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Evaluation of Precision, Accuracy, and Efficiency of Scale Stabilization Settings Using LeeO Pig Tracking System[1]

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Summary

This trial was conducted to evaluate the optimum scale head settings for LeeO scale systems to balance accuracy, precision, and efficiency in weighing pigs. LeeO scales allow for the adjustment of both stabilization time (mSec) and stabilization weight (g). The pig weight that is accepted by the technology is only registered after staying within the set stabilization weight for the set stabilization time. Prior to beginning animal research, precision and accuracy were assessed for two scales. The nursery scale used a 25-lb test weight and the finisher scale used a 50-lb test weight. The CV estimates were 0.1% or less when the test weight was measured multiple times within each combination of settings for both nursery and finishing weights. Accuracy did not differ ($P > 0.10$) based on stabilization time for either scale. However, when weighing the 25-lb test weight, the longest stabilization time of 1,000 mSec resulted in the smallest difference from the true weight ($P < 0.05$). To assess scale settings, 30 nursery and 33 finishing pigs were weighed multiple times using different settings to determine accuracy, precision, and efficiency. Each pig was weighed 5 times on the predetermined settings for a total of 45 weights for each nursery pig and 20 weights for each finishing pig. Coefficient of variation (CV) was used as an estimation of precision, which was calculated by dividing the standard deviation of the 5 weights for that combination of scale head settings by the average weight of the 5 weights for that setting. To estimate accuracy, the absolute difference of the average weight of the 5 weights for that setting combination from the overall average weight for that pig was calculated. Efficiency was measured one of two ways. The nursery pig procedure included the elapsed time from when the first weight was collected for that combination of scale head settings until the fifth weight that was collected was divided by the total number of weighing events for that setting. The finishing pig procedure included the sum of the times that it took to lock in all five weights for that combination of scale head settings and dividing that sum by the total number of weighing events for that setting. There were no differences in accuracy for nursery or finishing pig scales based on stabilization time or weight ($P > 0.10$). There

[1] Appreciation is expressed to LeeO by Prairie Systems (Spencer, IA) for technical support of this trial.
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was a significant difference in precision for the nursery pig scale based on both stabilization time ($P = 0.003$) and stabilization weight ($P = 0.003$); with CV improving as stabilization weight became smaller and stabilization time became longer. Conversely, efficiency for collecting both nursery and finishing weights improved with larger stabilization weight and shorter stabilization time ($P < 0.001$). In the finishing experiment, CV was improved ($P < 0.05$) for the 500 g × 1,000 mSec and 500 g × 500 mSec settings compared to the 1,000 g × 250 mSec setting, with the 1,000 g × 500 mSec setting intermediate. To balance precision and efficiency, a setting of 50 g × 500 mSec for the nursery and 500 g × 1,000 mSec for the finisher is recommended.

Introduction

LeeO is an animal technology system focused on traceability and individualized data collection. This technology utilizes high frequency radio frequency identification (RFID) tags to identify animals and subsequently record individual weights, injections, and other actions using a LeeO reader and Bluetooth technology. LeeO technology allows load cells to communicate with the LeeO platform to adjust two different stabilization settings, one setting is measured in grams and the other is measured in milliseconds. The pig weight that is accepted by the technology is only registered after staying within the set weight range (g) for the set amount of time (mSec). In theory, a higher stabilization weight or a shorter stabilization time can shorten the time required for the weight to be registered. Conversely, increasing the stabilization time or lowering the stabilization weight may allow for a more accurate and/or precise weight collection.

Accuracy refers to how close a measurement is to its true value. Precision refers to how close a set of measurements is to one another. Accuracy of a scale can be difficult to assess in real-world settings because the true animal weight is often not known. Precision is easier to obtain, as it is simply the measure of variation as measurements are collected repeatedly on the same animal. Increasing precision is paramount in animal research because reducing between-animal variation is one of the underlying goals. The primary objective of this trial was to determine the most beneficial combination of scale head settings for an intensive research system to balance accuracy, precision, and efficiency of data collection in nursery and finishing pigs.

Procedures

The protocol for this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was conducted at the Kansas State University Swine Teaching and Research Center.

Nursery LeeO scale heads are preprogrammed with a 100 g stabilization weight setting and a 500 mSec stabilization time setting. In the nursery study, the settings tested were 250, 500, or 1,000 mSec for stabilization time and 50, 100, or 200 g for stabilization weight. LeeO scales for finishing pigs are preprogrammed with a 500 g stabilization weight setting and a 1,000 mSec stabilization time setting. In the finishing study, the settings tested for Exp. 1 were 250 or 500 g for stabilization weight and 1,000 or 2,000 mSec for stabilization time. For finishing Exp. 2, the settings tested were 500 or 1,000 g for stabilization weight and 250, 500, or 1,000 mSec for stabilization time. A third LeeO scale setting which can be adjusted is the weight confirmation delay. The weight confirmation delay is the amount of time that the recorded weight stays on the screen, during which time the operator can choose to confirm the weight or reweigh the pig.

LeeO scales come preprogrammed with a 3 sec weight confirmation delay which was used for all weights taken in both the nursery and finishing portions of this trial.

Before research with animals began, the accuracy and precision of each combination of settings was determined using a 25-lb (11.34 kg) test weight on the nursery scale and a 50-lb (22.68 kg) test weight on the finisher scale. To accomplish this, the test weight was weighed 5 times on each of the predetermined combinations of scale settings. The coefficient of variation for that setting was calculated as the measure of precision. For accuracy, the absolute difference of each of the weights obtained by the scale for that combination of settings from the true weight of that test weight was determined. Because there was only 1 replication for calculating CV, statistics were not conducted for precision. A total of 30 nursery pigs (11.5 ± 0.24 lb; mean ± standard deviation), 18 finishing pigs in finishing Exp. 1 (191.8 ± 18.72 lb) and 15 finishing pigs in finishing Exp. 2 (186.1 ± 23.0 lb) were used. Each pig in the study was weighed 5 times on each of the combinations of stabilization settings for a total of 45 weights for each nursery pig and 20 weights for each finishing pig. The order of settings was randomized for each animal. All weights within each setting combination were collected within 20 min of beginning that setting to minimize variation in weights due to factors unrelated to the LeeO scale settings. To obtain repeated weights for each pig, the weight survey function in the LeeO app was utilized. Between each new scale setting, the scale was tared, and between each weight taken the scale was allowed to zero prior to weighing the pig again. Coefficient of variation (CV) for each setting on each pig was calculated by dividing the standard deviation of those 5 weights by the average of the weights collected for that setting. Average time required to collect each weight in nursery pigs was calculated by dividing the elapsed time between when the first weight was recorded for that setting until the fifth weight was recorded by the number of weighing events. Therefore, this average time includes the time required to remove the pig, begin another weight survey, allow the scale to zero, scan the pig again, place the pig back on the scale, weigh the pig, wait for the 3 second weight confirmation delay, and save the survey. In finishing pigs, the elapsed time from when the gate was closed on the scale until the weight was recorded, was timed to determine the average time required to weigh each pig on each setting. The accuracy of each setting was estimated by calculating the absolute difference between the average weight of that setting from the overall average of all weights collected for that pig using all settings.

Statistical analysis

Experimental data were analyzed as a completely randomized design for nursery (3 × 3 factorial), Exp. 1 finishing (2 × 2 factorial), and Exp. 2 finishing (incomplete 3 × 2 factorial) using the lmer function from the lme4 package in R (Version 4.0.0, R Foundation for Statistical Computing, Vienna, Austria). Each setting combination within each pig served as the experimental unit. The interaction of stabilization time and weight was tested, along with the main effects of stabilization time and stabilization weight. Differences for settings demonstrating a significant source of variation were determined through pairwise comparisons using the Tukey-Kramer multiplicity adjustment to control for type I error. All results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

When looking at the precision of weighing the 25- and 50-lb test weights, the CV estimates were 0.1% or less when the test weight was measured multiple times within each combination of settings. For accuracy, there was no difference ($P > 0.10$) in the absolute difference of the weights collected from the true value of the test weight, based on the stabilization weight for both the nursery pig and finishing pig scale settings. There was a significant effect of stabilization time on accuracy for the 25-pound test weight, with the longest stabilization time of 1,000 mSec, resulting in lower differences in the weights collected from the true value of the test weight ($P < 0.001$; Table 1).

For precision in nursery weights, there was a tendency for an interactive effect of stabilization time and stabilization weight settings ($P = 0.082$; Table 2). Within each stabilization weight setting, pairwise comparisons revealed that there was no evidence of a difference in CV based on stabilization time ($P > 0.05$). Within each stabilization time setting, pairwise comparisons revealed that there were no differences in CV based on stabilization weight ($P > 0.05$). There was a main effect of stabilization weight setting ($P = 0.023$) on CV, with the stabilization weight setting of 50 g having a lower ($P < 0.05$) CV than the stabilization weight setting of 200 g, with the 100 g setting intermediate. There was also an effect of stabilization time ($P = 0.003$) on CV, with the stabilization time setting of 250 mSec having a greater ($P < 0.05$) CV than the stabilization time setting of 1,000 mSec, with the 500 mSec setting intermediate. There was a tendency for an interaction between stabilization time and stabilization weight settings ($P = 0.091$) on absolute difference of the average of that setting from the overall mean, but no evidence of pairwise differences were observed. There was no main effect ($P > 0.10$) of stabilization time or stabilization weight setting on absolute difference of the average of that setting from the overall mean. It took less time ($P < 0.001$; Table 3) to weigh nursery pigs utilizing the stabilization weight settings of 100 or 200 g compared to the 50 g setting. Efficiency was improved ($P < 0.001$) when weighing nursery pigs with a stabilization time setting of 250 or 500 mSec compared to 1,000 mSec.

For finishing experiment 1, data indicate there were no interactive or main effects ($P > 0.10$) of stabilization time and stabilization weight settings in finishing weight precision or accuracy. There was an effect of stabilization time setting on average time required to collect each weight, with a setting of 1,000 mSec requiring half the time to lock in a weight as compared to the setting of 2,000 mSec ($P = 0.001$). Average time to collect a weight was more than 10 seconds shorter ($P < 0.001$) when weighing finishing pigs with a stabilization weight setting of 500 g compared to 250 g.

For finishing experiment 2, the most lenient setting of 1,000 g by 250 mSec had the largest CV of 0.878%, while the CV of the 500 g by 500 mSec and the 500 g by 1000 mSec settings were lower (0.431% and 0.228%, respectively), with that of the 1000 g by 500 mSec setting intermediate (0.462%; $P = 0.05$; Table 4). There were no significant differences in the accuracy based on the combination of scale settings for experiment 2 of the finisher ($P > 0.10$). The most stringent setting of 500 g × 1000 mSec took the longest time to collect weights followed by the 500 g × 500 mSec setting ($P < 0.05$; Table 4). The setting with the largest CV (1,000 g × 250 mSec) was the most efficient, taking 2.1 sec to collect weights on average.

This work is the first to describe the effects of different scale settings on the precision, accuracy, and efficiency of weight collection in an intensive swine research setting using the LeeO system. Using any of the scale settings, the precision was very high when weighing the test weights. For accuracy, there was no effect of stabilization weight or stabilization time on the difference from true weight for the finishing scale settings, as well as no effect of stabilization weight on the accuracy of the nursery scale settings. However, for the accuracy of the nursery scale settings with the test weight, the longest stabilization time (1,000 mSec) resulted in the closest accuracy to the true weight of the test weight. Importantly, these estimated accuracy results were very good across all scale settings, with the accuracy generally within 10 g of the true weight (representing approximately 99.9% accuracy) when measuring the accuracy and precision of an object of known weight.

The optimal settings for LeeO scales in the nursery depend on the operation's priorities. In a system where minimizing variability of weights is the priority, a lower stabilization weight and higher stabilization time setting would be the best fit. Conversely, for an operation that places more of a priority on efficiency of time to collect weights, a higher stabilization weight value and shorter stabilization time would be recommended. For the research setting with the goal to balance precision and efficiency of nursery pig data collection, the optimal settings appear to be the combination of 50 g for stabilization weight and 500 mSec for stabilization time. For an operation that wants to balance precision and efficiency in weighing finishing pigs, a setting of 500 g × 1,000 mSec is recommended. When utilizing the most efficient nursery scale setting (200 g × 250 mSec), the total time that it took to weigh nursery pigs under standard weighing conditions was 8.4 seconds each. This time included picking up the animal, scanning their ear tag, weighing the pig, and putting it back down. This translates to 428 pigs per hour that can be weighed utilizing the LeeO scale using the current setting recommendations. When utilizing the recommended finishing scale setting (500 g × 1000 mSec), the total time that it took to weigh finishing pigs under standard weighing conditions was 31.7 seconds each, equating to a rate of 113 finishing pigs per hour.

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Table 1. Main effects of LeeO scale stabilization settings on precision and accuracy in weighing 25-pound and 50-pound test weight

	No motion range, g[1]					No motion period, mSec[2]				
25-pound test weight	**50**	**100**	**200**	**SEM**	***P* =**	**250**	**500**	**1,000**	**SEM**	***P* =**
Precision										
CV, %[3]	0.082	0.085	0.094	---	---	0.107	0.106	0.048	---	---
Accuracy										
Difference from true, g[4]	4.20	7.53	3.53	2.735	0.547	10.87[a]	9.53[a]	-5.13[b]	2.735	< 0.001

	No motion range, g[1]				No motion period, mSec[2]			
50-pound test weight	**250**	**500**	**SEM**	***P* =**	**1000**	**2000**	**SEM**	***P* =**
Precision								
CV, %[3]	0.020	0.036	---	----	0.032	0.024	---	---
Accuracy								
Difference from true, g[4]	-11.60	-10.60	6.364	0.930	-8.60	-13.60	6.364	0.677

[a-c]Means within row with different superscripts differ ($P < 0.05$).
[1]No motion range: g is the terminology used in the scale settings portion of the LeeO app to denote stabilization weight which is the range that the weight has to stay within during the specified stabilization time for the weight to be registered.
[2]No motion period: mSec is the terminology used in the scale settings portion of the LeeO app to denote stabilization time which is the length of time that the weight has to stay within the specified weight range for the weight to be registered.
[3]Calculated by dividing the standard deviation of the 5 weights taken for the test weight on each unique setting by the average of those 5 weights.
[4]The difference of each weight recorded utilizing the combination of stabilization settings from the true weight of the test weight.

Table 2. Interactive effects of LeeO scale stabilization settings on precision, efficiency, and accuracy in weighing nursery pigs

No motion range, g[1]:	**50**			**100**			**200**				**Weight × time, *P* =**
No motion period, mSec[2]:	**250**	**500**	**1,000**	**250**	**500**	**1,000**	**250**	**500**	**1,000**	**SEM**	
Precision											
CV, %[3]	0.247[ab]	0.169[b]	0.204[b]	0.261[ab]	0.306[ab]	0.152[b]	0.373[a]	0.296[ab]	0.205[ab]	0.0410	0.082
Accuracy											
Difference from mean, g[4]	10.91	8.96	14.53	10.81	14.09	9.43	13.68	14.63	11.80	2.308	0.091
Efficiency											
Avg. time, sec[5]	11.30[bc]	11.39[bc]	13.36[a]	10.23[c]	10.84[bc]	12.27[ab]	10.23[c]	10.53[c]	11.74[a]	0.431	0.780

[a-c]Means within row with different superscripts differ ($P < 0.05$).
[1]No motion range: g is the terminology used in the scale settings portion of the LeeO app to denote stabilization weight which is the range that the weight has to stay within during the specified stabilization time for the weight to be registered.
[2]No motion period: mSec is the terminology used in the scale settings portion of the LeeO app to denote stabilization time which is the length of time that the weight has to stay within the specified weight range for the weight to be registered.
[3]Calculated by dividing the standard deviation of the 5 weights taken for each pig on each unique setting by the average of those 5 weights.
[4]Calculated by averaging the absolute difference of the average weight recorded utilizing that combination of stabilization settings from the overall average weight for that pig.
[5]Calculated by dividing the elapsed time from when the first weight was recorded to when the final weight for that setting combination was recorded, by the number of weighing events to obtain an average time. This time measurement includes the time required to remove the pig from the scale, begin another weight survey, allow the scale to reach zero, set the pig back on the scale, weigh the pig, wait for the 3 sec weight confirmation delay, and save the survey.

Table 3. Main effects of LeeO scale stabilization settings on precision, efficiency, and accuracy in weighing nursery pigs

	No motion range, g[1]					No motion period, mSec[2]				
	50	100	200	SEM	*P* =	250	500	1,000	SEM	*P* =
Precision										
CV, %[3]	0.206[b]	0.240[ab]	0.291[a]	0.0275	0.023	0.294[a]	0.257[ab]	0.187[b]	0.0275	0.003
Accuracy										
Difference from mean, g[4]	11.47	11.45	13.37	1.679	0.380	11.80	12.56	11.92	1.679	0.876
Efficiency										
Avg. time, sec[5]	12.02[a]	11.11[b]	10.83[b]	0.327	< 0.001	10.59[b]	10.92[b]	12.46[a]	0.327	< 0.001

[a-c]Means within row with different superscripts differ ($P < 0.05$).
[1]No motion range: g is the terminology used in the scale settings portion of the LeeO app to denote stabilization weight which is the range that the weight has to stay within during the specified stabilization time for the weight to be registered.
[2]No motion period: mSec is the terminology used in the scale settings portion of the LeeO app to denote stabilization time which is the length of time that the weight has to stay within the specified weight range for the weight to be registered.
[3]Calculated by dividing the standard deviation of the 5 weights taken for each pig on each unique setting by the average of those 5 weights.
[4]Calculated by averaging the absolute difference of the average weight recorded utilizing that combination of stabilization settings from the overall average weight for that pig.
[5]Calculated by dividing the elapsed time from when the first weight was recorded to when the final weight for that setting combination was recorded, by the number of weighing events to obtain an average time. This time measurement includes the time required to remove the pig from the scale, begin another weight survey, allow the scale to reach zero, set the pig back on the scale, weigh the pig, wait for the 3 sec weight confirmation delay, and save the survey.

Table 4. Interactive effects of LeeO scale stabilization settings on precision, efficiency, and accuracy in weighing finishing pigs

No motion range, g[1]:	250		500		
No motion period, mSec[2]:	**1,000**	**2,000**	**1,000**	**2,000**	**SEM**
Experiment 1[3]					
Precision					
CV, %[4]	0.253	0.222	0.259	0.207	0.0490
Accuracy					
Difference from mean, g[5]	163.96	225.03	162.00	217.69	40.250
Efficiency					
Avg. time, sec[6]	15.20	28.57	6.95	11.94	2.881

No motion range, g[1]:	500		1,000		
No motion period, mSec[2]:	**500**	**1,000**	**250**	**500**	**SEM**
Experiment 2[7]					
Precision					
CV, %[4]	0.431[b]	0.228[b]	0.878[a]	0.462[ab]	0.1242
Accuracy					
Difference from mean, g[5]	337.40	250.13	422.13	392.80	93.419
Efficiency					
Avg. time, sec[6]	3.26[b]	4.02[a]	2.06[d]	2.67[c]	0.134

[1]No motion range, g is the terminology used in the scale settings portion of the LeeO app to denote stabilization weight which is the range that the weight has to stay within during the specified stabilization time for the weight to be registered.
[2]No motion period, mSec is the terminology used in the scale settings portion of the LeeO app to denote stabilization time which is the length of time that the weight has to stay within the specified weight range for the weight to be registered.
[3]Weight × time, $P > 0.10$ for all responses.
[4]Calculated by dividing the standard deviation of the 5 weights taken for each pig on each unique setting by the average of those 5 weights.
[5]Calculated by averaging the absolute difference of the average weight recorded utilizing that combination of stabilization settings from the overall average weight for that pig.
[6]Calculated by averaging the elapsed time from when the scale door was shut until a weight was registered.
[7]Effect of setting, $P \leq 0.002$ for precision and efficiency; $P = 0.410$ for accuracy.

Table 5. Main effects of LeeO scale stabilization settings on precision, efficiency, and accuracy in weighing finishing pigs

	No motion range, g[1]				No motion period, mSec[2]			
	250	500	SEM	*P* =	1,000	2,000	SEM	*P* =
Precision								
CV, %[3]	0.238	0.233	0.0361	0.917	0.256	0.214	0.0361	0.374
Accuracy								
Difference from mean, g[4]	194.50	189.85	30.559	0.901	162.98	221.36	30.559	0.121
Efficiency								
Avg. time, sec[5]	21.89[a]	9.45[b]	2.264	< 0.001	11.08[b]	20.26[a]	2.264	0.001

[a-c]Means within row with different superscripts differ ($P < 0.05$).
[1]No motion range: g is the terminology used in the scale settings portion of the LeeO app to denote stabilization weight which is the range that the weight has to stay within during the specified stabilization time for the weight to be registered.
[2]No motion period: mSec is the terminology used in the scale settings portion of the LeeO app to denote stabilization time which is the length of time that the weight has to stay within the specified weight range for the weight to be registered.
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[4]Calculated by averaging the absolute difference of the average weight recorded utilizing that combination of stabilization settings from the overall average weight for that pig.
[5]Calculated by averaging the elapsed time from when the scale door was shut until a weight was registered.