Protein nutrition of farmed tilapia: searching for unconventional sources

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Tilapia culture

- Rank **third** in the world, in terms of production, after carps and Salmonids.
- One of the fastest growing farming activities, annual growth rate of 13.4% during 1970–2002.
- Practiced in about **100 countries**.
- The production increased from 383,654 mt in 1990 to **1,505,804 mt in 2002**
- 6% of total farmed finfish production in 2002.

- **Nutrition: > 50% of operating costs.**
- **Protein represents 50% of feed cost.**
- ***The selection of proper quantity and quality of dietary protein is a must***
- Tilapia:
  - **herbivorous / omnivorous**
  - **low on the food chain**
  - **Produce high quality protein from low quality food**
- **The challenge**
- **Develop commercial, cost effective tilapia feeds using locally available, cheap and unconventional resources.**

Protein requirements

Extensively studied

Results are varying, sometimes contradictory !!

Why?

- **Indoor studies**
- **Short- term (4-8 weeks)**
- **Sometimes imbalanced diets (Casein vs casein/gelatin)**
- **Ignored cost/benefit analysis**

Protein requirements

Species and life stage	Weight (g)	Protein source	Requirement
O. niloticus			
Fry	**0.012**	**FM**	**45%**
	0.51	**FM**	**40**
	0.80	**FM**	**40**
Fingerlings	**2.4**	**Casein/Gelatin**	**35**
	3.50	**Casein**	**30**
	6.1-16.5	**FM**	**30**
	45-264	**FM**	**30**
Broodstock		**FM/SBM**	**40**
		FM	**45**
		Casein/Gelatin	**35-40**

Species and life stage	Weight (g)	Protein source	Require-ment
O. mossambicus	Fry	FM	40-50
	6-30	FM	30-35
O. aureus	0.30-0.50	SBM or FM	36
	2.50	Casein/albumen	56
	7.5	Casein/albumen	34
T. zillii	1.35-1.80	Casein	35
	1.4-1.7	Casein/Gelatin	35-40
O. niloticus X *O. aureus*	145-242	FM+CSM	20
	0.6-1.1	FM	32
	21	SBM	28
O. niloticus X *O. hornorum*	1.24	-	32
O. mossambicus X O. hornorum	8.87	-	28

Essential Amino acid requirements of tilapia

Amino Acid	Requirement			
	O. mossamicus[1]	*O. mossambicus*[2]	*O. niloticus*[3]	*O. niloticus*[4]
Lysine	4.05 (1.62)	3.78 (1.51)	5.12 (1.43)	---
Arginine	3.80 (1.52)	2.82 (1.13)	4.20 (1.18)	4.1
Histidine		1.05 (0.42)	1.72 (0.48)	1.5
Threonine		2.93 (1.17)	3.75 (1.05)	3.3
Valine		2.20 (0.88)	2.80 (0.78)	3.0
Leucine		3.40 (1.35)	3.39 (0.95)	4.3
Isoleucine		2.01 (0.80)	3.11 (0.87)	2.6
Methionine	1.33 (0.53)	0.99 (0.40)	2.68 (0.75)	1.3
Cystine			0.53	2.1
Phenylalanine		2.50 (1.00)	3.75 (1.05) 1.79	3.2
Tyrosine				1.6
Tryptophan		0.43 (0.17)	1.00 (0.28)	0.6

[1]Jackson and Capper (1982); [2]Jauncey et al. (1983); [3]Santiago and Lovell (1988); [4]Fagbenro (2000).

Major protein sources

Animal protein sources:

- **Fish meal**
- **Fishery by-products**
- **Terrestrial animal by-products**

Plant protein sources:

- **Oilseed plants**
- ***Soybean Meal***
- ***Cottonseed meal/cake***
- ***Other oilseed by-products***
- ***Aquatic plants***
- ***Grain legumes***

Single-cell proteins

Ingredient	Limitations
Fish meal	Shortage in supply, increased prices, competition
Fish silage	free amino acids
PBM	deficient in EAA (Lys)
BM	deficient in Isol
HFM	deficient in Lys and Met
MBM	deficient in Met
SBM	• deficient in Met, Lys, Cys • antinutrients: – protease (trypsin) inhibitor – phytohaemagglutinin – anti-vitamins
CSM	– deficient in Cys, Lys and Met – gossypol

Protein sources tested and recommended for tilapia

Source (specification)	levels (%) tested	levels (%) recommended	Species (weight, g)
Animal sources:			
Shrimp meal	100	100	*O. niloticus* (20), Red tilapia
PBM	50	50	Hybrids (195)
PBM+HFM	10 -40	40	*O. niloticus* (1.4)
MBM	100	100	*O. niloticus* (20), Red tilapia
MBM + BM (2:3)	0-100	100	*O. mossambicus* (1)
BM	0-100	100	*O. mossambicus* (1)
BM	100	<100	*O. niloticus* (20)
BM	100	<100	Red tilapia (9)
BM	10-50	10	*O. niloticus* (3.9)
HFM	0-100	66	*O. niloticus* (0.01)
Animal by-products	0-100	100	*O. niloticus* (0.1)
Chicken offal silage	0-20	20	*O. niloticus* (10.8)

Oilseed plants

SBM +/-Met	**75**	**75**	***O. niloticus* (0.8)**
SBM +/- Met	**0-100**	**100**	***O. aureus* (0.3-0.5)**
SBM	**0-100**	**75**	***O. mossambicus* (50)**
SBM +/- Met	**0-100**	**67**	**Hybrids (4.47)**
Soy protein concentrate	**0-100**	**100**	***O. niloticus* (3.2)**
SBM + EAA+ DCP+oil	**0-100**	**100**	**Hybrids (84)**
SBM + DCP+oil	**0-100**	**100**	**Hybrids (169)**
CSM +/- lys	**100**	**100**	***O. niloticus* (20)**
CSM	**0-100**	**50**	***O. mossambicus* (12)**
CSM	**50**	**50**	**Hybrids (195)**
CSM	**0-100**	**80**	***T. zillii* (1.5)**

Sesameseed meal	**0-75**	**25**	***T. zillii* (2.4)**
Groundnut cake	**0-100**	**25**	***O. mossambicus* (30)**
Rapeseed meal	**15-75**	**15-75**	***O. mossambicus* (0.3 -13)**
Copra meal	**0-50**	**25-50**	***O. mossambicus* (31)**
Defatted cocoa cake	**100**	**100**	***T. guineensis* (52)**
Palm kernel cake	**0-100**	**60**	***O. niloticus* (2.5)**
Palm kernel cake	**20-50**	**50**	***O. mossambicus* (8.4)**
Macadamia press cake	**0-100**	**50**	***O. niloticus* (7.5-12)**
Macadamia press cake	**100**	**100**	***T. guineensis* (N.A.)**
Sunflower meal	**0-50**	**20**	***T. rendalli* (0.93)**

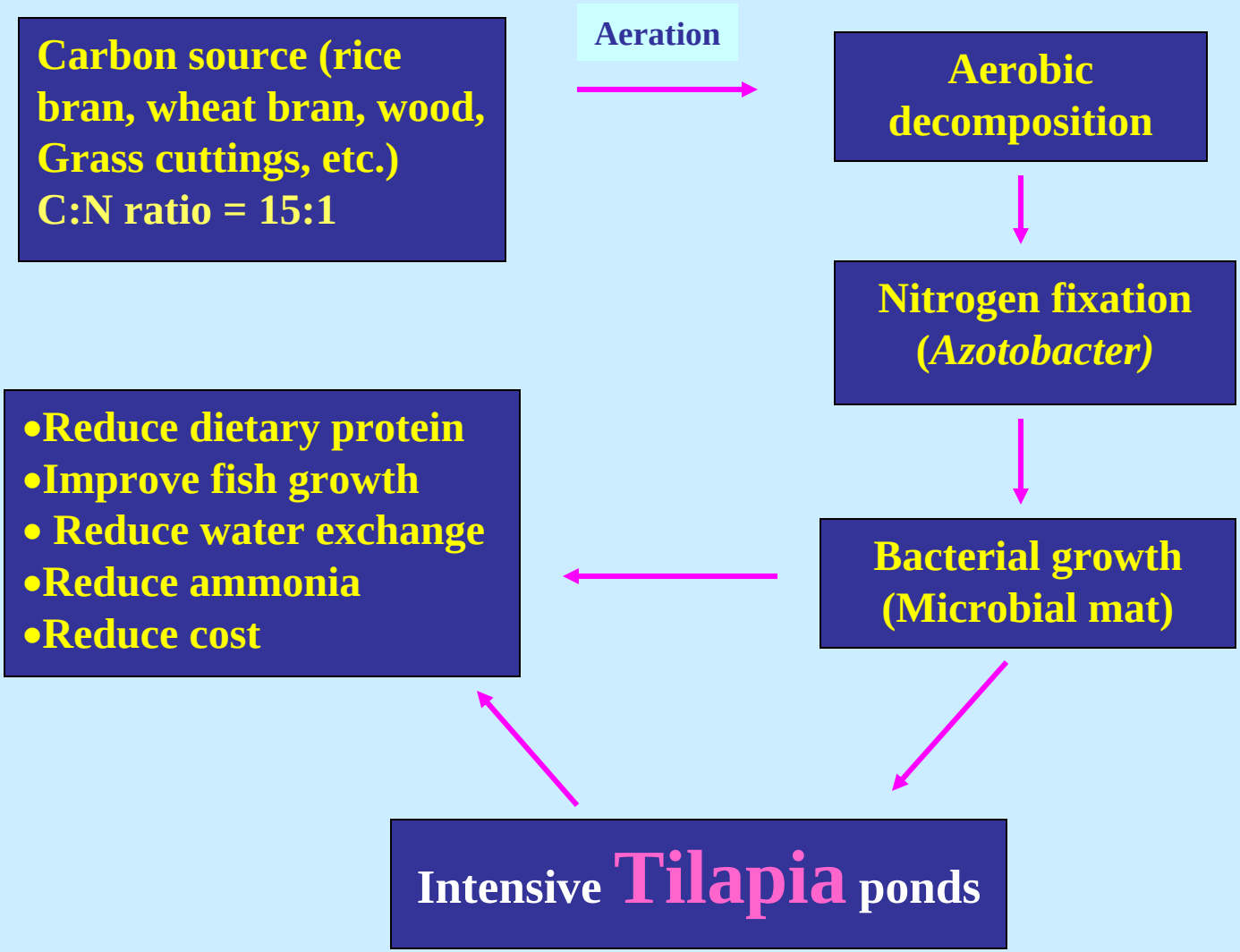
Aquatic plants

Spirulina	**0-100**	**40**	***O. mossambicus*** **(0.3)**
Azolla pinnata	**0-100**	**<25**	***O. niloticus*** **(4-40)**
Hydrodictyon	**0-100**	**20**	***O. niloticus*** **(1),** ***T. zillii*** **(1)**
Eleocharis ochrostachys	**20-40**	**20-30**	***O. niloticus*** **(7)**
Potamogeton	**25-50**	**25**	***O. niloticus*** **(14.5)**
Ceratopyhllum demersum	**20-40**	**20-30**	***O. niloticus*** **(7-14.5)**
Duckweed	**0-100**	**50-100**	***Tilapia sp*** **(not given)**
Duckweed (*Wolffia*)	**0-75**	**50**	***O. niloticus*** **(0.4)**
Duckweed (*Lemna*)	**0-50**	**50**	***O. niloticus*** **(14.5)**
Duckweed (*Spirodela*)	**0-100**	**30**	***O. niloticus*** **( )**
Yeast	**20-40**	**40**	***O. niloticus*** **(N.A)**

Grain legumes

Leucaena leaf meal (LLM)	**0-50** **0-100**	**<25** **100**	***O. mossambicus* (50)** ***O. mossambicus***
LLM	**0-50**	**15**	***O.aureus* (43-50)**
Cassava leaf meal	**20-100**	**<100**	***O. niloticus* (13.8-15.4)**
Green gram legume	**13-50**	**25-37**	***O. niloticus* (2.92)**
Jack bean meal	**0-35**	**25**	***O. mossambicus* (0.4-0.9)**
Alfalfa LPC	**15-55**	**35**	***O. mossambicus* (0.3)**
Cowpea LPC	**0-50**	**20-30**	***O. niloticus* (0.16)**
Corn gluten + SBM	**100**	**100**	***O. niloticus* (30)**
Corn distillers' grains	**16-49**	**35-49**	***Tilapia* (0.4)**
Pito brewery waste	**0-100**	**100**	***T. busumana* (1.5)**
Cocoa husks	**10-20**	**10**	***O. niloticus (...)***
Coffee pulp	**0-39**	**13- 30**	***O. aureus* (9-50)**
Toasted lima bean+ Met	**20-80**	**40-80**	***O. niloticus* (5)**

Production of natural food in tilapia fish ponds. After El-Sayed, 1999.



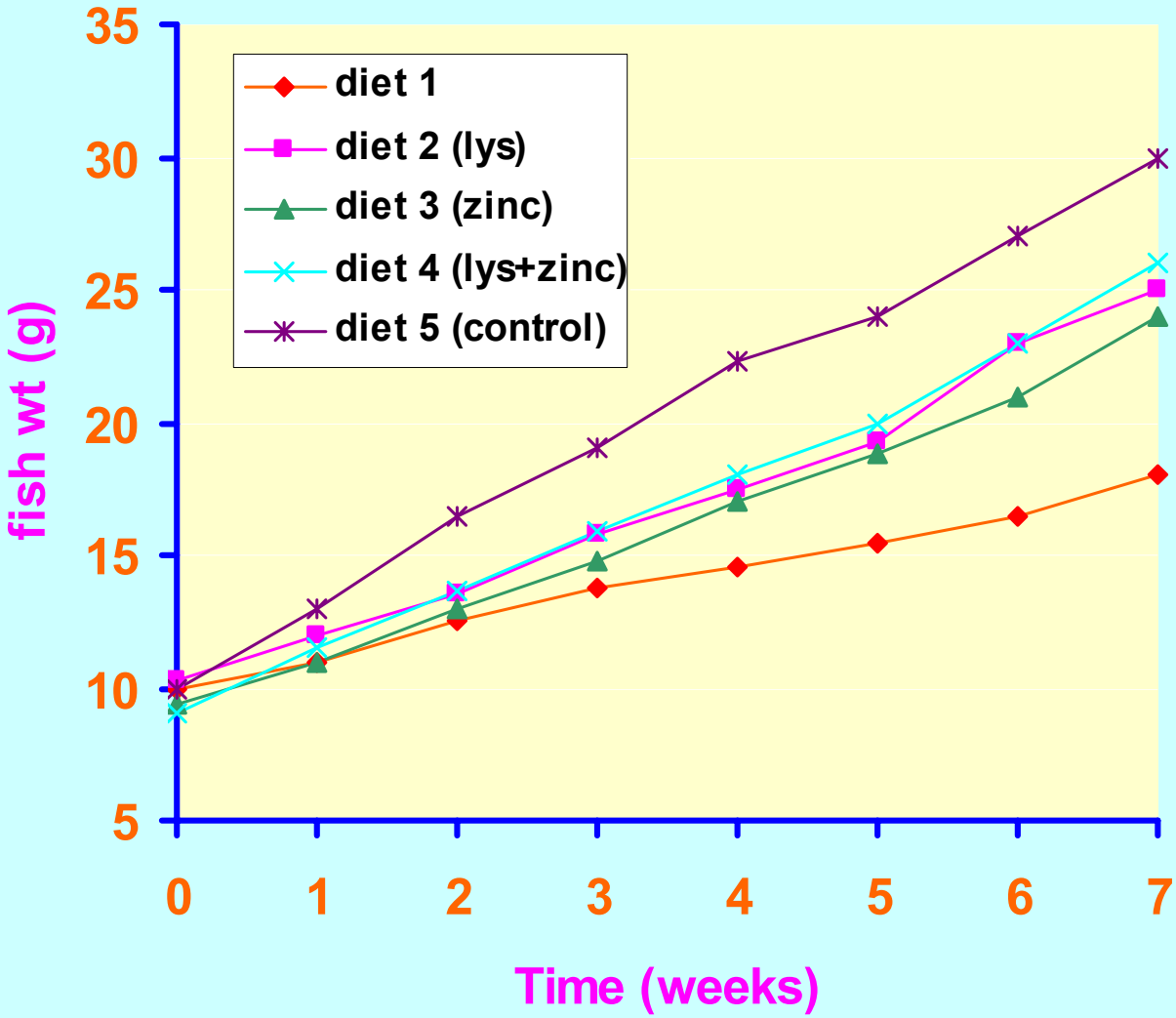
The use of unconventional protein sources

1- Amino acid **vs** mineral **supplementation**?

1. Is EAA supplementation necessary??
2. Can certain minerals meet the deficient EAA??

    1. **Sesame meal + Lys or Zinc or both**
    2. **SBM + Met or Phosphorus**
    3. **CSM + Lys**

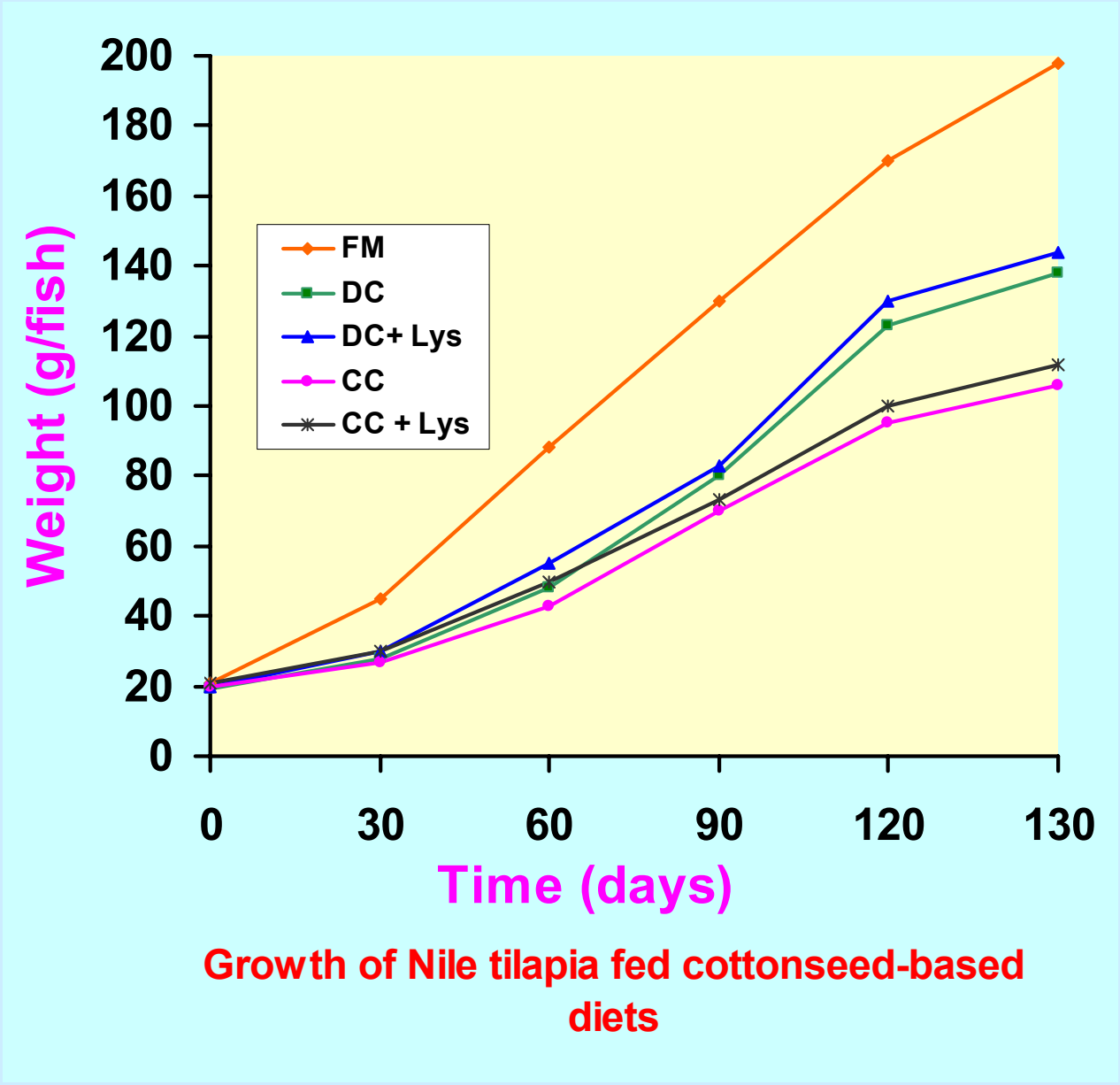
Ingredients	Test diets				
	1	2	3	4	5 (cont.)
Casein	18	18	18	18	24
Gelatin	8	8	8	8	11
Dextrin	27	27	27	27	34
Sesame meal	25	25	25	25	0
L-Lys	0	0.5	0	0.5	0
Zn SO_4 (mg/g)	0	0	30	30	0
α-cell	15	14.5	15	14.5	21
SB oil	1	1	1	1	3
Fish oil	2	2	2	2	2
Vit & min mix	4	4	4	4	3



Growth of *T. zillii* fed sesame seed based-diets

Growth of Nile tilapia fed CSM +/- Lysine supplementation

Protein source	IW	FW
FM	21	198[a]
Decorticated CSM	19	138[b]
Decorticated CSM + Lys	20	144[b]
Corticated CSM	20	106[c]
Corticated CSM + Lys	21	112[c]



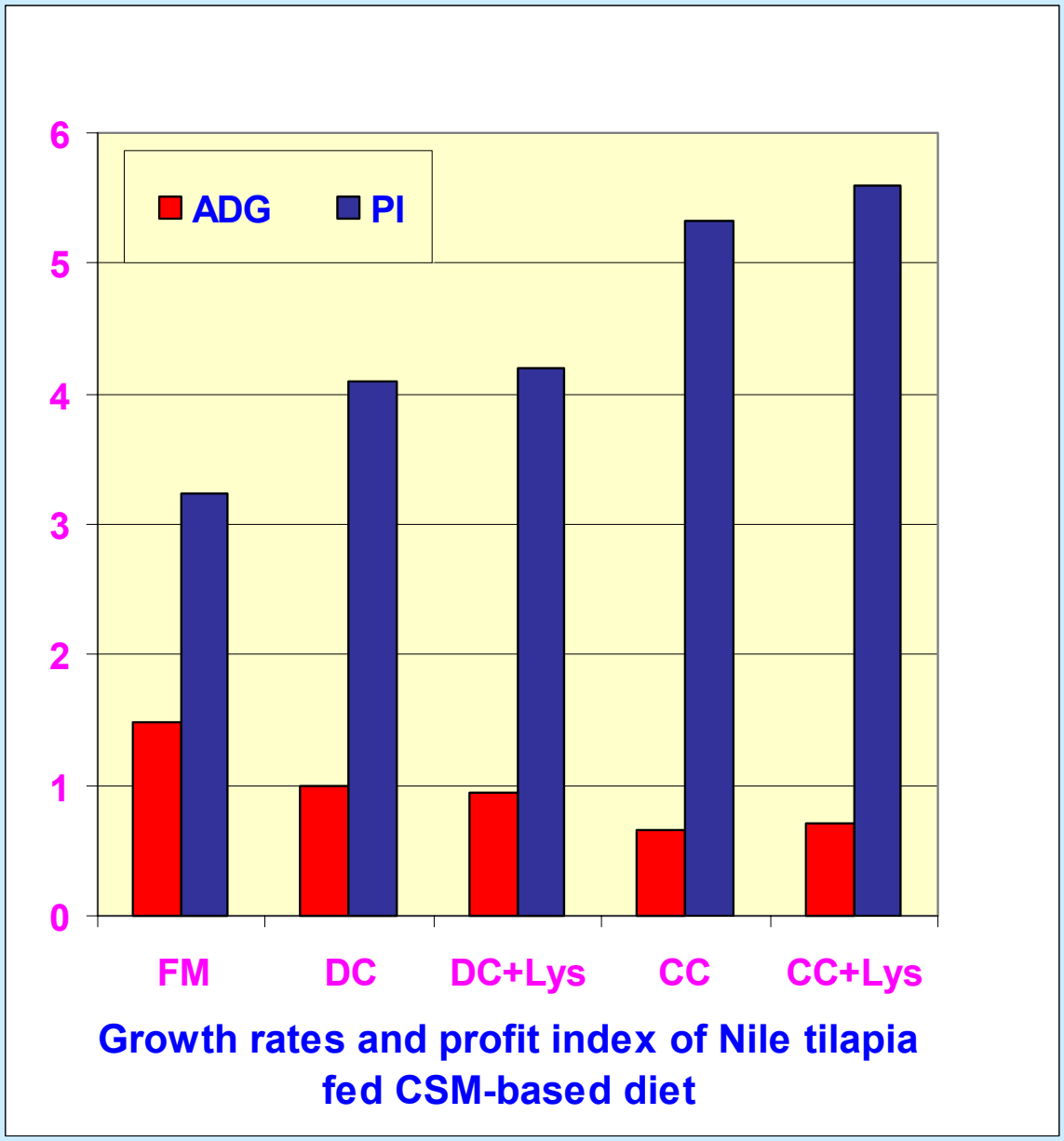
Growth of Nile tilapia fed cottonseed-based diets

Cost / benefit analyses

1. High quality protein diet may not be cost effective
2. Low quality protein diet may lead to poor growth, but more profitable.
3. Cost/benefit analyses of the feed is necessary
4. Consumer target

Performance of Nile tilapia fed CSM-based diets

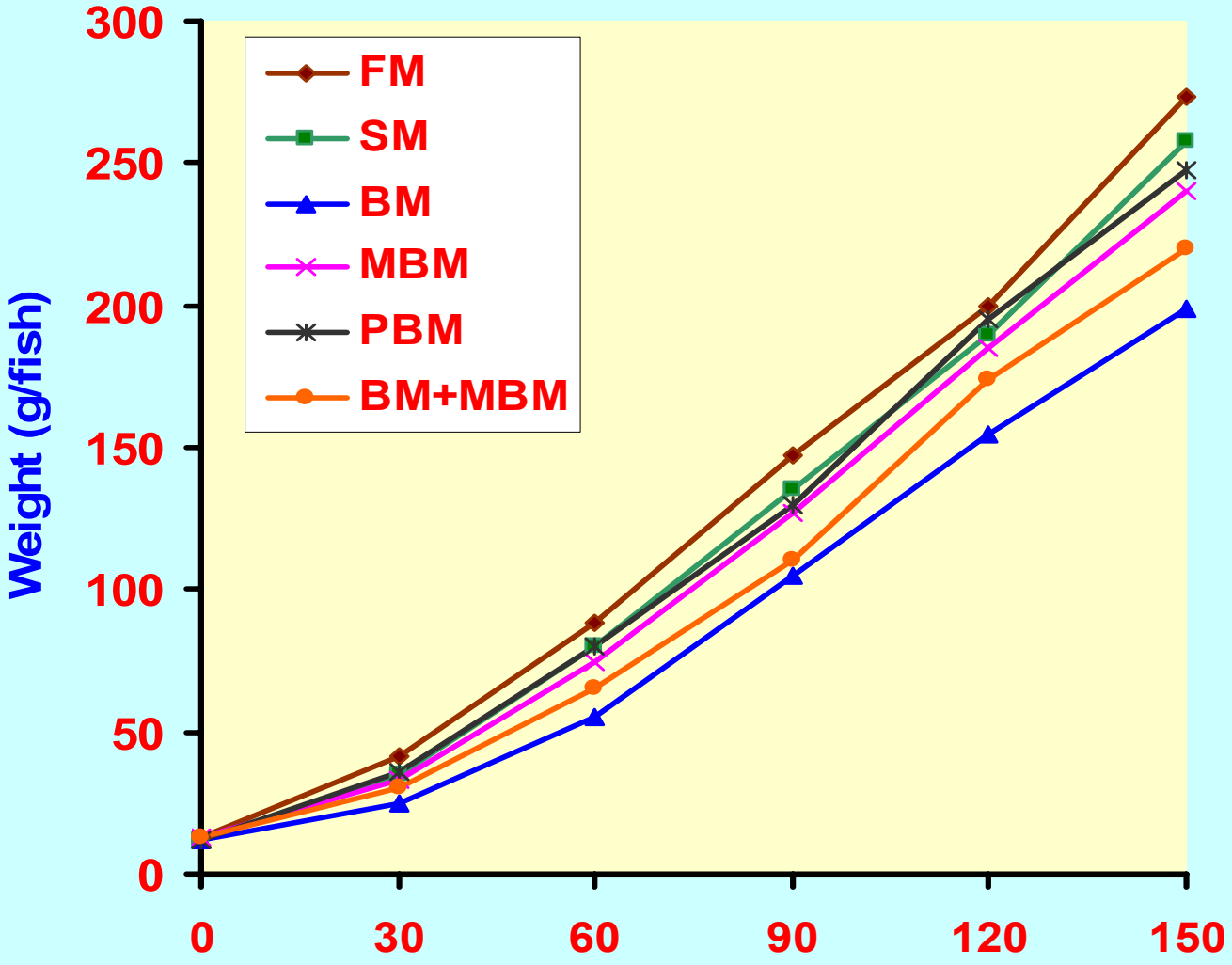
Protein source	IW	FW	Incidence cost	Profit index
FM	21	198[a]	1.07[a]	3.23[a]
DC	19	138[b]	0.77[b]	4.50[b]
DC + Lys	20	144[b]	0.76[b]	4.59[b]
CC	20	106[c]	0.66[b]	5.32[c]
CC + Lys	21	112[c]	0.62[bc]	5.60[c]



Growth rates and profit index of Nile tilapia fed CSM-based diet

Animal protein based-diets fed to Nile tilapia for 150 days.

Ingredient	1	2	3	4	5	6
FM	35.0					
Shrimp meal		50.0				
Blood meal			30.0			15.0
Meat & bone M				40.0		20.0
Poultry by- product					47.0	
Wheat bran	45.0	30.0	46.0	36.0	29.0	30.0
Starch	10.0	10.0	10.0	10.0	10.0	10.0
Sardine oil	1.0	2.0	1.5	2.5	1.0	3.0
SB oil	2.0	2.0	1.5	2.5	1.0	3.0
Vit & min. mix	2.0	2.0	2.0	2.0	2.0	2.0
Phosphorus			2.0			2.0
A-Cell	5.0	4.0	7.0	7.0	10.0	15.0
Crude protein	31.6	30.9	30.8	30.0	29.6	30.4



Growth of Nile tilapia fed different animal protein sources

Performance of Nile tilapia fed all-animal protein sources

Protein	IW	FW	Incidence cost	Profit index
FM	13	273^{a}	4.8^{a}	1.7^{a}
SM	12	258^{a}	3.4^{b}	2.3^{b}
BM	12	199^{b}	4.0^{c}	2.0^{b}
MBM	13	240^{ac}	3.6^{b}	2.2^{b}
PBM	12	248^{ac}	3.5^{b}	2.3^{b}
BM+MBM	13	220^{bc}	4.1^{c}	1.9^{c}

Improving protein quality

Phytase supplementation

- Many plant protein sources contain high levels of phytic acid.
- phytic acid binds with divalent minerals forming water-insoluble salts.
- The inclusion of bacterial phytase:
    1. reduces phytic acid activity
    2. improves the utilization of plant protein sources.
    3. reduces the effect of antinutritional factors.
    4. protects amino acids from degradation.
    5. decreases leaching of water soluble components.

Protein digestibility

- **Problems:**
- **interchangeable and inconsistent use of terminology.**
- **use of ME and DE values interchangeably**
- **use varying energy values for the same ingredient under the same terminology.**
- **Use of energy values reported for other fish species**

Digestibility of some protein sources by tilapia

Fish meal:	92.2	72 (58)	86 (80)	92			
Sardine						87 (80	
Anchovy						94	90 (86)
Fish silage					85 (83)		
MBM	92.2						
Poultry offal			74 (59)				
Shrimp meal				87		74 (59)	
Silkworm pupa	91.1						
Brewers grains		62 (42)	63 (30)			63 (30)	
Copra meal				56		81	
Corn gluten	90.7			97			
CSM						90	
Groundnut meal		79 (72.5)					
SBM	90.9		91 (56)	93		91 (57)	93
Sunflower SC							86-89

Conclusions

- Studies should be long enough!!, 2-3 months?
- Applied in the field, if possible
- Use GE, if DE is not available
- Supplementation of certain minerals may meet the requirement of deficient EAA
- EAA supplementation may not be necessary
- More work needed (case by case..)
- Supplementing plant proteins with Phytase may be necessary

Thank you