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Effect of immune system stimulation and divergent selection for residual feed intake on digestive capacity of the small intestine in growing pigs

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Abstract
Little is known of the consequences of divergent selection for residual feed intake (RFI) on intestinal digestion capacity, particularly during immune system stimulation (ISS). Our objective was to evaluate the impact of ISS and divergent selection for RFI on apparent ileal digestibility (AID) and apparent fecal digestibility (AFD) of nutrients and intestinal nutrient active transport and barrier function. Twenty-eight gilts (63 ± 4 kg BW) from low RFI (LRFI; n = 14) and high RFI (HRFI; n = 14) Yorkshire lines were randomly selected from the Iowa State University RFI herd. Following adaptation, 8 pigs in each line were injected intramuscularly and every 48 h for 7 d with increasing amounts of *Escherichia coli*lipopolysaccharide (ISS+). Remaining pigs were injected with saline (ISS−). Pigs were then euthanized and ileal digesta was collected for measuring AID of nutrients. Fecal samples were collected on a daily basis and pooled for measuring AFD of nutrients. A segment of ileum was used to measure nutrient transport and transepithelial resistance (TER) and/or barrier integrity by Ussing chambers. No effects of line or its interaction with ISS on AID of CP (N × 6.25) and OM, TER, and active nutrients transport were observed. However, ISS decreased ($P < 0.05$) and tended to ($P < 0.1$) decrease AID of CP and OM, respectively. Decrease in AFD of CP as result of ISS was greater in the LRFI line compared to the HRFI line ($P < 0.05$). Relative to ISS−, active glucose and P transport was greater in ISS+ pigs ($P < 0.05$). Genetic selection for LRFI increases the AFD but has no effect on AID of nutrients. It also reduces the total tract digestive capacity of growing pigs during ISS. Immune system stimulation affects both AID and AFD of dietary CP.

Keywords
Swine Feed Efficiency, ileal digestibility, immune system stimulation, nutrient transport, residual feed intake

Disciplines
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Effect of immune system stimulation and divergent selection for residual feed intake on digestive capacity of the small intestine in growing pigs[1]

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ABSTRACT: Little is known of the consequences of divergent selection for residual feed intake (RFI) on intestinal digestion capacity, particularly during immune system stimulation (ISS). Our objective was to evaluate the impact of ISS and divergent selection for RFI on apparent ileal digestibility (AID) and apparent fecal digestibility (AFD) of nutrients and intestinal nutrient active transport and barrier function. Twenty-eight gilts (63 ± 4 kg BW) from low RFI (LRFI; n = 14) and high RFI (HRFI; n = 14) Yorkshire lines were randomly selected from the Iowa State University RFI herd. Following adaptation, 8 pigs in each line were injected intramuscularly and every 48 h for 7 d with increasing amounts of *Escherichia coli* lipopolysaccharide (ISS+). Remaining pigs were injected with saline (ISS–). Pigs were then euthanized and ileal digesta was collected for measuring AID of nutrients. Fecal samples were collected on a daily basis and pooled for measuring AFD of nutrients. A segment of ileum was used to measure nutrient transport and transepithelial resistance (TER) and/or barrier integrity by Ussing chambers. No effects of line or its interaction with ISS on AID of CP (N × 6.25) and OM, TER, and active nutrients transport were observed. However, ISS decreased ($P < 0.05$) and tended to ($P < 0.1$) decrease AID of CP and OM, respectively. Decrease in AFD of CP as result of ISS was greater in the LRFI line compared to the HRFI line ($P < 0.05$). Relative to ISS–, active glucose and P transport was greater in ISS+ pigs ($P < 0.05$). Genetic selection for LRFI increases the AFD but has no effect on AID of nutrients. It also reduces the total tract digestive capacity of growing pigs during ISS. Immune system stimulation affects both AID and AFD of dietary CP.

Key words: ileal digestibility, immune system stimulation, nutrient transport, residual feed intake.

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INTRODUCTION

The gastrointestinal tract is involved in defense activities during systemic immune system stimulation (**ISS**). This involvement results in physiological changes in intestinal tissues including edema, change in gut motility, permeability, microflora (Barbara et al., 2005; Dharmani et al., 2009), expression of digestive enzymes (Jurjus et al., 2006), increased mucin production (Faure et al., 2007), and disordering of epithelial transport systems (Hang et al., 2003). However, little is known about the impact of ISS on measures of nutrient digestibility as it relates to feed efficiency in pigs. Residual feed intake (**RFI**) is a measure of feed efficiency that reflects differences in the efficiency of the use of feed for maintenance and growth, and genetic selection for low RFI (**LRFI**) substantially reduced the amount of feed required for growth and backfat without affecting meat quality (Cai et al., 2008). One of the major physiological processes that contributes to variation in RFI is the digestion of feed (Herd and Arthur, 2009). However, the consequences of genetic selection for RFI on intestinal nutrient digestion capacity, particularly during ISS, are poorly documented for growing pigs. The objective of this study was to evaluate the impact of ISS in pigs divergently selected for RFI on apparent ileal digestibility (**AID**) and apparent fecal digestibility (**AFD**) of nutrients, intestinal nutrient transport, and barrier function.

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MATERIAL AND METHODS

Twenty-eight Yorkshire gilts (63 ± 4 kg initial BW) from pigs selected for LRFI (n = 14) and high RFI (**HRFI**; n = 14) were randomly selected from the Iowa State University RFI herd and used in this study. Pigs were fed a corn (*Zea mays*)–soybean (*Glycine max*)-based diet containing 15.9 MJ/kg DE and 5.2 g/kg standardized ileal digestible Lys twice daily and feed restricted (1.5 kg/d) (Rakhshandeh and de Lange, 2012). Titanium dioxide was used as an indigestible marker. Immune system stimulation was induced according to Rakhshandeh and de Lange (2012). Following adaptation, 8 pigs in each line were injected intramuscularly and every 48 h for 7 d with increasing amounts of *Escherichia coli* O5:B55 lipopolysaccharide (**ISS+**; initial dose of 30 μg/kg BW). Remaining pigs were injected with sterile saline (**ISS–**). Eye temperatures were measured on a daily basis using infrared imaging technique (Rakhshandeh and de Lange, 2012). Blood samples were taken at 0, 24, 72, 120, and 168 h after ISS. At the end of the 7-d period, pigs were euthanized and digesta was collected from the distal 1.5 m of the small intestine for measuring AID of dietary nutrients. The electrophysiological parameters, including transepithelial resistance (**TER**) and short circuit current changes of ileal segment, were determined using Ussing chambers according to Gabler et al. (2007). Feces were collected at least twice daily and pooled for a 7-d collection period for measuring AFD of dietary nutrients. Data were analyzed using a factorial randomized complete block design [PROC MIXED of the SAS system (SAS Institute Inc., Cary, NC)]. Data collected over time were analyzed as repeated measurements.

RESULTS AND DISCUSSION

Repeated injection with lipopolysaccharide (ISS– vs. ISS+) increased ($P < 0.03$) eye temperature (37.7 vs. 38.4ºC; SE = 0.03), plasma levels of IL-1β (0 vs. 152 ng/L; SE = 35) and haptoglobin (2.2 vs. 3.5 g/L; SE = 0.27), and decreased white blood cell count (21.7 vs. 19.6 $\times 10^3/\mu L$; SE = 0.89) confirming successful ISS (Gabler et al., 2008; Rakhshandeh and de Lange, 2012). No line or line × ISS interaction effects on AID of nutrients were observed ($P > 0.90$). Immune system stimulation decreased ($P < 0.05$) AID and AFD of dietary CP and tended to decrease ($P < 0.07$) AID of OM (Table 1). It has been suggested that systemic ISS increases gut endogenous nutrient losses and reduces intestinal absorptive capacity by compromising intestinal integrity and interfering with nutrient transport system (Hang et al., 2003; Faure et al., 2007). However, in the current study, systemic ISS did not affect intestinal integrity (TER) but increased ileal glucose and P active transport as measured by modified Ussing chambers ($P < 0.05$; Table 1). Therefore, in the present study, the decrease in AID of nutrients could largely be attributed to increased intestinal endogenous nutrient, especially protein losses. Increase in glucose use and reabsorption of anions have also been reported by other investigators during ISS (Klasing and Leshchinsky, 2000; Yajima et al., 2009). Immune system stimulation decreased ($P < 0.05$) and tended to decrease ($P < 0.06$) AFD of CP and OM, respectively, in the LRFI line. This probably is associated with compromised microbial activity and increased large intestinal mucin secretion (Barbara et al., 2005; Dharmani et al., 2009). We have observed more exaggerated immune response to a controlled ISS in the

Table 1. Effect of immune system stimulation (ISS) and divergent selection for residual feed intake (RFI) on apparent ileal digestibility (AID) and apparent fecal digestibility (AFD) of dietary nutrients and electrophysiological parameters of ileum[1]

	HRFI[2]			LRFI[2]			*P*		
	ISS–	ISS+	SE	ISS–	ISS+	SE	Line	ISS	Line × ISS
AID, %									
CP (N × 6.25)	82	76	5.6	81	72	5.8	0.39	0.05	0.97
OM	89	80	6.3	87	79	5.2	0.70	0.07	0.90
AFD, %									
CP (N × 6.25)	80	78	1.1	82	79	0.6	0.01	0.04	0.02
OM	90	90	0.3	91	90	0.2	0.01	0.21	0.06
Nutrient transport, $\mu A^3/cm^2$									
Glucose	7.0	9.6	2.01	6.3	11.6	2.32	0.74	0.05	0.48
Glutamine	1.0	1.6	0.94	0.5	0.6	0.2	0.17	0.56	0.70
Phosphorous	7.0	8.4	2.01	5.3	12.7	2.93	0.53	0.04	0.15
TER, Ω^4 cm^2	110	126	15	135	139	29	0.34	0.60	0.75

[1]Data are least squares means and represent data obtained on day 7 after the start of ISS. The AID and AFD was determined using indicator method and slaughter technique.

[2]HRFI = high RFI; LRFI = low RFI; ISS– = repeatedly injected with sterile saline; ISS+ = repeatedly injected with increasing amounts of *Escherichia coli* lipopolysaccharide.

[3]A = ampture.

[4]TER = transepithelial resistance; Ω = ohm.

LRFI line compared to the HRFI line (unpublished data). Apparent fecal digestibility of CP and OM were lower ($P < 0.01$) in the HRFI line compared to the LRFI line (Table 1). Higher AFD of nutrients in animals selected for LRFI largely has been associated with level of feed intake (Herd and Arthur, 2009). However, in the current study feed intake was controlled and identical for both lines. Therefore, the higher AFD of nutrients in the LRFI line can most likely be attributed to lower endogenous (i.e., mucins) losses or higher microbial activity and lower colonic motility or both (McDonald et al., 2010). These results are in general agreement with findings in lines of sheep, cattle, and chicken selected for LRFI (Richardson et al., 2004; Herd and Arthur, 2009). Genetic selection for LRFI increases AFD, but it has no effect on AID of nutrients. The latter suggests that differences in AFD might not be important sources of variation in RFI. Immune system stimulation affects both AID and AFD of dietary nutrients in pigs and may be a major source of feed efficiency variation. Genetic selection for LRFI reduces the total tract digestive capacity of growing pigs during ISS.

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