Standardized ileal digestible threonine requirement for broilers

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Preface

In 2017 a new Table has been introduced called; Table 'Standardized ileal digestibility of amino acids in feedstuffs for poultry' and has been described in the CVB Documentation report nr. 61. As a feed evaluation system has two pillars – the supply of nutrients by the diet on the one hand and the requirement for these nutrients by the animals on the other hand (both expressed in the same units) – it was also necessary to also update and express the amino acid requirements on a standardized ileal digestibility (SID) basis.
Therefore a large meta-analysis dataset was constructed from studies in which amino acid requirements in broilers were estimated. The SID amino acid concentrations of the diets used in the studies were recalculated based on the new CVB SID amino acid Table (CVB Documentation report nr. 61) and requirements of SID amino acids were subsequently estimated. The results of this meta-analysis for standardized ileal digestible threonine (SID-THR) are presented in the present CVB Documentation report. Compared to the former CVB apparent faecal digestible THR recommendation for broilers described in CVB Documentation report nr. 18 and published in 1996 the present established SID-THR amino acid recommendations for broilers are:

1. Based on a substantial larger dataset of requirement studies
2. Based on studies with modern broiler types in the period 1990 – 2017
3. Based on standardized ileal digestible amino acid values in feedstuffs instead of apparent faecal digestible amino acid values.

The in this report estimated requirement of SID-THR will be incorporated in the Dutch CVB Tabellenboek Veevoeding Pluimvee 2018 and in the English version CVB Table Poultry Nutrition 2018.

This study was guided and assessed by the Technical Committee of CVB

Wageningen, June 2018

J.W. Spek

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Abbreviations

AA	Amino acids
AFD	Apparent faecal digestible
ARG	Arginine
BWG	Body weight gain
CP	Crude protein
FCR	Feed conversion ratio
ILE	Isoleucine
LYS	Lysine
ME	Metabolic energy
MET	Methionine
M+C	Methionine plus Cysteine
N	Number
R^2	Coefficient of determination
Req	Requirement
SID	Standardized ileal tract digestible
Std. Dev.	Standard deviation
Std. Err.	Standard error
THR	Threonine
TRP	Tryptophan
VAL	Valine

1 Introduction

In 2012 a large meta-analysis was carried out by Veldkamp and others in order to determine the dietary requirements for standardized ileal tract digestible (SID) amino acids (AA) for broilers. This study resulted in a report published by Veldkamp et al. (2016). Before the start of this meta-analysis by Veldkamp et al. another large meta-analysis was carried out in order to determine the SID-AA levels for the various feed ingredients. This meta-analysis resulted in a CVB table with SID-AA concentrations for the various feed ingredients and this Table was used by Veldkamp et al. (2016) in order to recalculate the dietary SID-AA levels for the individual AA titration studies in order to estimate AA requirements. However, in 2017 this CVB Table has been updated with new data published in the years between 2012 and 2017 as there were questions about the SID cysteine digestibility value for soybean meal. As a result, not only the SID-AA values for soybean meal have been updated but also for other feedstuffs. As a consequence it was necessary to recalculate all the diets used in the AA titration studies that Veldkamp et al. (2016) used to determine AA requirements. In this CVB documentation report the results of estimated dietary SID threonine (SID-THR; %) requirements are presented that are based on the new Table values as presented in CVB documentation report nr. 61. Furthermore, the dataset used by Veldkamp et al. has been extended with new studies that were not included in the study of Veldkamp et al.. This resulted in a dataset that is substantially larger than the dataset used by Veldkamp. The SID-THR requirements of the individual titration trials were estimated using a quadratic broken line model. This model was also used in estimation of SID-lysine requirements in the individual lysine titration trials as described in CVB documentation report nr. 62.

2 Materials and Methods

Threonine titration studies were selected from literature (1989 – 2017) in which only the dietary THR content was varied by means of addition of graded levels of dietary synthetic threonine. Furthermore, only those titration studies were selected in which non-test apparent digestible amino acid levels of the basal diet (diet with the lowest THR content) did not come below 10% of the recommended CVB (2012) levels and where dietary digestible THR levels of the basal diets where at least 20% below the recommended CVB (2012) level. Furthermore, performance characteristics such as body weight gain (BWG: g/d) and feed conversion ratio (FCR; g feed : g BWG) had to be recorded and information with respect to dietary composition, sex, age of the broilers and duration of the experiment had to be provided in the studies.

Requirements were estimated using a quadratic broken-line model. The quadratic broken line model is as follows:

If (SID-THR (%) < R) then BWG or FCR = L + U × (R – SID-THR)$^{\wedge 2}$;
Else BWG or FCR = L + U × 0;
Where:
L = plateau value for BWG or FCR
R = break-point value for SID-THR (%)
U = slope value, representing the increase in BWG or decrease in FCR per unit increase in dietary SID-THR.

As THR requirements are normally expressed as a percentage of lysine (LYS) requirement the estimated SID-THR requirements of the individual THR titration trials were expressed as a percentage of SID-LYS level. The SID-LYS level was in a number of cases the SID-LYS level used in the THR titration studies. However, in a number of cases the SID-LYS levels used in the THR titration studies were larger than the SID-LYS requirements as predicted from the factors mean age of the birds and the dietary ME value as described in the prediction formulas F.5. and F.9. in CVB documentation report nr. 62. In those cases where the SID-LYS levels used in the THR titration studies were larger than the SID-LYS requirements as predicted from the prediction formula for SID-LYS requirements in CVB documentation report nr. 62 the predicted SID-LYS requirement levels using formulas F.5. (for BWG) and F.9. (for FCR) were used for the calculation of the SID-THR : SID-LYS ratios (SID-THR:LYS) of the individual experiments.

Via the PROC MIXED procedure of SAS the estimated SID-THR:LYS requirements for BWG and FCR were regressed against factors such as age, sex and the dietary factors CP, ME and CP : ME ratio with study effect included as a random factor. Furthermore, non-test SID-AA : SID-LYS ratios were calculated and it was checked whether some of the non-test SID AA negatively affected the estimated SID-THR:LYS levels.

3 Results and Discussion

In Table 1 a summary of the total dataset is given. The dataset consisted of 13 studies with in total 25 titration trials and 140 observations.

Table 1. Summary of the total dataset

	N	Mean	Std. Dev.	Minimum	Maximum
ME Recalculated (kcal/kg)	140	3110	131.1	2620	3238
ME Publication (kcal/kg)	140	3148	61.9	2945	3201
CP Recalculated (%)	140	20	1.7	17	22
CP Publication (%)	140	20	2.3	17	24
Year	140	2005	4.8	1996	2015
Starting age (d)	140	12	10.1	1	30
Duration (d)	140	18	3.7	6	21
finishing age (d)	140	30	11.9	7	42
BWG (g/d)	140	52.5	23.17	17.8	91.7
FCR	140	1.681	0.4026	1.060	4.160

In Appendix A for each titration trial the relationship between dietary SID-THR supply and FCR between dietary SID-THR and BWG is presented graphically together with the estimated SID-THR requirements. In Appendix B the estimated quadratic broken-line model parameters for each titration trial is given.

For a number of titration trials (5 titration trials for FCR and 3 titration trials for BWG) it was not possible to estimate reliable or unique SID-THR requirements.
The estimated SID-THR:LYS requirement ratios for BWG and FCR were not significantly related to sex, age, dietary protein concentration, and dietary ME.

The average estimated SID-THR:LYS ratios for the remaining 20 SID-THR:LYS requirement observations for FCR and the 22 SID-THR:LYS requirement observations for BWG were:

SID-THR:LYS for BWG = 62.9±8.20 % (average ± Std. dev.)
SID-THR:LYS for FCR = 60.6±8.64 % (average ± Std. dev.)

Furthermore, there was one outlier SID-THR requirement estimate value that deviated more than two standard deviations from the average estimated SID-THR requirement estimate for both BWG and FCR. This was an observation from the study of Corzo et al. (2009). When removing this outlier value the average estimated SID-THR:LYS requirement ratios for the remaining 19 FCR trials and 21 BWG trials were:

SID-THR:LYS for BWG = 61.8±6.65 % (average ± St. dev.)
SID-THR:LYS for FCR = 59.6±7.38 % (average ± St. dev.)

There were some studies that contained a large number of titration trials whereas some studies contained only one titration trial. This results in average calculated SID-THR:LYS requirement ratios for BWG and FCR that are strongly influenced by the studies containing a large number of titration trials. In order to weigh the estimated SID-THR:LYS ratios from each study equally it is possible to take into account the effect of study. When this is done (using the PROC MIXED procedure of SAS and by including study as a random effect in the model) the estimated SID-THR:LYS ratios for BWG and FCR became:

SID-THR:LYS for BWG = 66.5±3.17% (estimate ± St. error)
SID-THR:LYS for FCR = 63.7±3.01 % (estimate ± St. error)

The exercise of estimating SID-THR:LYS requirement ratios for BWG and FCR in which each study is equally weighted was now repeated but in this case the outlier observation from the study of Corzo et al. (2009) was excluded. When this was done (by using the PROC MIXED procedure of SAS and including study as a random effect in the model) the estimated SID-THR:LYS requirement ratios for BWG and FCR became:

SID-THR:LYS for BWG = 64.4±2.67% (estimate ± St. error)
SID-THR:LYS for FCR = 62.0±2.72 % (estimate ± St. error)

In Table 2 the dietary non-test SID-AA : estimated SID-LYS requirements ratios using the quadratic broken-line procedure for FCR and BWG are given together with the recommended CVB apparent faecal digestible (AFD) ratios. Results in Table 2 show that on average the estimated SID-THR requirement estimates were not negatively impacted by limiting non-test AA levels although in a number of trials some non-test AA levels could have had a negative impact on estimated SID-THR levels as a comparison between recommended CVB ratios and minimal ratios for both FCR and BWG observed in this study show. However, a visual inspection of graphs in which the various AA:LYS ratios were plotted against estimated SID-THR:LYS requirement did not show that the low non-test SID-AA levels negatively impacted the estimated SID-THR:LYS requirements.

Table 2. Dietary non-test SID-AA : SID-LYS ratios.

Ratio	**Rec. CVB AFD ratio**	**FCR**				**BWG**			
		Mean	**St.dev**	**Min**	**Max**	**Mean**	**St.dev**	**Min**	**Max**
M+C:LYS	65	78	5.6	71	95	80	5.3	75	100
TRP:LYS	16	18	1.6	16	20	18	1.5	16	21
ILE:LYS	66	69	3.8	64	77	70	4.1	64	79
ARG:LYS	105	134	28.3	99	184	140	30.0	99	184
VAL:LYS	80	79	5.2	68	95	81	5.2	68	100

It furthermore appeared that the estimated SID-THR:LYS ratio was related to the model estimated steepness of the increase in BWG or decrease in FCR per unit increase in dietary SID-THR as shown in Figure 1 (for BWG) and Figure 2 (for FCR) with estimated SID-THR:LYS requirement ratios of around 50 - 55% for titration trials with steep model estimated increases in BWG or decreases in FCR per unit increase in dietary SID-THR and increasing up to 85% estimated SID-THR:LYS requirement ratios at very low model estimated increases in BWG per unit increase in dietary SID-THR. The steepness of the modelled curve was also positively related to the difference between the basal level of FCR and the estimated minimum FCR (= L) as shown in Figure 3. Furthermore, there was a significant relationship between the difference between the basal level of FCR and the estimated minimum FCR and the estimated SID-THR:LYS requirement ratio as shown in Figure 4. These relationships indicate that choice of the basal level of THR in a titration study affects the estimated SID-THR:LYS ratio (the lower the basal level, the higher the difference between the basal level of FCR and the estimated minimum FCR and the lower the estimated SID-THR:LYS ratio). These relationships furthermore suggest that a SID-THR:LYS ratio of around 54% is the absolute minimum requirement for SID-THR resulting in a strong impairment of FCR below 54% whereas smaller improvements in FCR may be expected above 54%.

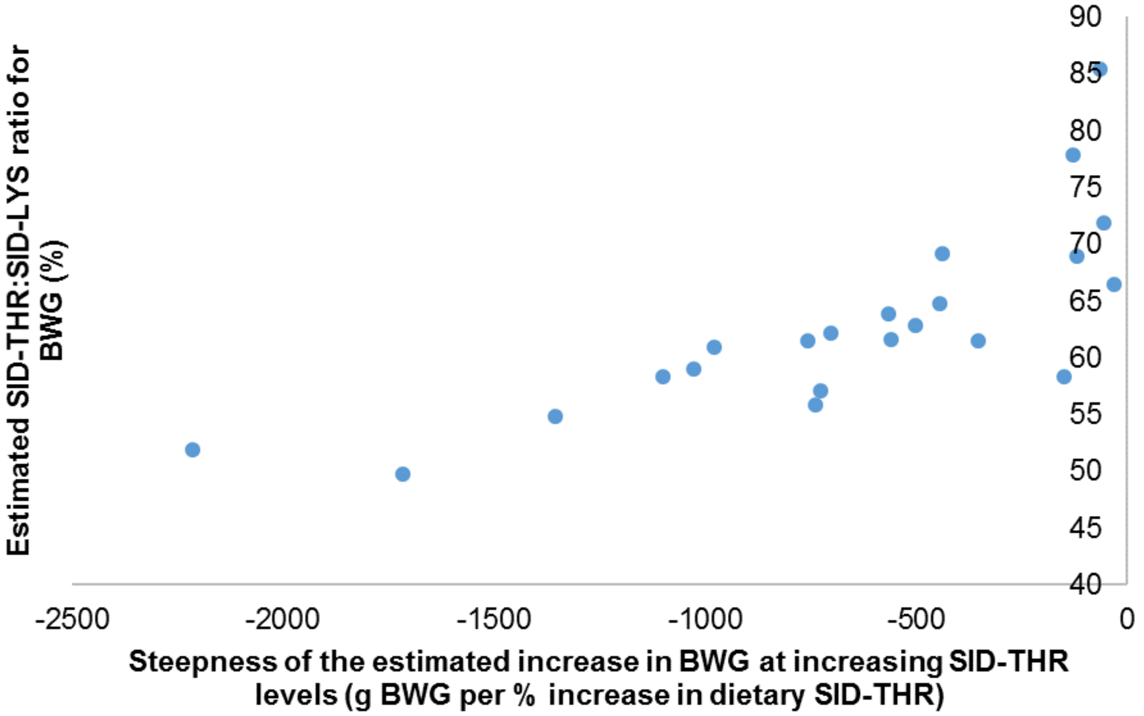


Figure 1. Relationship between the model estimated SID-THR:SID-LYS requirement ratios for maximum BWG and the steepness of the modelled increase in BWG at increasing dietary SID-THR levels (g BWG per percent increase in dietary SID-THR).

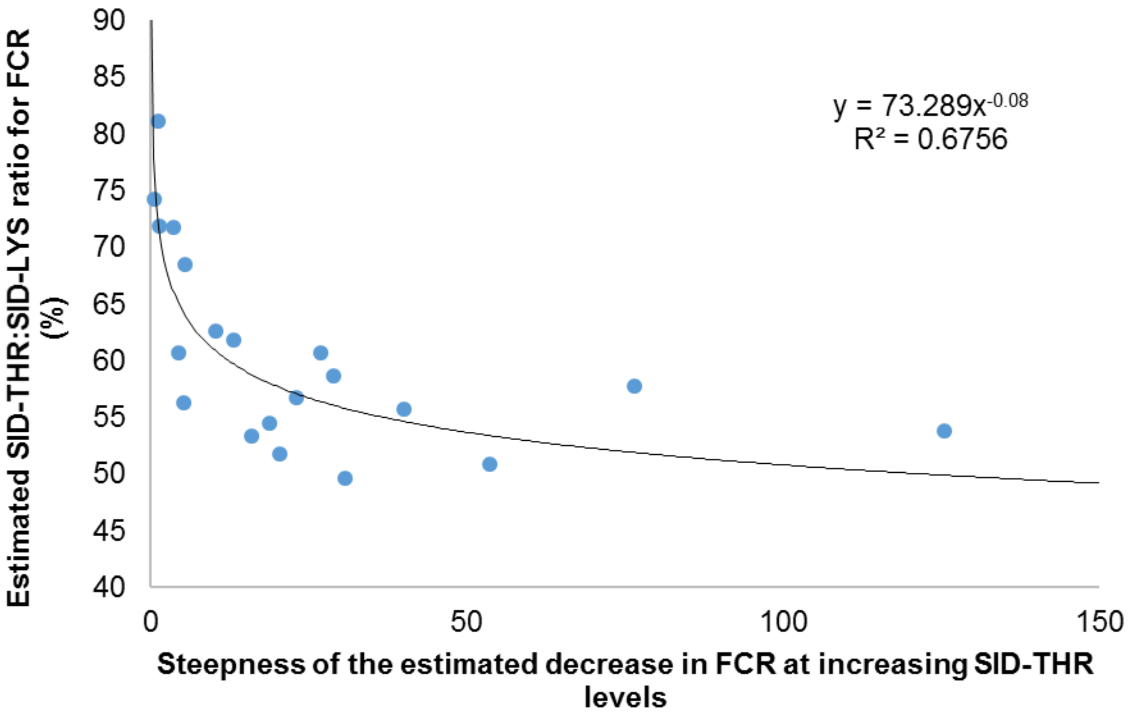


Figure 2. Relationship between the model estimated SID-THR:SID-LYS requirement ratios for minimum FCR and the steepness of the modelled decrease in FCR at increasing dietary SID-THR levels.

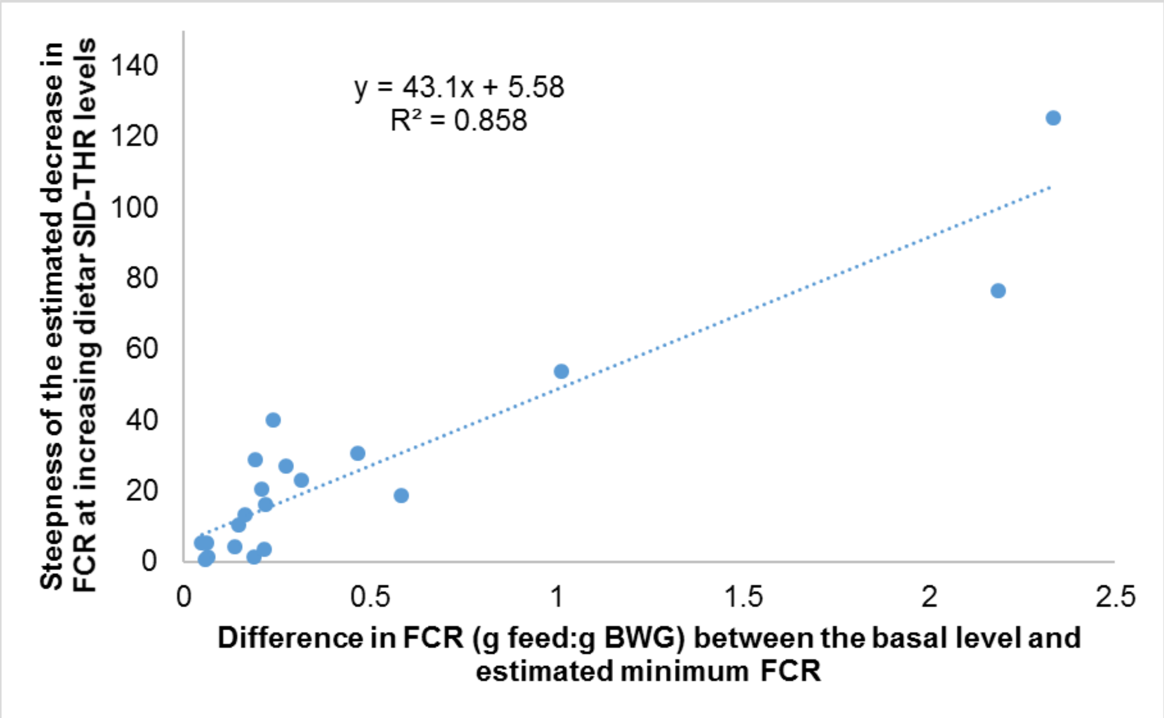


Figure 3. Relationship between the difference in FCR between the basal diet and the model estimated minimum FCR and the model estimated steepness of the decrease in FCR at increasing dietary SID-THR levels.

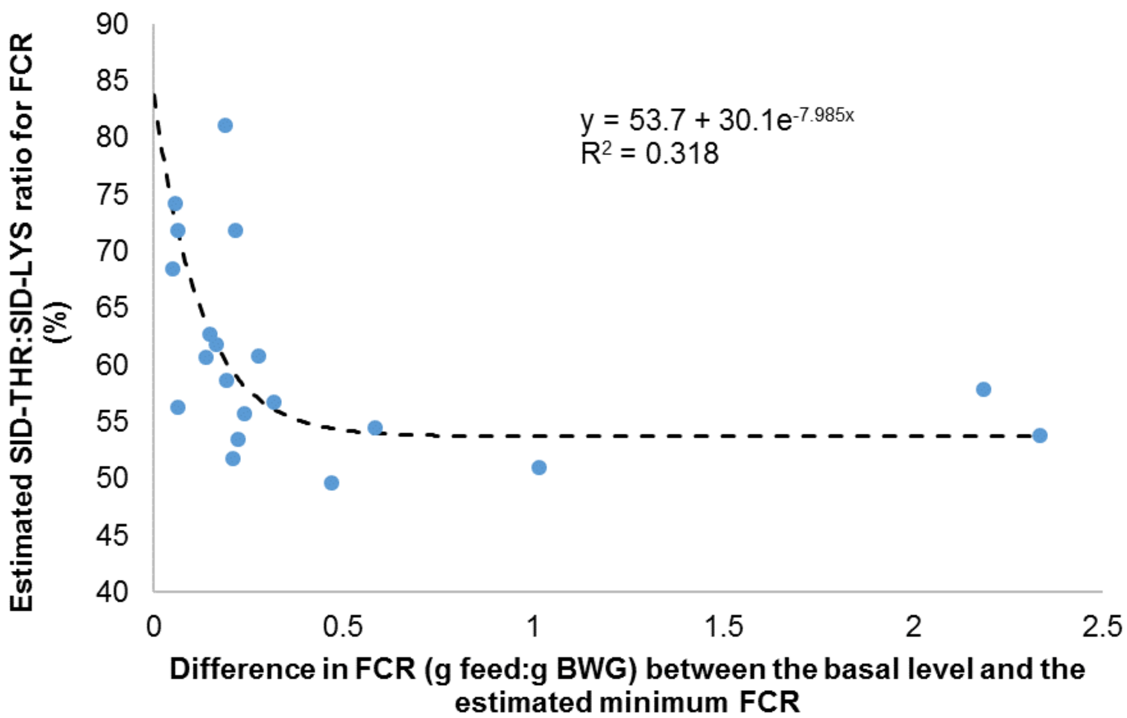


Figure 4. Relationship between the difference in FCR between the basal diet and the model estimated minimum FCR and the estimated SID-THR:SID-LYS requirement ratios for FCR.

Furthermore, it was observed that variation in estimated SID-THR:LYS requirement ratios were not significantly related to sex, age and dietary energy and protein. It is furthermore concluded that part of the variation in estimated SID-THR:LYS ratios is related to the steepness of the decrease in FCR per unit increase in dietary SID-THR and that this steepness is affected by the choice of the basal level of SID-THR in the diet (the lower the basal level, the higher the difference between FCR at the basal level and the estimated plateau level, the steeper the decrease in in FCR per unit increase in dietary SID-THR, and the lower the estimated SID-THR:LYS requirement ratio).

It is therefore difficult to decide what the optimal dietary SID-THR:LYS ratio is. Because of this difficulty it might be most prudent to base the dietary SID-THR:LYS ratio recommendation on the complete dataset of SID-THR trials and correct for a (random) study effect. This results in the following recommendations:

SID-THR:LYS for BWG = 64.4±2.67% (estimate ± St. error)
SID-THR:LYS for FCR = 62.0±2.72 % (estimate ± St. error)

4 Conclusions

Based on the results of this study it is concluded that it is most prudent to base dietary SID-THR:LYS requirement ratios on the complete dataset of SID-THR trials and correct for a (random) study effect. This results in the following SID-THR:LYS requirements:

SID-THR:LYS for BWG = 64%
SID-THR:LYS for FCR = 62%

List of studies included in the meta-analysis

Ayasan, T., F. Okan, and H. Hizli. 2009. Threonine requirement of broiler from 22-42 days. International Journal of Poultry Science 8(9):862-865.

Çiftci, I. and N. Ceylan. 2004. Effects of dietary threonine and crude protein on growth performance, carcase and meat composition of broiler chickens. British Poultry Science 45(2):280-289.

Corzo, A., W. A. Dozier Iii, R. E. Loar Ii, M. T. Kidd, and P. B. Tillman. 2009. Assessing the threonine-to-lysine ratio of female broilers from 14 to 28 days of age. Journal of Applied Poultry Research 18(2):237-243.

Corzo, A., M. T. Kidd, W. A. Dozier Iii, G. T. Pharr, and E. A. Koutsos. 2007. Dietary threonine needs for growth and immunity of broilers raised under different litter conditions. Journal of Applied Poultry Research 16(4):574-582.

Corzo, A., M. T. Kidd, and B. J. Kerr. 2003. Threonine need of growing female broilers. International Journal of Poultry Science 2(6):367-371.

Dozier, W. A., K. J. Meloche, P. B. Tillman, and Z. Jiang. 2015. Growth performance of male broilers fed diets varying in digestible threonine to lysine ratio from 1 to 14 days of age1. Journal of Applied Poultry Research 24(4):457-462.

Duarte, K. F., O. M. Junqueira, R. S. Filardi, J. C. de Siqueira, E. A. Garcia, and A. C. de Laurentiz. 2012. Threonine requirements of 22 to 42-day-old broilers. Revista Brasileira de Zootecnia 41(1):72-79.

Kidd, M. T., A. Corzo, D. Hoehler, B. J. Kerr, S. J. Barber, and S. L. Branton. 2004. Threonine needs of broiler chickens with different growth rates. Poultry Science 83(8):1368-1375.

Kidd, M. T., B. J. Kerr, J. D. Firman, and S. D. Boling. 1996. Growth and carcass characteristics of broilers fed low-protein, threonine-supplemented diets. Journal of Applied Poultry Research 5(2):180-190.

Mack, S., D. Bercovici, G. De Groote, B. Leclercq, M. Lippens, M. Pack, J. B. Schutte, and S. Van Cauwenberghe. 1999. Ideal amino acid profile and dietary lysine specification for broiler chickens of 20 to 40 days of age. British Poultry Science 40(2):257-265.

Mehri, M., H. Nassiri-Moghaddam, H. Kermanshahi, and M. Danesh-Mesgaran. 2010. Digestible threonine needs of straight-run broiler during the growing period. Journal of Animal and Veterinary Advances 9(16):2190-2193.

Neto, R. C. L., F. G. P. Costa, R. L. Furlan, P. E. N. Givisiez, C. C. Goulart, C. F. S. Oliveira, S. A. N. Morais, R. M. Bezerra, and M. R. Lima. 2012. Levels of digestible threonine for male broilers from 1 to 7 days of age. Journal of Applied Poultry Research 21(4):757-763.

Rosa, A. P., G. M. Pesti, H. M. Edwards Jr, and R. I. Bakalli. 2001. Threonine requirements of different broiler genotypes. Poultry Science 80(12):1710-1717.

References

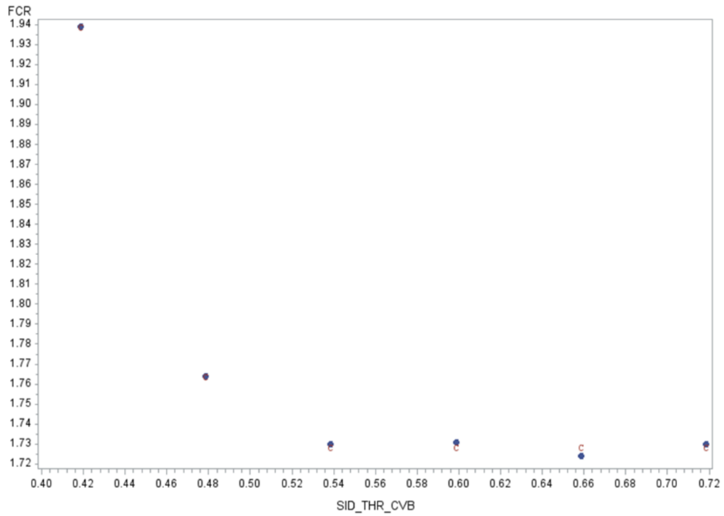
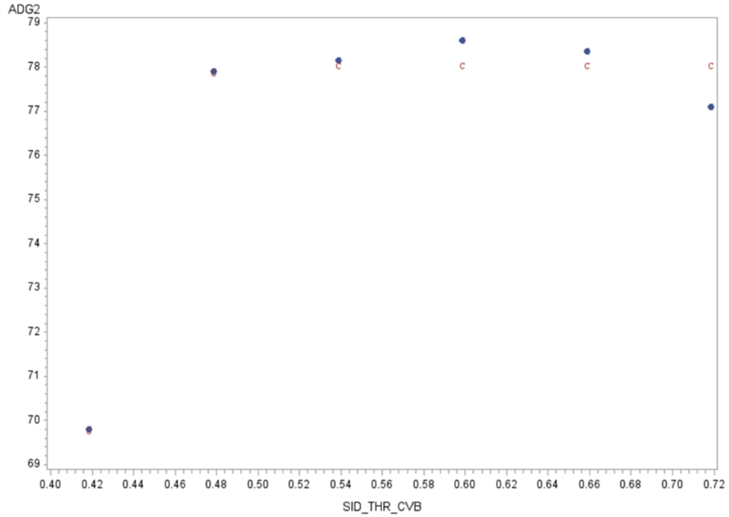
Blok and Dekker. 2017. Table ‘Standardized ileal digestibility of amino acids in feedstuffs for poultry’. CVB Documentation report nr. 61.

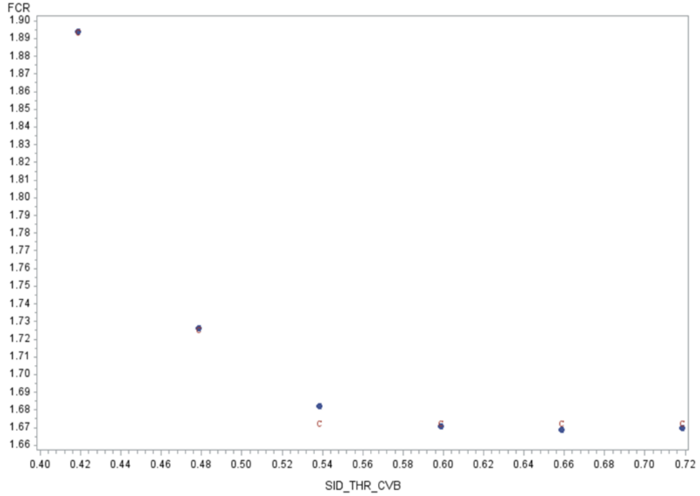
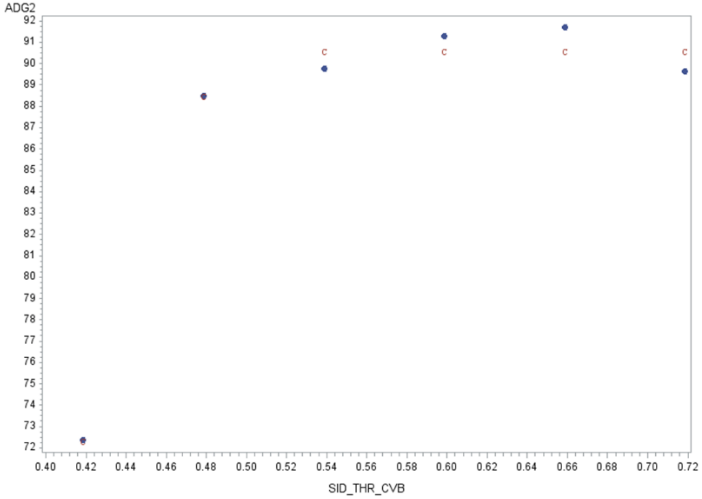
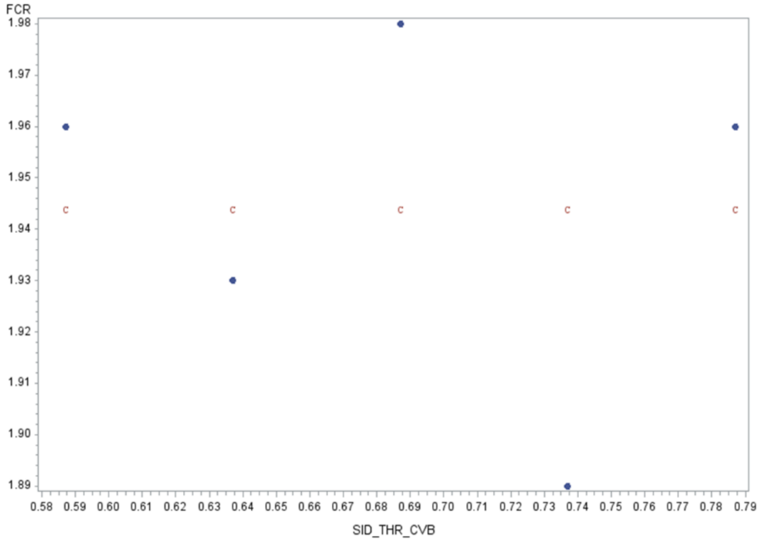
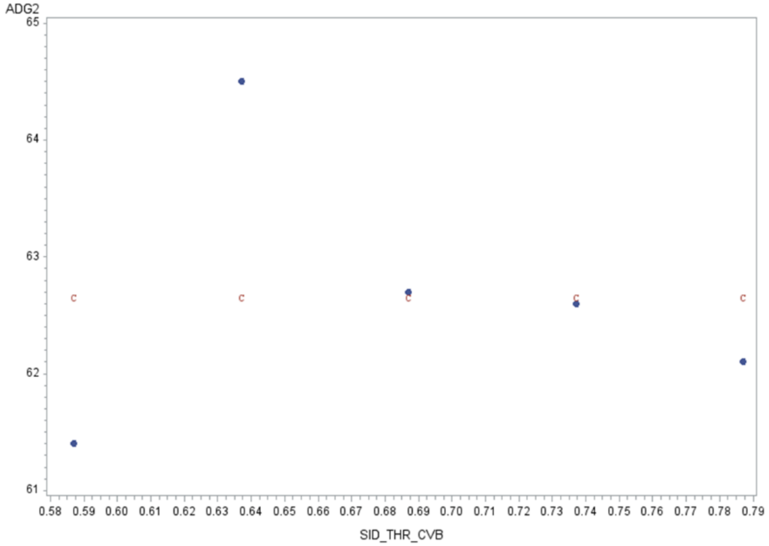
Spek, J.W. 2018. Standardized ileal digestible lysine requirement for broilers. CVB Documentation report n. 62.

Veldkamp, T., J.W. van Riel, R.A. Dekker, S. Khalaji, V. Khaksar, H. Hashemipour, M.M. van Krimpen, and M.C. Blok. 2016. Estimating requirement values for apparent faecal digestible and standardised ileal digestible threonine in broilers by a meta-analysis approach.

Appendix A. Relationship between dietary SID-THR supply and performance parameters FCR and BWG for the various titration trials.

On the x-axis of the Figures the dietary THR concentration (%) is given and on the y-axis of the Figures the FCR (left hand Figures) and BWG (right hand figures) are given. The closed circles are the observed values and the ‘c’ symbols are the fitted values.

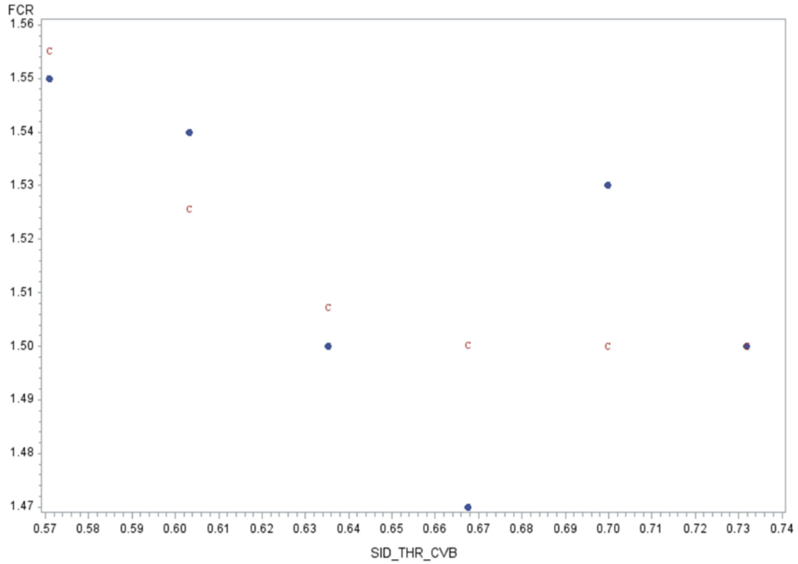
Trial	FCR	BWG
1. Mack et al. (1999) Trial 1 Optimal SID-THR FCR (%): 0.520 Optimal SID-THR BWG (%): 0.488		

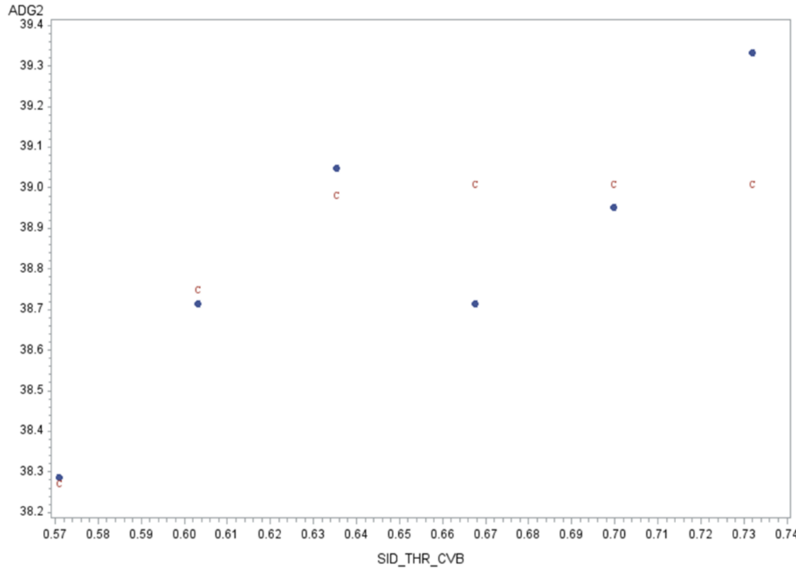
2. Mack et al. (1999) Trial 2 Optimal SID-THR FCR (%): 0.536 Optimal SID-THR BWG (%): 0.509		
3. Ayasan et al. (2009) Optimal SID-THR FCR (%): could not be estimated Optimal SID-THR BWG (%): could not be estimated		

4.
Kidd et al. (1996)

Optimal SID-THR FCR (%): 0.672

Optimal SID-THR BWG (%): 0.650

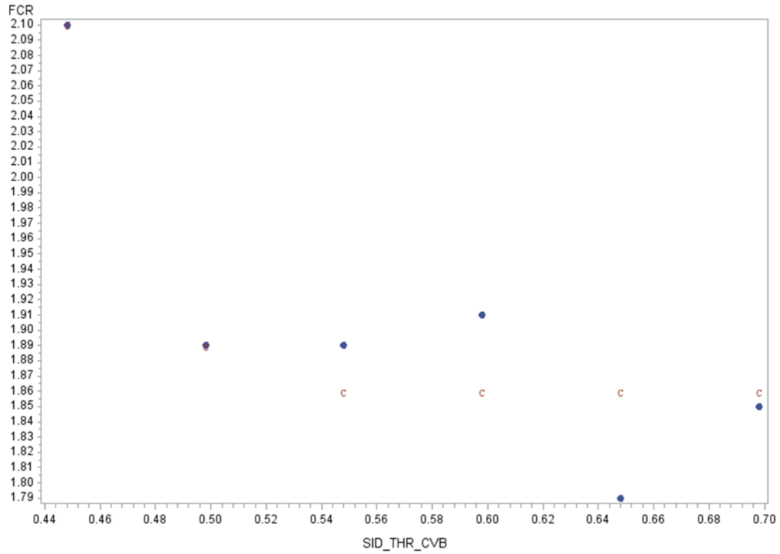


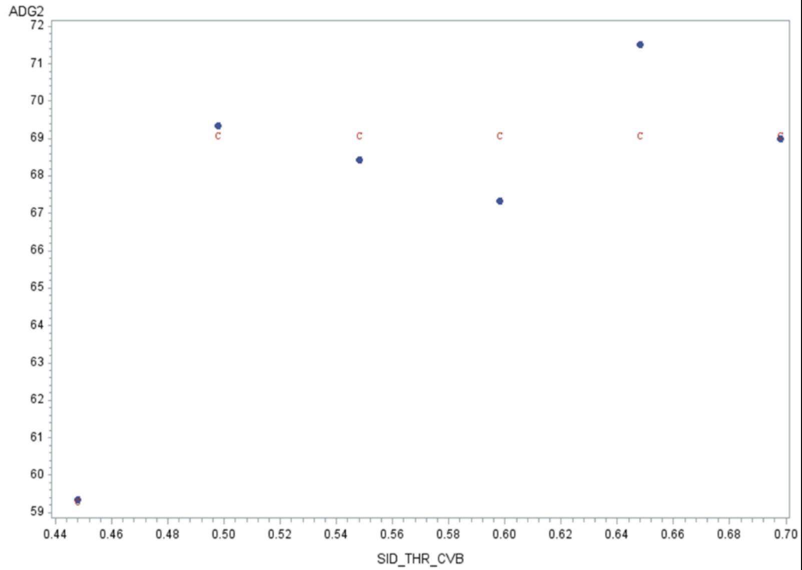


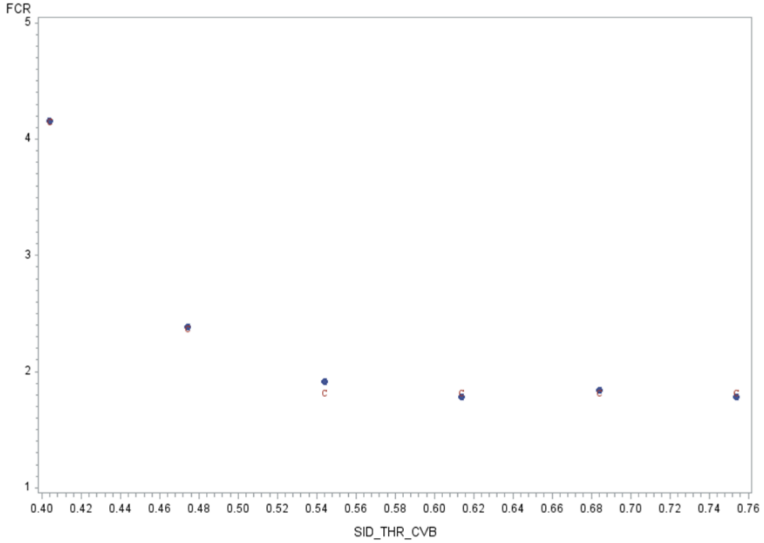
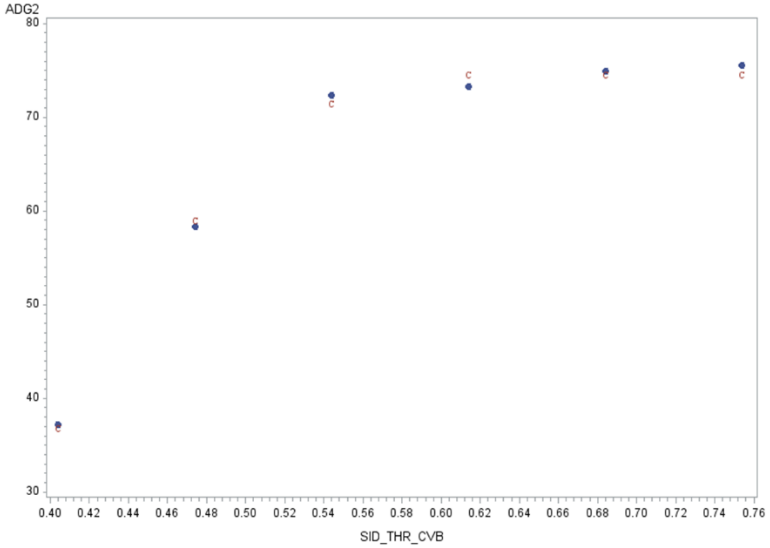
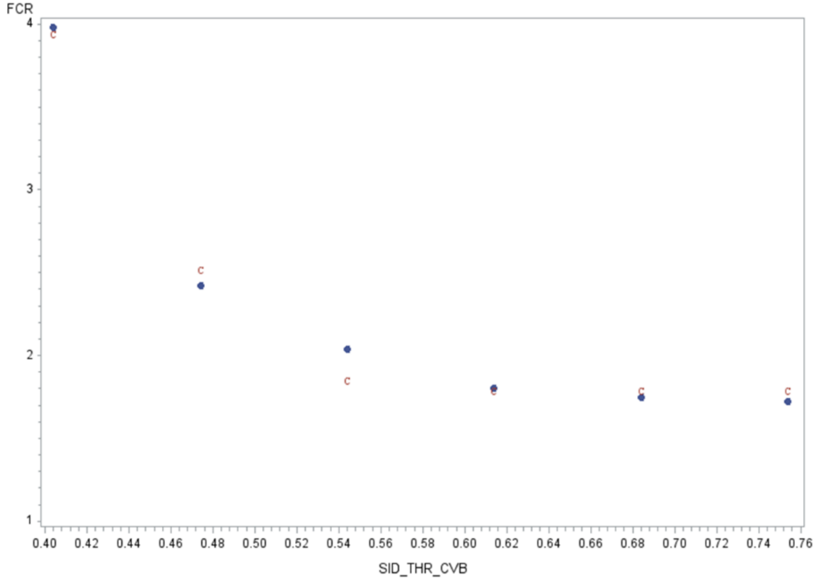
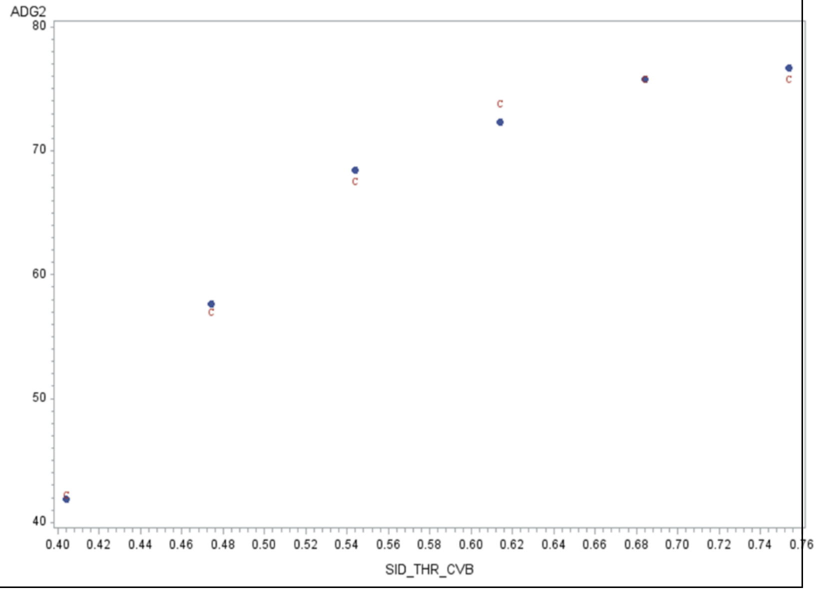
5.
Corzo et al. (2003)

Optimal SID-THR FCR (%): 0.525

Optimal SID-THR BWG (%): 0.460 (no unique estimate possible)



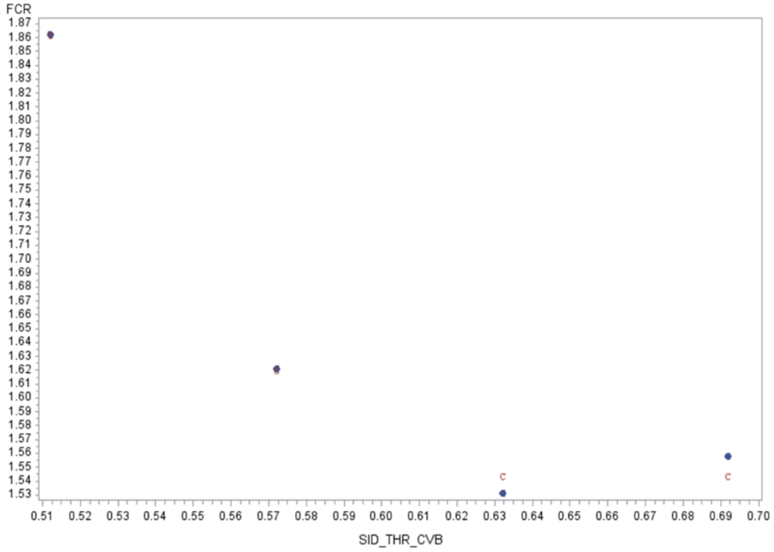


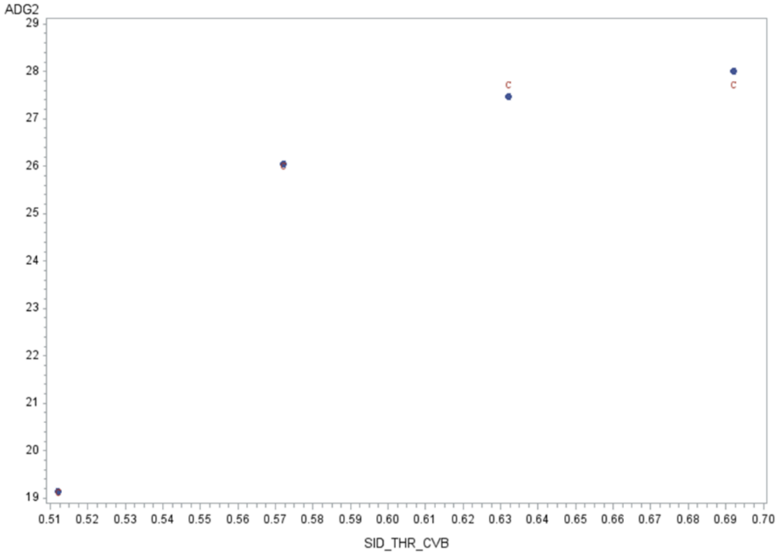
6. Corzo et al. (2007) Trial 1 Optimal SID-THR FCR (%): 0.540 Optimal SID-THR BWG (%): 0.600		
7. Corzo et al. (2007) Trial 2 Optimal SID-THR FCR (%): 0.572 Optimal SID-THR BWG (%): 0.681		

8.
Ciftci and Ceylan (2004)
Trial 1

Optimal SID-THR FCR (%):

Optimal SID-THR BWG (%): 0.620

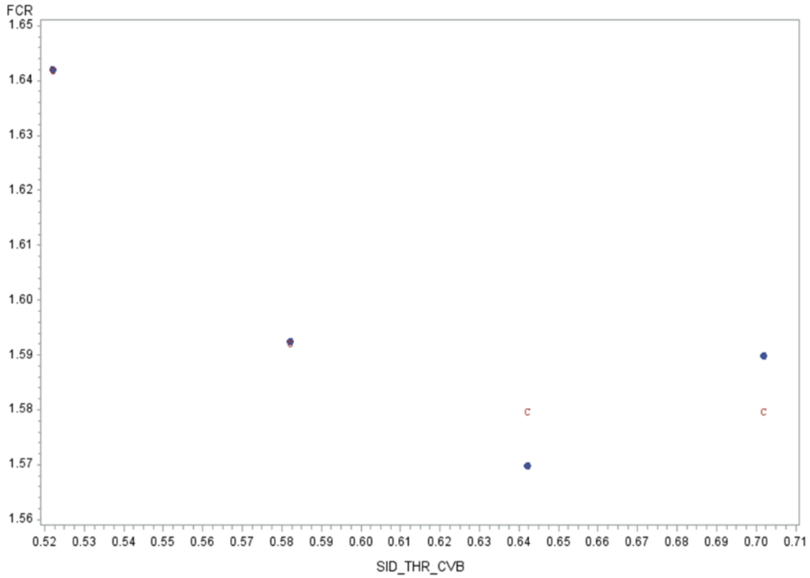


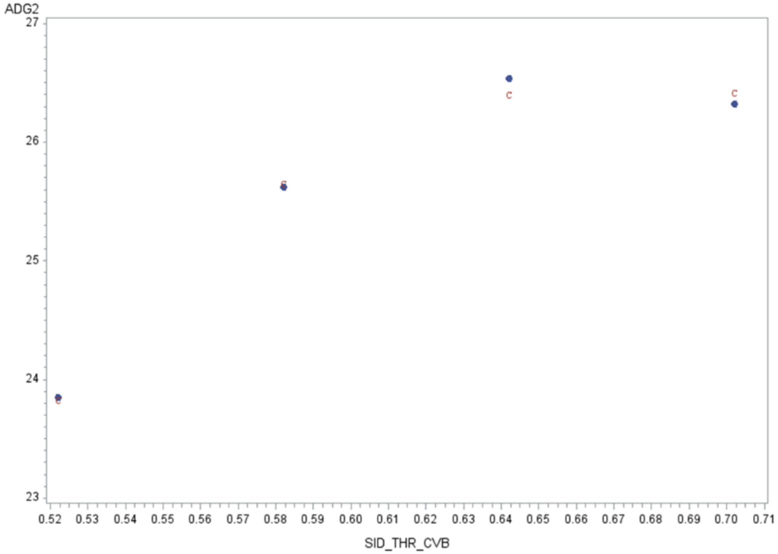


9.
Ciftci and Ceylan (2004)
Trial 2

Optimal SID-THR FCR (%):

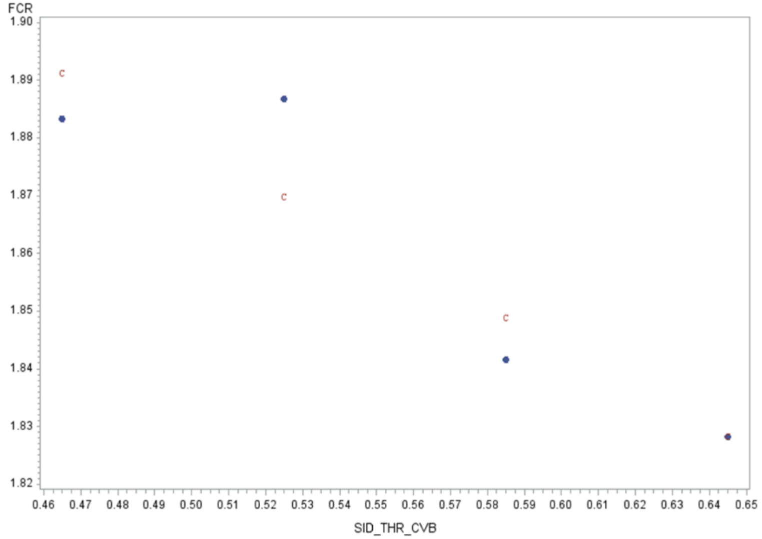
Optimal SID-THR BWG (%): 0.653





<table>
<tr>
<td>10.
Ciftci and Ceylan (2004)
Trial 3

Optimal SID-THR FCR (%): 4.203 (value outside measurement range)

Optimal SID-THR BWG (%): 0.560</td>
<td>
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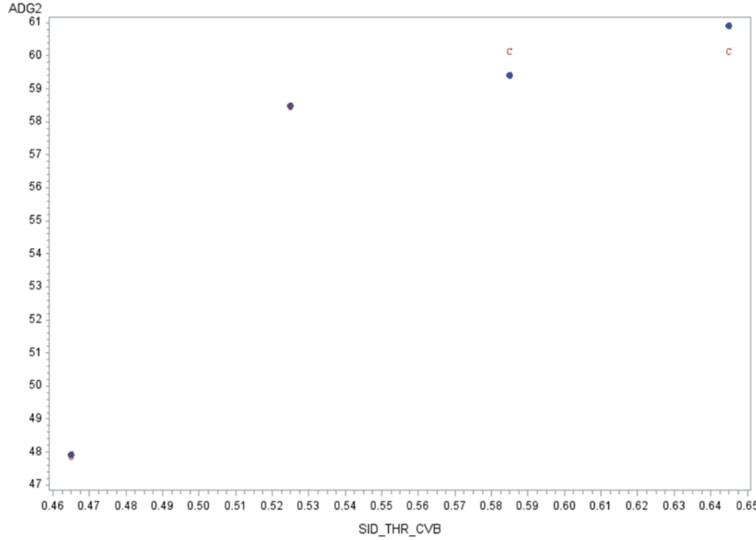
<td>
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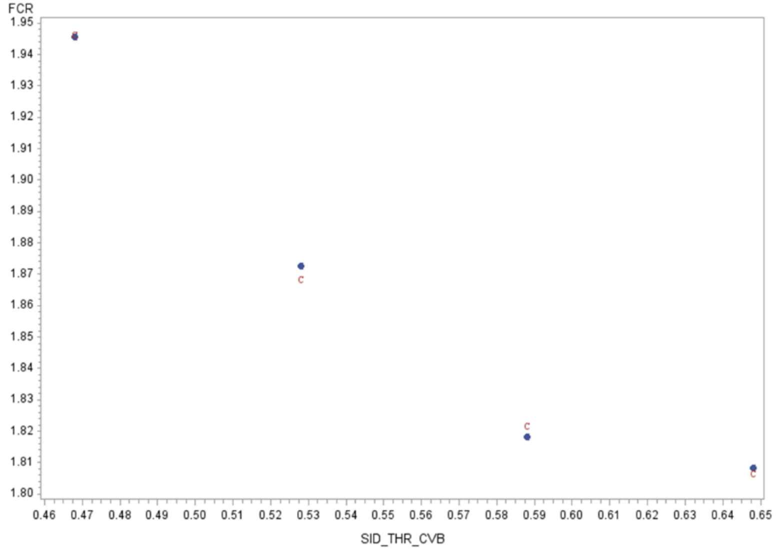
<td>11.
Ciftci and Ceylan (2004)
Trial 4

Optimal SID-THR FCR (%): 0.647

Optimal SID-THR BWG (%): 0.587</td>
<td>
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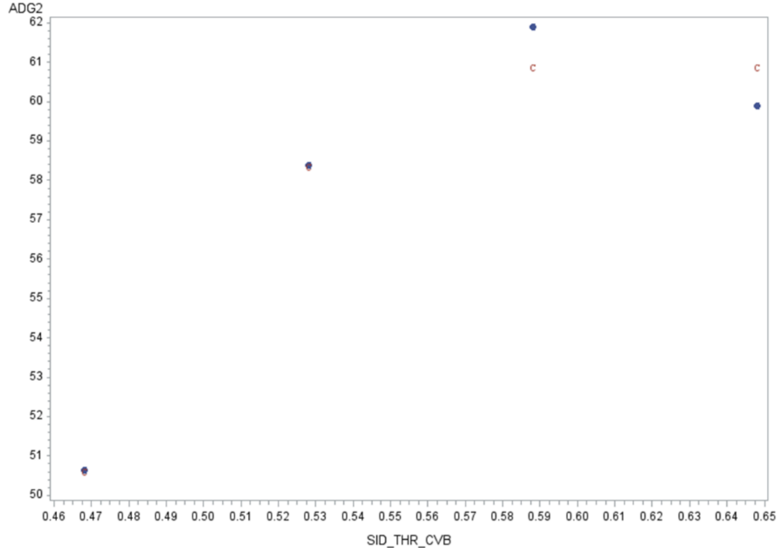
<td>
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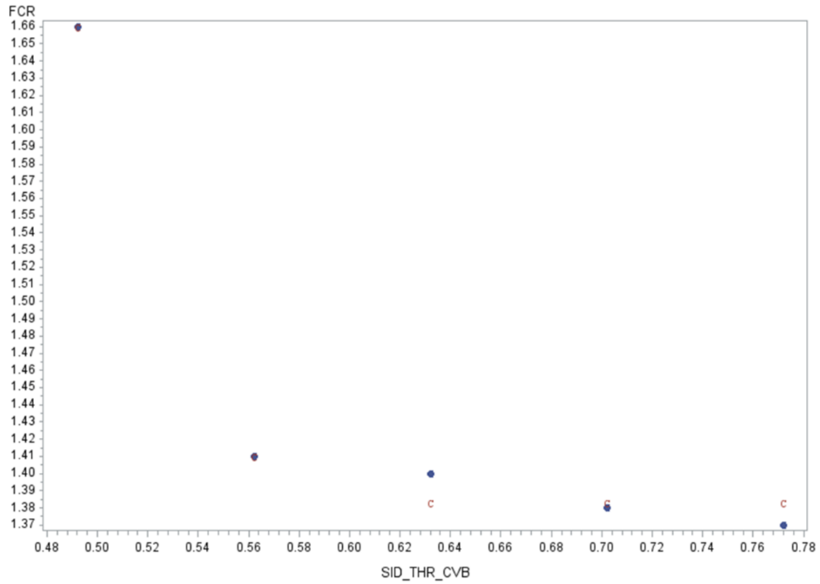
<td>12.
Rosa et al. (2001)
Trial 1

Optimal SID-THR
FCR (%): 0.594

Optimal SID-THR
BWG (%): 0.577</td>
<td>
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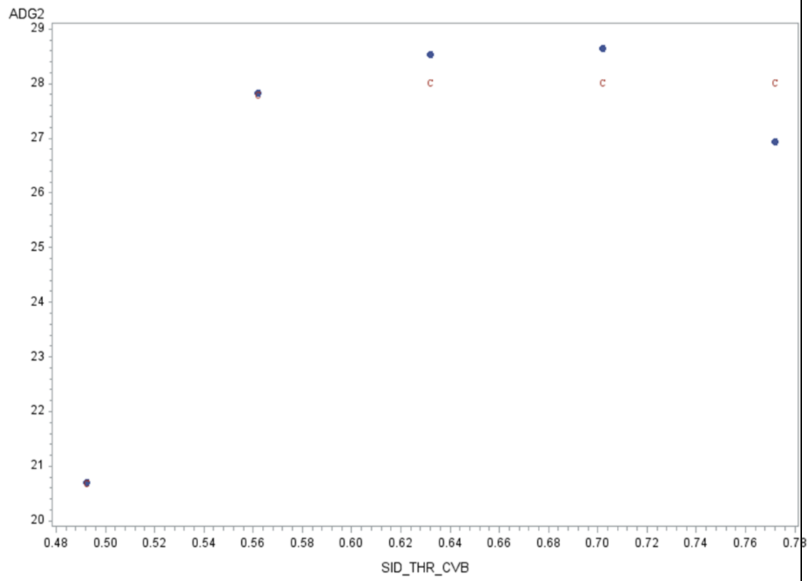
<td>
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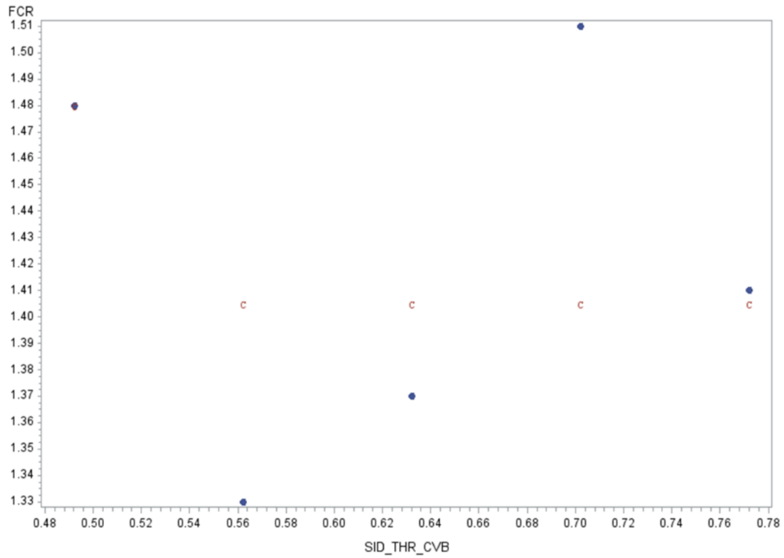
<td>13.
Rosa et al. (2001)
Trial 2

Optimal SID-THR
FCR (%): 0.560
(no unique
estimate possible)

Optimal SID-THR
BWG (%): 0.601</td>
<td>
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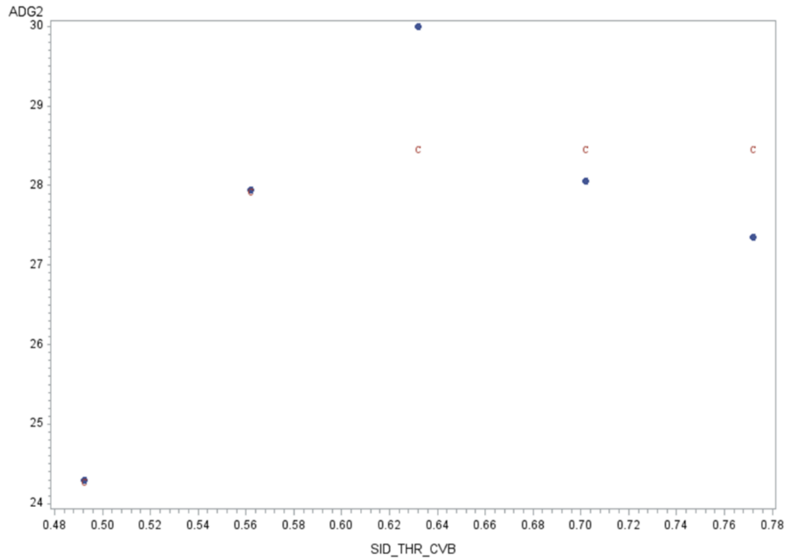
<td>
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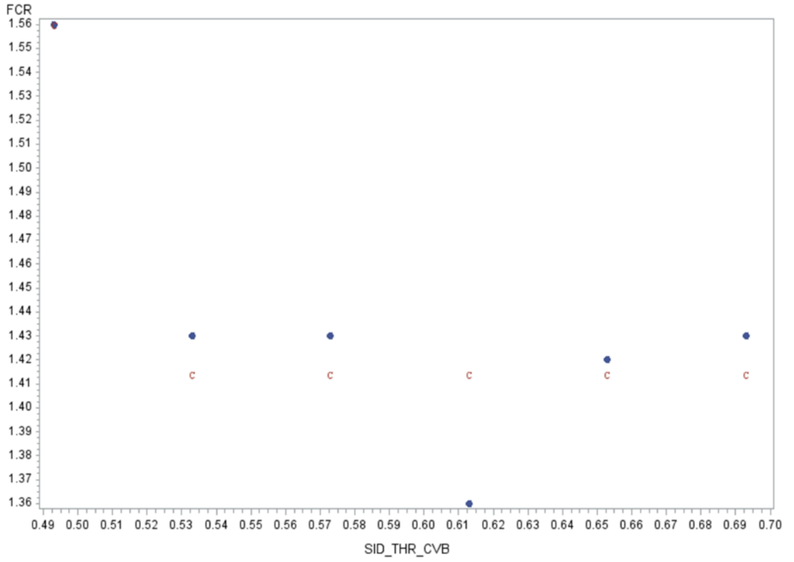
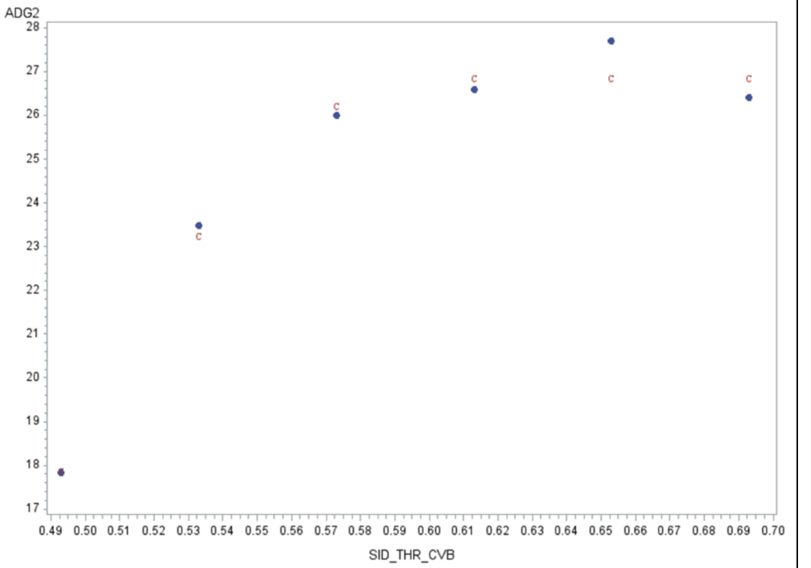
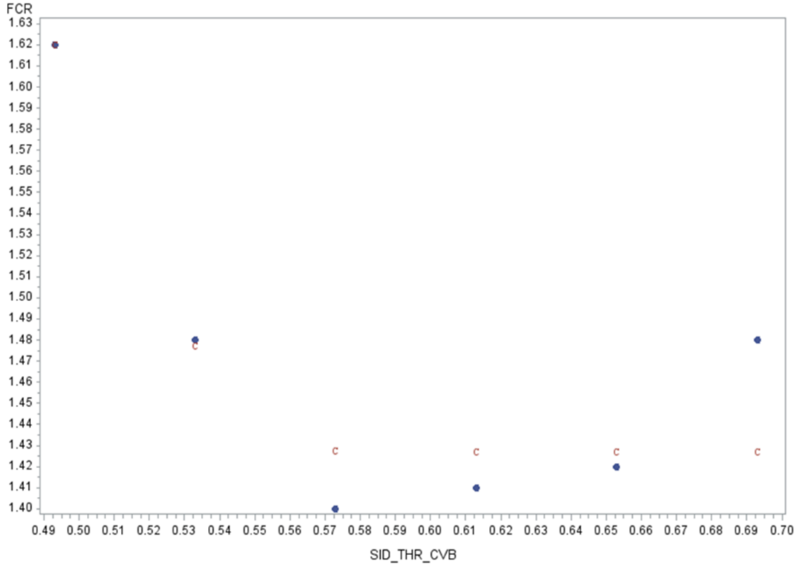
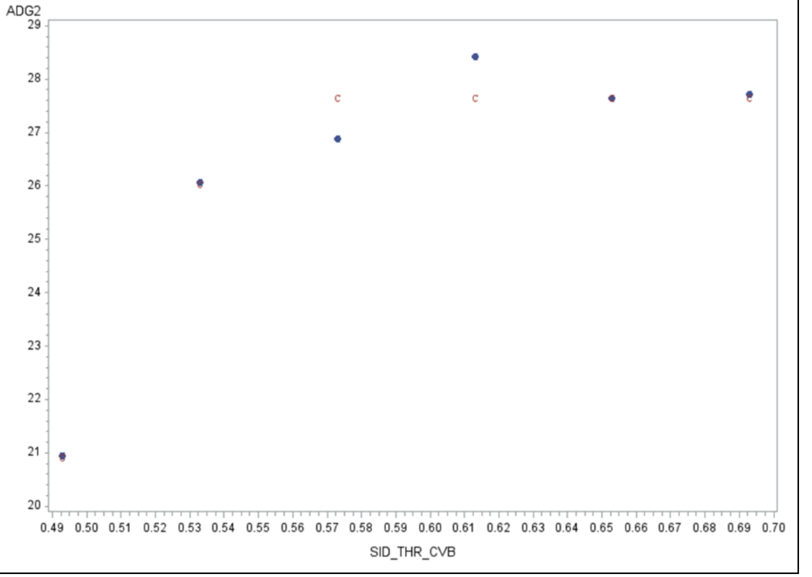
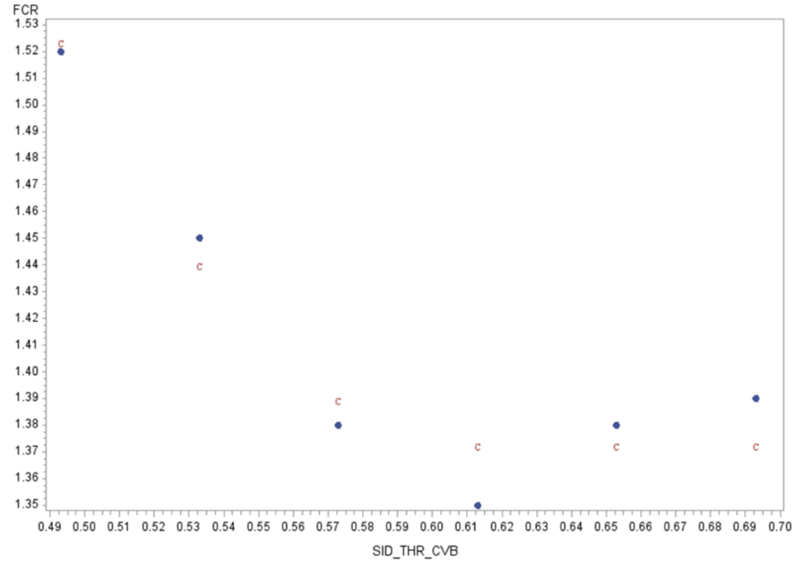
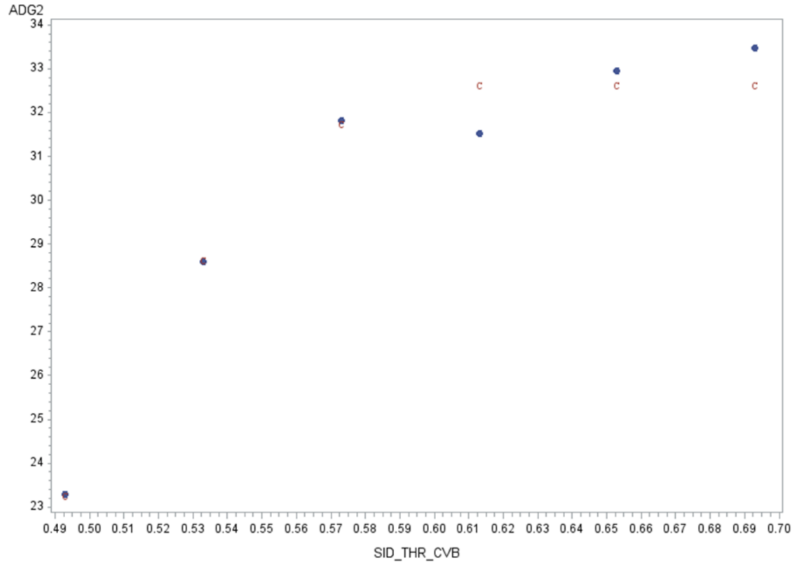
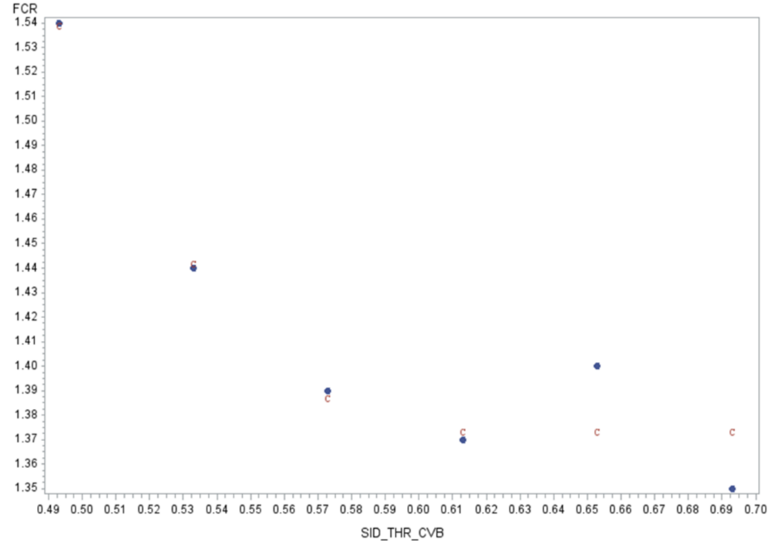
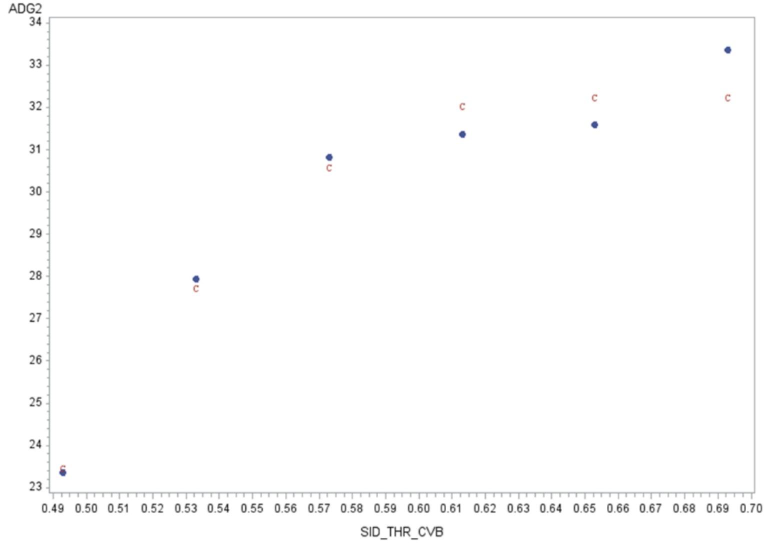
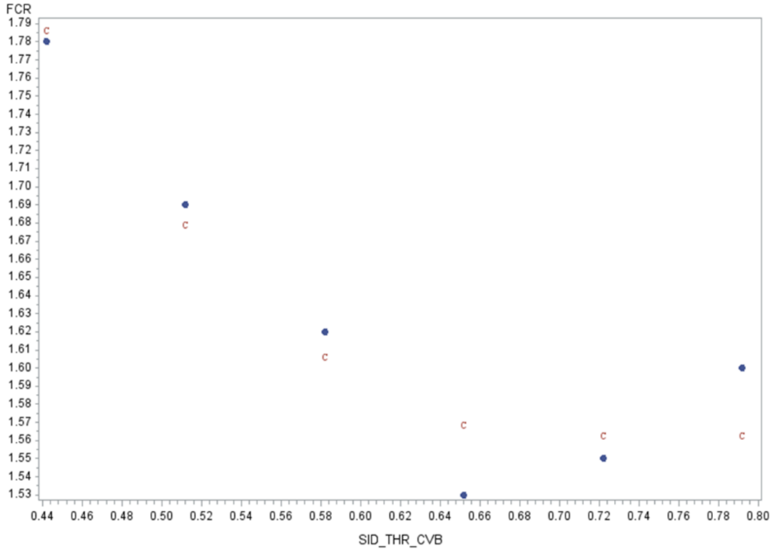
14. Rosa et al. (2001) Trial 3 Optimal SID-THR FCR (%): 0.520 (no unique estimate possible) Optimal SID-THR BWG (%): 0.602		
15. Rosa et al. (2001) Trial 4 Optimal SID-THR FCR (%): 0.575 Optimal SID-THR BWG (%): 0.571		

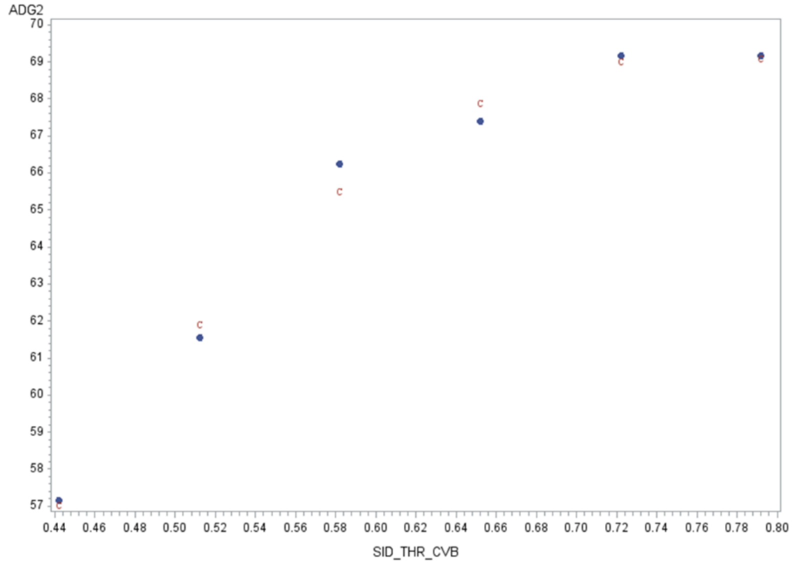
16. Rosa et al. (2001) Trial 5 Optimal SID-THR FCR (%): 0.614 Optimal SID-THR BWG (%): 0.609		
17. Rosa et al. (2001) Trial 6 Optimal SID-THR FCR (%): 0.605 Optimal SID-THR BWG (%): 0.634		

18.
Mehri et al. (2010)

Optimal SID-THR FCR (%): 0.692

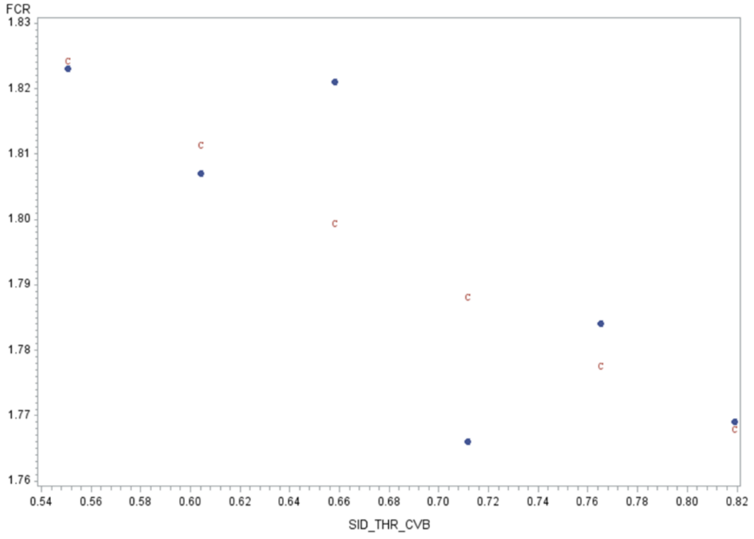
Optimal SID-THR BWG (%): 0.750

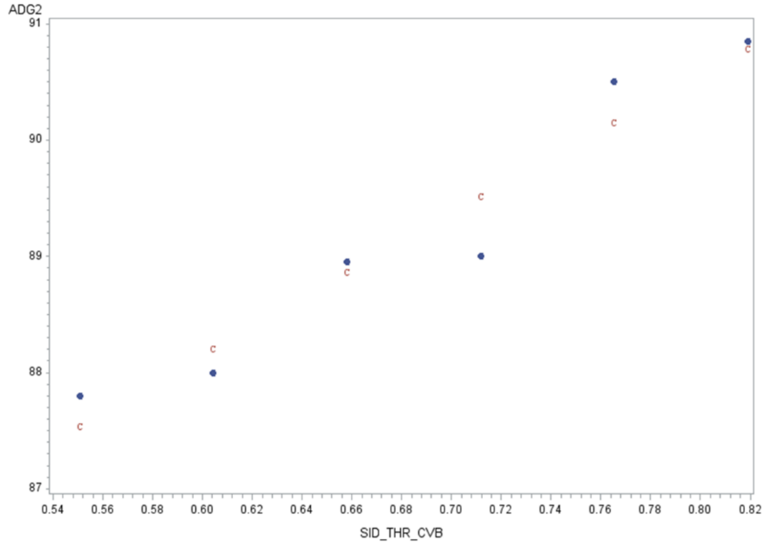


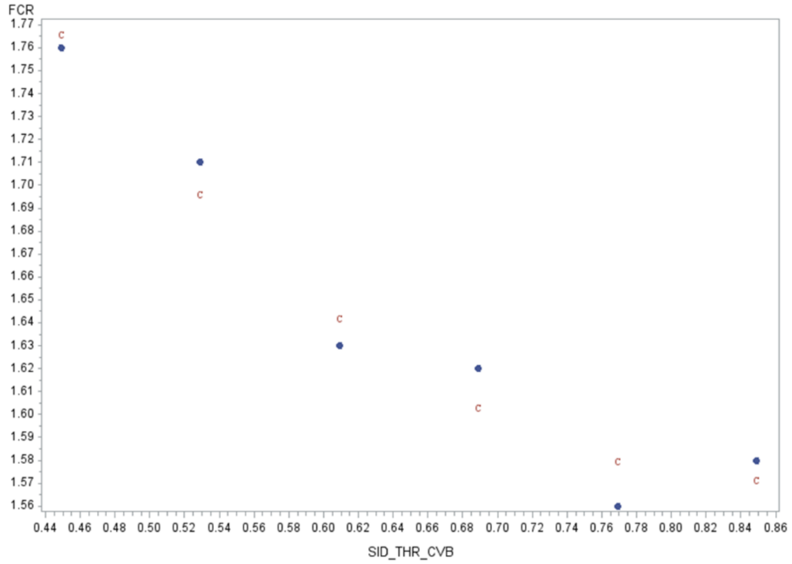
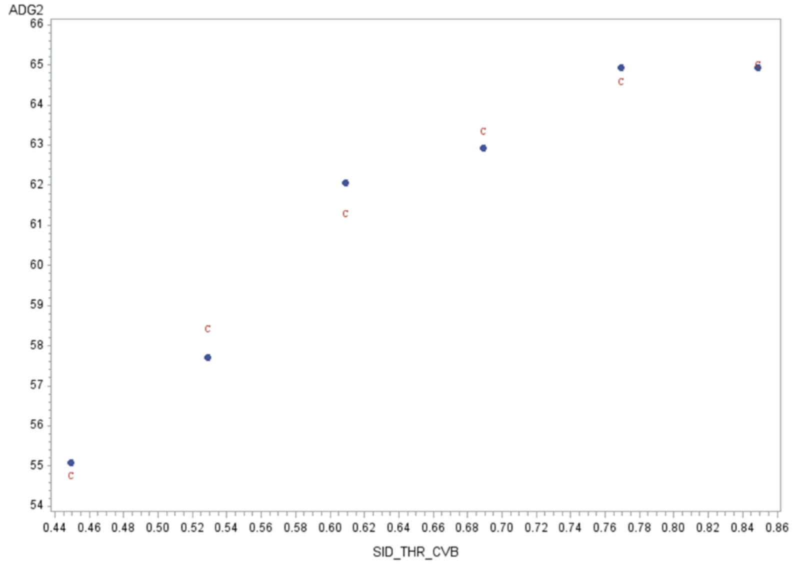
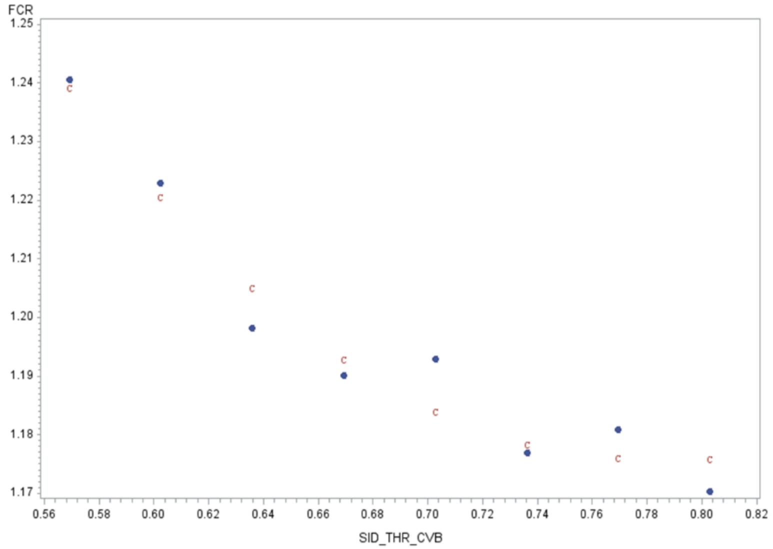
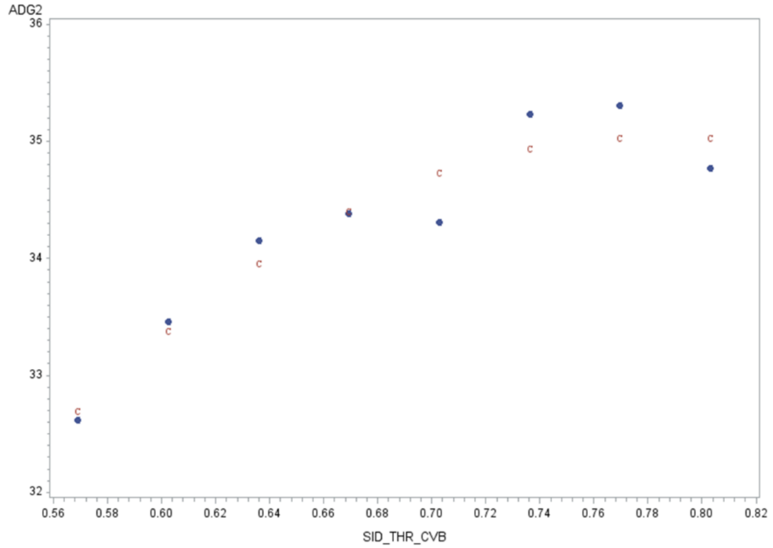


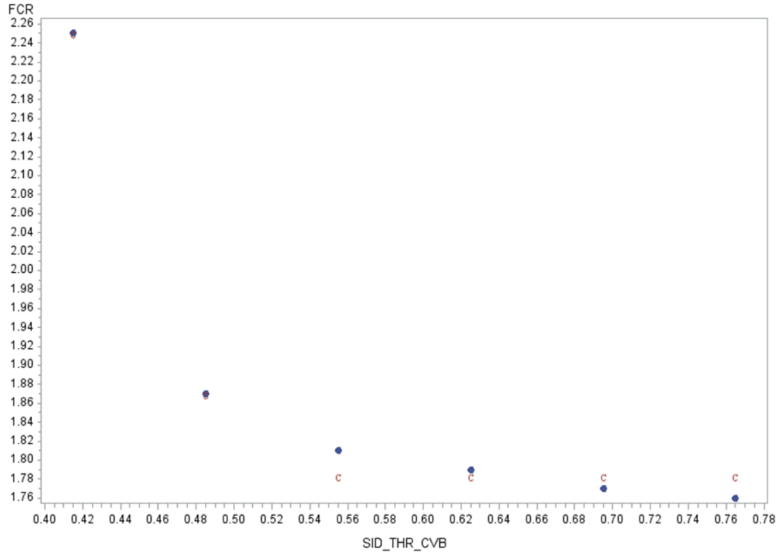
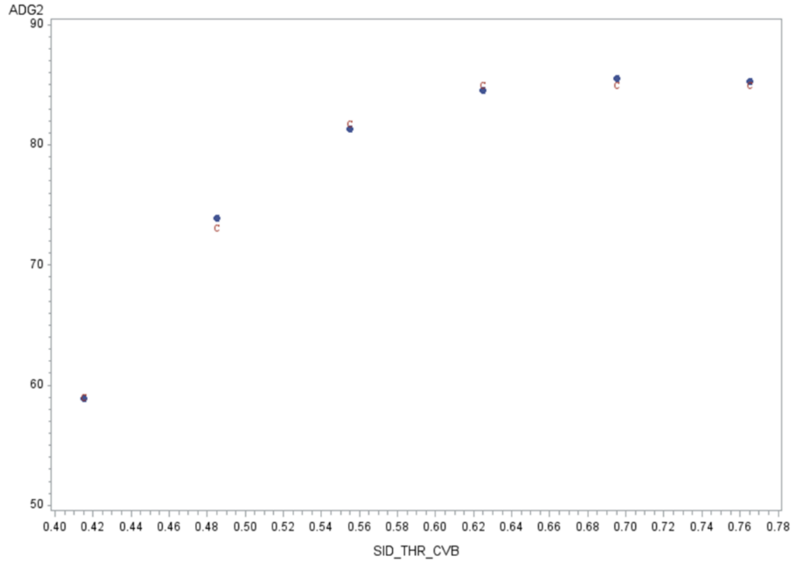
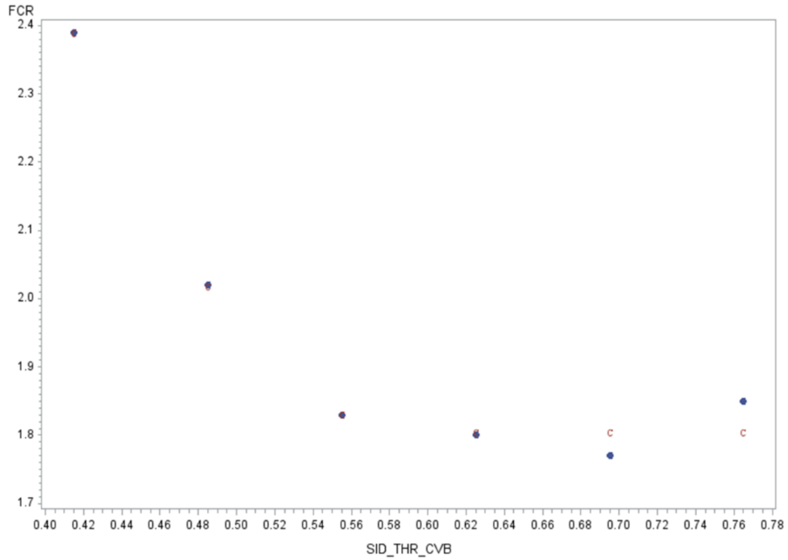
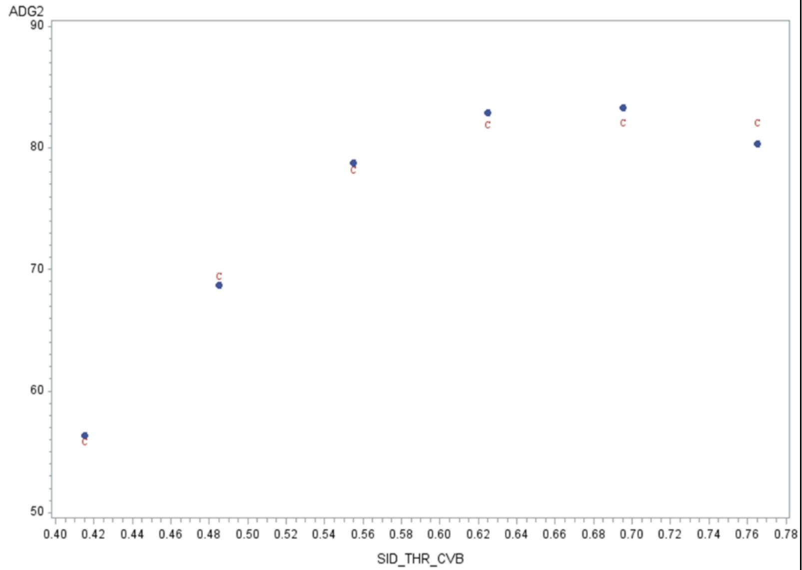
19.
Duarte et al. (2012)
Optimal SID-THR FCR (%): 1.485 (value outside measurement range)

Optimal SID-THR BWG (%): 4.47 (value far outside measurement range)





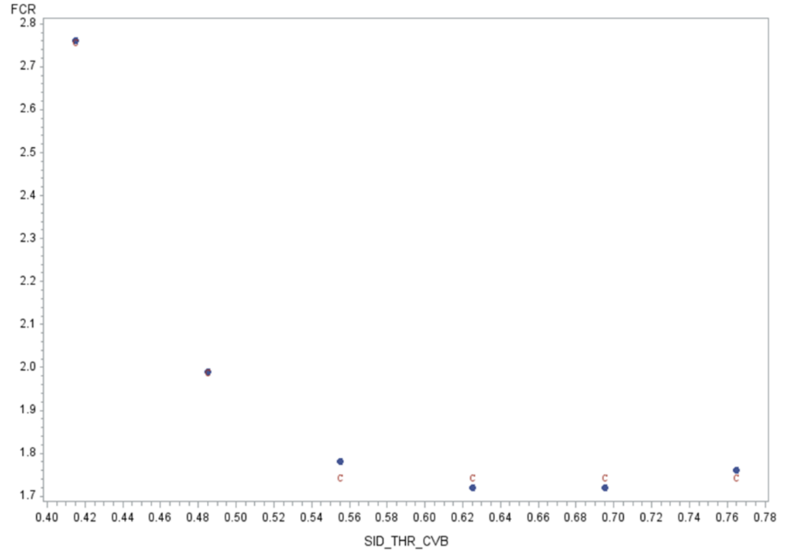
20. Corzo et al. (2009) Optimal SID-THR FCR (%): 0.851 Optimal SID-THR BWG (%): 0.852		
21. Dozier et al. (2015) Optimal SID-THR FCR (%): 0.777 Optimal SID-THR BWG (%): 0.777		

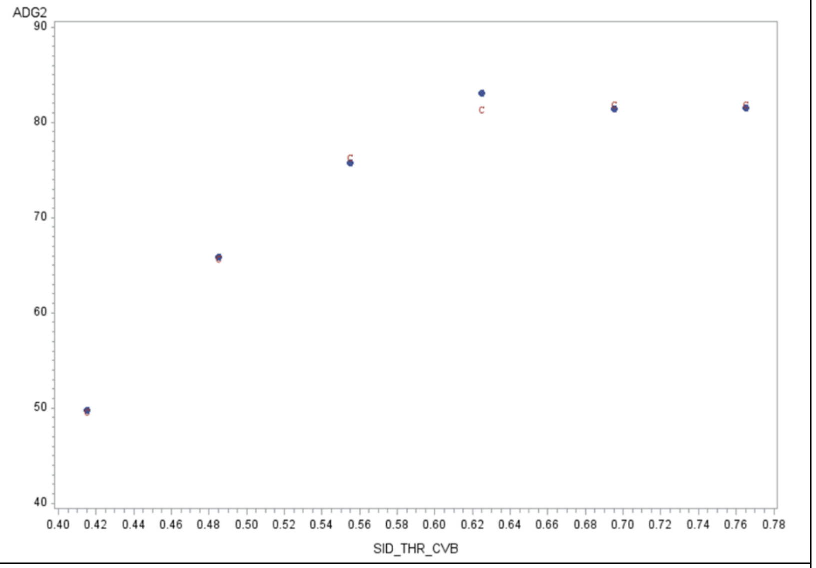
22. Kidd et al. (2004) Trial 1 Optimal SID-THR FCR (%): 0.538 Optimal SID-THR BWG (%): 0.630		
23. Kidd et al. (2004) Trial 2 Optimal SID-THR FCR (%): 0.592 Optimal SID-THR BWG (%): 0.644		

24.
Kidd et al. (2004)
Trial 3

Optimal SID-THR
FCR (%): 0.553

Optimal SID-THR
BWG (%): 0.654

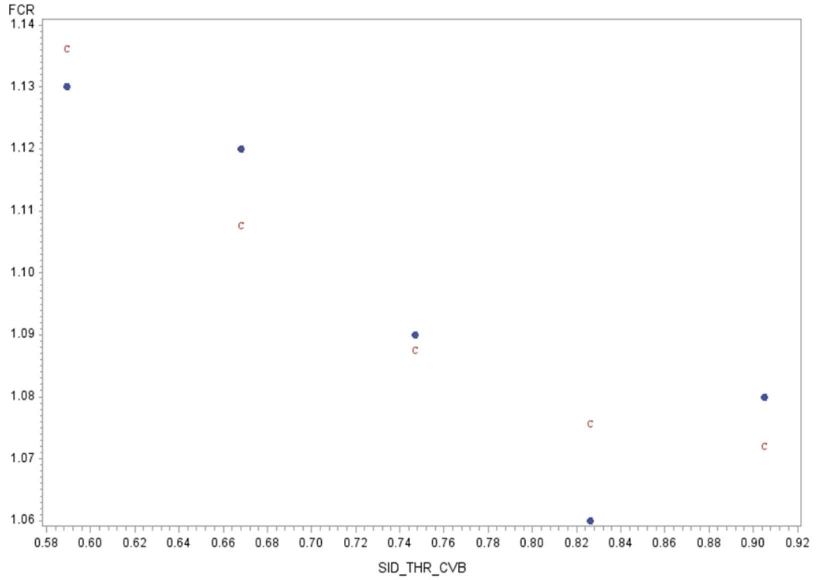


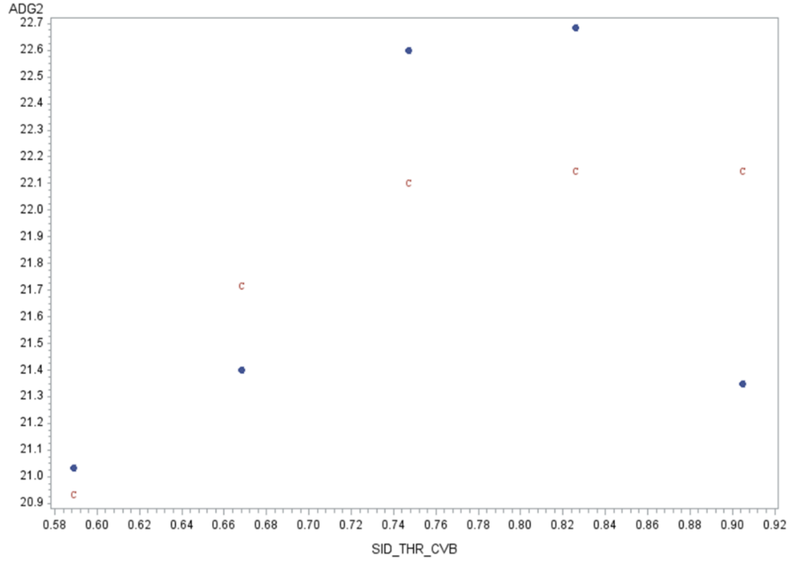


25.
Neto et al. (2012)

Optimal SID-THR
FCR (%): 0.900

Optimal SID-THR
BWG (%): 0.785





Appendix B. SID-THR model estimates using the quadratic broken-line model for minimum FCR and maximum BWG

SID-THR model estimates using the quadratic broken-line model for minimum FCR

Trial nr.	Estimate L	Std. Err. L	Estimate R	Std. Err. R	Estimate U	Std. Err. U	R^2
1	1.729	0.0016	0.520	0.0035	20.4	1.44	0.999
2	1.673	0.0030	0.536	0.0071	16.0	2.00	0.997
3							
4	1.500	0.0159	0.672	0.0969	5.4	10.77	0.540
5	1.860	0.0265	0.525	0.0410	40.1	42.91	0.847
6	1.828	0.0309	0.540	0.0079	125.4	15.19	0.997
7	1.794	0.0747	0.572	0.0226	76.5	21.26	0.986
8	1.545	0.0131	0.630	0.0159	23.0	6.28	0.995
9	1.580	0.0100	0.631	0.0582	5.3	5.61	0.930
10	1.221	37.0445	4.203	211.7000	0.0	2.79	0.846
11	1.807	0.0057	0.647	0.0177	4.4	0.83	0.997
12	1.383	0.0088	0.594	0.0148	26.8	7.76	0.992
13	1.405	0.0386	0.560	.	16.3	18.77	0.201
14	1.414	0.0136	0.520	.	200.3	45.83	0.827
15	1.428	0.0183	0.575	0.0338	29.0	25.02	0.885
16	1.372	0.0109	0.614	0.0296	10.4	5.34	0.945
17	1.374	0.0118	0.605	0.0279	13.1	6.79	0.945
18	1.564	0.0222	0.692	0.0752	3.6	2.19	0.922
19	1.710	0.6650	1.485	6.4017	0.1	1.05	0.686
20	1.572	0.0178	0.851	0.0863	1.2	0.49	0.963
21	1.176	0.0045	0.777	0.0379	1.5	0.53	0.951
22	1.783	0.0111	0.538	0.0131	30.7	6.68	0.992
23	1.806	0.0185	0.592	0.0209	18.7	4.59	0.988
24	1.745	0.0150	0.553	0.0089	53.6	7.24	0.997
25	1.072	0.0148	0.900	0.1720	0.7	0.71	0.848

SID-THR model estimates using the quadratic broken-line model for maximum BWG

Trial nr.	Estimate L	Std. Err. L	Estimate R	Std. Err. R	Estimate U	Std. Err. U	R^2
1	78.1	0.33	0.488	0.0265	-1715	1290.5	0.977
2	90.6	0.53	0.509	0.0128	-2214	630.3	0.988
3							
4	39.0	0.14	0.650	0.0589	-118	182.1	0.685
5	69.1	0.69	0.460	.	-67940	11668.6	0.895
6	74.7	0.66	0.600	0.0121	-979	125.7	0.997
7	75.9	0.80	0.681	0.0188	-437	60.5	0.995
8	27.7	0.27	0.620	0.0112	-738	152.5	0.997
9	26.4	0.14	0.653	0.0220	-150	49.3	0.993
10	60.2	0.76	0.560	0.0211	-1354	587.8	0.989
11	60.9	1.00	0.587	0.0378	-726	466.5	0.973
12	28.0	0.55	0.577	0.0443	-1027	1053.6	0.959
13	28.5	0.79	0.601	0.0877	-354	569.1	0.780
14	26.9	0.34	0.602	0.0147	-757	212.7	0.984
15	27.7	0.31	0.571	0.0160	-1100	467.3	0.969
16	32.7	0.47	0.609	0.0199	-702	253.1	0.972
17	32.3	0.57	0.634	0.0278	-443	179.0	0.965
18	69.1	0.45	0.750	0.0298	-127	24.1	0.992
19	112.1	334.30	4.472	55.2012	-2	23.3	0.936
20	65.1	0.66	0.852	0.0606	-63	18.1	0.981
21	35.0	0.22	0.777	0.0498	-54	25.8	0.918
22	85.1	0.40	0.630	0.0111	-559	60.3	0.998
23	82.2	0.93	0.644	0.0264	-503	119.8	0.988
24	81.9	0.71	0.654	0.0165	-566	80.4	0.996
25	22.2	0.54	0.785	0.2879	-32	93.9	0.460