

日粮铜水平和来源对断奶仔猪铜的代谢和氧化应激的影响

Y. L. Huang, M. S. Ashwell, R. S. Fry, K. E. Lloyd, W. L. Flowers 和 J. W. Spears

本试验研究饲喂不同水平和来源的铜对 48 头断奶阉公猪铜代谢、十二指肠氧化应激、盲肠挥发性脂肪酸 (VFA) 比例的影响。在 21 日龄时将断奶仔猪按体重组 (平均体重 $7.03 \pm 1.20\text{kg}$)，随机分为以下三组：1) 对照组，5mg 铜/kg 日粮，硫酸铜；2) 225mg 铜/kg 日粮，硫酸铜；3) 225mg 铜/kg 日粮，碱式氯化铜 TBCC。每圈饲养 2 头，饲喂全价日粮 11-12 天后屠宰。屠宰时，收集胆囊、肝脏分析矿物元素，取肝脏样品分析铜调节蛋白 mRNA 的表达。收集十二指肠、空肠前段、回肠的食糜，分析可溶铜含量。刮取十二指肠、空肠前段和回肠的黏膜，分析黏膜铜含量和铜调节蛋白 mRNA 的表达，以及丙二醛 (MDA) 的含量。日粮中添加高水平铜可以显著提高十二指肠、空肠前段和回肠黏膜中铜含量 ($P < 0.0001$)。硫酸铜组比碱式氯化铜组猪只十二指肠黏膜中铜含量更高 ($P = 0.003$)。硫酸铜组十二指肠中丙二醛含量高于对照组 ($P = 0.003$)，与碱式氯化铜组猪只相比有提高的趋势 ($P = 0.06$)。与对照组相比，高铜组猪只十二指肠抗氧化剂 1 (Atox1) mRNA 表达量显著降低 ($P < 0.01$)，不同铜源之间无显著差异。添加高铜日粮组猪只肝脏和胆汁中铜水平更高 ($P < 0.001$)。并且碱式氯化铜组肝脏中铜含量高于硫酸铜组。高铜提高了肝脏铜转运 β -多肽 ATP 酶 (Atp7b) 酶活 ($P = 0.02$)，并且不同添加形式没显著差异。高铜组猪只盲肠内容物乙酸:丁酸比大大高于对照组。在铜添加量为 225mg/kg 时，碱式氯化铜组猪只氧化应激比硫酸铜组更少。断奶仔猪饲喂高铜日粮能调节十二指肠 Atox1 和肝脏 Atp7b 转录水平。

Effect of dietary copper amount and source on copper metabolism and oxidative stress of weanling pigs in short-term feeding

Y. L. Huang, M. S. Ashwell, R. S. Fry, K. E. Lloyd, W. L. Flowers and J. W. Spears

Forty-eight weanling barrows were used to determine the effects of amount and source of dietary Cu on Cu metabolism, oxidative stress in the duodenum, and VFA ratios in the cecum of weanling pigs in short-term feeding. At 21 d of age, newly weaned pigs were stratified by BW (7.03 ± 1.20 kg) and equally assigned to 1 of the following dietary treatments: 1) control (5 mg supplemental Cu/kg diet from CuSO_4), 2) 225 mg supplemental Cu/kg diet from CuSO_4 , or 3) 225 mg supplemental Cu/kg diet from tribasic Cu chloride (TBCC). Pigs were housed 2 pigs per pen and were fed a complex diet until harvest on d 11 and 12. During harvest, bile and liver were obtained for mineral analysis, and liver samples were obtained for analysis of mRNA expression of Cu regulatory proteins. Digesta of duodenum, proximal jejunum, and ileum were collected for soluble Cu analysis. Mucosal scrapings of duodenum, proximal jejunum, and ileum were obtained for analysis of mucosal Cu concentration and mRNA expression of Cu regulatory proteins. Duodenal mucosal scrapings were also collected for analysis of malondialdehyde (MDA). Pigs fed high Cu had markedly greater ($P < 0.0001$) Cu concentrations in the duodenal, proximal jejunal, and ileal mucosa than controls. Copper in the duodenal mucosa was greater ($P = 0.003$) in CuSO_4 than TBCC pigs. Duodenal MDA concentrations were greater ($P = 0.003$) in CuSO_4 vs. control pigs and tended ($P = 0.06$) to be greater than in TBCC pigs. Duodenal antioxidant 1 (Atox1) mRNA was downregulated ($P < 0.01$) in pigs fed high Cu compared to controls and was not affected by Cu source. Compared with control pigs, those fed CuSO_4 and TBCC had greater ($P < 0.001$) liver and bile Cu concentrations. Liver Cu was also greater ($P = 0.0007$) in TBCC than CuSO_4 -fed pigs. Hepatic Cu transporting β -polypeptide ATPase (Atp7b) was upregulated ($P = 0.02$) in

the Cu-supplemented pigs compared with controls and did not differ among Cu sources. The acetate:propionate ratio in cecal contents was much greater in pigs supplemented with 225 mg Cu/kg diet than in controls. When fed at 225 mg Cu/kg diet, TBCC may cause less oxidative stress in the duodenum than CuSO₄. Feeding weanling pigs increased Cu resulted in modulation of duodenal Atox1 and liver Atp7b at the transcription level.