement</th>
<th>PAYa</th>
<th>NCONb</th>
<th>COMBOc</th>
<th>PAYPLUSd</th>
<th>SE</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate pH</td>
<td>5.57</td>
<td>5.54</td>
<td>5.55</td>
<td>5.53</td>
<td>0.02</td>
<td>0.87</td>
</tr>
<tr>
<td>CIE L’-value</td>
<td>50.22</td>
<td>49.09</td>
<td>50.07</td>
<td>49.41</td>
<td>0.69</td>
<td>0.61</td>
</tr>
<tr>
<td>CIE a’-value</td>
<td>5.20</td>
<td>5.86x</td>
<td>6.49</td>
<td>5.81xy</td>
<td>0.23</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>CIE b’-value</td>
<td>3.66</td>
<td>3.76</td>
<td>4.14</td>
<td>3.85</td>
<td>0.25</td>
<td>0.56</td>
</tr>
<tr>
<td>Japanese color, chopf</td>
<td>2.61</td>
<td>2.8</td>
<td>2.84</td>
<td>2.60</td>
<td>0.11</td>
<td>0.25</td>
</tr>
<tr>
<td>Japanese color, ribg</td>
<td>2.65</td>
<td>2.75</td>
<td>2.82</td>
<td>2.57</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Intramuscular fatf (%)</td>
<td>2.17</td>
<td>2.43</td>
<td>2.30xy</td>
<td>2.45s</td>
<td>0.08</td>
<td>0.07</td>
</tr>
<tr>
<td>Total lipid (%)</td>
<td>3.08</td>
<td>3.73</td>
<td>3.61</td>
<td>3.75</td>
<td>0.23</td>
<td>0.15</td>
</tr>
<tr>
<td>WBSF (N)</td>
<td>39.82</td>
<td>35.89x</td>
<td>37.56</td>
<td>39.23y</td>
<td>1.18</td>
<td>0.08</td>
</tr>
<tr>
<td>Cooking lossi (g)</td>
<td>34.16</td>
<td>31.45</td>
<td>31.73</td>
<td>32.63</td>
<td>0.95</td>
<td>0.18</td>
</tr>
</tbody>
</table>

a,b,c,d,e,f Within a row, least squares means not bearing a common superscript differ significantly.

A treatment effect (P < 0.01) was noted when comparing Minolta a’-values. Loin chops from barrows fed the COMBO diet were more red (higher a’-value) than the loin chops of barrows fed diets containing Paylean® (PAY and PAYPLUS). It is important to note that of the diets containing Paylean®, only PAY differed significantly (P < 0.01) from NCON (PAY = 5.20 vs. NCON = 5.86). A study conducted by Lawler, Barnes, Wu, Song, and Demaree (2002) suggested that creatine possesses antioxidant properties, specifically the ability to remove superoxide anions and peroxynitrite. Given that antioxidants decelerate the oxidation of myoglobin, this may potentially explain the higher Minolta a’-values observed in pork from COMBO barrows and subsequently accounts for the numeric differences noted when comparing the loins from barrows fed PAY and PAYPLUS. There is some evidence that feeding Paylean® can significantly decrease the a’-values of pork loin chops when fed at 10 (Ivers et al., 2000) and 20 (Uttaro et al., 1993) ppm/909 kg batch of complete feed. Research conducted by Herr, Schinckel, Watkins, Weldon, and Richard (2001) have found this difference in a’-values to be negligible while Stites et al. (1991), Stites et al. (1994) and Watkins et al. (1990) found no differences when comparing the a’-values of chops from pigs fed 5 ppm Paylean® to those from control animals. This said, the data collected within the present study suggest that the addition of 5 ppm Paylean® may significantly reduce Minolta a’-values when fed for 27 d prior to harvest and that such a reduction in Minolta a’-value can be diminished by adding 0.92% creatine and 2.75% dextrose to the diet.

3.2.3. Intramuscular fat content
Dietary treatment tended (P = 0.07) to influence the intramuscular fat (IMF) content of the loin muscle when evaluated using NPPC marbling standards (NPPC, 2000) (Table 3). Similar to the findings of Stoller et al. (2003), the IMF content of the PAY fed pork loin chops tended to be lower than the IMF content of loin chops of barrows fed the NCON diet. When evaluated using NPPC marbling standards, it appeared that the addition of creatine and dextrose to diets containing 5 ppm Paylean® inhibited the tendency of Paylean® to lower the IMF content within the loin muscle (PAY = 2.17% vs. PAYPLUS = 2.45%). Nevertheless, total lipid analysis of the loin muscle (Table 3) did not substantiate these findings (PAY: 3.08% vs. PAYPLUS: 3.75%, P = 0.15).

3.2.4. Warner Bratzler shear force
Warner Bratzler shear force measurements were 35.89, 39.82, 37.56, and 39.23 N for NCON, PAY, COMBO, and PAYPLUS, respectively. Loin chops from barrows fed Paylean® tended to be less tender (P = 0.08) than chops from animals fed the NCON and COMBO diets (Table 3). Previous research has reported that chops from pigs fed Paylean® tend to be less tender (higher WBSF value) than chops from pigs fed a traditional corn-soybean diet (Aalhus, Best, Murray, & Jones, 1998; Carr & McKeith, 1998; Uttaro et al., 1993). However, work conducted by Stites et al. (1994) found no difference in tenderness between the loin chops from control and Paylean® fed pigs. In addition to these findings, Goerl, Eilert, Mandigo, Chen, and Miller (1995) and Karlsson et al. (1993) have provided evidence that an inverse relationship exists between dietary CP level and meat tenderness. The present study agrees with Aalhus et al. (1998), Uttaro et al. (1993) and Carr and McKeith (1998), who reported loin chops from pigs fed Paylean® tended to be less tender than chops from pigs not receiving Paylean®.
### 3.3. Carcass measures and objective color parameters of the ham

#### 3.3.1. Weights and yields

Dietary treatment did not affect rough-cut bone-in ham weight \((P = 0.10)\), yet influenced the weight of the inside \((\text{semitendinosus})\) and outside \((\text{biceps femoris})\) ham muscles (Table 4). Both the inside and outside ham muscles of barrows fed PAYPLUS were heavier \((P < 0.05)\) than those coming from animals fed the NCON and COMBO diets yet were no heavier than the inside and outside ham muscles of barrows fed the PAY diet. When compared as a percentage of the total (bone-in) ham weight, no differences \((P > 0.10)\) for inside and outside ham weight were noted across treatment groups. These findings are in agreement with previous data collected from pigs fed Paylean\(^a\) (Herr et al., 2001). To date, no published studies involving creatine and a high glycemic carbohydrate have conducted a partial ham dissection.

#### 3.3.2. Color

Consistent with the fresh pork color evaluation of the loin chops, dietary treatment did not affect the Minolta \(L^* (P = 0.71)\) and \(b^* (P = 0.51)\) values of the ham (Table 4). However, a treatment effect \((P < 0.05)\) was noted for Minolta \(a^*\)-values, as the \textit{biceps femoris} of barrows fed the COMBO diet was more red (higher \(a^*\)-value) than the \textit{biceps femoris} of barrows fed diets containing Paylean\(^b\) (Table 4). Unlike the boneless loins, the inclusion of creatine and dextrose did not influence the Minolta \(a^*\)-values of pigs fed Paylean\(^c\). Ivers et al. (2000) found that the cured hams of pigs fed 18 g Paylean\(^a\) per 909 kg feed batch were less red (lower \(a^*\)-value) than were the hams of control animals. Nevertheless, limited research exists regarding the effect of Paylean\(^c\) on fresh ham color, specifically fresh ham color obtained from the cut lean surface of the \textit{biceps femoris} muscle of pigs fed Paylean\(^c\) at 5 ppm/909 kg batch of complete feed.

### 4. Conclusions

The inclusion of creatine and dextrose did not affect the growth performance and carcass merit of market barrows fed 5 ppm Paylean\(^d\) 27 d prior to harvest. Moreover, no significant differences in intramuscular pH, objective color and Warner Bratzler shear force values were noted when comparing the hams and loins of barrows fed diets containing Paylean\(^d\). However, the present study does suggest that the inclusion of creatine and dextrose to diets containing 5 ppm Paylean\(^d\) can potentially improve fresh pork quality of barrows prone to producing higher quality cuts of meat via the improvement of both intramuscular fat (marbling) content and Minolta \(a^*\)-values (redness). Further research must be conducted to determine if the addition of 0.92% creatine and 2.75% dextrose can consistently improve and/or maintain the intramuscular fat content of pigs fed Paylean\(^d\) at levels greater than 5 ppm/909 kg feed batch and to determine if this feeding strategy will enable producers to feed higher levels of Paylean\(^d\) to genetic lines that can potentially improve fresh pork quality.

### Acknowledgements

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**Table 4**

<table>
<thead>
<tr>
<th>Dietary treatments</th>
<th>PAY(^a)</th>
<th>NCON(^b)</th>
<th>COMBO(^c)</th>
<th>PAYPLUS(^d)</th>
<th>SE</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rough-cut, bone-in (kg)</td>
<td>10.09</td>
<td>9.88</td>
<td>9.80</td>
<td>10.32</td>
<td>0.17</td>
<td>0.10</td>
</tr>
<tr>
<td>Inside ham (kg)</td>
<td>1.84(^e)</td>
<td>1.74(^f)</td>
<td>1.77(^g)</td>
<td>1.87(^h)</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Inside ham(^i) (%)</td>
<td>18.20</td>
<td>17.63</td>
<td>18.04</td>
<td>18.13</td>
<td>0.22</td>
<td>0.24</td>
</tr>
<tr>
<td>Outside ham (kg)</td>
<td>2.04(^j)</td>
<td>1.91(^k)</td>
<td>1.93(^l)</td>
<td>2.09(^m)</td>
<td>0.05</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Outside ham(^n) (%)</td>
<td>20.20</td>
<td>19.34</td>
<td>19.68</td>
<td>20.26</td>
<td>0.31</td>
<td>0.10</td>
</tr>
<tr>
<td>Intramuscular fat(^o)</td>
<td>1.93</td>
<td>2.18</td>
<td>2.17</td>
<td>1.97</td>
<td>0.14</td>
<td>0.42</td>
</tr>
<tr>
<td>CIE (L^*)-value</td>
<td>50.85</td>
<td>50.95</td>
<td>51.61</td>
<td>52.06</td>
<td>0.87</td>
<td>0.71</td>
</tr>
<tr>
<td>CIE (a^*)-value</td>
<td>5.41(^p)</td>
<td>6.24(^q)</td>
<td>6.51(^r)</td>
<td>5.38(^s)</td>
<td>0.31</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>CIE (b^*)-value</td>
<td>2.82</td>
<td>3.25</td>
<td>3.50</td>
<td>3.31</td>
<td>0.33</td>
<td>0.51</td>
</tr>
</tbody>
</table>

\(^{sv}\) Within a row, least squares means not bearing a common superscript differ significantly.

\(^{a}\) Pelletted corn-soybean base containing 4.5 g/ton Paylean\(^c\).

\(^{b}\) Pelletted corn-soybean base formulated to meet or exceed the NRC (1998) requirements for growing pigs.

\(^{c}\) Pelletted corn-soybean base containing 0.92% creatine monohydrate and 2.75% dextrose.

\(^{d}\) Pelletted corn-soybean base containing 0.92% creatine monohydrate, 2.75% dextrose, and 4.5 g/ton Paylean\(^a\).

\(^{e}\) The inside ham (\textit{semitendinosus}) as a percentage of the entire bone-in ham.

\(^{f}\) The outside ham (\textit{biceps femoris} and \textit{semitendinosus}) as a percentage of the entire bone-in ham.

\(^{g}\) Determined using a scoring system of 1–4 (1 = little to no marbling, 4 = excessive marbling/steatosis (unacceptable)).

\(\text{PAY}a\ \text{NCON}b\ \text{COMBO}c\ \text{PAYPLUS}d\)

References


