PREDICTION OF FEED INTAKE BY INDIVIDUAL PIGS HOUSED IN GROUPS USING LITHIUM CHLORIDE.

Report prepared for the
Co-operative Research Centre for an Internationally Competitive Pork Industry

By

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Executive Summary

This research project was undertaken to:

- Establish the optimum dietary inclusion levels of lithium chloride for pigs without compromising feed intake.
- Establish the time of blood sampling after ingestion that provides the best estimate of feed intake.
- Validate feed intake measurements determined using lithium chloride of individual pigs housed in groups.
- Apply lithium chloride feed intake measurements of individuals housed in commercial production systems.
- Compare feed intake measurements determined using lithium chloride with other markers such as bromide.

Detectable levels of lithium in blood plasma were able to be established at intake levels that did not cause feed aversion in pigs. Whilst no significant differences in daily feed intake were seen at any of the intake levels investigated in this study, there was a noticeable reduction in feed intake as the inclusion rate increased. A dietary inclusion level of 0.8 mg of lithium chloride per kg of feed offered a good level of plasma lithium concentrations without compromising feed intake. Sodium bromide was discounted as a marker on its own or in combination with lithium chloride. It added no benefit in accuracy over lithium chloride alone and appeared to influence the intake of pigs, with experiments showing increased feed intakes when sodium bromide was included.

Feed intake of individual pigs was able to be well estimated through the analysis of plasma lithium concentration when the diet was fed on an *ad libitum* basis. Whilst the variation in plasma lithium concentration as a response to feed intake increased the longer it was fed, the highest correlation occurred at 36 hours after the initial feeding (R^2=0.81), with a strong linear relationship existing during this period.

The feeding behaviour of individual pigs and the dynamics of group housing influenced the ability of lithium chloride to be used as a measure of feed intake. Feed intake as calculated from plasma lithium concentration explained less than half (R^2=0.43) the variation in feed intake between individuals at less than normal stocking rates and performed worse (R^2=0.18) at normal stocking rates. The results would appear to be greatly influenced by the time of initial feeding which ranged from 8 minutes to almost 6 hours. Given the 36 hour period gave the best relationship, the deviation from this would be significant.

Whilst this method showed some value when applied to individually housed pigs, when applied to the group situation the ability to predict feed intake from plasma lithium concentrations appear limited. It may however still be useful as a measure of uptake to identify animals that have or have not consumed feed in, for example, a specific in-feed medication program.

The continued investigation of lithium chloride as a feed marker is not warranted. Future investigations into measuring the feed intake of individual pigs in group housing need to take into account the feeding behaviour and group-dynamics that exist when pigs are housed in groups.

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1. Introduction

Measurement of feed intake of individual pigs housed in groups is a difficult task. Capacity to achieve this would not only facilitate a reduction in variation in pig performance within groups, but would also allow identification of those animals within a group that are not eating and are either predisposed to disease, or poor lifetime performance.

Lithium chloride has been used by ruminant nutritionists to estimate supplement intake in grazing ruminants (Kahn, 1994). Lithium chloride has a lot of potential as a marker given it is cheap, it is not radioactive, it can be analysed easily, and is not present in normal pig feed ingredients. Although lithium salts have pharmacological and toxic effects and can cause feed aversion, the amounts necessary to cause these effects in ruminants are much greater than the amounts generally required as a marker with the same, hopefully, applying to monogastrics.

Suharyono *et al.* (1991) and Kahn (1994) determined supplement intake in sheep by monitoring lithium levels in blood plasma 4-14 hours after offering animals a single feed of supplement containing lithium chloride. Having assumed that lithium distribution volume was proportional to liveweight, the product (lithium concentration x live weight) for each animal was expressed as a proportion of the sum of these products across all animals; this gave an estimate of the proportion of the total supplement offered that was consumed by each animal. It is hypothesised that the same process could be applied to measure the individual feed intake of pigs housed in groups.

In the event that a marker such as lithium chloride can be used to routinely monitor feed intake of individuals housed in groups, many practical applications exist within a commercial pig production system. Apart from measurement of variation in intake within a group, or the prediction of the onset of disease, lithium chloride measurements of feed intake could be applied in the following ways:

1. To measure the intake of creep feed by suckling piglets and the value of different creep feeding regimes.
2. To assess feeder types and the placement of feeders within a pen.
3. To assess the influence of weaning and boxing on feed intake and the appropriateness of post-weaning/mixing feeding strategies.
4. As a basis for the establishment of new, or a review of, nutrition programs within commercial herds and the relative dietary energy content of diet phases.
5. As a tool in the assessment of shed environment and the potential influences on feed intake.
6. To determine the potential benefit of phase feeding programs based on variation in intake within respective groups.
7. Capacity exists to utilise the technology within genetic selection programs where feed intake may be a selection parameter.

2. Experiments

This work was conducted under the auspicious of the Queensland Department of Primary Industries Animal Ethics Committee (SA 2006/09/148 & SA 2007/09/210) and QAF Meat Industries Animal Ethics Committee (08N012C).

Experiment 1. *Determination of optimum dietary inclusion level of lithium chloride for pigs without compromising feed intake.*

Lithium chloride has been assessed as a marker for supplement intake in ruminants (Kahn, 1994; Suharyono, 1992). This compound is suited for this use as naturally occurring lithium salts are only found in very low concentrations (<10 ppb) in both plant and animal fluids. Lithium chloride is also relatively cheap, chemically stable, easily analysed, not present in normal pig feed ingredients, relatively safe to handle and has an analogous taste to sodium chloride. However, lithium chloride can be an emetic agent and is used in this role to cause feed aversion in grazing animals (Burritt and Provenza, 1990; Ralphs, 1992).

As a consequence of lithium chloride's emetic properties it is important that a dietary inclusion level be established that allows for a detectable concentration of lithium in blood plasma, whilst not disrupting feeding patterns or intakes.

Two experiments were conducted to determine the optimum dietary inclusion level of lithium chloride.

Methods

Experiment 1a

Twenty-five male pigs (hybrid, mainly Large White x Landrace) housed in individual pens were allocated to one of five dietary treatments based on a randomised block design (blocked by liveweight) at eight weeks of age and 25.1 ± 1.4 (mean ± SD) kg live weight. A basal mash diet (13.9 MJ Digestible Energy (DE)/kg; 0.68 g Available Lysine (AvL)/MJ DE) was fed for 14 days to allow for the determination of voluntary feed intake. On day 15 and 16 diets were individually prepared for each pig, based on observed feed intake and body weight (BW) on day 14, to deliver lithium chloride (LiCl, Sigma-Aldrich, 213233) at 10, 20, 30, 40 or 50 mg/kg BW. Diets were prepared fresh each day by blending the basal diet with a diet pre-mixed with 2,500 mg/kg LiCl. Daily feed intake was recorded for both days, and a blood sample was taken 48 hours after treatment diet introduction, via jugular venapuncture (BD Vacutainer, Red Serum Tube, 367895) to allow for the determination of plasma lithium concentration.

Pigs were weighed on day 17, fed the basal diet, reblocked and allocated to one of five treatments, LiCl at 10, 20, 30, 40, 50 mg/kg BW plus sodium bromide (NaBr, Sigma-Aldrich, 220345) at 30 mg/kg BW. On day 18 and 19 diets were individually prepared as previously, blending the basal diet with a LiCl pre-mixed diet and a NaBr pre-mixed diet.

Daily feed intake was recorded for both days and two blood samples were taken 48 hours after treatment diet introduction, via jugular venapuncture to allow for the determination of plasma lithium and bromide concentrations. Lithium and bromide concentrations were determined by inductively coupled plasma mass spectrometry (ICP-MS, Symbio Alliance, Eight Mile Plains, QLD).

Individual pigs were their own controls with results analysed by ANOVA, feed intake during the non-treatment period was used as a covariate.

Experiment 1b

Twenty-five male pigs (hybrid, mainly Large White x Landrace) housed in individual pens were allocated to one of five dietary treatments based on a randomised block design (blocked by liveweight) at eight weeks of age and 26.4 ± 1.2 (mean ± SD) kg live weight. A basal mash diet (13.9 MJ DE/kg; 0.68 g AvL/MJ DE) was fed to all animals for three days. On the fourth day, pigs were offered treatment diets containing 0.2, 0.4, 0.6, 0.8 and 1.0 g/kg LiCl, daily feed intake was recorded throughout this period. Pigs were offered the basal diet for the next three days, then on the eighth day pigs were offered treatment diets containing 0.2, 0.4, 0.6, 0.8 and 1.0 g/kg LiCl and 0.04, 0.08 0.12, 0.16 and 0.20 g/kg NaBr respectively, with daily feed intake recorded throughout.

Individual pigs were their own controls with results analysed by ANOVA, feed intake during the non-treatment period was used as a covariate.

Results

The inclusion of lithium chloride (LiCl), on a bodyweight basis, did not significantly affect the feed intake of treatment animals either when fed on its own or in combination with sodium bromide (NaBr, Table 1), however, there was a tendency for pigs fed higher concentrations of LiCl, alone, to have a lower feed intake. Feed intake did not appear to alter with the inclusion of LiCl alone, although when NaBr was also included, average daily feed intake rose substantially.

Table 1. Average daily feed intake (kg/d) of male pigs (25.1±1.4 kg) fed a basal diet (Control) for 14 days, a diet containing lithium chloride (LiCl) for two days, or a diet containing LiCl and sodium bromide (LiCl & NaBr). Treatment concentrations based on pig bodyweight.

	Treatment					SED	P-value
LiCl (mg/kg BW)	10	20	30	40	50		
NaBr (mg/kg BW)	30	30	30	30	30		
Control	1.41	1.33	1.41	1.37	1.32	0.10	0.841
LiCl	1.41	1.41	1.39	1.36	1.24	0.06	0.065
LiCl & NaBr	1.68	1.72	1.71	1.68	1.62	0.04	0.148

Plasma lithium concentration reflected dietary inclusion level (Figure 1) with a strong linear regression between plasma lithium concentration and diet inclusion level. However when NaBr was included with LiCl the relationship weakened (R^2=0.87 *c.f.* R^2=0.71)

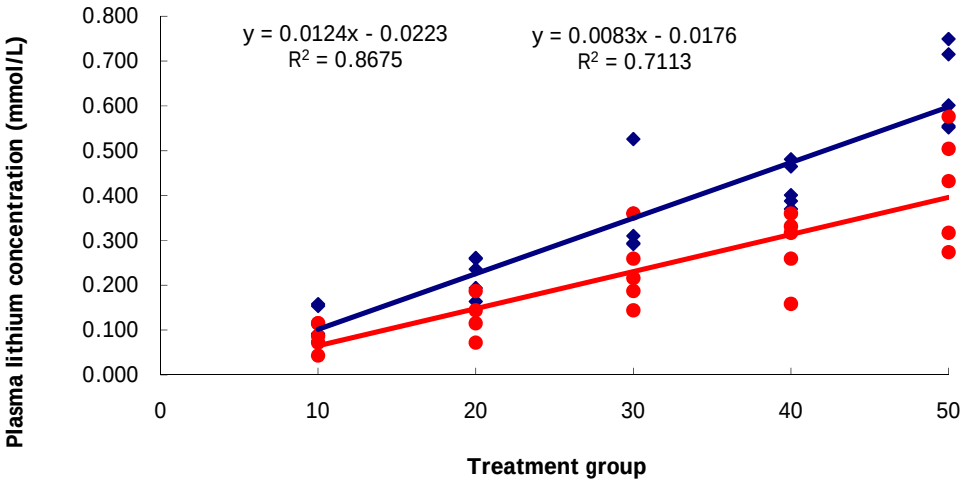

Figure 1. Regression of plasma lithium concentration (mmol/L) with treatment level (10, 20, 30, 40, 50 mg/kg body weight) when lithium chloride was included alone (♦) or in combination with sodium bromide (•).

The inclusion of varying concentrations of LiCl, with or without NaBr, in diets did not result in significant changes in the feed intake of pigs (Table 2), although there was, again, a trend for higher concentrations of LiCl to reduce feed intake, especially when fed in combination with NaBr.

Table 2. Average daily feed intake (kg/d) of male pigs (26.4±1.2 kg) fed a basal diet (Control) during the non-treatment period, a diet containing lithium chloride (LiCl), or a diet containing LiCl and sodium bromide (LiCl & NaBr). Treatment concentrations on a per kg feed basis.

	Treatment					SED	P-value
LiCl (g/kg)	0.2	0.4	0.6	0.8	1.0		
NaBr (g/kg)	0.04	0.08	0.12	0.16	0.20		
Control	1.22	1.37	1.36	1.41	1.38	0.13	0.669
LiCl	1.44	1.27	1.40	1.33	1.21	0.18	0.732
LiCl & NaBr	2.17	2.16	2.09	1.98	1.83	0.23	0.556

A back calculation was performed on the diets fed to pigs in *experiment 1a* to allow for comparison between plasma lithium concentration and dietary inclusion rate. Plasma lithium concentration was well correlated with dietary inclusion rate (R^2=0.86, Figure 2), although there does appear to be a funnelling effect with greater variation in plasma concentration as the inclusion level increased.

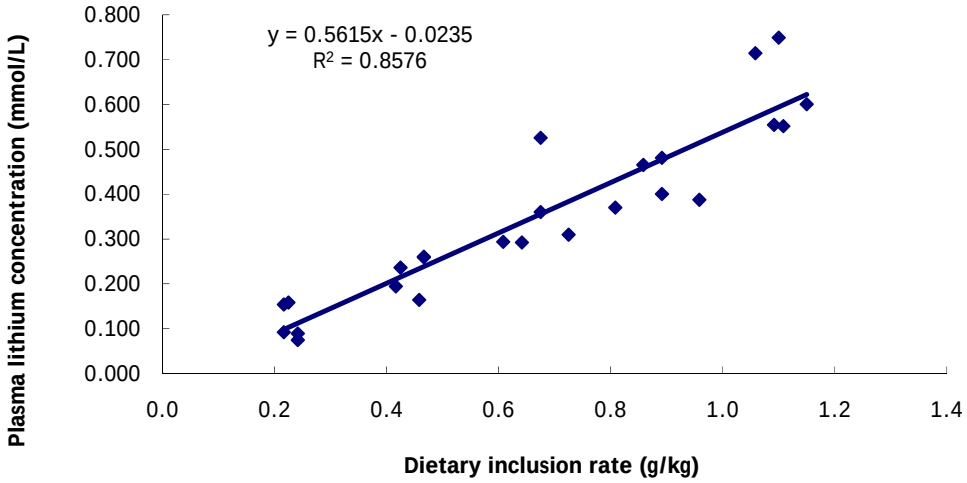

Figure 2. Regression of plasma lithium concentration (mmol/L) with dietary inclusion level (g/kg) as determined by back calculation, when lithium chloride was included alone.

Discussion

Detectable levels of lithium in blood plasma were able to be established at intake levels that did not cause feed aversion in pigs. Whilst no significant differences in daily feed intake were seen at any of the intake levels investigated in this study, there was a noticeable reduction in feed intake as the inclusion rate increased, such that pigs appear to be more sensitive to lithium than sheep, which had a tolerance level of 50 mg/kg body weight (Suharyono, 1992).

Whilst this is important information, to be practical the use of lithium chloride as a marker of feed intake needed to work on a set dietary inclusion level rather than a body weight basis, hence the conduct of *experiment 1b*.

Sodium bromide was discounted as a marker on its own or in combination with lithium chloride. It added no benefit in accuracy over lithium chloride alone and appeared to influence the intake of the pigs, with both experiments showing increased feed intakes when sodium bromide was included. The use of potassium bromide in dogs to control epilepsy also sees this increase in feed intake (Boothe, 2001) although this is associated with long-term rather than short-term use.

Through the comparison of detectable plasma lithium concentrations, resultant daily feed intakes, funnelling effects in data and issues surrounding diet preparation, we have concluded that a dietary inclusion level of 0.8 g lithium chloride per kg of feed offered gives a good level of plasma lithium concentration (~0.425 mmol/L) without compromising feed intake. This is equivalent to approximately 36 mg/kg body weight, below the tolerance level of sheep, and evidently pigs.

Experiment 2. *Kinetic studies to establish plateau levels of lithium chloride (LiCl) in pig blood plasma.*

In assessing the suitability of lithium chloride as a marker of feed intake it is important to understand how plasma lithium concentrations change with time. By establishing a pattern of plasma lithium concentration in response to feeding we will be able to establish a sampling time that is best correlated with actual feed intake.

Experiment 2a

Ten male pigs (12 weeks of age, approximately 40kg) were allowed to acclimatize to individual pens (0.75m x 2.2m, plastic flooring) and fed a standard grower diet (14.0 MJ DE/kg, 0.70g AvL/MJ DE) *ad libitum* for one week. The pigs were then fitted with auricular-external jugular vein catheters as described below.

Auricular-external jugular vein catheterization procedure.

Pigs were premedicated with a single intramuscular injection consisting of a cocktail of Xylazil (Xylazine hydrochloride 20 mg/ml; 2 ml Troy Laboratories, Smithfield, NSW) and Ketamil (Ketamine hydrochloride 100 mg/ml; 5 ml Troy Laboratories, Smithfield , NSW). They were left, undisturbed, in their holding pens for 15 minutes. When sedate, pigs were transferred to the surgery table and an intravenous injection of 5% Thiobarb (Thiopentone sodium 50 mg/ml; 10 ml Jurox Pty Ltd, Rutherford, NSW) was administered via an ear vein to induce deep anaesthesia. An intravenous catheter placement unit (Optiva 16G x 32 mm, Jelco, Carlsbad, CA, USA) was inserted into the middle or lateral auricular vein, the needle was withdrawn, leaving the sheath intact in the vein. A calibrated sterile poly-vinyl catheter (Single lumen, 0.50 mm ID, 0.90 mm OD, Dural Plastics and Engineering, Dural, NSW) fitted with a wire guide (0.46 mm OD, 145cm long, Heparin coated, William A. Cook Australia Pty Ltd, Eight Mile Plains, QLD) was passed through the sheath into the vein a distance of approximately 40cm, placing the end of the catheter in the external jugular vein. A luer lock was placed on the end of the catheter to allow attachment to a syringe. Heparinised saline (1,000 IU/ml, Pfizer Australia Pty Ltd, West Ryde, NSW) was immediately injected into the catheter to keep it free of blockages.

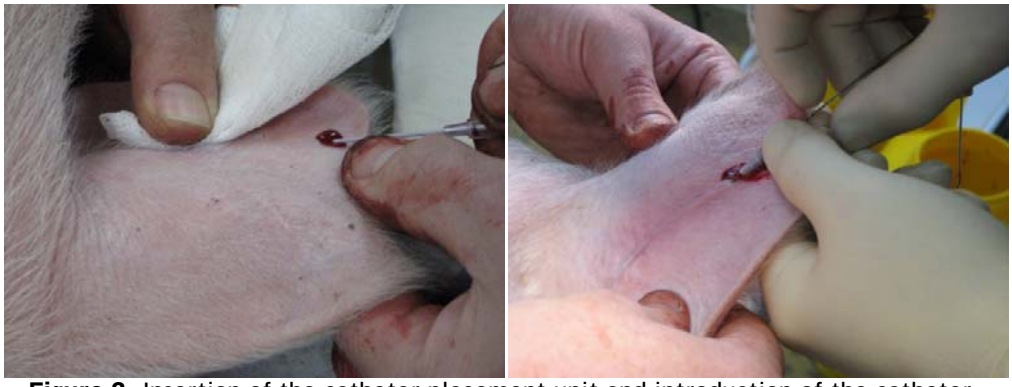

Figure 3. Insertion of the catheter placement unit and introduction of the catheter.

The ear was then folded back against the neck of the pig and the catheter was checked for blood flow, if no flow occurred the ear was moved until free flow was achieved or the catheter was retracted slightly. Once flow was established the ear was secured in place against the neck of the pig with self-adhesive bandage (Elastoplast, 7.5 cm x 2.75 m, Beiersdorf Australia Pty Ltd, North Ryde, NSW) and waterproof tape, forming a collar to prevent the pig from dislodging the catheter. A small vinyl pouch was placed under the collar to hold the external portion of the catheter.

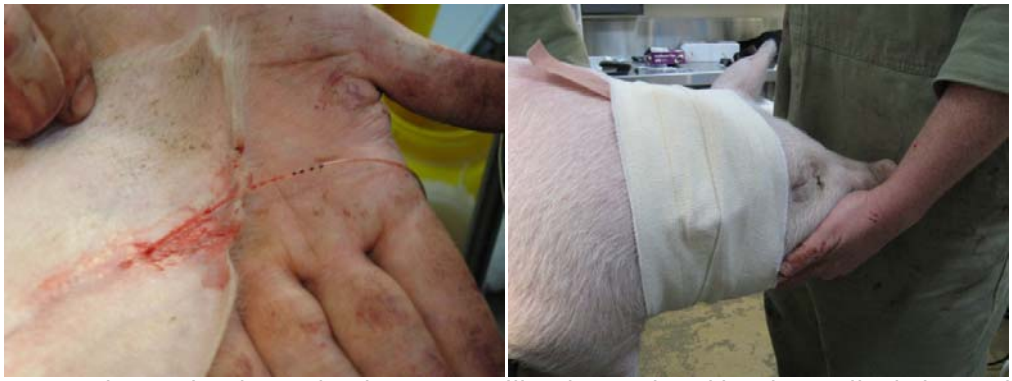

Figure 4. An inserted catheter showing 40 cm calibration mark and bandage collar being applied.

The catheter was filled with 1,000 IU/ml heparinised saline and capped prior to placement in the pouch. Catheters were flushed daily with 2 ml of 1,000 IU/ml heparinised saline.

Figure 5. Attachment of vinyl pouch to house external portion of the catheter and a recovered pig the day after catheter placement.

Feeding and blood collection.

An initial sample of blood (9 ml) was obtained 30 minutes prior to feeding to establish a baseline reading for plasma lithium concentration. Pigs were offered 2.5 kg of the standard grower diet to which 0.8 g/kg lithium chloride had been incorporated; eight pigs had their residual feed removed after 1 hour, whilst the remaining two pigs were allowed to consume feed on an *ad libitum* basis. Blood samples were taken 1, 2, 4, 8, 12, 16, 24

and 28 hours after feed was offered; feed intake was recorded at these times for the *ad libitum* fed pigs.

Experiment 2b

Ten male pigs (12 weeks of age, approximately 40kg) were allowed to acclimatize to individual pens (0.75m x 2.2m, plastic flooring) and fed a standard grower diet (14.0 MJ DE/kg, 0.70g AvL/MJ DE) *ad libitum* for one week. The pigs were then fitted with auricular-external jugular vein catheters as described previously.

Pigs were offered *ad libitum* access to a standard grower diet to which 0.8 g/kg lithium chloride had been incorporated. Blood samples were taken, and feed intake recorded, at 4, 8 and 12 hours after initial feed was offered and every 12 hours for the next five days.

Results

Plasma lithium concentration rose rapidly in response to feeding and began to plateau at four hours, remaining at this level for eight hours before gradually declining (Figure 6). However this plateau level was not well correlated with feed intake, with only a moderate explanation of the relationship at 4 (R^2=0.41), 8 (R^2=0.68) or 12 (R^2=0.60) hours (Figure 7). There was a considerable difference in the shape of the curve between those animals fed a single-event or continuously (Figure 6).

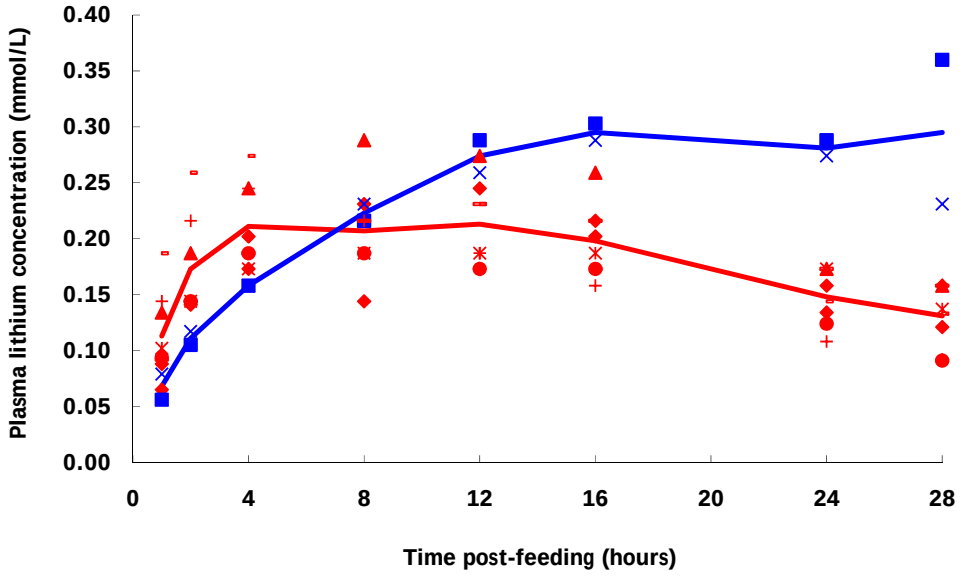

Figure 6. Plasma lithium concentration as a response, over time, to a single feeding event, red, and continuous feeding, blue – experiment 2a. Symbols represent individual animals, lines represent averages.

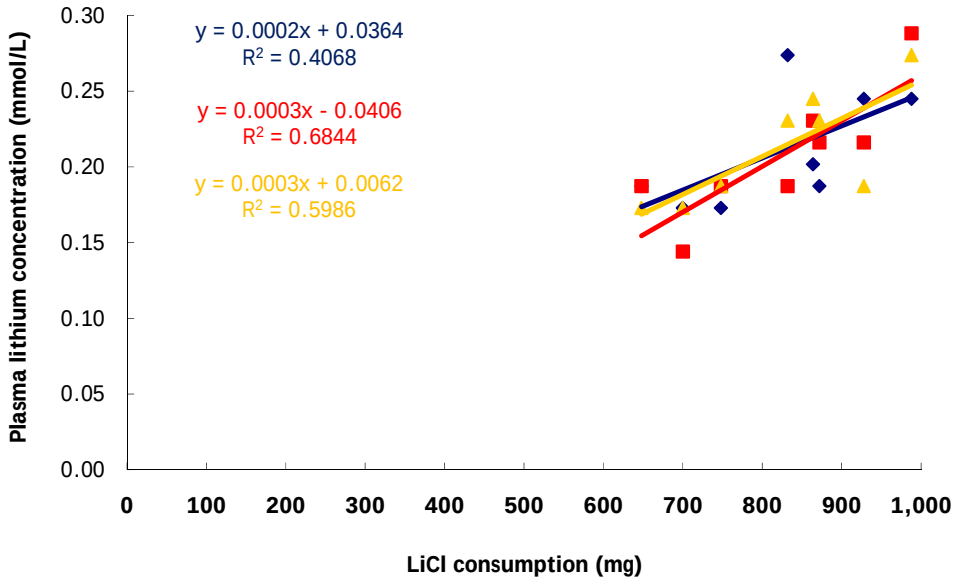

Figure 7. Regression of plasma lithium concentration with consumption at 4 (◆), 8 (■) and 12 (▲) hours post-feeding, single event – experiment 2a.

Those animals fed continuously had a slower build-up of plasma lithium concentration and reached a higher concentration without plateauing. Plasma lithium concentration better reflected intake (R^2=0.86) when fed continuously (Figure 8).

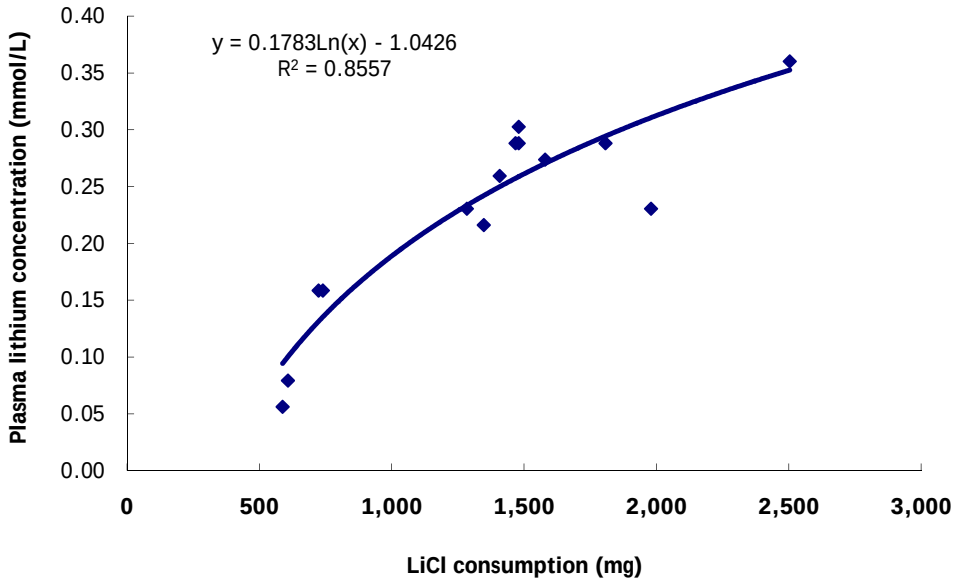

Figure 8. Regression of plasma lithium concentration with consumption for continuously fed pigs – experiment 2a.

The variation in plasma lithium concentration became greater the longer pigs remained on the diet (Figure 9) and consequently their level of consumption (Figure 10). However, the relationship between intake and plasma concentration was linear and strong until 36 hours (Figure 11.)

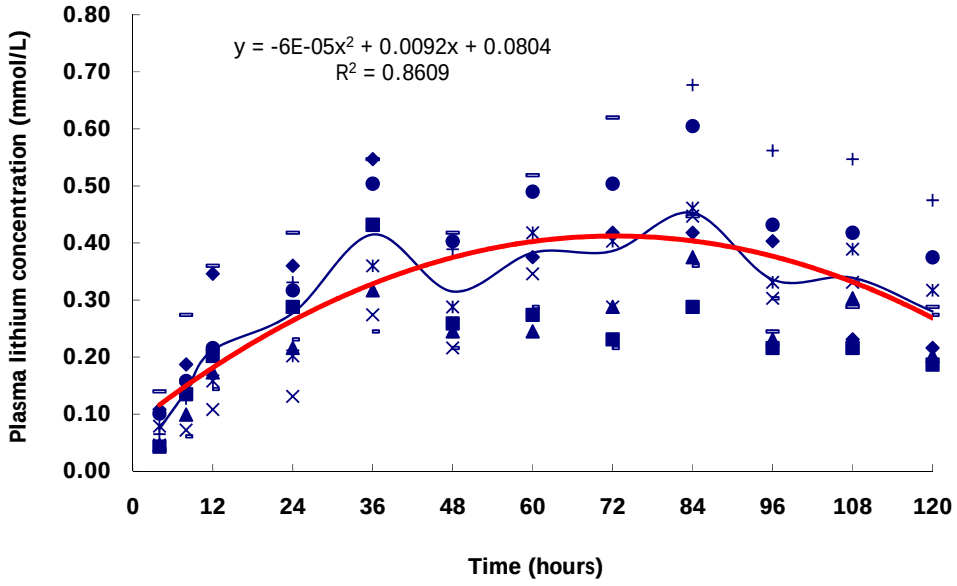

Figure 9. Plasma lithium concentration as a response, over time, to continuous feeding – experiment 2b. Symbols show individual pigs, blue line shows the average and red line shows the best-fit trend line.

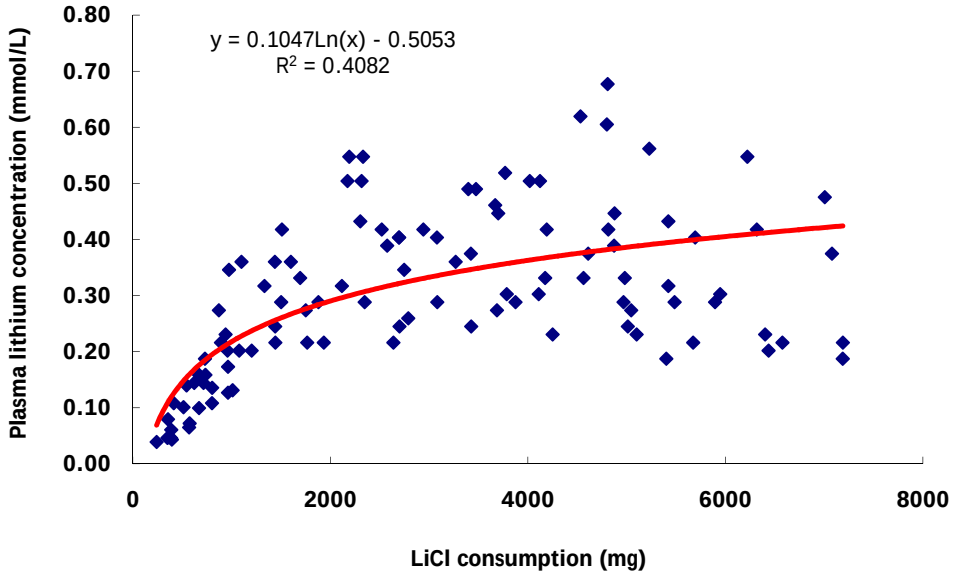

Figure 10. Regression of plasma lithium concentration with consumption for continuously fed pigs - experiment 2b.

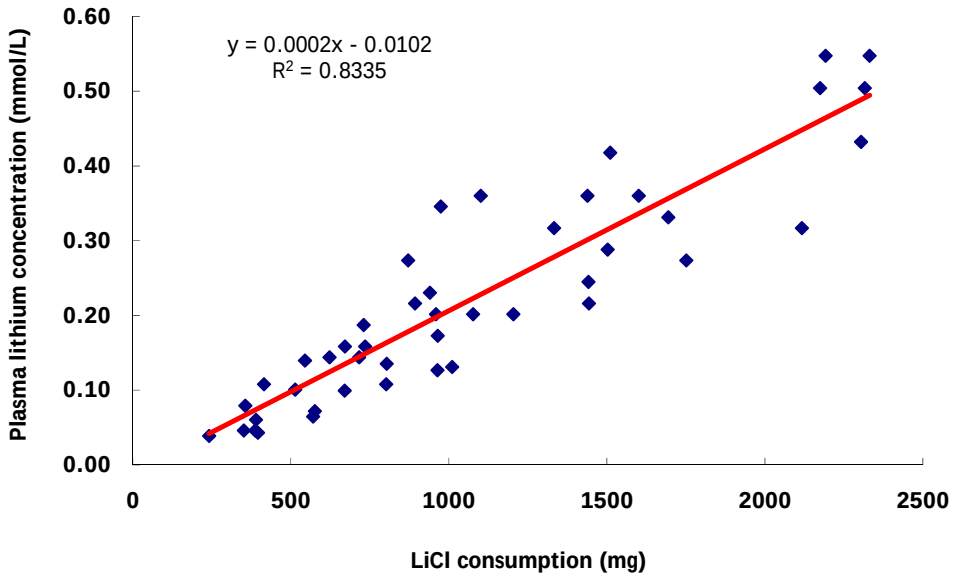

Figure 11. Regression of plasma lithium concentration with consumption for continuously fed pigs for the first 36 hours of feeding - experiment 2b.

The correlation between consumption and plasma lithium concentration (Table 3) was also strongest at 36 hours after initial feeding. The increased variation that existed the longer the diet was fed is also reflected in these correlations with almost no relationship existing after 72 hours.

Table 3. Pearson correlation between plasma lithium concentration and lithium chloride consumption at each bleed event.

Time (hours)	4	8	12	24	36	48	60	72	84	96	108	120
Correlation (R^2)	0.62	0.63	0.54	0.72	0.81	0.65	0.27	0.58	0.20	0.19	-0.08	0.17

Discussion

Feed intake was able to be well estimated through the analysis of plasma lithium concentration when the diet was fed on an *ad libitum* basis. Using a single feed event was neither a good reflection of the consumption pattern of the pig, one-third of daily intake was consumed in the first hour, nor well correlated with plasma lithium at four, eight or twelve hours post-weaning. Whilst the variation in plasma lithium concentration with feed intake grew larger the longer animals were fed, plasma lithium concentration was most highly correlated with consumption 36 hours after initial feeding, and a strong linear relationship exists during this period.

Experiment 3. *Validation of feed intake measurements using lithium chloride.*

An optimum inclusion rate for lithium chloride to be used as a feed marker has been established such that it provides detectable levels of plasma lithium without causing feed aversion. Similarly, a kinetic study has found that by feeding diets containing lithium chloride for 36 hours and collecting blood at this time results in the best prediction of feed intake. This experiment was conducted at QAF Meat Industries, utilising the QAF electronic feeding system to record the individual intake of group-housed pigs, to test the hypothesis that the inclusion of lithium chloride in feed will allow for the accurate determination of feed intake of individual animals when housed in groups.

Experiment 3a

Methods

Twenty-four (24) male pigs, 42.0±1.7 kg, were housed in two group pens (12 per pen) and allowed to acclimatise for 1 week. A basal pellet diet (14.0 MJ DE/kg; 0.70 g AvL/MJ DE) was offered *ad libitum* each day, with the intake of the group recorded on an event basis using the QAF electronic feeding system. On day 8 (48.9±4.0 kg) the basal diet was replaced with a hand-mixed diet containing 0.8 g/kg of lithium chloride and feed was recorded for 36 hours post-introduction. After this period, blood was collected via jugular venopuncture from each animal and stored for testing, and animals returned to the basal diet. This procedure was also followed on day 24 (61.1±5.9 kg) of this experiment. The amount of feed consumed during this period, by both the individuals and the group, was also recorded.

The calculation of feed intake was done according to the method suggested by Suharyono (1992). This author suggested that the effective volume of distribution of lithium would be proportional to liveweight. Thus plasma lithium concentration should be scaled according to liveweight to correct for this dilution effect. This value (lithium*liveweight) for each pig in the trial was summed to give a pen value and each individual's value expressed as a proportion of the summed pen value. This proportion was then multiplied by the mass of feed the entire pen consumed to give estimated individual intake.

$$Feed\ intake\ animal = \left(([Li] \times Wt) \div \sum([Li] \times Wt)\right) \times Group\ feed\ intake$$

Results

Plots of plasma lithium concentration versus feed intake during the 36 hour period show poor correlation (Figures 12 & 13). The correlation between plasma lithium concentration and feed intake during the first feeding event at day 8 (Figure 12) is moderate and practically linear (R^2=0.37) however the correlation during the event at day 24 (Figure 13) is poorer (R^2=0.14) and cubic in nature.

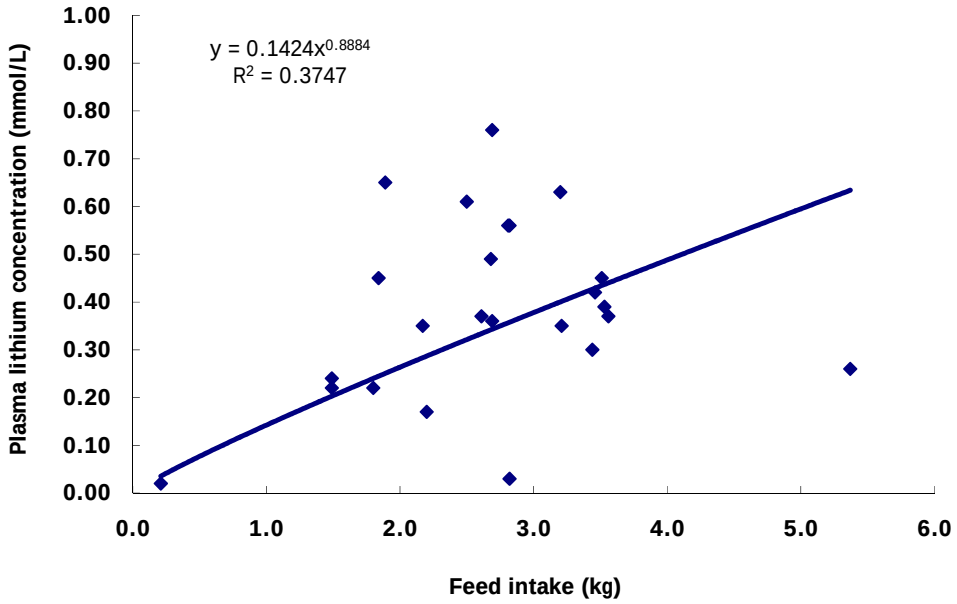

Figure 12. Plasma lithium concentration versus feed intake during the 36 hour period of feeding at day 8.

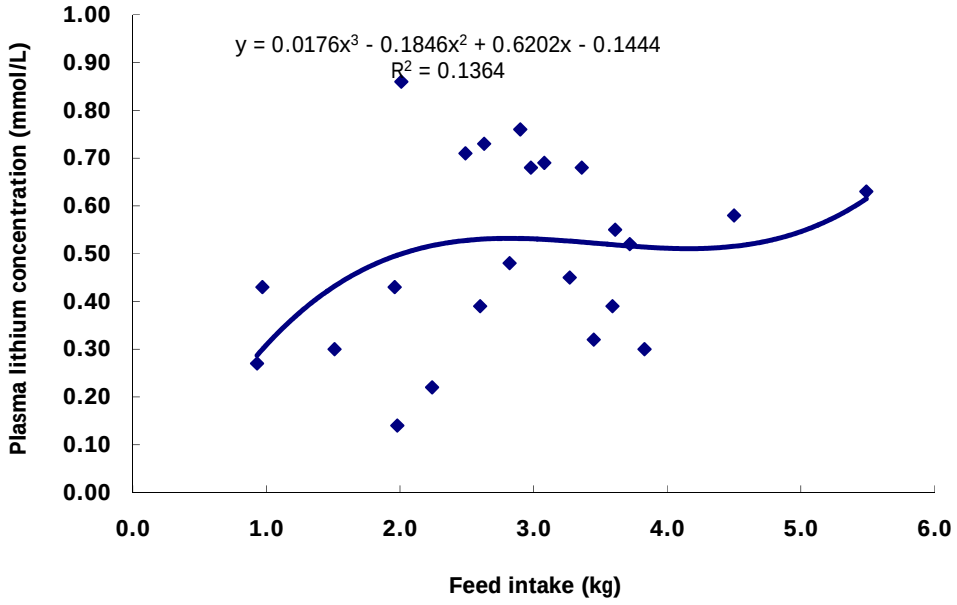

Figure 13. Plasma lithium concentration versus feed intake during the 36 hour period of feeding at day 24.

When intake was estimated using the method described by Suharyono (1992) a slight improvement in correlation between estimated and actual feed intake occurred at day 8 (Figure 14) however this was still relatively poor (R^2=0.43). Whilst the best predictive model for estimated intake versus actual intake remained cubic in the day 24 event (Figure 15) there was a weakening in the correlation (R^2=0.14).

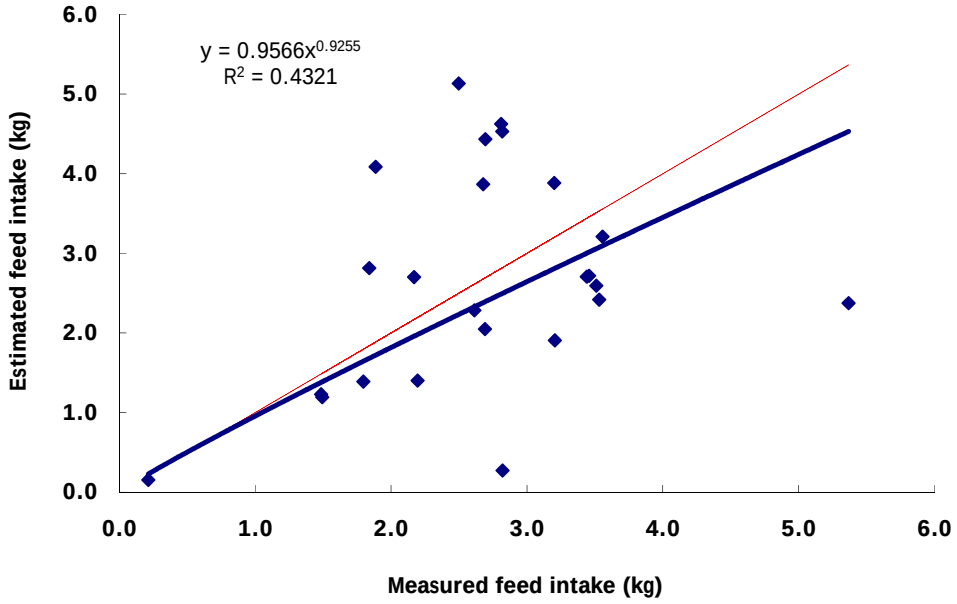

Figure 14. Estimated feed intake calculated from plasma lithium concentration versus feed intake during the 36 hour period of feeding at day 8. Line of identity is shown in red.

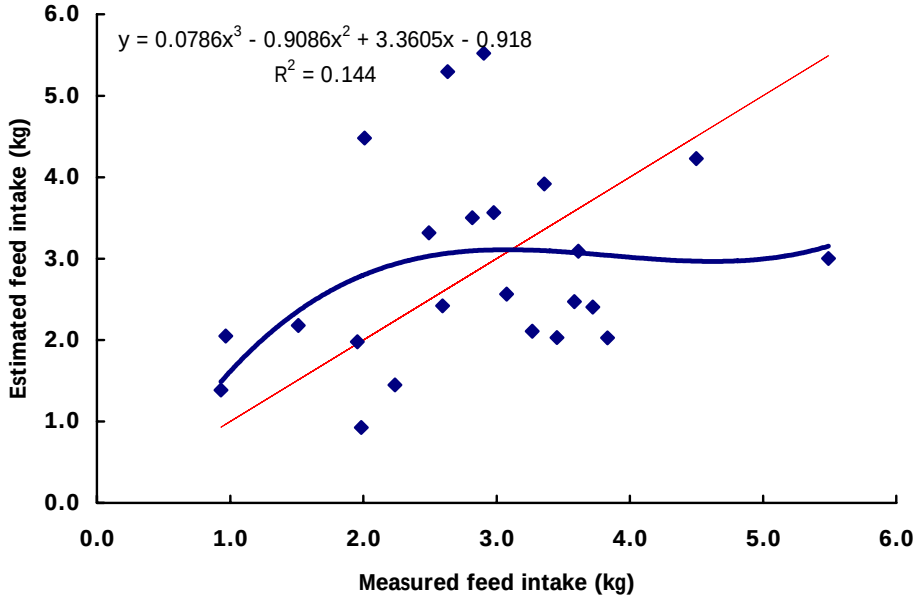

Figure 15. Estimated feed intake calculated from plasma lithium concentration versus feed intake during the 36 hour period of feeding at day24. Line of identity is shown in red.

Discussion

Reasonable correlations were seen between plasma lithium concentration and feed intake during the initial feeding period but these results were not maintained at subsequent events. The estimation of feed intake using the methods of Suharyono (1992) increased the predictive ability of plasma lithium concentration, but only marginally.

However, further investigation of the data suggested these results may have been compromised. Issues identified included:

- An extended time period between the diet being offered and first feeding event, up to 12 hours.
- A significant time lapse between last feeding event and bleed event.
- Low start weight and low stocking density on the electronic feeders.
- Issues with mixing of lithium chloride into diet.

As a consequence of these issues a secondary investigation was undertaken to develop a more robust protocol for the utilization of lithium chloride as a measure of individual feed intake within group-housing.

Experiment 3b

Method

One-hundred and twenty (120) male pigs, average weight 63.2±7.1kg, were housed in four group pens (30 per pen) and allowed to acclimatise for 1 week. A basal pellet diet (13.8 MJ DE/kg; 0.70 g AvL/MJ DE) was offered *ad libitum* each day, with the intake of the group recorded on an event basis using the QAF electronic feeding system. At 4.00 pm on day 8 feeders were turned off and filled with a diet, of the same specification, containing 0.8 g/kg of lithium chloride (lithium chloride was included in vitamin and mineral premix prior to milling).Feeders were turned on at 6:00 am on the following morning (day 9) and feed was recorded for 36 hours post-introduction. After this period, feeders were turned off and residual feed was recorded, and, blood was collected via jugular venopuncture from each animal and stored for testing.

The calculation of feed intake was done according to the method suggested by Suharyono (1992). This author suggested that the effective volume of distribution of lithium would be proportional to liveweight. Thus plasma lithium concentration should be scaled according to liveweight to correct for this dilution effect. This value (lithium*liveweight) for each pig in the trial was summed to give a pen value and each individual's value expressed as a proportion of the summed pen value. This proportion was then multiplied by the mass of feed the entire pen consumed to give estimated individual intake.

$$Feed\ intake\ animal = \left(([Li] \times Wt) \div \sum([Li] \times Wt)\right) \times Group\ feed\ intake$$

Results

There is little relationship (R^2=0.04) between an individual's plasma lithium concentration and measured feed intake (Figure 16) when housed in groups. Taking into account the

animal's weight and the feed consumption of the group improves the relationship somewhat (R^2=0.18; Figure 17), but not to a level that has practical value.

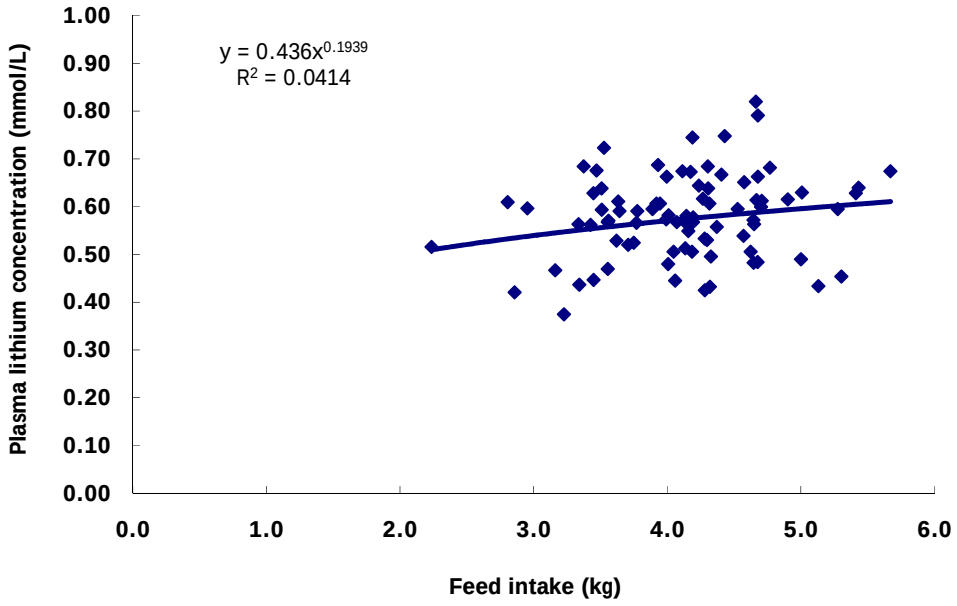

Figure 16. Plasma lithium concentration versus feed intake during the 36 hour period of feeding.

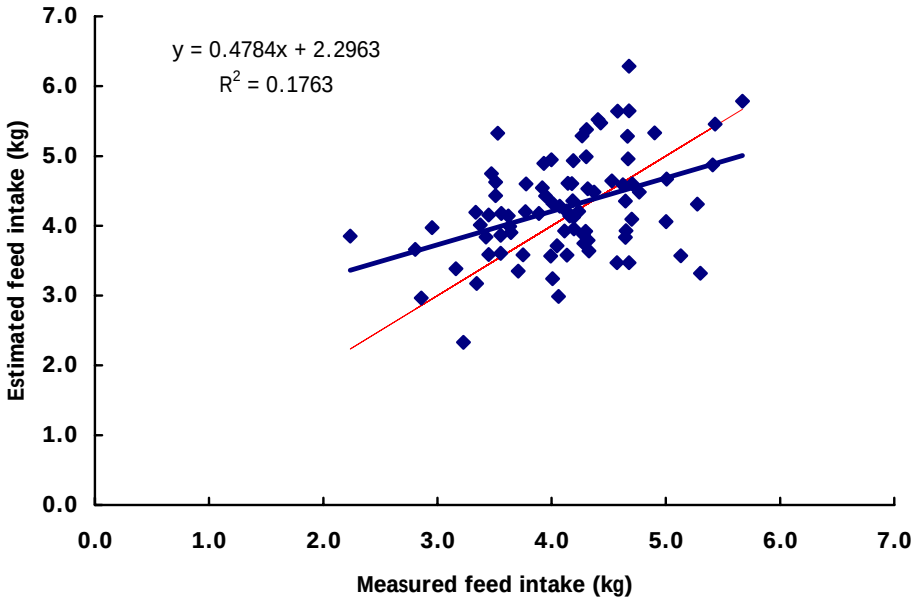

Figure 17. Estimated feed intake calculated from plasma lithium concentration versus feed intake during the 36 hour period of feeding. Line of identity is shown in red.

Discussion

The ability to accurately predict feed intake using lithium chloride appears to be limited, with significant variation between real and predicted intakes appearing to be a result of differences in the consumption pattern of pigs. The time from feed being offered to the first feeding event ranged from 8 minutes to almost 6 hours, which resulted in deviation from the critical 36 hour window.

3. Outcomes

This project has shown that lithium chloride can be fed at levels that do not create feed aversion yet allow for plasma levels that are detectable, with these inclusion levels similar to those found in other species. A feeding level of 0.8 g/kg of feed results in plasma lithium concentrations of approximately 0.425 mmol/L and equates to approximately 36 mg LiCl/kg of body weight, below the tolerance level of sheep (50 mg/kg; Suharyono, 1992). The inclusion of a second marker, sodium bromide, did not improve the variation in plasma lithium concentrations and appears to actually have an appetite stimulating effect.

Feed intake of the lone individual pig was able to be well estimated through the analysis of plasma lithium concentration when the diet was fed on an *ad libitum* basis. The relationship between intake and plasma concentration was better when fed *ad libitum* rather than from a single feed event. The variation in the relationship increased the longer lithium chloride was fed for, however, the relationship was strongest thirty-six (36) hours after feed was first offered (R^2=0.83), and the relationship was strongly linear during this phase.

Group-dynamics and feeding behaviour appeared to significantly influence the ability to predict feed intake from plasma lithium concentration from group-housed pigs. At best, feed intake calculated from plasma lithium concentration explained less than half the variation in feed intake (R^2=0.43), however, when a more standard commercial stocking density was applied this fell substantial (R^2=0.18). The time of the initial feed event, ranging from 8 minutes to almost 6 hours, alters the 36 hour time window that best explained intake in experiment 2. It is also likely that differences in consumption patterns, less large feeds versus frequent small feeds, will influence plasma lithium concentrations.

Whilst this method showed some value when applied to individually housed pigs, when applied to the group situation and the associated dynamics that exist within a group, the ability to predict feed intake from plasma lithium concentrations appears limited.

4. Application of Research

The ability to use lithium chloride as a marker of feed intake in group-housed animals appears to be limited by the group dynamics and the variation in individual feeding behaviour that is apparent.

Lithium chloride may however still be a useful marker of uptake, similar to its use in sheep as a marker of supplement intake. It could, for instance, be added to a specific in-feed medication program and used to identify animals that have and have not consumed feed.

5. Conclusion

Whilst levels of dietary lithium chloride were established that gave detectable levels of plasma lithium without causing feed aversion, and there was a good relationship established between feed intake and plasma lithium concentration in individually housed pigs, when applied to group-housed pigs the relationship decreased significantly. The feeding behaviour of individual pigs and the dynamics of group housing meant that meeting the critical windows for blood sampling were not possible as each individual within the group consumed differently. Lithium chloride cannot be used to predict the feed intake of individual pigs housed in groups.

6. Limitations/Risks

The limited ability of lithium chloride to describe the variation in intake within group-housed pigs is unlikely to see it applied.

7. Recommendations

As a result of the outcomes in this study the following recommendations have been made:

- The continued investigation of lithium chloride as a feed marker is not warranted.
- Future investigations into measuring the individual feed intake of group-housed pigs, especially those that may be looking at time-sensitive systems, needs to take into account the feeding behaviour and group-dynamics that exist when pigs are housed in groups.

8. References

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