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Effect of dietary cinnamon on growth performance and adiposity in pigs

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Executive Summary

Cinnamon is the dried inner bark and twig in the Lauracea family that is native to Sri Lanka and India but is cultivated extensively in the tropical regions around the world. Cinnamon is widely added to food and beverages to improve taste and flavour and has been used for centuries in Chinese medicine. Research has suggested that cinnamon may have pharmacological benefits for treatment of diabetes by improving insulin sensitivity. As part of his PhD research Hung (2013) conducted a study with a single dose of cinnamon 1.25% and found improved feed conversion ratio (FCR), daily gain and glucose clearance after an intravenous glucose tolerance test in pigs. Dietary cinnamon also increased ($P<0.05$) the expression of some of the insulin-signaling and other genes in skeletal muscle. This study was conducted to determine the optimum dose of cinnamon and whether it varied with sex of the pig.

The major finding from this study was that dietary cinnamon may increase growth rate and feed efficiency in finisher pigs but that the responses seem to be limited to gilts and may be only transient in nature. Also, there was no clear plateau in response with the response being maximised at the highest dose investigated. Dietary additives and other growth promoters offer a means to manipulate growth performance and carcass quality. However, reported responses have been plagued with variability and inconsistencies and thus further research and development of technologies with known potential is needed to clearly determine under which circumstances they are most effective. It appears that dietary cinnamon may be one of these technologies that deliver inconsistent responses that might not be predictable until the exact mechanism is understood.

In conclusion, dietary cinnamon did appear to improve growth performance in gilts but these effects were transitory and only evident over a 3 week period. Dietary cinnamon may offer benefits for the pig industry in animals that are displaying a degree of insulin resistance such as gilts and gestating and lactating sows and animals exposed to high temperatures. Since there was no clear dose response, the inclusion rate appears to be at least 1.25% (based on study of Hung 2013) or even higher (based on present study) which may preclude its use commercially. Any further work should focus on females in targeted physiological states displaying insulin resistance.

Introduction

Cinnamon is the dried inner bark and twig in the Lauracea family that is native to Sri Lanka and India but is cultivated extensively in the tropical regions around the world. Cinnamon is widely added to food and beverages to improve taste and flavor and has been used for centuries in Chinese medicine. Research has suggested that cinnamon may have pharmacological benefits for treatment of diabetes (Akilen et al., 2012) by improving insulin sensitivity. For example, Mang et al. (2006) found that cinnamon extracts can reduce fasting plasma glucose concentrations in poor glycaemic control diabetic patients while several studies showed that cinnamon extracts can improve insulin sensitivity in mice and in adipocyte cell cultures (Roffry et al., 2006; Sheng et al., 2008). Cinnamon extract has been reported to reduce circulating glucose, insulin, triglycerides and cholesterol concentrations in fructose-fed rats through enhancing of insulin signaling mediated via the regulation of the expression of multiple genes related to carbohydrate and lipid metabolism in adipose tissue (Qin et al., 2004; Qin et al., 2010). Cao et al. (2007) also reported that cinnamon increased the concentration of proteins involved in insulin signaling such as GLUT4, and the anti-inflammatory response in mouse 3T3-L1 adipocyte.

A short-term study in healthy human subjects consuming 2 g of cinnamon 12 hours before an oral glucose tolerance test found that cinnamon was able to lower postprandial blood glucose concentrations and improved insulin sensitivity (Hlebowicz et al., 2009). However, a meta-analysis reported by Baker et al. (2008) reviewed five clinical studies and concluded that the intake of cinnamon did not significantly affect fasting blood glucose concentration. Similarly, a meta-analysis conducted by Kirkham et al. (2009) reported that the evidence was considered as inconclusive as to whether dietary cinnamon reduced fasting blood glucose. More recently, Davis and Yokoyama (2011) conducted a meta-analysis and concluded that cinnamon and/or cinnamon extract can lower fasting blood glucose in people with type 2 diabetes or prediabetes. As part of his PhD research Hung (2013) conducted a study with a single dose of cinnamon 1.25% and found improved feed conversion ratio (FCR) ($P<0.05$), daily gain ($P=0.10$) and glucose clearance ($P<0.05$) after an intravenous glucose tolerance test in pigs. Dietary cinnamon also increased ($P<0.05$) the expression of some of the insulin-signaling and other genes in skeletal muscle. For example, 1.25% dietary cinnamon increased the expression of muscle protein kinase B (Akt), glucose transporter-4 (GLUT-4) and uncoupling protein-3 (UCP-3) by 370, 410 and 760%, respectively (Hung 2013). Unfortunately, some of the effects of dietary cinnamon on growth performance and carcass lean were not significant, possibly because the dose was incorrect or because there were too few pigs per treatment. Regardless, all of the responses are in the desired direction. However, we do not know what the optimal dose of cinnamon is and so the purpose of this project was to conduct a dose response study to define the optimum dose if this technology is to be used commercially.

Methodology

Sixty Large White and Landrace cross-bred finisher boars (n=30) and gilts (n=30) with an initial average live weight of 61.5 kg were weighed and stratified on live weight into 5 blocks within each sex. Within each block pigs were randomly allocated to an individual pen and then randomly allocated into one of 6 diets containing either 0, 0.33, 0.67, 1.0, 1.33 and 1.66% cinnamon offered ad libitum. The control diet was a wheat-based diet containing 14.0 MJ digestible energy/kg, and 0.69 g available lysine/MJ DE and 3.0% fat. The diets were formulated to meet requirements. Feed intake and live weight were recorded weekly. The procedures used in the experiment were approved by The University of Melbourne, School of Land and Environment Animal Ethics Committee.

Pigs were housed in individual pens in The University of Melbourne, Dookie College Piggery Facility. Individual live weight was obtained weekly. Feed intake was recorded weekly throughout the experimental period as estimated by feed disappearance. All pigs had *ad libitum* access to feed and water. At the end of the experiment (day 47, after metabolic challenges; average BW= 105.3 kg), all pigs were transported to a commercial abattoir for slaughter. Slaughter practices included CO_2 stunning followed by exsanguinations. After slaughter, all pigs underwent an ultrasound scan (Pork Scan Pty. Ltd. Australia) to determine P2 backfat depth and hot standard carcase weight (HCWT) and dressing percentage were measured. HCWT was standardized as head on (including tongue); kidneys removed (kidney fat remaining), fore and hind trotters on.

On day 42 pigs had an ear vein cannulated as described by Hung (2013) and were subjected to an intravenous glucose tolerance test (IVGTT). For the IVGTT, basal blood glucose levels were determined in animals by taking small samples (approximately 5 mL), three times during a 30 minute period prior to administration of glucose (-30, -15, -1 minute) from the jugular catheter. At time 0, a bolus of glucose was administered intravenously at a dose rate of 0.4g/kg liveweight as a 50% glucose (dextrose) solution (#AHB0253; Baxter Healthcare, Toongabbie, NSW, Australia). Blood samples (5 mL) were taken at 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20, 22, 25, 30, 35, 40, 45, 50, 60, 75, 90, 120, 150, 180, 210 and 240 minute post glucose administration. In between samples, the catheter was flushed with sterile saline and heparin (diluted to 25 IU/mL).

After slaughter, half-carcasses (right side) were refrigerated for 24 hours and then transported to Werribee Department of Primary Industries for DXA scanning to determine body composition parameters as described by Suster et al. (2004).

Growth performance and carcass data were analysed using the Generalised ANOVA with the respective factors being sex and dose of cinnamon using GENSTAT Version 15.02. The data were also analysed for the effects of pooled doses of cinnamon as well as linear and quadratic dose response effects and interactions. Plasma glucose and NEFA responses to the IVGTT were analysed using the Residual Maximal Likelihood procedure in GENSTAT to ascertain treatment x time effects.

Outcomes

Over the first 21 days average daily gain (ADG) was greater in boars than in gilts (1.14 vs 0.94 kg/d, $P<0.001$) (Table 1). Although there was no main effect ($P=0.21$) of dietary cinnamon on ADG, there was a tendency for a linear increase in ADG ($P=0.063$) with increasing dose of dietary cinnamon, particularly in gilts as indicated by the interaction ($P=0.043$) between sex and dietary cinnamon (Table 1). Over the first 21 days feed conversion ratio (FCR) was lower in boars than in gilts (2.50 vs 2.91 kg/kg, $P<0.001$) (Table 1). Although there was no main effect ($P=0.17$) of dietary cinnamon on FCR, there was a linear decrease in FCR ($P=0.013$) with increasing dose of dietary cinnamon, particularly in gilts as indicated by the strong interaction ($P=0.002$) between sex and dietary cinnamon (Table 1). There were no effects of sex or dietary cinnamon on feed intake over the first 21 days of the study.

While the sex effects that were apparent over the first 21 days were maintained over the period between 21 and 41 days, the linear effects of dietary cinnamon disappeared as did the interactions with sex (Table 1). As a consequence boars grew faster (1.16 vs 0.96 kg/d, $P<0.001$) and with a lower FCR (3.00 vs 2.59 kg/kg, $P<0.001$) but there were no main effects of dietary cinnamon over the entire study. However, there was an interaction ($P=0.027$) between sex and dietary cinnamon on FCR such that while there was no effect of dietary cinnamon on FCR in boars, FCR was lower in

gilts fed the highest dose (1.67%) of dietary cinnamon than those fed the control diet or lower doses of dietary cinnamon (Table 1). The final live weight of boars was greater than that of gilts (109.3 vs 101.2 kg, P<0.001) but there was no effect of dietary cinnamon (Table 1).

Boars had heavier half carcasses (38.5 vs 36.5 kg, P=0.049) containing more lean tissue (25.3 vs 23.3 kg, P-0.004) and wet bone (6.19 vs 5.84 kg, P=0.008) than gilts with no significant difference in fat mass (6.95 vs 7.75 kg, P=0.21) (Table 2). There were no effects of dietary cinnamon on tissue mass (Table 2). There was a trend towards an interaction (P=0.061)between sex and dietary cinnamon for lean percentage such that lean percentage was decreased in boars fed the highest dose of dietary cinnamon but increased for gilts fed the highest dose (Table 2).

As anticipated blood glucose was increased in response to an IVGTT as indicated by the significant effect (P<0.001) of time (Figure 1). While there was no main effect of sex (P=0.18) on plasma glucose there was an interaction (P=0.031) with time such that plasma glucose was increased to a greater extent in gilts than in boars after the IVGTT before declining to a similar value (Figure 1a). There was no effect of any dose of dietary cinnamon or interactions on plasma glucose during an IVGTT and so the pooled (0.33 to 1.67% dietary cinnamon) responses are compared to those of the control (0% dietary cinnamon) (Figure 1b).

Discussion

The major finding from this study was that dietary cinnamon may increase growth rate and feed efficiency in finisher pigs but that the responses seem to be limited to gilts and may be only transient in nature. Also, there was no clear plateau in response with the response being maximised at the highest dose investigated. Previously, Hung (2013) conducted a study with 1.25% dietary cinnamon and found improved FCR (P<0.05) and ADG (P=0.10) gilts. Interestingly, the responses observed by Hung (2013) were in gilts which are consistent with the findings from the present study. Information on the effects of cinnamon supplementation in farm animals is limited, and in particular, there have been no other studies (apart from Hung 2013) examining the effects of cinnamon on the performance and body composition in growing-finishing pigs. Dietary cinnamon supplementation has been shown to improve FCR in broiler chicks (Toghyani et al., 2011) and Yang et al. (2010) found that cinnamaldehyde, one of the active components of cinnamon, can increase DMI in cattle. In rats, dietary cinnamon supplementation has been shown to reduce body fat when fed in conjunction with high fat diet (Couturier et al., 2010).

There was no effect of dietary cinnamon on glucose clearance after an IVGTT indicating that insulin sensitivity was not altered by dietary cinnamon, even at the highest doses. Conversely, Hung (2013) observed improved insulin sensitivity and glucose clearance (P<0.05) after IVGTT in gilts fed 1.25% dietary cinnamon. In that study, dietary cinnamon also increased (P<0.05) the expression of some of the insulin-signaling and other genes in skeletal muscle. For example, 1.25% dietary cinnamon increased the expression of muscle protein kinase B (Akt), glucose transporter-4 (GLUT-4) and uncoupling protein-3 (UCP-3) by 370, 410 and 760%, respectively (Hung 2013). Given that the effects of dietary cinnamon appeared to be transitory in the present study it may be that the failure to detect a difference in insulin sensitivity may be because the effects of dietary cinnamon had subsided by the end of the study.

On the other hand, boars were more insulin sensitive than gilts as indicated by a lower increase in plasma glucose after the IVGTT and more rapid clearance of glucose. This may be related to the greater lean tissue content of the boars compared to the gilts since the degree of insulin sensitivity is negatively related to body fat content and fat deposition in pigs (Dunshea and Cox, 2008).

Dietary additives and other growth promoters offer a means to manipulate growth performance and carcass quality. However, reported responses have been plagued with variability and inconsistencies and thus further research and development of technologies with known potential is needed to clearly determine under which circumstances they are most effective. It appears that dietary cinnamon may be one of these technologies that deliver inconsistent responses that might not be predictable until the exact mechanism is understood. There did appear to be an improvement in growth performance in gilts fed dietary cinnamon up to 1.66% but these effects were transitory and only evident over a 3 week period. There was no clear evidence of improved body composition or insulin sensitivity after 7 weeks in the present study although Hung (2013) did see improvements over a similar period. It should be noted that the source of cinnamon and perhaps purity of cinnamon was different for this study and the study of Hung (2013) which may also impact upon the responses.

It may be that a more appropriate target for dietary cinnamon supplementation could be the lactating sow since they are insulin resistant and responsive to insulin (Dunshea et al. 2005) and only require a short term treatment period. Also, dietary cinnamon may be a useful additive during heat stress as dietary additives that can improve insulin sensitivity can improve resilience against heat stress (Dunshea et al. 2013).

Conclusions and Recommendations

Dietary cinnamon did appear to improve growth performance in gilts but these effects were transitory and only evident over a 3 week period. Dietary cinnamon may offer benefits for the pig industry in animals that are displaying a degree of insulin resistance such as gilts and gestating and lactating sows and animals exposed to high temperatures. Since there was no clear dose response, the inclusion rate appears to be at least 1.25% (based on study of Hung 2013) or even higher (based on present study) which may preclude its use commercially. Any further work should focus on females in targeted physiological states displaying insulin resistance.

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Table 1: Effect of dietary cinnamon and sex on growth performance of pigs

		Dose (%)							Significance				
	Sex	0	0.33	0.67	1.00	1.33	1.67	sed	Sex	Cinn.	Linear	Quad.	Interac.
0-21 days													
ADG (kg/d)	Boar	1.08	1.24	1.13	1.14	1.09	1.15	0.106	<0.001	0.21	0.063	0.73	0.043
	Gilt	0.86	0.82	0.94	0.93	0.98	1.12						
Feed (kg/d)	Boar	2.75	2.89	2.75	2.84	2.80	2.83	0.209	0.15	0.72	0.65	0.94	0.84
	Gilt	2.68	2.60	2.67	2.73	2.73	2.71						
FCR	Boar	2.58	2.35	2.43	2.52	2.62	2.50	0.197	<0.001	0.17	0.013	0.52	0.002
	Gilt	3.14	3.20	2.93	2.93	2.83	2.40						
22-41 days													
ADG (kg/d)	Boar	1.18	1.21	1.16	1.11	1.22	1.16	0.119	<0.001	0.40	0.67	0.54	0.75
	Gilt	1.07	0.88	1.02	0.95	0.96	0.97						
Feed (kg/d)	Boar	3.05	3.19	3.06	3.11	3.29	3.16	0.275	0.32	0.64	0.81	0.53	0.57
	Gilt	3.24	2.89	2.97	2.92	3.13	3.03						
FCR	Boar	2.61	2.67	2.66	2.82	2.73	2.71	0.202	<0.001	0.42	0.41	0.69	0.83
	Gilt	3.06	3.3	2.94	3.19	3.26	3.15						
0-41 days													
ADG (kg/d)	Boar	1.13	1.22	1.14	1.13	1.16	1.16	0.097	<0.001	0.83	0.44	0.58	0.34
	Gilt	0.97	0.85	0.98	0.94	0.97	1.04						
Feed (kg/d)	Boar	2.90	3.04	2.90	2.97	3.04	2.99	0.217	0.19	0.90	0.72	0.72	0.79
	Gilt	2.96	2.74	2.82	2.83	2.92	2.87						
FCR	Boar	2.59	2.50	2.54	2.65	2.66	2.60	0.152	<0.001	0.64	0.22	0.54	0.027
	Gilt	3.09	3.23	2.89	3.04	3.03	2.73						
Final (kg)	Boar	108.1	112.1	108.8	108.1	109.3	109.5	4.176	<0.001	0.96	0.44	0.57	0.37
	Gilt	101.6	96.7	102.1	100.4	101.7	104.8						

Table 2: Effect of dietary cinnamon and sex on half carcass composition of pigs

		Dose (%)							Significance				
	Sex	0	0.33	0.67	1.00	1.33	1.67	sed	Sex	Cinn.	Linear	Quad.	Interac.
Lean (kg)	Boar	24.9	26.3	25.6	25.1	24.9	24.9	1.544	0.004	0.89	0.64	0.69	0.25
	Gilt	23.7	21.5	23.5	22.4	24.3	24.4						
Lean (%)	Boar	67.1	67.8	66.7	65.3	64.8	63.7	3.085	0.064	0.80	0.83	0.62	0.061
	Gilt	61.6	62.3	64.2	63.1	65.6	64.3						
Fat (kg)	Boar	6.12	6.19	6.8	7.41	7.3	7.89	1.500	0.21	0.96	0.70	0.49	0.62
	Gilt	8.77	8.24	7.2	7.51	6.79	7.98						
Fat (%)	Boar	16.2	15.9	17.7	18.9	18.9	20.3	3.18	0.033	0.96	0.81	0.63	0.36
	Gilt	22.6	23.5	19.3	20.9	18.2	20.5						
Bone (kg)	Boar	6.19	6.37	6.01	6.05	6.30	6.25	0.287	0.008	0.77	0.79	0.36	0.52
	Gilt	6.09	5.62	6.00	5.66	5.96	5.80						
Bone %	Boar	16.7	16.3	15.7	15.8	16.3	16.0	0.513	0.59	0.45	0.12	0.70	0.23
	Gilt	15.8	16.3	16.4	16.1	16.2	15.3						
Total (kg)	Boar	37.2	39.1	38.5	38.6	38.6	39.1	2.362	0.049	0.86	0.59	0.31	0.51
	Gilt	38.7	34.2	36.7	34.7	36.9	38.1						

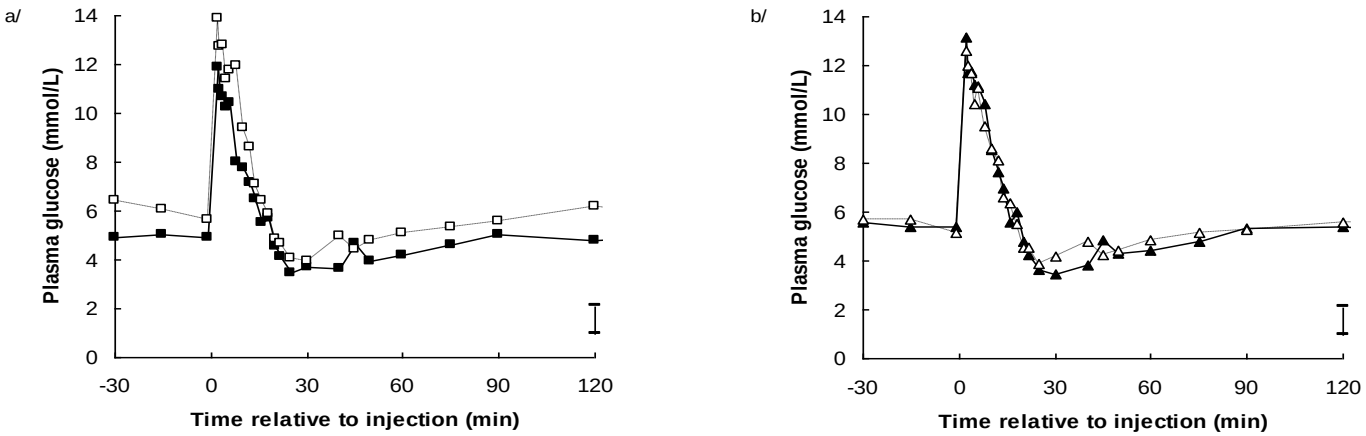
a/
b/
Plasma glucose (mmol/L)
Time relative to injection (min)
0
2
4
6
8
10
12
14
-30
0
30
60
90
120

Figure 1: Relationships between plasma glucose and time relative to either an intravenous glucose tolerance test i(IVGTT) in finisher pigs. Data are for a/ gilts (□) and boars (■) or b/ no added cinnamon (Δ) and added cinnamon(▲). The P-values for the effects of time, sex, cinnamon, sex x time, cinnamon x time, sex x cinnamon and sex x cinnamon x time were <0.001, 0.18, 0.90, 0.031, 1.00, 0.44 and 1.00 , respectively. The standard error of the difference for the interaction between time and either a/ sex or b/ cinnamon is given at time = 120 min. The graphs have been truncated at time = 120 min to allow the acute effect of the IVGTT to be observed.