Standardized ileal digestible tryptophan 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 tryptophan (SID-TRP) are presented in the present CVB Documentation report. Compared to the former CVB apparent faecal digestible TRP recommendation for broilers described in CVB Documentation report nr. 18 and published in 1996 the present established SID-TRP 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-TRP 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

Members of the Technical Committee of the CVB

Contents

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 tryptophan (SID-TRP; %) 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-TRP 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

Tryptophan titration studies were selected from literature (1990 – 2017) in which only the dietary TRP content was varied by means of addition of graded levels of dietary synthetic TRP. Furthermore, only those titration studies were selected in which non-test apparent digestible amino acid levels of the basal diet (diet with the lowest TRP content) did not come below 10% of the recommended CVB (2012) levels and where dietary digestible TRP 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-TRP (%) < R) then BWG or FCR = $L + U \times (R - SID\text{-}TRP)^{^2}$;
Else BWG or FCR = $L + U \times 0$;
Where:
L = plateau value for BWG or FCR
R = break-point value for SID-TRP (%)
U = slope value, representing the increase in BWG or decrease in FCR per unit increase in dietary SID-TRP.

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

Via the PROC MIXED procedure of SAS the estimated SID-TRP: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, the estimated SID-LYS requirement levels were also used to calculate ratios of other non-test SID-AA with the estimated requirement SID-LYS levels and it was checked whether some of the non-test SID AA were negatively affecting the estimated SID-TRP:LYS levels.

3   Results and Discussion

In Table 1 a summary of the total dataset is given. The dataset consisted of 7 studies with in total 12 titration trials and 75 observations.

Table 1. Summary of the total dataset

	N	Mean	Std Dev	Minimum	Maximum
ME Recalculated (kcal/kg)	75	3180	130.9	3008	3572
ME Publication (kcal/kg)	75	3247	117.7	3086	3400
CP Recalculated (%)	75	22	1.4	18	23
CP Publication (%)	75	22	2.2	17	25
Year	75	2002	2.0	1999	2005
Starting age (d)	75	5	5.4	1	20
Duration (d)	75	17	2.7	13	20
finishing age (d)	75	21	5.7	18	40
Mean age (d)	75	13	5.4	10	30
BWG (g/d)	75	28.9	21.12	4.1	93.0
FCR	75	1.831	0.6978	1.304	5.260

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

It was observed that for trial 2 (study of Fatufe et al. 2005), the estimated SID-TRP requirement for BWG was substantially larger than would be expected from a visual interpretation of the curve. This overestimation of the SID-TRP requirement in trial 2 could be avoided by removing the first 5 observations leaving still some 5 observations on which the curve fitting could be carried out. Removing these 5 observations resulted in a substantially lower estimated SID-TRP requirement which closely agreed with the SID-TRP requirement as would be judged from a visual interpretation of the relationship between SID-TRP supply and BWG as shown in Appendix A in trial 2b. The effect of removing the lowest dietary SID-TRP levels on estimated SID-TRP requirements was also investigated for the other titration trials. In Appendix A and Appendix B the titration results with all observations are represented with the letter 'a' whereas the titration results in which the lowest SID-TRP level(s) was/were removed before estimation of the SID-TRP requirement are represented with the letter 'b'. In some cases (trials 9, 10 and 11) it was not possible to remove the lowest dietary SID-TRP level as it resulted in too few observations for a successful model estimation of SID-TRP requirements. Comparing results 'a' with results 'b' for both BWG and FCR it was observed that in two cases (trials 7 and 8) removal of the lowest SID-TRP observation resulted in a situation in which no unique SID-TRP value could be estimated. It was judged that only for trial 2 it was justified to remove the lowest SID-TRP values in order to estimate SID-TRP values for BWG whereas in all other situations SID-TRP requirement estimates for BWG and FCR should be based on all observations.

Furthermore, for 2 titration trials for FCR and 2 titration trials for BWG it was not possible to estimate reliable or unique SID-TRP requirements.

The estimated SID-TRP:LYS requirement ratios for BWG and FCR were not significantly related to sex, age and the dietary factors ME, CP or CP : ME ratio. Furthermore, there was a significant (P=0.004) effect of the dietary SID-MET+CYS : SID-LYS ratio on estimated SID-TRP:LYS requirement ratios for BWG as shown in Figure 1. However, the relationship between dietary SID-M+C : SID-LYS ratio and estimated SID-TRP:LYS requirement ratios for minimum FCR was not significant (P=0.110) and was highly dependent on one very

influential observation (observation from study of Corzo et al., 2005). Furthermore, even after removal of the observation of the study of Corzo et al. (2005), the positive relationship between dietary SID-MET+CYS : SID-LYS ratio and estimated SID-TRP:LYS ratio for BWG remained positive and significant (P=0.041).
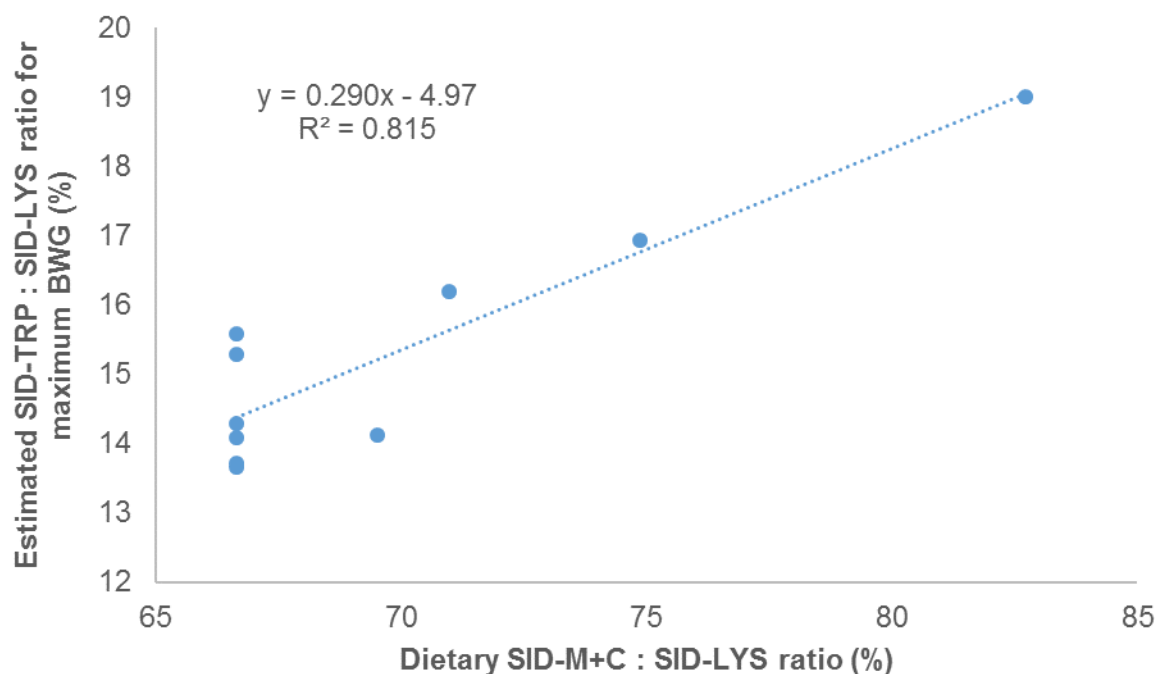

Figure 1. Relationship between dietary SID-M+C : SID-LYS ratio (%) and estimated SID-TRP : SID-LYS requirement ratio for maximum BWG (%).
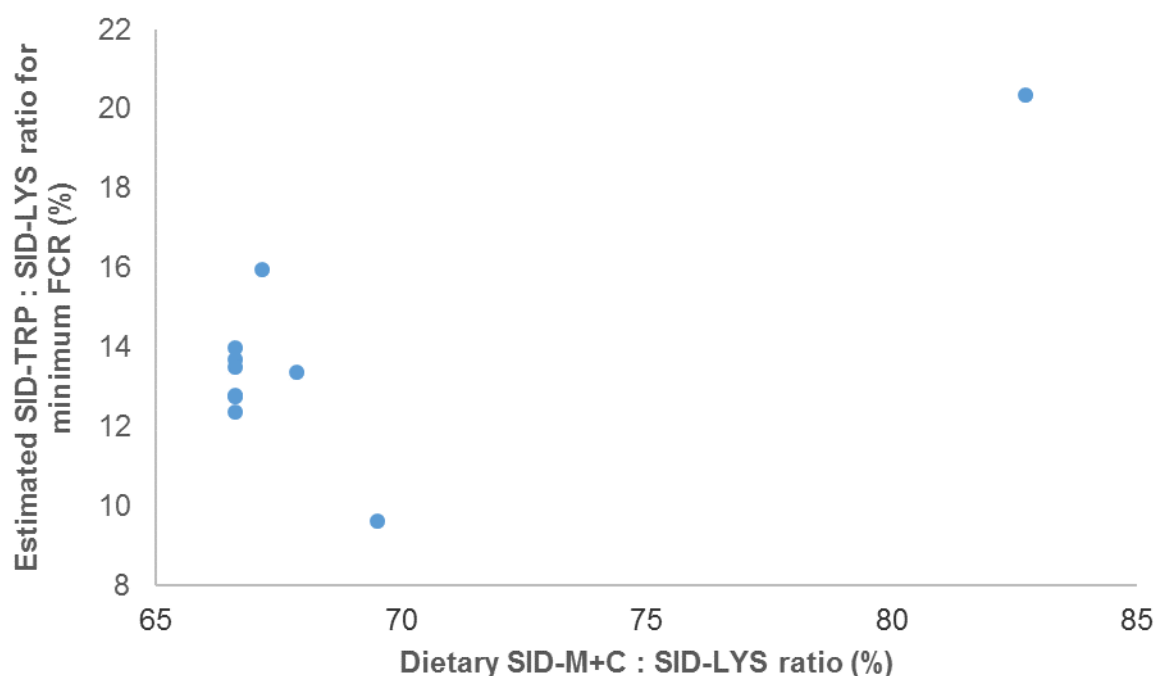

Figure 2. Relationship between dietary SID-M+C : SID-LYS ratio (%) and estimated SID-TRP : SID-LYS requirement ratio for minimum FCR (%).

From a physiological point of view it is difficult to explain the positive effect of dietary SID-M+C on the estimated requirement of SID-TRP. It cannot be explained by the fact that dietary SID-M+C was offered in sub-optimal concentrations as there were two observations with SID-M+C:SID-LYS ratios higher than 75% that strongly determined this positive relationship.

Assuming an optimal SID-M+C:SID-LYS ratio of 73% and using the regression equation shown in Figure 1 on the relationship between dietary SID-M+C : SID-LYS ratio (%) and estimated SID-TRP : SID-LYS ratio (%) for maximum BWG (%) it can be calculated that the optimal dietary SID-TRP:SID-LYS according to the relationship shown in Figure 1 is 16%.

The average estimated SID-TRP:SID-LYS requirement ratios for the 10 SID-TRP:LYS requirement observations for BWG and FCR were:

SID-TRP:LYS for BWG = 15.3±1.71 % (average ± Std. Dev.)
SID-M+C:LYS for FCR = 13.8±2.78 % (average ± Std. Dev.)

Furthermore, there was one outlier SID-TRP requirement estimate that deviated more than two standard deviations from the average estimated SID-TRP requirement estimates. This was the observation from the study of Corzo et al. (2005).

When removing this outlier value the average estimated SID-TRP:SID-LYS requirement ratios for the remaining 9 FCR and BWG observations were:

SID-TRP:SID-LYS for BWG = 14.9±1.17 % (average ± Std. Dev.)
SID-TRP:SID-LYS for FCR = 13.1±1.67 % (average ± Std. Dev.)

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

SID-TRP:SID-LYS for BWG = 15.8±0.76% (estimate ± Std. Err)
SID-TRP:SID-LYS for FCR = 14.3±1.46% (estimate ± Std. Err)

In case the results of the study of Corzo et al. (2015) were not included the estimated SID-TRP:SID-LYS requirement ratios for BWG and FCR corrected for study effect were:

SID-TRP:SID-LYS for BWG = 15.2±0.53% (estimate ± Std. Err)
SID-TRP:SID-LYS for FCR = 13.1±0.98% (estimate ± Std. Err)

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 fecal digestible (AFD) ratios. Results in Table 2 show that at least in some of the trials some non-test AA levels could have had a negative impact on estimated SID-TRP requirement 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-TRP:SID-LYS requirements did not show any study in which the estimated SID-TRP requirements substantially differed from the rest of the SID-TRP requirement estimates combined with suboptimal low ratios of non-test AA:LYS ratios of M+C:LYS, THR:LYS ILE:LYS, ARG:LYS en VAL:LYS.

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	73	69	4.8	67	83	69	4.9	67	83
THR:LYS	65	65	4.0	57	69	65	3.8	58	70
ILE:LYS	66	61	5.7	57	73	62	6.0	57	73
ARG:LYS	105	112	16.5	83	144	112	16.3	84	144
VAL:LYS	80	76	6.3	72	92	77	7.4	72	97

4   Conclusions

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

SID-TRP:LYS for BWG = 15%
SID-TRP:LYS for FCR = 13%

List of studies included in the meta-analysis

Baker, D. H., A. B. Batal, T. M. Parr, N. R. Augspurger, and C. M. Parsons. 2002. Ideal ratio (relative to lysine) of tryptophan, threonine, isoleucine, and valine for chicks during the second and third weeks posthatch. Poultry Science 81(4):485-494.

Corzo, A., M. T. Kidd, J. P. Thaxton, and B. J. Kerr. 2005. Dietary tryptophan effects on growth and stress responses of male broiler chicks. British Poultry Science 46(4):478-484.

De Castro, A. J., P. C. Gomes, J. M. R. Pupa, H. S. Rostagno, L. F. T. Albino, and A. H. Nascimento. 2000. Tryptophan Requirement for Broilers from 1 to 21 Days of Age. Revista Brasileira de Zootecnia 29(6):1743-1749.

Fatufe, A. A., F. Hirche, and M. Rodehutscord. 2005. Estimates of individual factors of the tryptophan requirement based on protein and tryptophan accretion responses to increasing tryptophan supply in broiler chickens 8-21 days of age. Archives of Animal Nutrition 59(3):181-190.

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.

Rosa, A. P., G. M. Pesti, H. M. Edwards Jr, and R. Bakalli. 2001. Tryptophan requirements of different broiler genotypes. Poultry Science 80(12):1718-1722.

Shan, A. S., K. G. Sterling, G. M. Pesti, R. I. Bakalli, J. P. Driver, and A. A. Tejedor. 2003. The influence of temperature on the threonine and tryptophan requirements of young broiler chicks. Poultry Science 82(7):1154-1162.

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 tryptophan in broilers by a meta-analysis approach.

Appendix A. Relationship between dietary SID-TRP supply and performance parameters FCR and BWG for the various titration trials.
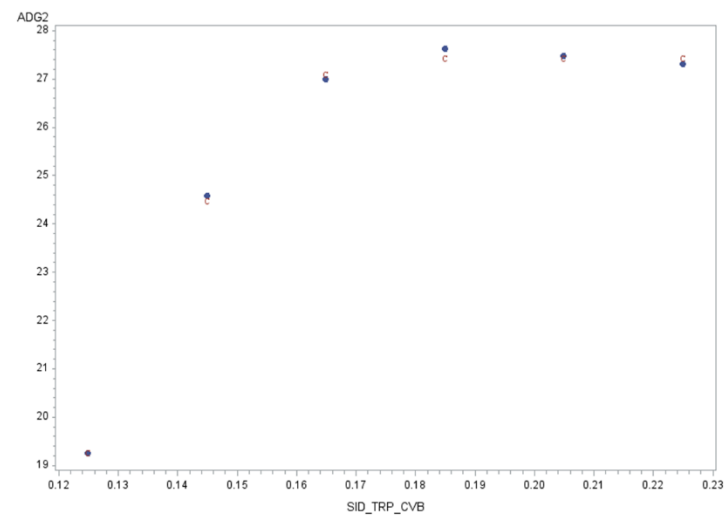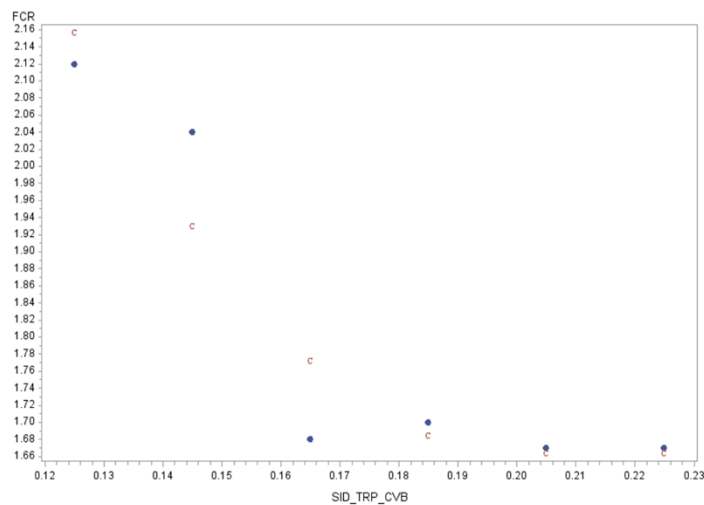
On the x-axis of the Figures the dietary TRP concentration (%) is given and on the y-axis of the Figures the FCR (left hand Figures) and BWG (right hand figures) are given. The closed circles are the observed values and the 'c' symbols are the fitted values. The letter 'a' behind the trial number (shown in the first column) means the model is fitted on all observations whereas the letter 'b' behind the trial number (shown in the first column) means the model is fitted on all observations except the observations(s) with the lowest dietary SID-TRP level(s). If no letter is shown behind the trial number it means that the model is fitted based on all observations of the trial.

Trial	FCR	BWG
1a. Corzo et al. (2005) Optimal SID-TRP FCR (%): 0.205 Optimal SID-TRP BWG (%): 0.1911		
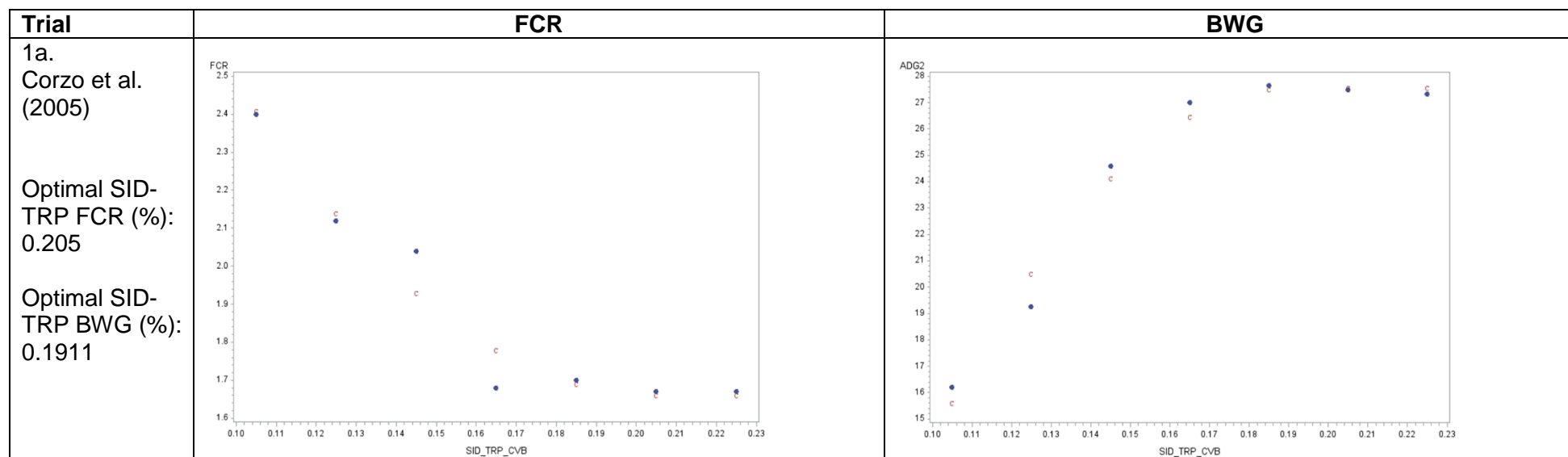
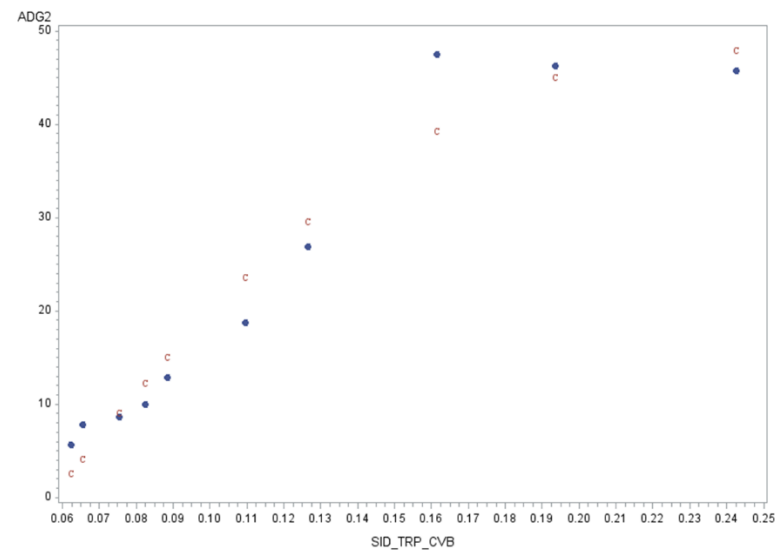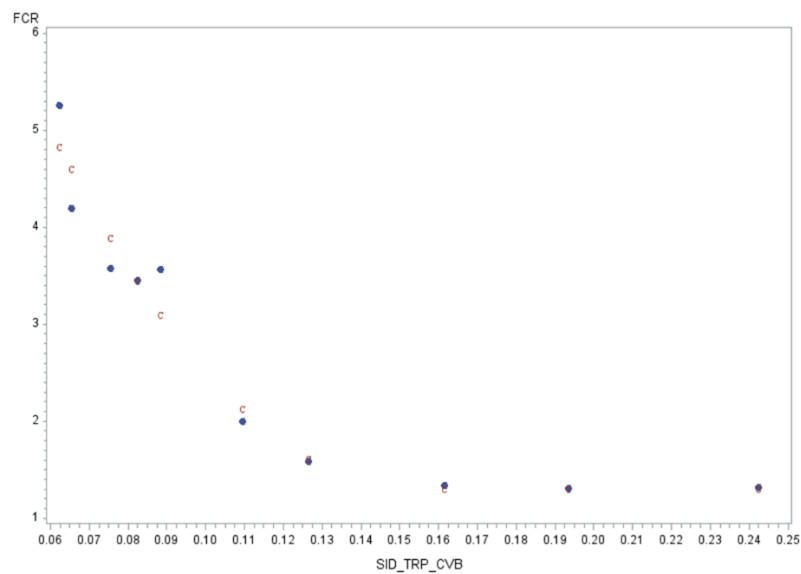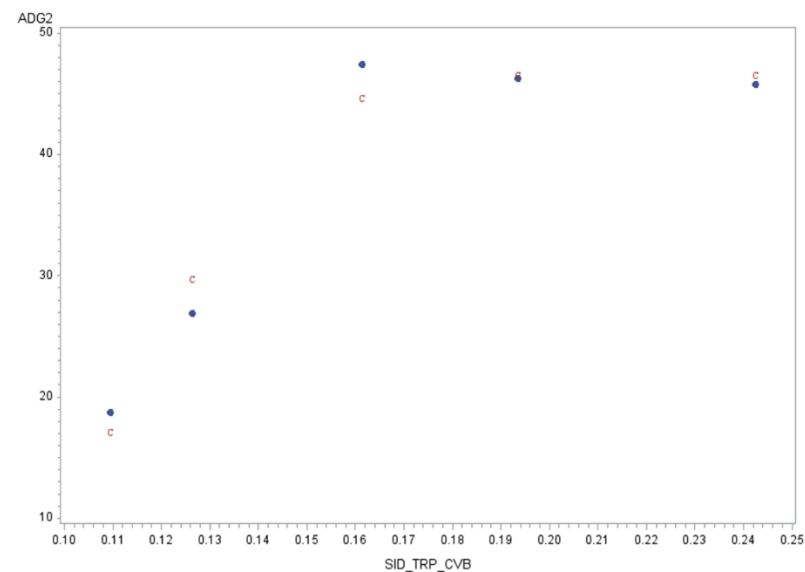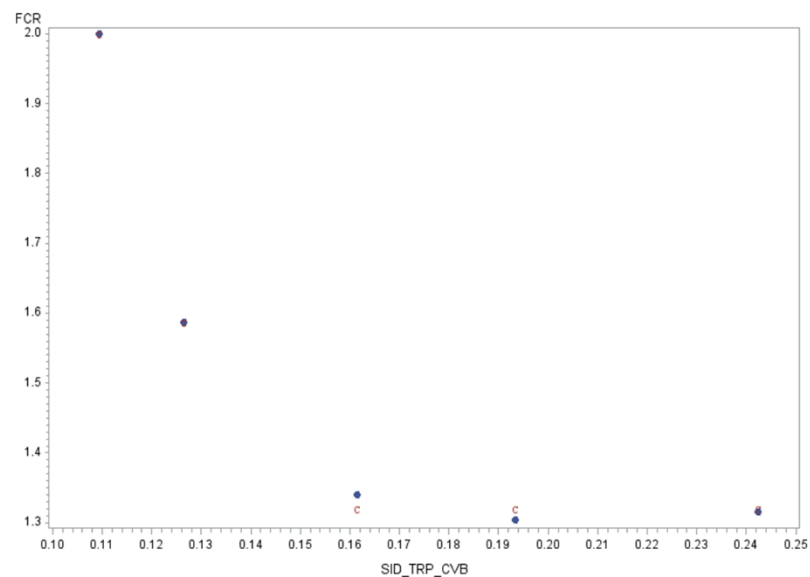|		
1b. Corzo et al. (2005) Optimal SID- TRP FCR (%): 0.200 Optimal SID- TRP BWG (%): 0.175		
2a. Fatufe et al. (2005) Optimal SID- TRP FCR (%): 0.153 Optimal SID- TRP BWG (%): 0.238		

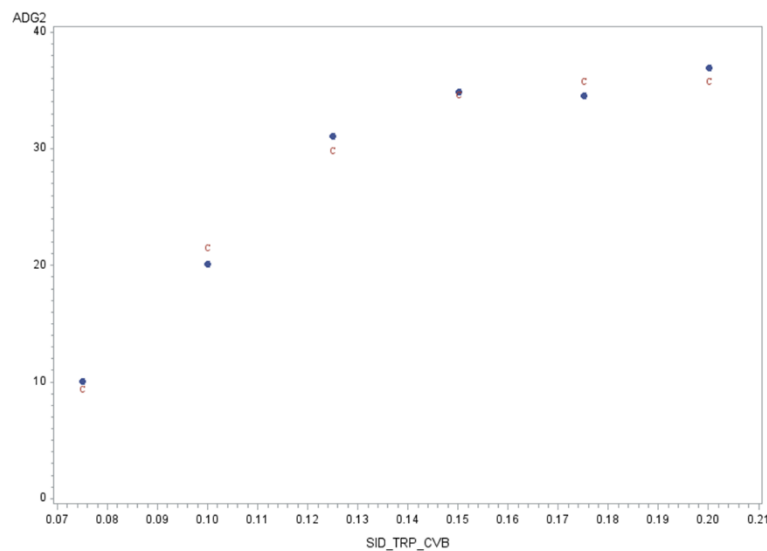|		
2b. Fatufe et al. (2005) Optimal SID-TRP FCR (%): 0.155 Optimal SID-TRP BWG (%): 0.180		
3a. Shan et al. (2003): Trial 1 Optimal SID-TRP FCR (%): 0.149 Optimal SID-TRP BWG (%): 0.170		

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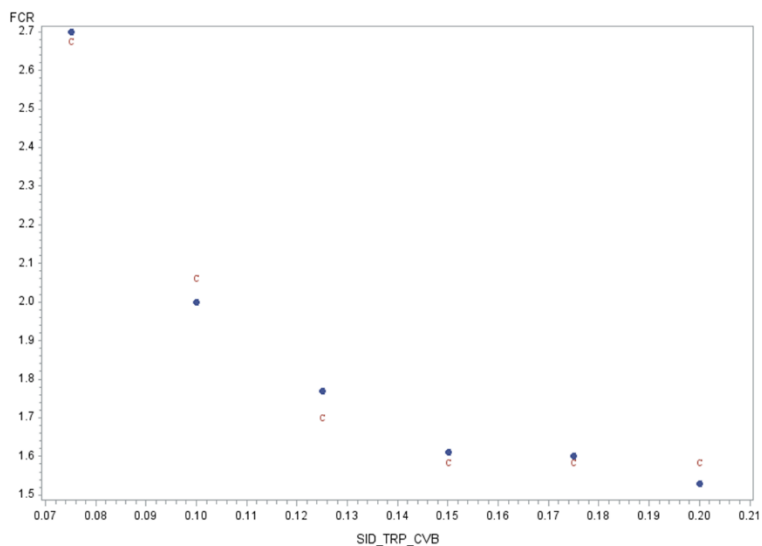
3b. Shan et al. (2003): Trial 1 Optimal SID- TRP FCR (%): 0.180 Optimal SID- TRP BWG (%): 0.156		
4a. Shan et al. (2003): Trial 2 Optimal SID- TRP FCR (%): 0.135 Optimal SID- TRP BWG (%): 0.153		
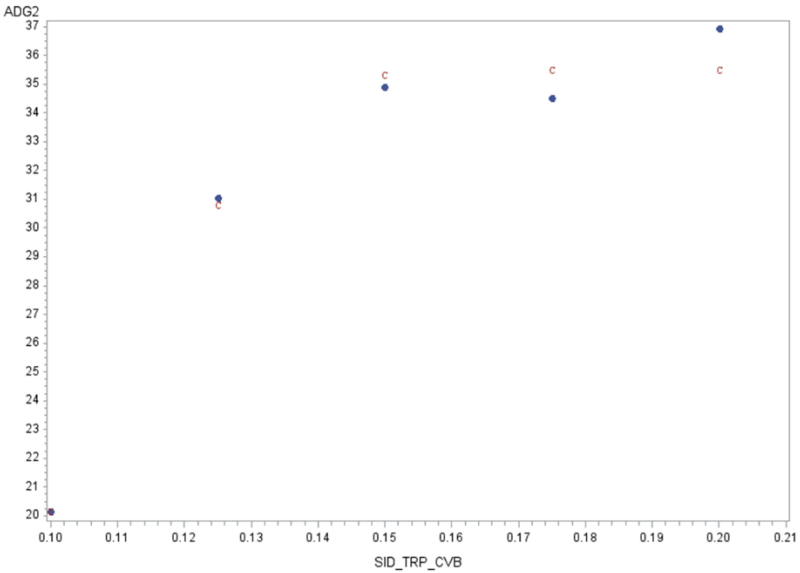
18
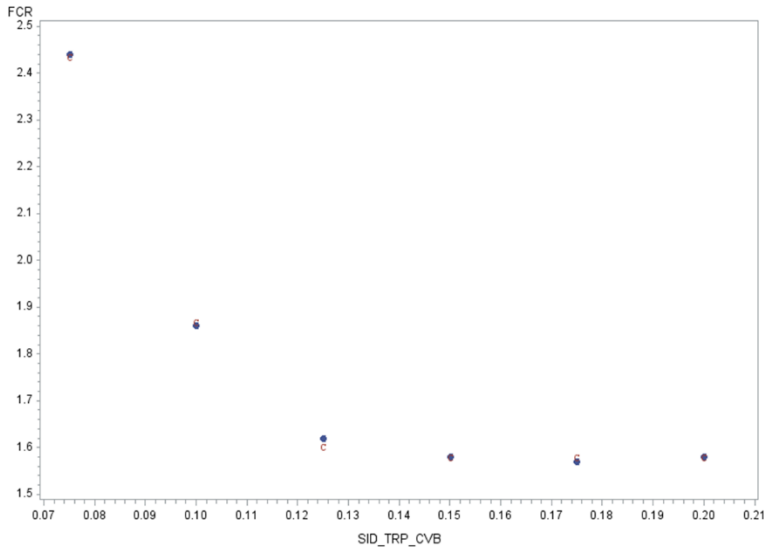
4b. Shan et al. (2003): Trial 2 Optimal SID-TRP FCR (%): 0.141 Optimal SID-TRP BWG (%): 0.140		
5a. Rosa et al. (2001): Trial 1 Optimal SID-TRP FCR (%): 0.139 Optimal SID-TRP BWG (%): 0.166		

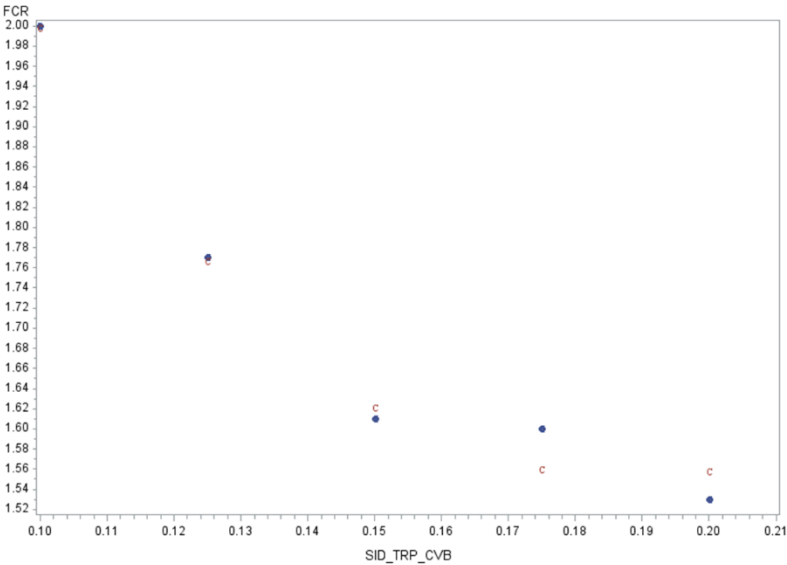|		
5b. Rosa et al. (2001): Trial 1 Optimal SID-TRP FCR (%): 0.141 Optimal SID-TRP BWG (%): 0.148		
6a. Rosa et al. (2001): Trial 2 Optimal SID-TRP FCR (%): 0.147 Optimal SID-TRP BWG (%): 0.156		

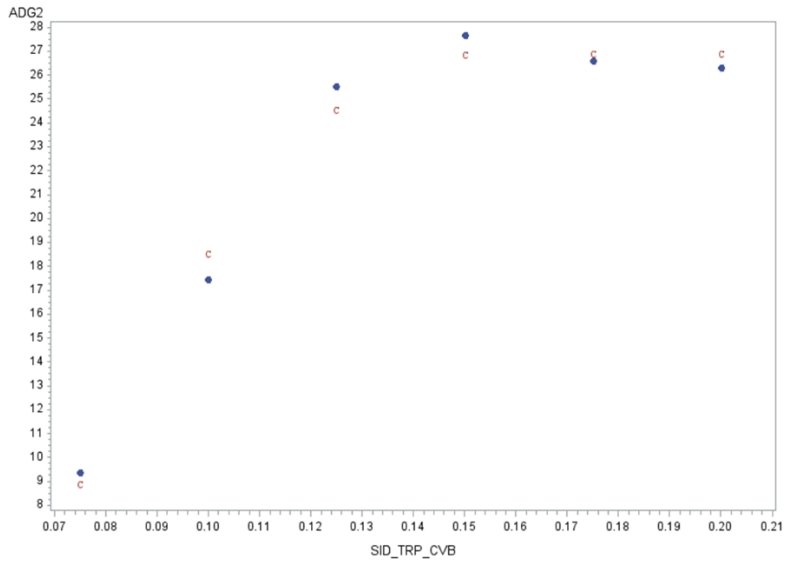|		
6b. Rosa et al. (2001): Trial 2 Optimal SID-TRP FCR (%): 0.149 Optimal SID-TRP BWG (%): 0.151		
7a. Rosa et al. (2001): Trial 3 Optimal SID-TRP FCR (%): 0.139 Optimal SID-TRP BWG (%): 0.149		

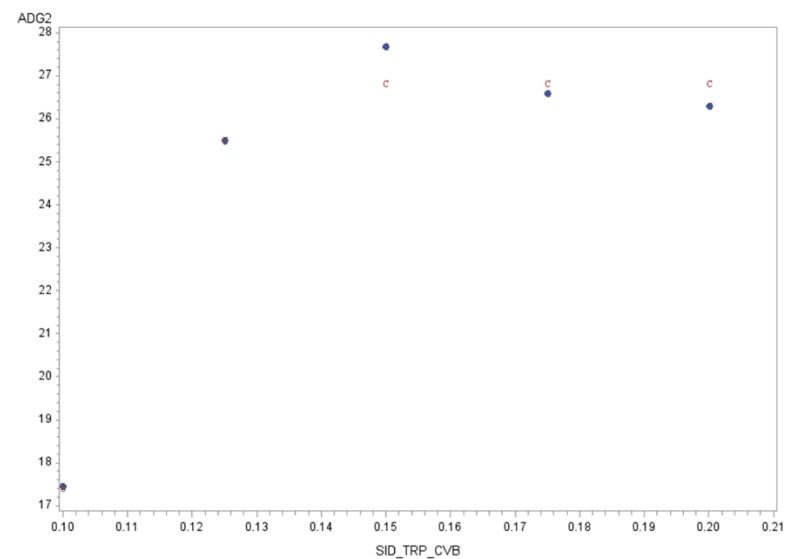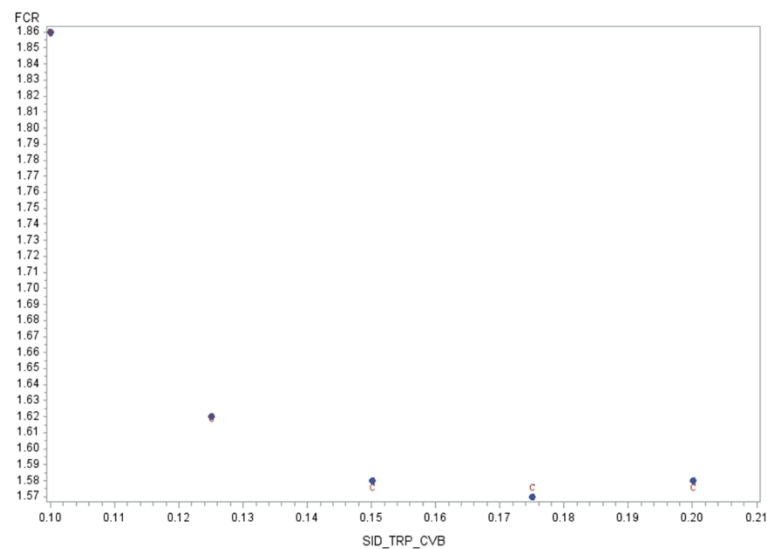| 7b. Rosa et al. (2001): Trial 3 Optimal SID- TRP FCR (%): 0.173 Optimal SID- TRP BWG (%): 0.135 (unreliable estimate)		
8a. Rosa et al. (2001): Trial 4 Optimal SID- TRP FCR (%): 0.152 Optimal SID- TRP BWG (%): 0.149		

8b. Rosa et al. (2001): Trial 4 Optimal SID-TRP FCR (%): 0.152 Optimal SID-TRP BWG (%): 0.129 (unreliable estimate)		
9. Castro et al. (2000): Trial 1 Optimal SID-TRP FCR (%): 0.1752 Optimal SID-TRP BWG (%): 0.133 (unreliable estimate)		

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10. Castro et al. (2000): Trial 2 Optimal SID-TRP FCR (%): 5.519 (unreliable estimate) Optimal SID-TRP BWG (%): 0.133 (unreliable estimate)		
11. Mack et al. (1999): Optimal SID-TRP FCR (%): Could not be estimated Optimal SID-TRP BWG (%): 0.167		

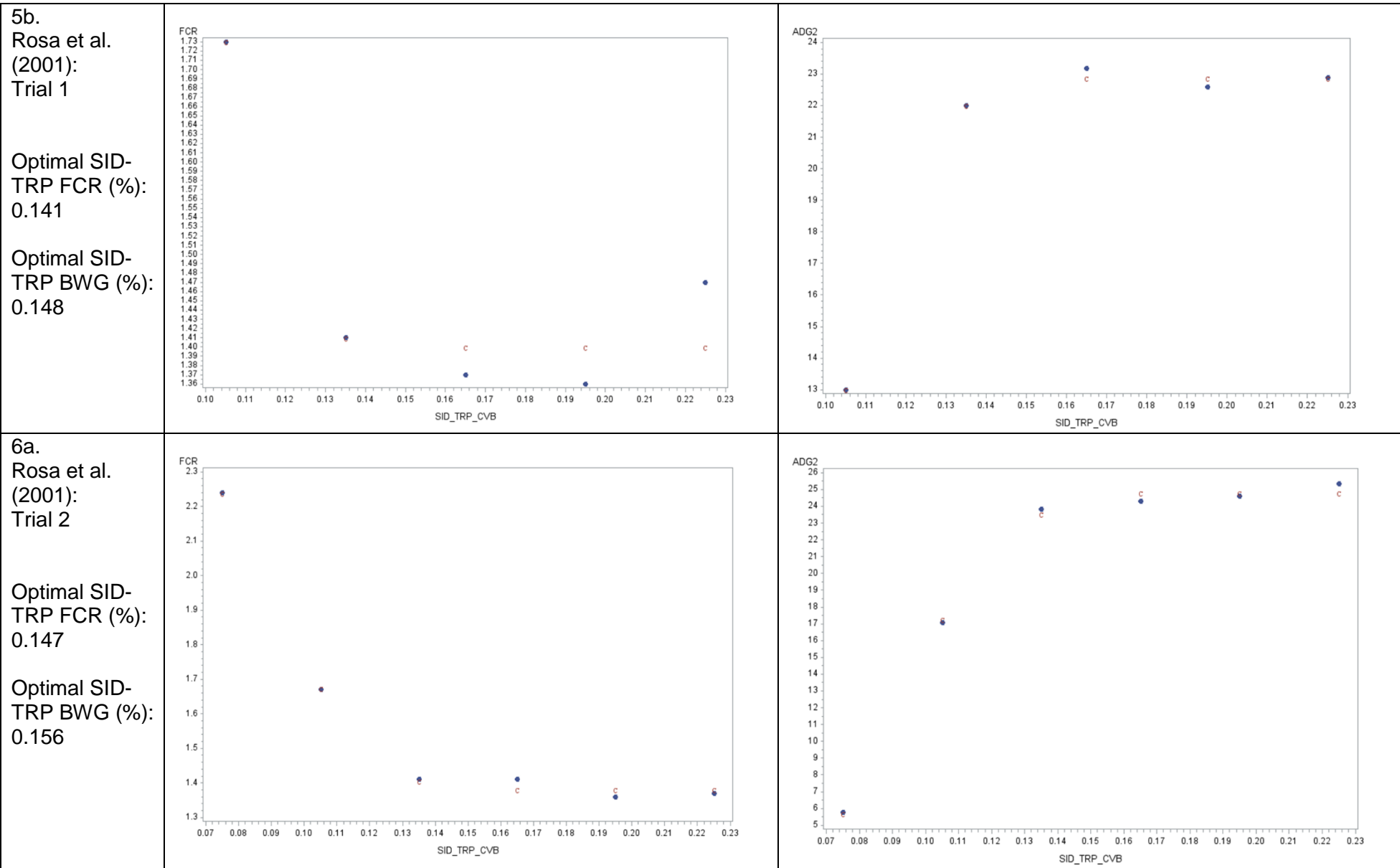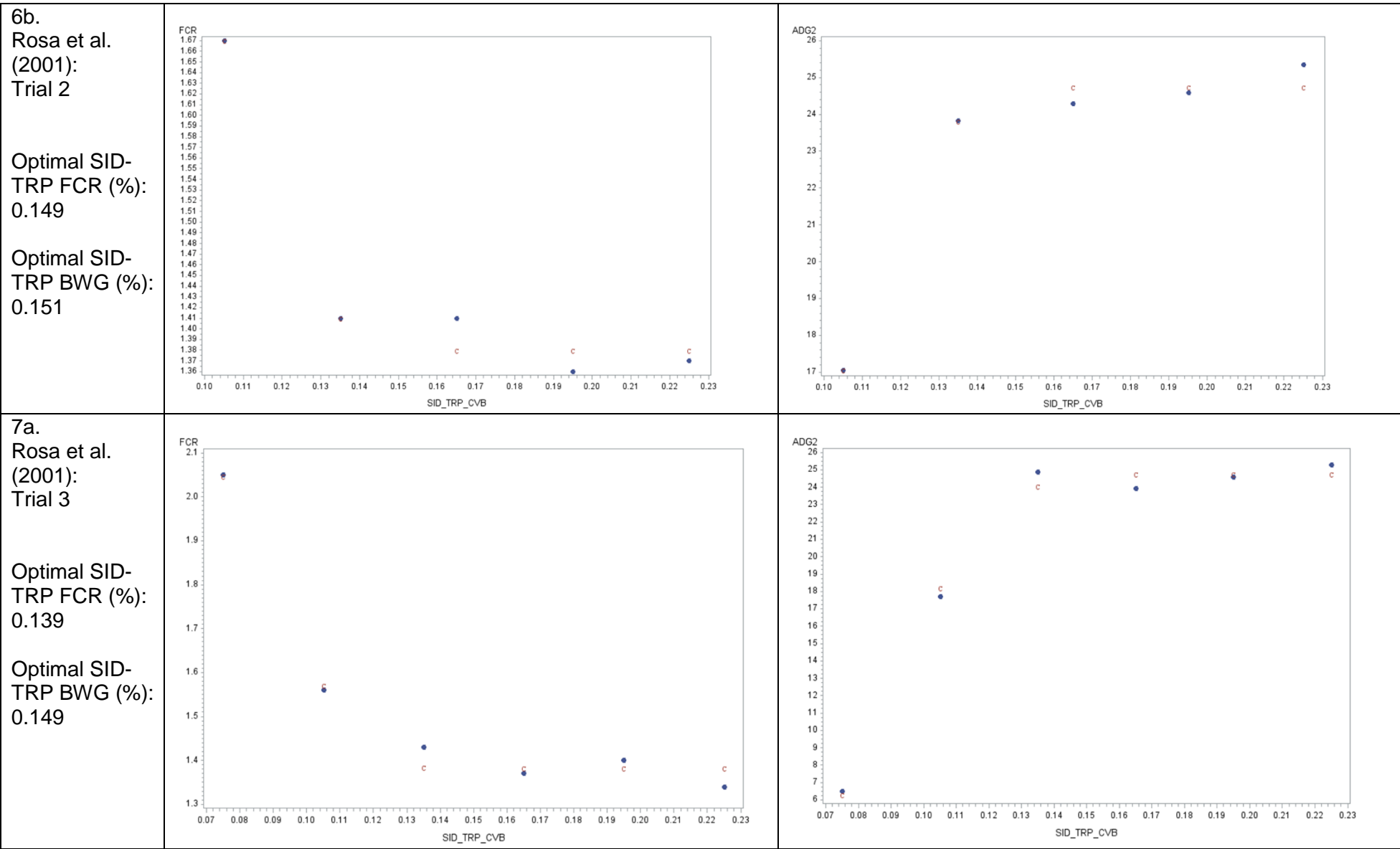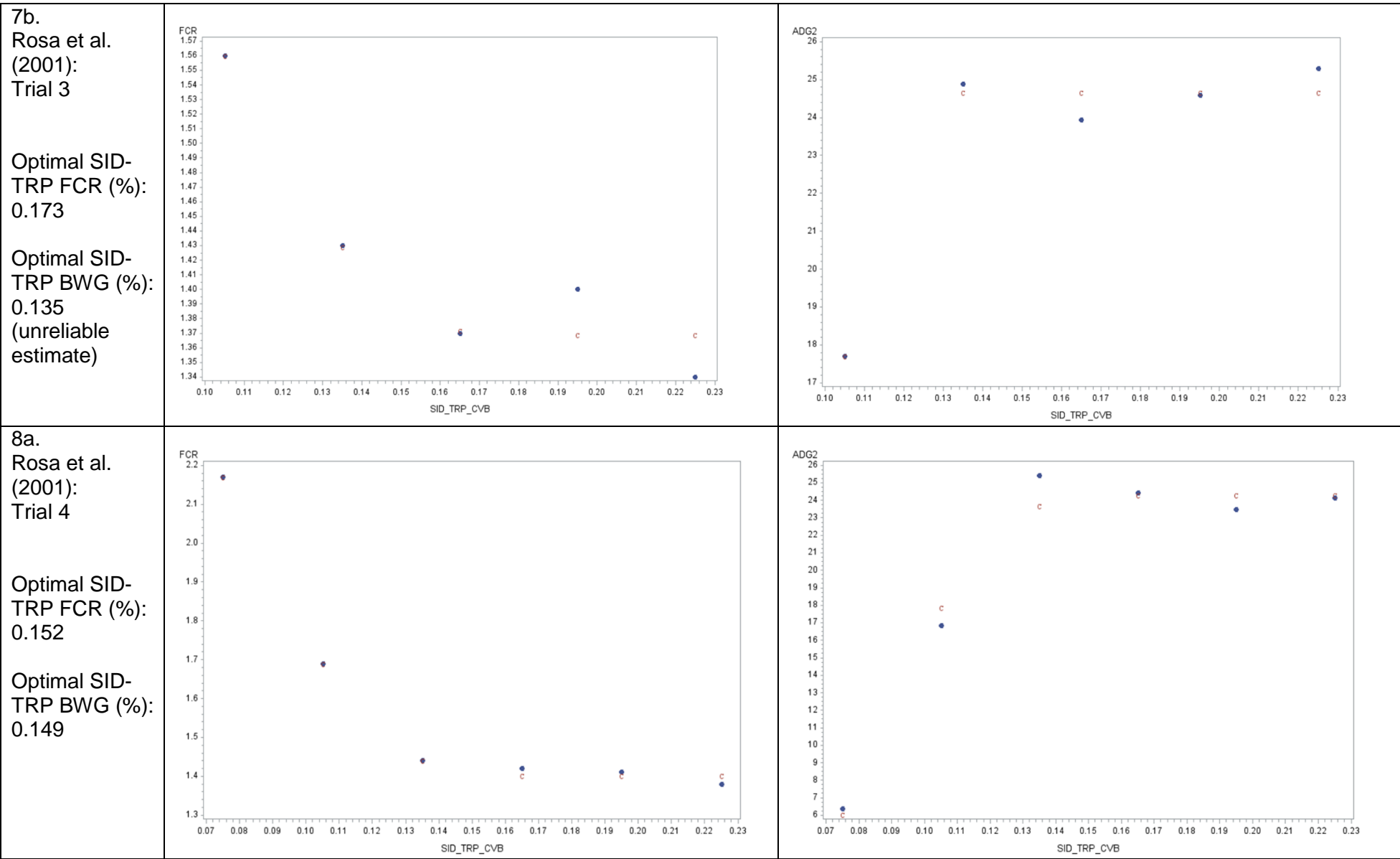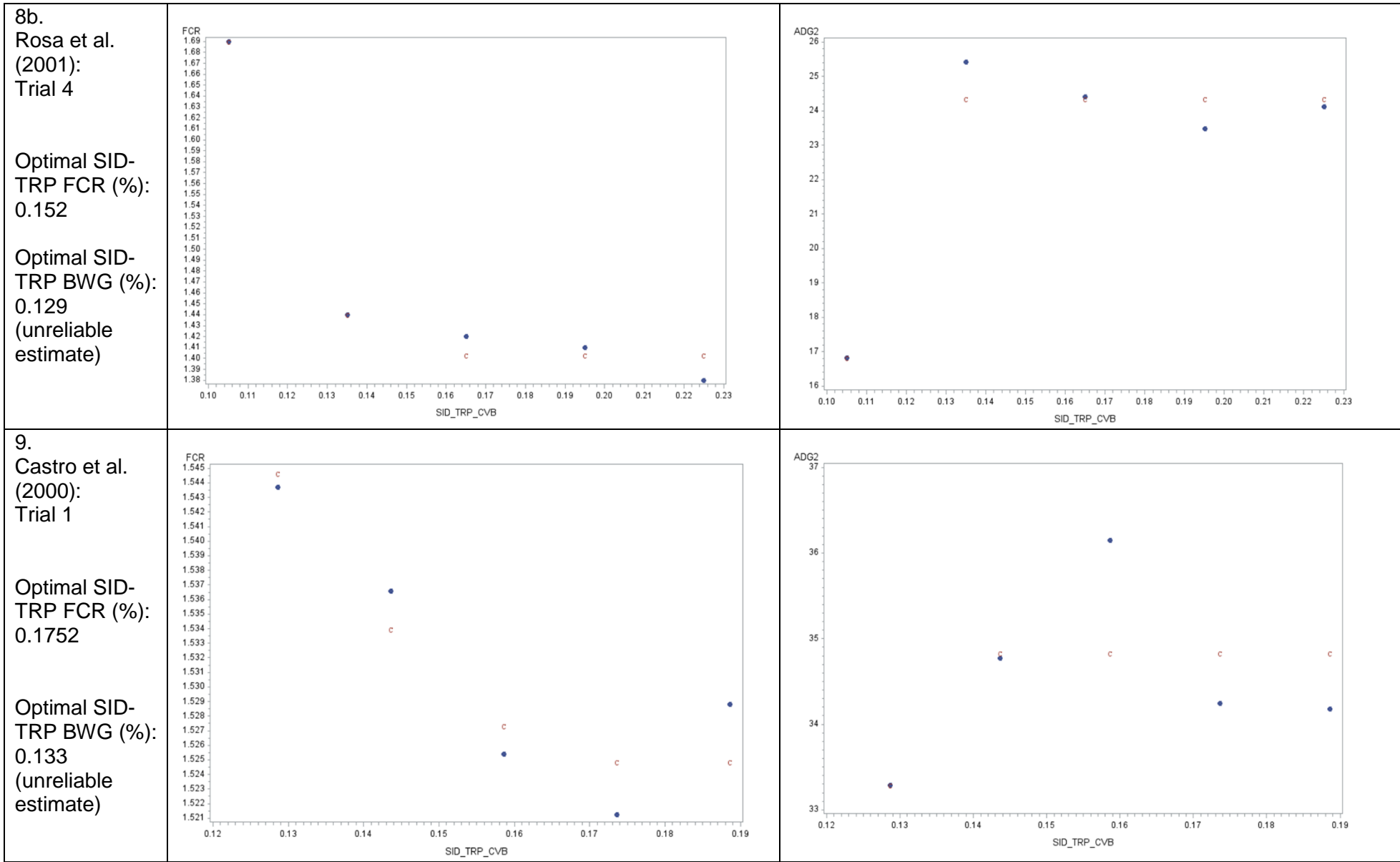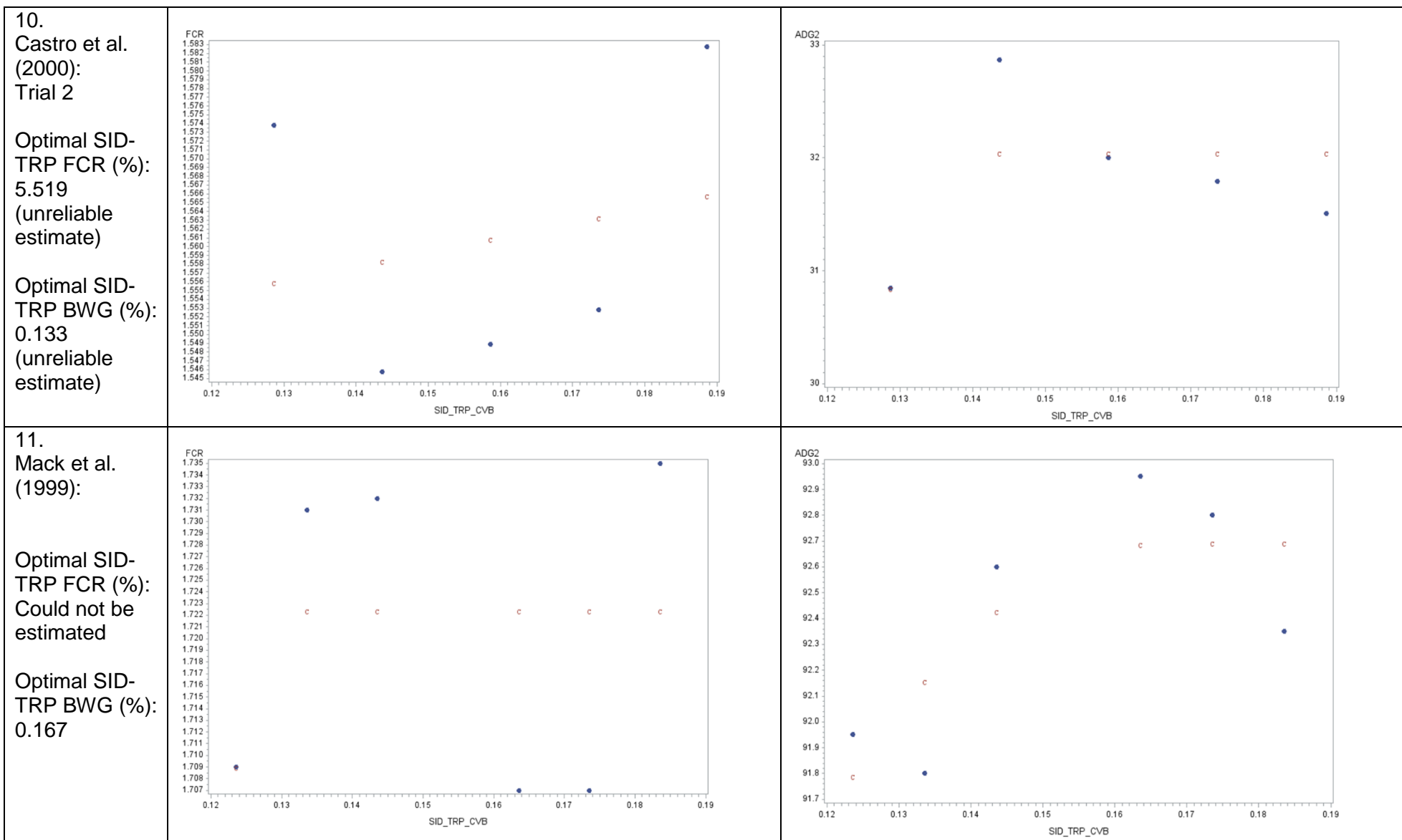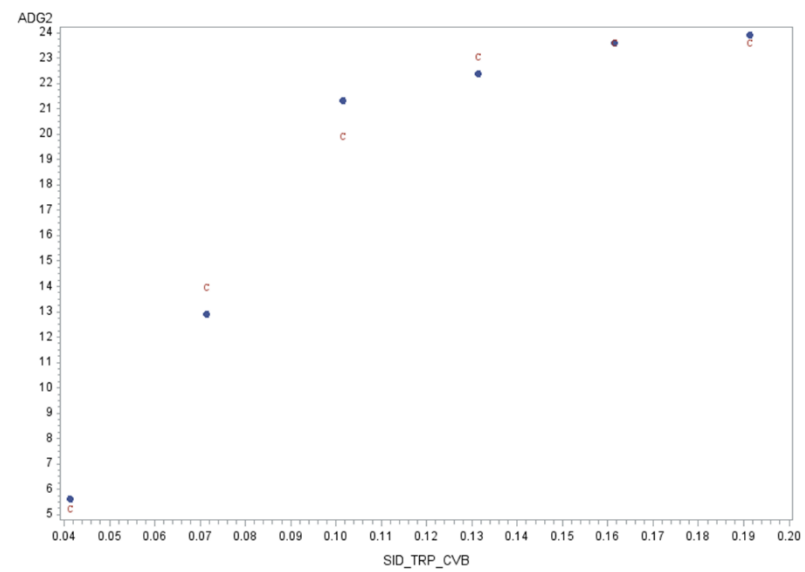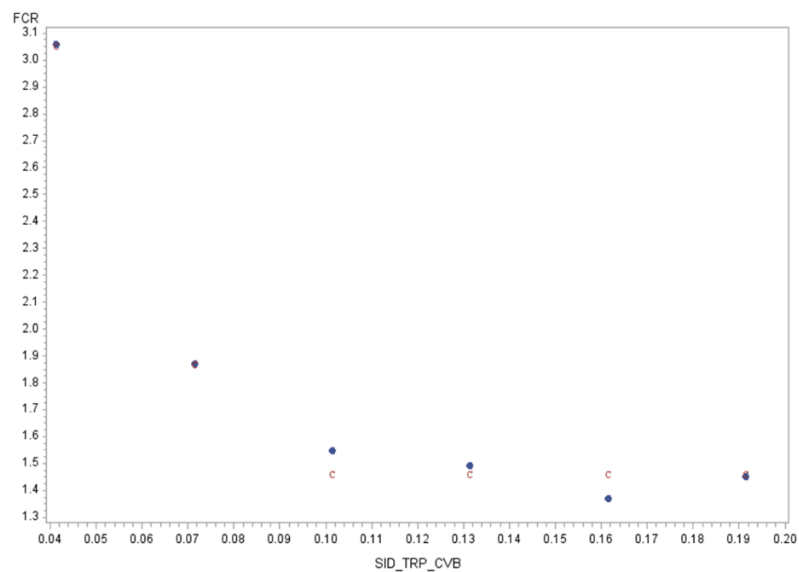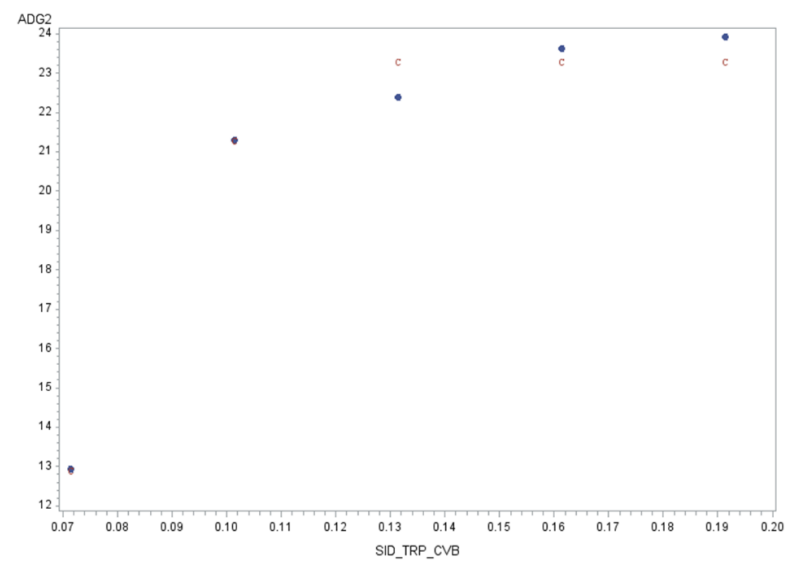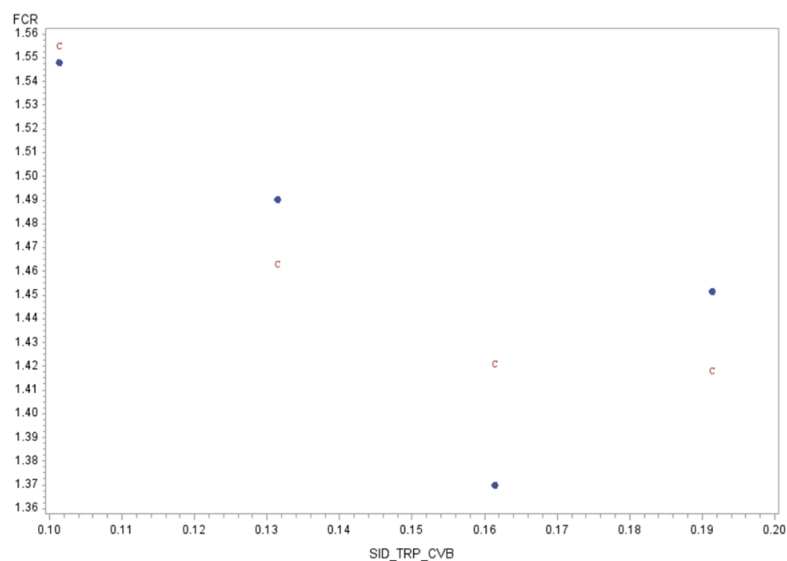|		
12a. Baker et al. (2002): Optimal SID- TRP FCR (%): 0.1023 Optimal SID- TRP BWG (%): 0.167		
12b. Baker et al. (2002): Optimal SID- TRP FCR (%): 0.1718 Optimal SID- TRP BWG (%): 0.167		

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

SID-TRP model estimates using the quadratic broken-line model for minimum FCR. The letter 'a' behind the trial number (shown in the first column) means the model is fitted on all observations whereas the letter 'b' behind the trial number (shown in the first column) means the model is fitted on all observations except the observation(s) with the lowest dietary SID-TRP level(s). If no letter is shown behind the trial number it means that the model is fitted based on all observations of the trial.

Trial nr.	Estimate L	Std. Err. L	Estimate R	Std. Err. R	Estimate U	Std. Err. U	R^2
1a	1.663	0.0507	0.205	0.0185	75	28.5	0.955
1b	1.665	0.0582	0.200	0.0259	87	60.7	0.897
2a	1.313	0.1779	0.153	0.0131	427	127.2	0.962
2b	1.320	0.0106	0.155	0.0030	328	45.3	0.998
3a	1.588	0.0382	0.149	0.0089	199	49.9	0.986
3b	1.559	0.0276	0.180	0.0142	68	24.1	0.982
4a	1.580	0.0072	0.135	0.0019	241	16.2	0.999
4b	1.577	0.0033	0.141	0.0020	168	16.3	0.999
5a	1.401	0.0260	0.139	0.0060	291	57.1	0.993
5b	1.400	0.0351	0.141	0.0267	250	359.6	0.921
6a	1.381	0.0121	0.147	0.0040	166	18.8	0.998
6b	1.380	0.0153	0.149	0.0105	148	69.5	0.979
7a	1.382	0.0201	0.139	0.0083	161	43.1	0.988
7b	1.369	0.0194	0.173	0.0248	41	30.3	0.938
8a	1.403	0.0096	0.152	0.0035	129	12.3	0.998
8b	1.403	0.0120	0.152	0.0083	131	46.7	0.986
9	1.525	0.0033	0.175	0.0227	9	9.0	0.875
10	2.003	771.4000	5.519	9349	0	26.8	0.057
11							
12a	1.464	0.0378	0.102	0.0063	429	93.0	0.992
12b	1.419	0.0587	0.172	0.0878	28	66.7	0.731

SID-TRP model estimates using the quadratic broken-line model for maximum BWG. The letter 'a' behind the trial number (shown in the first column) means the model is fitted on all observations whereas the letter 'b' behind the trial number (shown in the first column) means the model is fitted on all observations except the observation(s) with the lowest dietary SID-TRP level(s). If no letter is shown behind the trial number it means that the model is fitted based on all observations of the trial.

Trial nr.	Estimate L	Std. Err. L	Estimate R	Std. Err. R	Estimate U	Std. Err. U	R^2
1a	28	0.5	0.191	0.0107	-1606	412	0.981
1b	27	0.1	0.175	0.0020	-3244	267	0.999
2a	48	4.1	0.238	0.0337	-1474	517	0.949
2b	47	2.1	0.180	0.0178	-5996	3107	0.973
3a	36	1.0	0.170	0.0104	-2940	659	0.988
3b	36	0.8	0.156	0.0108	-4917	1928	0.982
4a	27	0.6	0.153	0.0094	-2930	729	0.987
4b	27	0.4	0.140	0.0074	-5837	2161	0.985
5a	23	0.6	0.166	0.0103	-2318	548	0.988
5b	23	0.2	0.148	0.0034	-5399	859	0.998
6a	25	0.3	0.156	0.0042	-2950	321	0.998
6b	25	0.3	0.151	0.0081	-3650	1288	0.987
7a	25	0.4	0.149	0.0068	-3353	634	0.993
7b	25	0.3	0.135	.	-7812	713	0.976
8a	24	0.7	0.149	0.0110	-3372	1043	0.982
8b	24	0.4	0.129	.	-12694	1523	0.959
9	35	0.5	0.133	.	-71964	47471	0.434
10	32	0.3	0.142	.	-6392	3516	0.524
11	93	0.2	0.167	0.0363	-473	831	0.643
12a	24	0.7	0.150	0.0131	-1557	383	0.987
12b	23	0.5	0.125	0.0095	-3633	1318	0.984