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Formulation Techniques for Capturing Genetic Potential of Aqua Species and Optimising Digestible Amino Acid Content

Abstract

Feed formulation in poultry has grown in sophistication to be able to capture both digestibility of raw materials and how they can be formulated to maximize the genetic potential of chickens. Similar research and formulation techniques can be applied to formulation of diets for aqua species to achieve both the optimum diet digestibility and the optimum density to capture genetic growth potential. Examples will be given of how to deliver optimum nutrition, extending the current practices in poultry feeding into the aqua sector.

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A shared vision for aquaculture in Asia

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"Formulation Techniques for capturing genetic potential of aqua species and optimising digestible amino acid content"

Matthew Clark

FeedGuys Resources Pte Ltd

Introduction – learnings from Poultry?

- Feed formulation in Poultry has grown in sophistication to be able to capture:
  - digestibility of raw materials
  - Formulation to maximize the genetic potential of chickens.

- Similar research and formulation techniques can be applied to formulation of diets for aqua species to achieve:
  - Optimum diet digestibility
  - Optimum density to capture genetic growth potential.

- Selecting raw materials and evaluating new sources

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Agenda

- Reduction of excess nutrients
  - Crude protein
  - Phosphorous
- Reduces cost and pollution

- Discovery of optimal amino acid supply
  - Titration of amino acid leve
  - Calculation of the most cost effective

- Alternative ingredient studies

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Minimise Excess Protein – Lessons From Layers

Parameters	Crude protein (g/kg)		
	140.0	155.0	170.0
Feed (g/day)	116.0	115.4	113.9
Lysine (mg/day)	940.9	936.0	924.1
Production (%)	77.22	76.02	75.24
Egg weight (g)	66.63	66.82	66.67
Egg output (g/day)	51.45	50.82	50.18
Yolk (%)	24.94	24.39	24.19
Manure crude protein (g/kg)	338.8	385.4	464.9

Excess crude protein:

- increases cost
- Increases nitrogen excretion
- Increases pollution and disease risk

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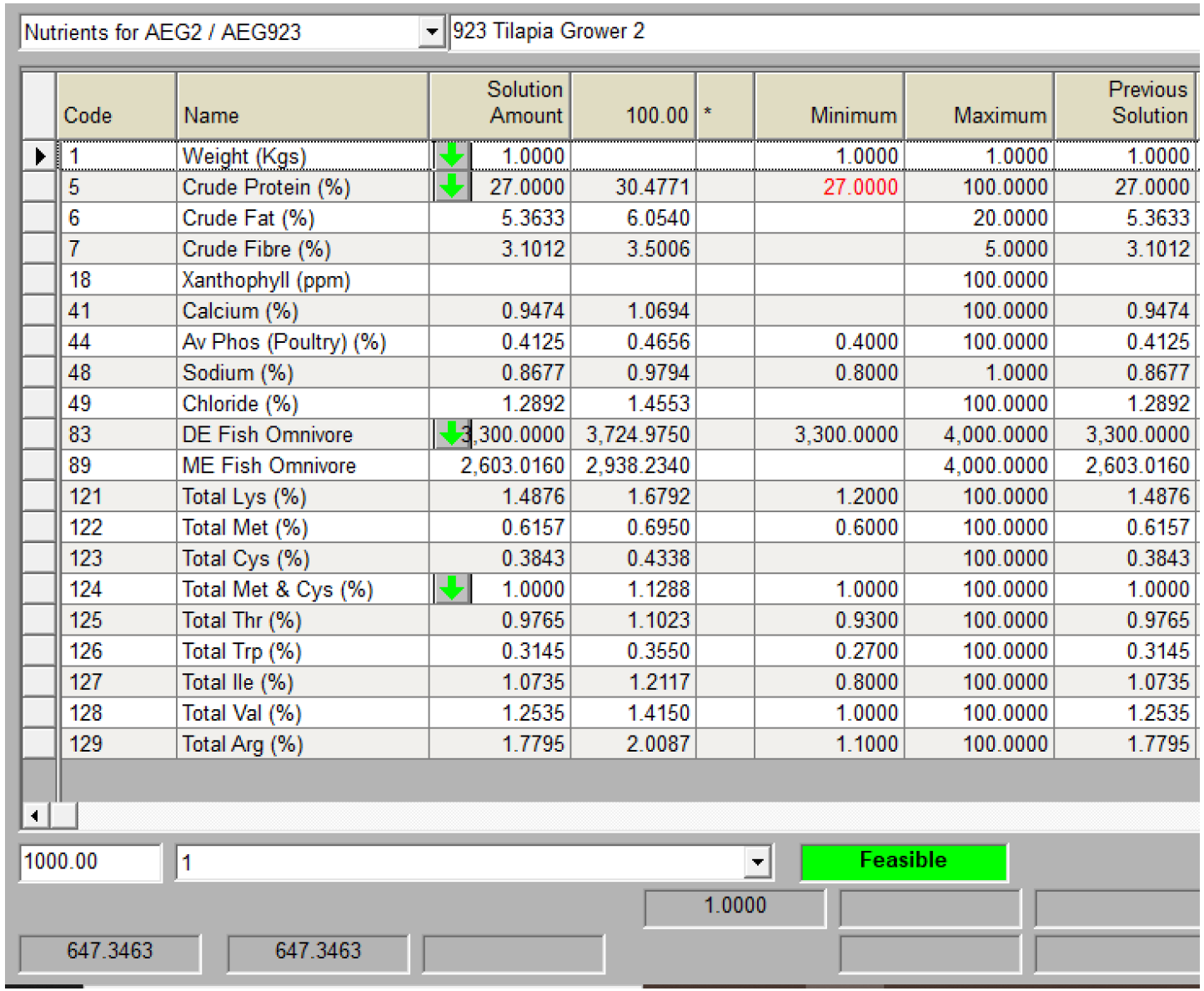
Effect of reduction in the crude protein level



Nutrients for AEG2 / AEG923 — 923 Tilapia Grower 2

Code	Name	Solution Amount	100.00	*	Minimum	Maximum	Previous Solution
1	Weight (Kgs)	1.0000			1.0000	1.0000	1.0000
5	Crude Protein (%)	27.0000	30.4771		27.0000	100.0000	27.0000
6	Crude Fat (%)	5.3633	6.0540			20.0000	5.3633
7	Crude Fibre (%)	3.1012	3.5006			5.0000	3.1012
18	Xanthophyll (ppm)					100.0000	
41	Calcium (%)	0.9474	1.0694			100.0000	0.9474
44	Av Phos (Poultry) (%)	0.4125	0.4656		0.4000	100.0000	0.4125
48	Sodium (%)	0.8677	0.9794		0.8000	1.0000	0.8677
49	Chloride (%)	1.2892	1.4553			100.0000	1.2892
83	DE Fish Omnivore	3,300.0000	3,724.9750		3,300.0000	4,000.0000	3,300.0000
89	ME Fish Omnivore	2,603.0160	2,938.2340			4,000.0000	2,603.0160
121	Total Lys (%)	1.4876	1.6792		1.2000	100.0000	1.4876
122	Total Met (%)	0.6157	0.6950		0.6000	100.0000	0.6157
123	Total Cys (%)	0.3843	0.4338			100.0000	0.3843
124	Total Met & Cys (%)	1.0000	1.1288		1.0000	100.0000	1.0000
125	Total Thr (%)	0.9765	1.1023		0.9300	100.0000	0.9765
126	Total Trp (%)	0.3145	0.3550		0.2700	100.0000	0.3145
127	Total Ile (%)	1.0735	1.2117		0.8000	100.0000	1.0735
128	Total Val (%)	1.2535	1.4150		1.0000	100.0000	1.2535
129	Total Arg (%)	1.7795	2.0087		1.1000	100.0000	1.7795

1000.00 | 1 | Feasible

1.0000

647.3463 | 647.3463

- Starting formula has crude protein minimum
- Methionine and cysteine level is limiting
- Crude protein may be on minimum for legal reasons or for safety margins

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Effect of reduction in the crude protein level

Nutrients for AEG2 / AEG923 — 923 Tilapia Grower 2

Code	Name	Solution Amount	100.00	*	Minimum	Maximum	Previous Solution
1	Weight (Kgs)	1.0000			1.0000	1.0000	1.0000
5	Crude Protein (%)	24.1521	27.2640			100.0000	27.0000
6	Crude Fat (%)	5.9545	6.7218			20.0000	5.3633
7	Crude Fibre (%)	2.9091	3.2839			5.0000	3.1012
18	Xanthophyll (ppm)					100.0000	
41	Calcium (%)	0.9304	1.0503			100.0000	0.9474
44	Av Phos (Poultry) (%)	0.4000	0.4515		0.4000	100.0000	0.4125
48	Sodium (%)	0.8000	0.9031		0.8000	1.0000	0.8677
49	Chloride (%)	1.1868	1.3397			100.0000	1.2892
83	DE Fish Omnivore	3,300.0000	3,725.1970		3,300.0000	4,000.0000	3,300.0000
89	ME Fish Omnivore	2,603.6430	2,939.1170			4,000.0000	2,603.0160
121	Total Lys (%)	1.2939	1.4607		1.2000	100.0000	1.4876
122	Total Met (%)	0.6542	0.7385		0.6000	100.0000	0.6157
123	Total Cys (%)	0.3458	0.3904			100.0000	0.3843
124	Total Met & Cys (%)	1.0000	1.1288		1.0000	100.0000	1.0000
125	Total Thr (%)	0.9300	1.0498		0.9300	100.0000	0.9765
126	Total Trp (%)	0.2700	0.3048		0.2700	100.0000	0.3145
127	Total Ile (%)	0.9386	1.0596		0.8000	100.0000	1.0735
128	Total Val (%)	1.1135	1.2570		1.0000	100.0000	1.2535
129	Total Arg (%)	1.5559	1.7563		1.1000	100.0000	1.7795

1000.00 | 1 | Feasible

1.0000

641.5671 | 647.3463 | -5.7792

- Crude protein minimum removed
- Threonine and tryptophan become limiting
- Cost of feed reduced
- ‘non-essential amino acids may be too low nd cause carcass quality effects

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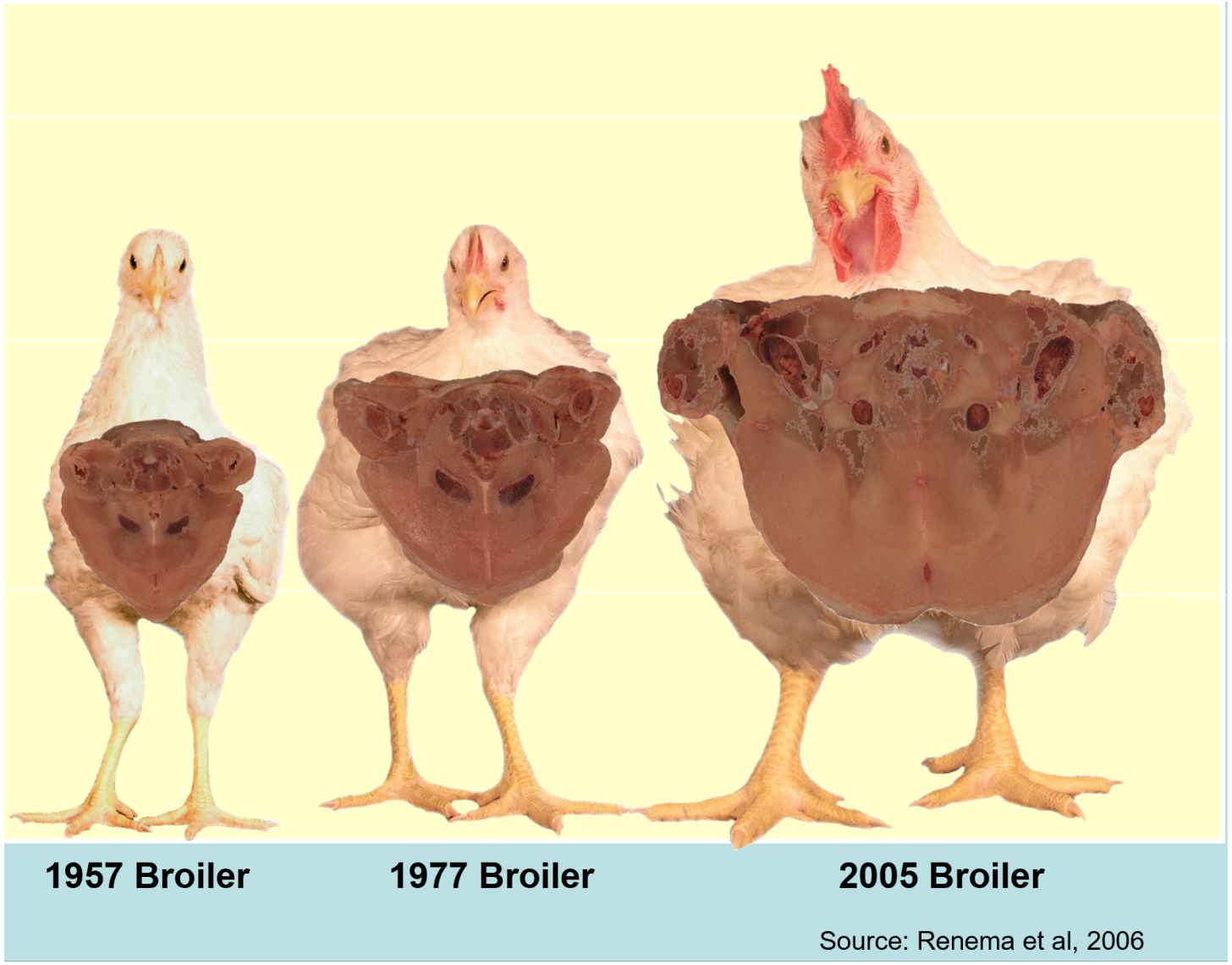
Genetic advances and potential - Broilers



- Carcass composition has changed dramatically by genetic selection
- Improved genetics require re-engineered feeds
- Titration required to find correct protein level

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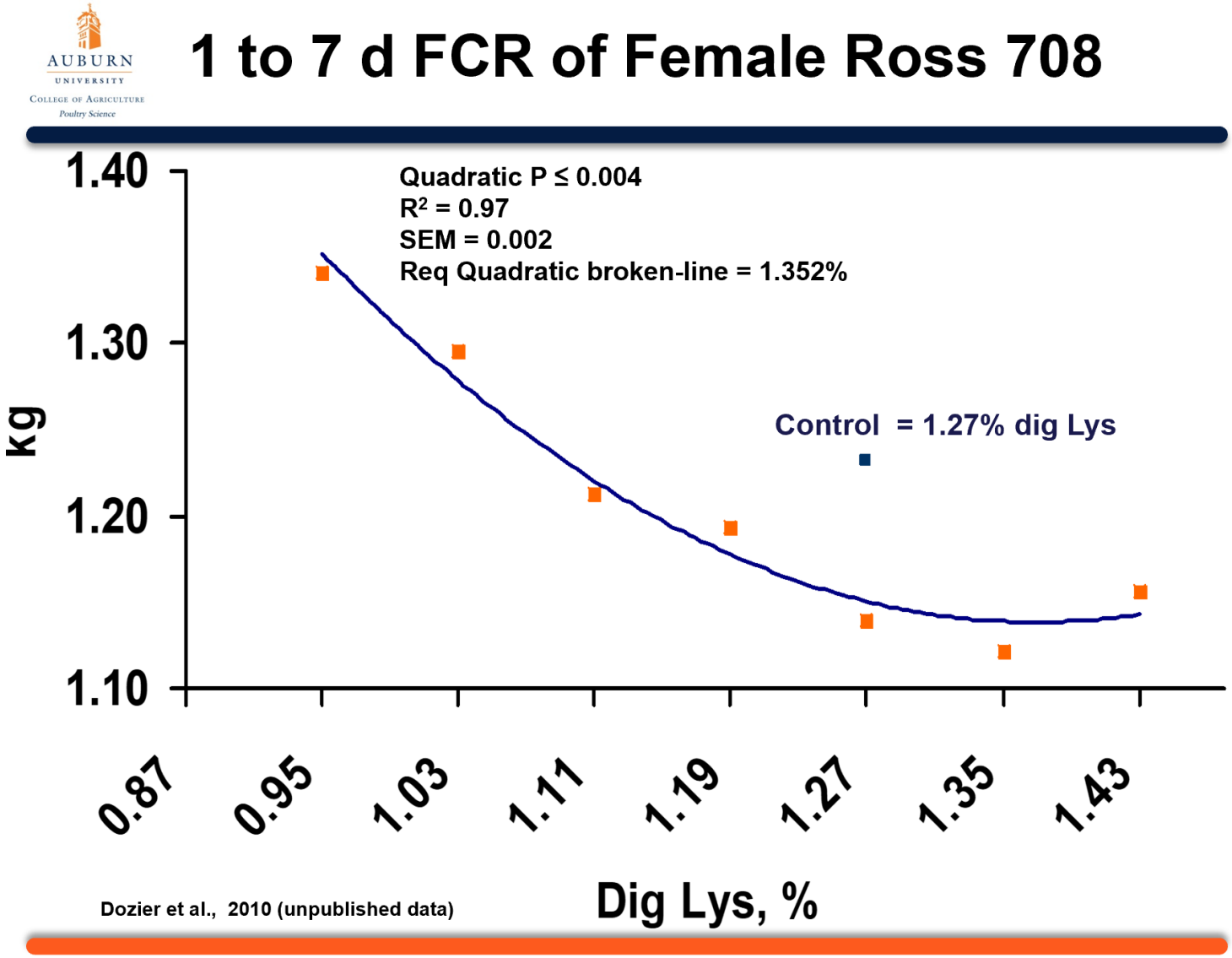
Finding the right protein level - Broilers



- As Digestible lysine increases, FCR decreases
- Diminishing returns begin at 1.25%
- Optimum is 1.35%
- Much higher than 1996 levels

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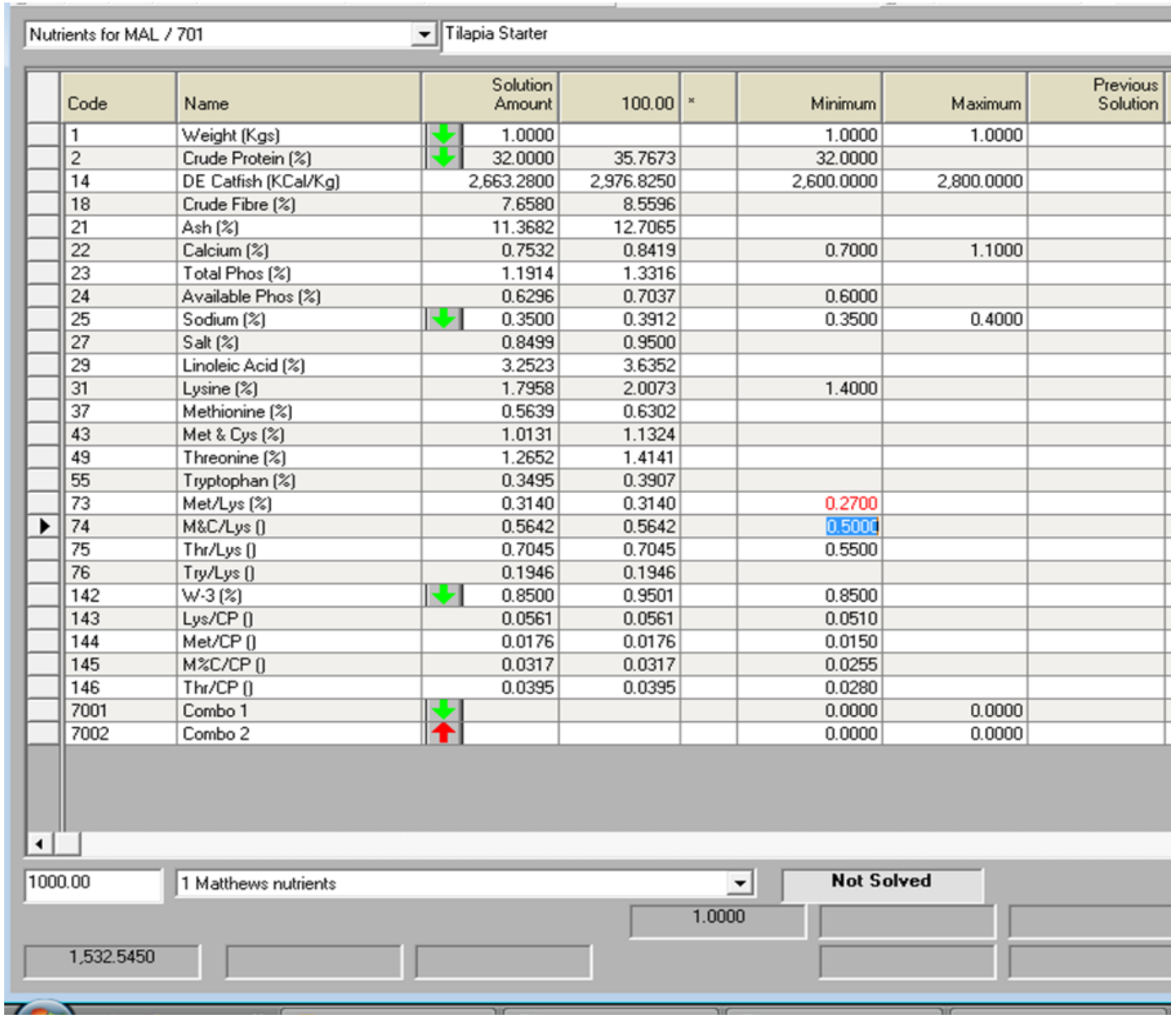
Amino Acid Ratios needed for titration study



Nutrients for MAL / 701 — Tilapia Starter

Code	Name	Solution Amount	100.00	*	Minimum	Maximum	Previous Solution
1	Weight (Kgs)	1.0000			1.0000	1.0000	
2	Crude Protein (%)	32.0000	35.7673		32.0000		
14	DE Catfish (KCal/Kg)	2,663.2800	2,976.8250		2,600.0000	2,800.0000	
18	Crude Fibre (%)	7.6580	8.5596				
21	Ash (%)	11.3682	12.7065				
22	Calcium (%)	0.7532	0.8419		0.7000	1.1000	
23	Total Phos (%)	1.1914	1.3316				
24	Available Phos (%)	0.6296	0.7037		0.6000		
25	Sodium (%)	0.3500	0.3912		0.3500	0.4000	
27	Salt (%)	0.8499	0.9500				
29	Linoleic Acid (%)	3.2523	3.6352				
31	Lysine (%)	1.7958	2.0073		1.4000		
37	Methionine (%)	0.5639	0.6302				
43	Met & Cys (%)	1.0131	1.1324				
49	Threonine (%)	1.2652	1.4141				
55	Tryptophan (%)	0.3495	0.3907				
73	Met/Lys (%)	0.3140	0.3140		0.2700		
74	M&C/Lys ()	0.5642	0.5642		0.5000		
75	Thr/Lys ()	0.7045	0.7045		0.5500		
76	Try/Lys ()	0.1946	0.1946				
142	W-3 (%)	0.8500	0.9501		0.8500		
143	Lys/CP ()	0.0561	0.0561		0.0510		
144	Met/CP ()	0.0176	0.0176		0.0150		
145	M%C/CP ()	0.0317	0.0317		0.0255		
146	Thr/CP ()	0.0395	0.0395		0.0280		
7001	Combo 1				0.0000	0.0000	
7002	Combo 2				0.0000	0.0000	

1000.00 — 1 Matthews nutrients — Not Solved

1.0000

1,532.5450

- Digestible lysine is very close to the minimum ration of Lys:CP
- Lysine is the only limiting amino acid
- Additional raw materials with different AA profiles can help to make AA supply more efficient

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Parametric Analysis shows cost effective protein Level

Parametric Results

Nutrients for MAL / 701 — **Minimum : 2 - Crude Protein**

Code	Name	32.0000 436.8688 1,000.00	31.8000 435.4390 -1.4298 1,000.00	31.6000 434.0092 -1.4298 1,000.00	31.4000 432.5793 -1.4298 1,000.00	31.2000 431.1495 -1.4298 1,000.00	31.0000 429.7197 -1.4298 1,000.00	30.8000 428.2898 -1.4298 1,000.00	30.6000 426.8599 -1.4299 1,000.00	30.4000 425.4301 -1.4298 1,000.00	30.2000 424.0002 -1.4298 1,000.00
1	Weight	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	Crude Protein	32.0000	31.8000	31.6000	31.4000	31.2000	31.0000	30.8000	30.6000	30.4000	30.2000
14	DE Catfish	2,663.1240	2,657.0510	2,650.9770	2,644.9040	2,638.8300	2,632.7560	2,626.6830	2,620.6090	2,614.5350	2,608.4620
18	Crude Fibre	7.6584	7.7150	7.7717	7.8284	7.8850	7.9417	7.9984	8.0550	8.1117	8.1684
21	Ash	11.3683	11.4110	11.4536	11.4963	11.5390	11.5816	11.6243	11.6670	11.7097	11.7523
22	Calcium	0.7532	0.7518	0.7504	0.7490	0.7476	0.7462	0.7448	0.7434	0.7420	0.7405
23	Total Phos	1.1914	1.1943	1.1972	1.2002	1.2031	1.2060	1.2090	1.2119	1.2148	1.2178
24	Available Phos	0.6296	0.6292	0.6288	0.6285	0.6281	0.6277	0.6273	0.6269	0.6265	0.6262
25	Sodium	0.3500	0.3500	0.3500	0.3500	0.3500	0.3500	0.3500	0.3500	0.3500	0.3500
27	Salt	0.8499	0.8498	0.8496	0.8495	0.8494	0.8492	0.8491	0.8490	0.8488	0.8487
29	Linoleic Acid	3.2525	3.2738	3.2951	3.3164	3.3378	3.3591	3.3804	3.4017	3.4231	3.4444
31	Lysine	1.7985	1.7985	1.7985	1.7985	1.7985	1.7985	1.7985	1.7985	1.7985	1.7985
37	Methionine	0.5638	0.5612	0.5585	0.5559	0.5532	0.5506	0.5479	0.5453	0.5427	0.5400
43	Met & Cys	1.0130	1.0069	1.0007	0.9945	0.9883	0.9821	0.9759	0.9698	0.9636	0.9574
49	Threonine	1.2650	1.2555	1.2459	1.2364	1.2268	1.2173	1.2078	1.1982	1.1887	1.1791
55	Tryptophan	0.3495	0.3462	0.3430	0.3397	0.3364	0.3332	0.3299	0.3267	0.3234	0.3201
73	Met/Lys	0.3135	0.3120	0.3105	0.3091	0.3076	0.3061	0.3047	0.3032	0.3017	0.3003
74	M&C/Lys	0.5633	0.5598	0.5564	0.5530	0.5495	0.5461	0.5426	0.5392	0.5358	0.5323
75	Thr/Lys	0.7034	0.6981	0.6928	0.6875	0.6821	0.6768	0.6715	0.6662	0.6609	0.6556
76	Try/Lys	0.1943	0.1925	0.1907	0.1889	0.1871	0.1853	0.1834	0.1816	0.1798	0.1780
142	W-3	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500	0.8500
143	Lys/CP	0.0562	0.0566	0.0569	0.0573	0.0576	0.0580	0.0584	0.0588	0.0592	0.0596
144	Met/CP	0.0176	0.0176	0.0177	0.0177	0.0177	0.0178	0.0178	0.0178	0.0179	0.0179
145	M%C/CP	0.0317	0.0317	0.0317	0.0317	0.0317	0.0317	0.0317	0.0317	0.0317	0.0317
146	Thr/CP	0.0395	0.0395	0.0394	0.0394	0.0393	0.0393	0.0392	0.0392	0.0391	0.0390
7001	Combo1										
7002	Combo2										

- Each 0.2% reduction in the crude protein level saves US$ 1.43 per tonne
- Amino acids remain in balance to crude protein due to formulation on ratios

Parametric Analysis for Ingredient Evaluation

Ingredients for MAL / 701 — Tilapia Starter

Code	Name	Solution Amount %	Price	*	Minimum	Maximum	Low Cost
2403	Ricebran 13/13/13	33.1654	199.5000				195.2002
3111	Soybean Meal 48% Sol	31.4448	530.0000				476.0306
2422	Rice Bran Ext 14%	16.5827	185.2500				176.6504
4112	Chilean Fishmeal 61%	7.0000	826.5000		7.0000		822.6201
4131	Fishmeal Thai 60%	7.0000	855.0000				851.1201
4261	Feather Meal 80% DHB	2.5000	570.0000			2.5000	570.0000
5240	Fish Oil	1.3667	1,482.0000		1.0000		62.0270
6111	Salt	0.4537	114.0000				62.1140
9317	Fish Minerals	0.2500	997.5000		0.2500	0.2500	62.0270
9137	Fish Vitamins	0.1500	17,100.0000		0.1500	0.1500	62.0270
6153	MDCP	0.0867	599.9999				66.1742
4912	L-Lysine 78%		3,500.0000				966.2495
4913	Alimet 88%		4,000.0000				62.0270
4914	Ca-HMB 80%		3,990.0000				62.0270
6123	Limestone Powder		85.5000				64.7236
8603	Mould Inhibitor		1,425.0000				62.0270
2205	DDGS		260.0000	-0			308.3237
2206	DDGS New		260.0000	-0		10.0000	349.5539

- Base formula for introducing new ingredients
- DDGS New has a shadow price higher than the buying price
- Indicates potential profits

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Parametric Analysis for Ingredient Evaluation

Parametric Results

Ingredients for MAL / 701

Price : 2206 - DDGS New

Code	Name	250.0000 438.6742 1,000.00	260.0000 439.6742 1.0000 1,000.00	270.0000 440.6742 1.0000 1,000.00	280.0000 441.6742 1.0000 1,000.00	290.0000 442.6742 1.0000 1,000.00	300.0000 443.6742 1.0000 1,000.00	310.0000 444.5437 0.8695 1,000.00	320.0000 444.9069 0.3633 1,000.00	330.0000 444.9322 0.0253 1,000.00	340.0000 444.9322 1,000.00
2403	Ricebran 13/13/13	28.8581	28.8581	28.8581	28.8581	28.8581	28.8581	**31.6517**	31.6517	**33.1654**	33.1654
3111	Soybean Meal 48% Sol	28.0267	28.0267	28.0267	28.0267	28.0267	28.0267	**30.1819**	30.1819	**31.4448**	31.4448
2422	Rice Bran Ext 14%	14.4290	14.4290	14.4290	14.4290	14.4290	14.4290	**15.8258**	15.8258	**16.5827**	16.5827
2206	DDGS New	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000	**3.6328**	3.6328		
4112	Chilean Fishmeal 61%	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000
4131	Fishmeal Thai 60%	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000
4261	Feather Meal 80% DHB	2.5000	2.5000	2.5000	2.5000	2.5000	2.5000	2.5000	2.5000	2.5000	2.5000
5240	Fish Oil	1.3667	1.3667	1.3667	1.3667	1.3667	1.3667	1.3667	1.3667	1.3667	1.3667
6111	Salt	0.4196	0.4196	0.4196	0.4196	0.4196	0.4196	**0.4412**	0.4412	**0.4537**	0.4537
9317	Fish Minerals	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500
9137	Fish Vitamins	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500	0.1500
4912	L-Lysine 78%										
4913	Alimet 88%										
4914	Ca-HMB 80%										
6123	Limestone Powder										
6153	MDCP									**0.0867**	0.0867
8603	Mould Inhibitor										
2205	DDGS										

- Price sensitivity of DDGS can be seen
- Optimal volume to price can be established
- Ingredient substitutions can be studied

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Evaluation methods for new ingredients

- The Shadow Price data is calculated by the Least Cost Formulation
- Price at which a commodity can be included in a formula without changing the formula cost.
- If the commodity price is above the shadow price then the commodity will be rejected. If the prices is below the shadow price then the commodity will be used.
- The **‘SBM Ref’** price is the approximate market price for Argentine SBM in the South East Asian region.
- **‘Protein Parity’** shows the equivalent price of HF Canola (CAN-HF1) if the product was broadly evaluated purely on a crude protein basis ignoring the starch contribution to animal nutrition.
- Study across SE Asia for the different protein types

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Selected Alternative Proteins

	SBM	**Field Peas**	**Faba beans**	Chick peas	Lentils	Lupin Seed Meal	**DH lupin seed**	Canola Meal	**Canola Hi Fat 1**
Crude Protein	45.50	22.20	27.60	22.10	23.50	32.00	**39.00**	36.70	31.00
AMEn Poultry	2,269	**2,606**	**2,662**	3,080	2,741	1,911	**2,279**	2,200	**2,650**
AMEn Broiler	2,109	2,543	2,662	3,030	2,679	1,911	2,279	2,200	2,650
ME Swine	3,112	3,294	3,115	3,294	3,249	2,387	3,818	2,903	3,250
ME Ruminants	3,001	2,860	2,830	2,812	2,768	3,177	3,177	2,331	3,051
DE Fish Omnivore	3,618	3,441	3,523	3,213	3,091	3,452	3,560	3,395	3,986
Crude Fat	1.66	**12.00**	**12.00**	4.40	1.40	5.96	**7.54**	3.30	**13.00**
Crude Fibre	4.32	6.20	7.60	9.24	4.30	14.20	3.42	11.20	10.00
Ash	6.54	2.90	3.70	2.90	3.10	2.99	3.11	6.70	5.20
N Free Extract	29.98	47.20	38.10	50.36	67.70	34.85	36.93	32.10	30.80
Sucrose	**8.65**	1.40	1.50	1.00				-	-
Glucose	-	0.02	0.20	0.05		1.70	2.90	6.75	5.94
Starch	1.00	**40.63**	**38.50**	**44.18**	**45.70**	1.10	1.40	-	-
Dry Matter	88.00	90.50	89.00	89.00	89.00	90.00	90.00	88.00	90.00
Neutral Det Fibre	9.57	18.90	12.90	20.06	12.60	22.92	8.76	25.40	22.95
Acid Det Fibre	5.69	6.10	9.10	12.14	4.80	17.87	5.11	16.20	14.67
Calcium	0.34	0.08	0.14	0.12	0.13	0.23	0.13	0.65	0.51
Av Phos (Poultry)	0.26	0.18	0.19	0.11	0.10	0.12	0.15	0.35	0.36
Dig Phos (Swine)	0.31	0.13	0.21	0.19	0.18	0.13	0.16	0.40	0.36
Sodium	0.03	0.01	0.01	0.01	0.04	0.03	0.03	0.07	0.08
Chloride	0.05	0.02	0.01	0.12	0.06	0.15	0.15	0.01	0.10
Potassium	2.32	0.93	0.01	0.96	0.87	0.82	0.97	1.13	1.00

- Be cautious not to evaluate on protein base only
- Some of the proteins are ‘dual purpose’ contributing protein, starch and energy, not only protein.
- Field peas and Faba beans are good starch sources
- DH Lupins medium energy and 7.5% fat
- Hi Fat Canola – many types – important to know and test the type

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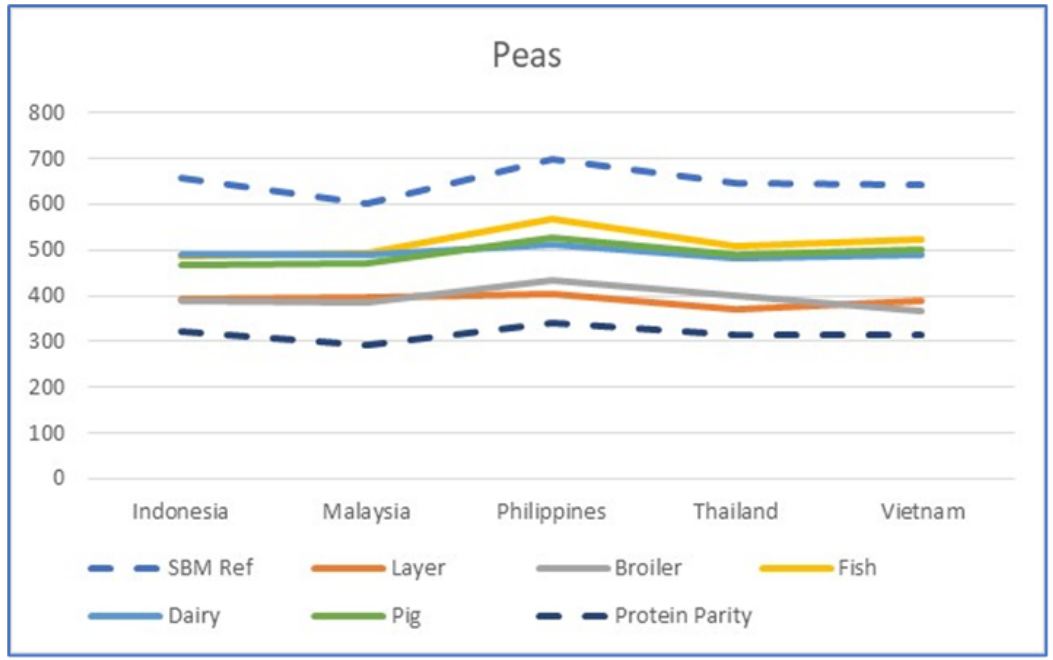
Field Peas



Peas	Indonesia	Malaysia	Philippines	Thailand	Vietnam
Layer	60%	66%	58%	57%	60%
Broiler	59%	64%	62%	62%	57%
Pigs	74%	82%	81%	78%	81%
Fish	74%	81%	73%	75%	76%
Dairy	71%	78%	75%	75%	78%
Protein Index	49%	49%	49%	49%	49%

- Be cautious not to evaluate on protein base only
- Peas are a dual-purpose crop supplying both energy and protein.
  - Protein 22% as fed.
  - Starch 40% or more as fed.
- On a protein basis the pricing would be 49% of the price of SBM across the SE Asia countries.
- Pigs, Fish and Dairy show relative values in the range 71% to 82% with pigs showing the strongest value.
- Nutritional value of peas can be enhanced by:
  - Heating (extrusion, pelleting etc).
  - Dehulling.
- Potential for special applications in Aqua feeds and young pigs.

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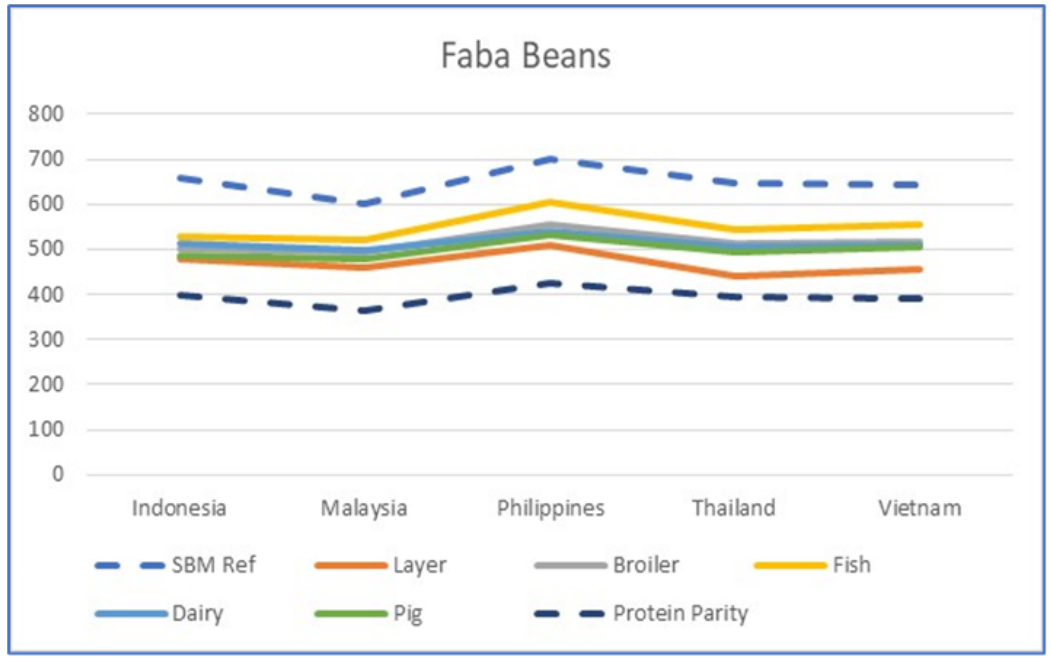
Faba Beans



Faba Beans	Indonesia	Malaysia	Philippines	Thailand	Vietnam
Layer	72%	76%	73%	68%	70%
Broiler	76%	82%	79%	79%	80%
Fish	80%	86%	86%	84%	86%
Dairy	78%	83%	77%	78%	79%
Pig	74%	80%	76%	76%	78%
Protein Index	61%	61%	61%	61%	61%

- Faba Beans are a dual-purpose crop supplying both energy and protein.
  - Protein 27% as fed.
  - Starch 38% or more as fed.
- Faba beans are relatively low in protease inhibitors and can be complimentary to the trypsin inhibitor content of SBM when blended.
- Pigs, Fish and Dairy show relative values in the range 77% to 88% with fish feeds showing the highest value. This indicates a good nutritional content over and above the protein content.
- Nutritional value of faba beans can be enhanced by:
  - Heating (extrusion, pelleting etc).
  - Dehulling to reduce the fibre and increase the SID amino acid levels as well as energy.
- Potential for special applications in Aqua feeds and young pigs when processed to reduce the ANFs.
- Faba beans included in extruded sinking feeds for fish make the pelleting process less prone to

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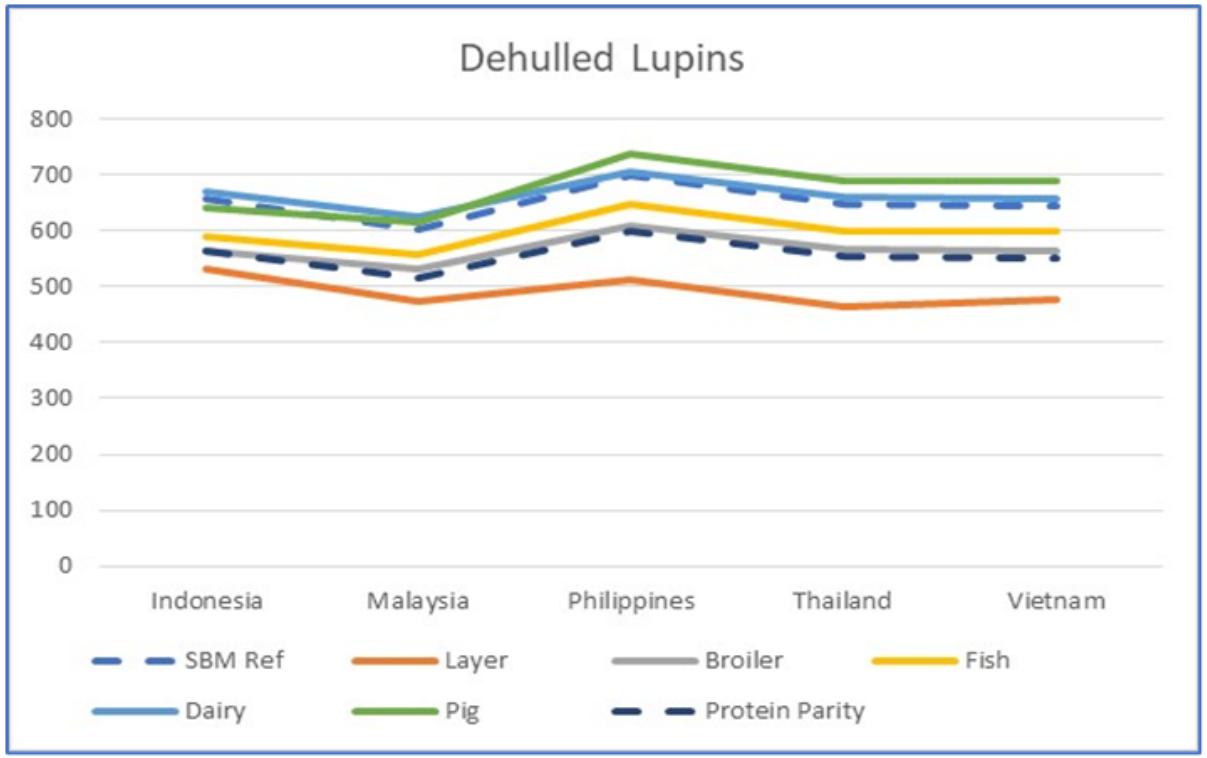
Dehulled Lupins



Lupins DH	Indonesia	Malaysia	Philippines	Thailand	Vietnam
Layer	81%	79%	73%	71%	74%
Broiler	86%	88%	87%	88%	87%
Fish	90%	93%	93%	92%	93%
Dairy	102%	104%	101%	102%	102%
Pig	97%	102%	105%	106%	107%
Protein Index	86%	86%	86%	86%	86%

- Shadow prices of Dehulled Lupin seed meal show gains from the processing for fish, dairy and pig feeds.
- Protein 39% as fed compared to the lower values for pulses in the range 22-27%.
- Starch is only 1% compared to typical levels of 40% found in pulses.
- Dehulling the lupin seeds raises the poultry AMEn from 1191 to 2279 Kcals/Kg.
- Pig and dairy feeds show good economic positioning with relative values averaging 104% and 102% respectively.
- Nutritional value of lupin seed meal can be enhanced by:
  - Dehulling (preferred).
  - Supplementation with NSP enzymes to aid digestion of the raffinose.

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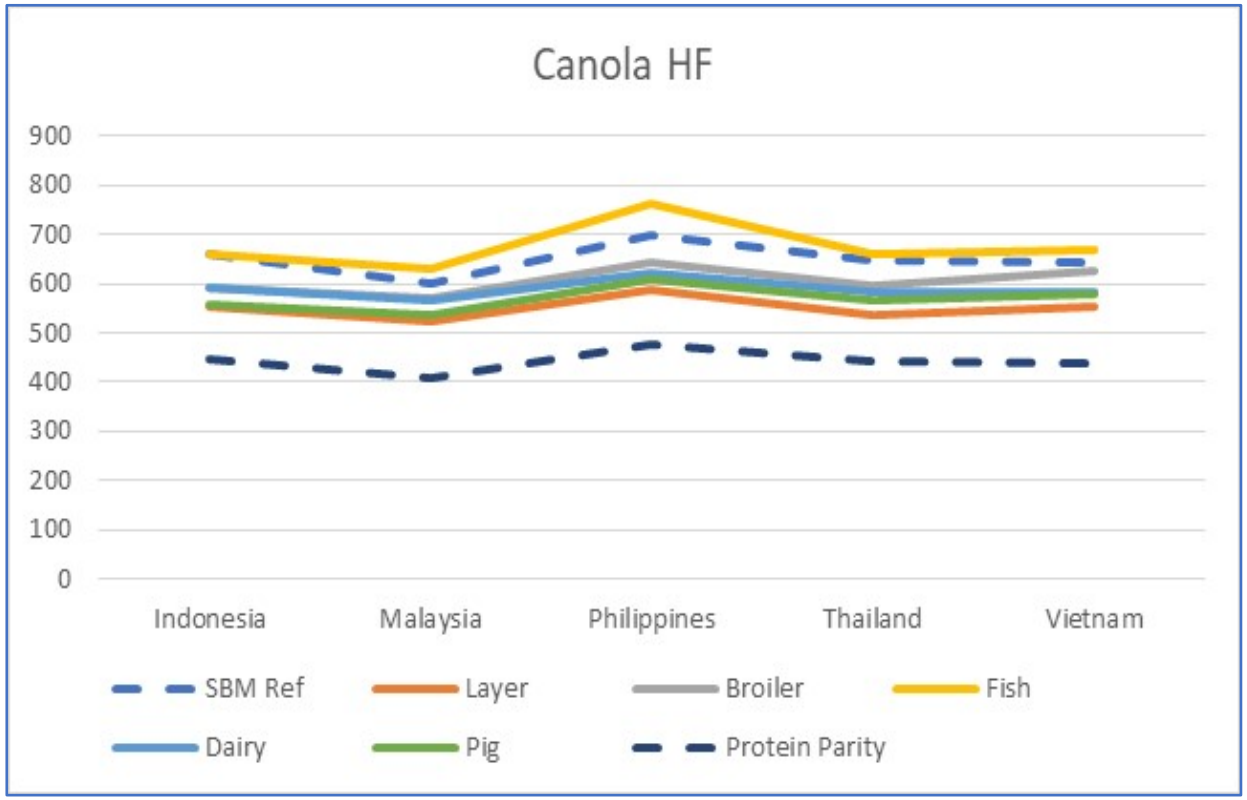
Hi Fat Canola



Canola HF	Indonesia	Malaysia	Philippines	Thailand	Vietnam	
Layer	84%	87%	84%	83%	86%	85%
Broiler	90%	95%	92%	92%	97%	93%
Fish	100%	105%	109%	102%	104%	104%
Dairy	90%	94%	89%	90%	91%	91%
Pig	84%	89%	87%	88%	90%	88%
Protein Index	68%	68%	68%	68%	68%	68%

- High fat canola is an interesting variation in the ingredient supply chain with medium protein and relatively high energy:
  - Protein 31%.
  - Fat 13% (in this case, but this level is part of product design and is not a standard figure.
  - AMEn broiler 2650 Kcals per Kg compared to 2200 Kcals per Kg for canola meal.
- Good source of highly digestible fat.
- Can be used at 10-15% in broiler feeds and is also well accepted in layer feeds as an energy/protein source.
- Strong economic position in pig feeds.
- Should not be confused with cold pressed canola which is good for dairy cattle but can be unsuitable for monogastric animals if the glucosinolate and mryosinase activities are above normal.
- High Fat Canola products have several different production methods, content and application.
- Variables involved would be targets on the residual oil level and the degree of dehulling and heat treatment

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Conclusions

- Avoid excess nutrients, especially protein and phosphorous
- Using amino acid ratios enables faster calculation of savings in crude protein. Crude protein is only an estimate of the amino acids. More accurate calculation of amino acids is preferred
- Experiments on protein density are necessary to find cost effective nutrient levels
- Optimization allows us to evaluate new ingredients. In this example DDGS has the potential to save feed cost
- Optimization can be used for prospecting for alternative raw materials using shadow price analysis to determine possible cost effective supplies
- Potential exists for using digestible amino acids more extensively in aqua diets to improve accuracy

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