An overview of lipid nutrition with emphasis on alternative lipid sources in tilapia feeds

Wing-Keong Ng & Cheong-Yew Chong

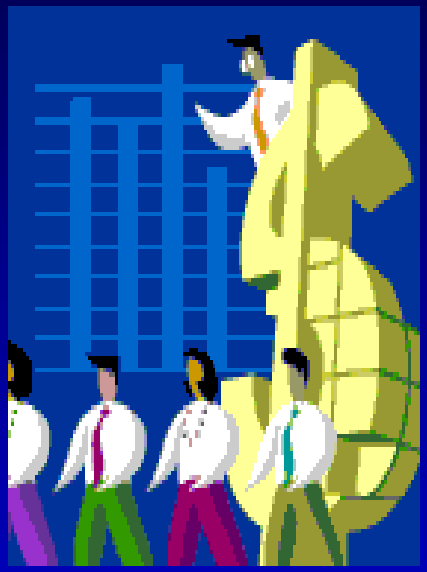
Fish Nutrition Laboratory
School of Biological Sciences
Universiti Sains Malaysia
Penang, Malaysia

Tilapia aquaculture is one of the fastest growing industry in the world.

With increasing intensification of culture systems, complete formulated feeds are required.

Feed Cost versus Tilapia Prices

- The critical need to reduce feed costs to match low ex-farm prices of tilapia:
  - Korea: 45%
  - Malaysia: 65%
  - Indonesia: 82%
  - Thailand: 84%



- The escalating cost of imported feed ingredients such as fish meal, soybean meal, wheat flour, fish oil, etc.

Source: International Aquafeed, 2000

Tilapia Feeds

- Protein sources – fish meal, vegetable proteins.
- Carbohydrates – wheat flour, corn flour, etc.
- Lipids – fish oil, vegetable oils.
- Vitamins and minerals.
- Binder and other additives.

Feed formulation depends mainly on fish size

Least-cost formulation for tilapia feeds

Nutrient	Limit	Prestarter	Starter	Grower	Finisher
Protein	Min	40	30	25	20
Lipid	Min	4	4	4	4
Lysine	Min	2.04	1.53	1.28	1.02
Total P	Max	1.5	1.5	1.5	1.5
Fiber	Max	4	4	4	8
Fishmeal	Min	15	12	10	8

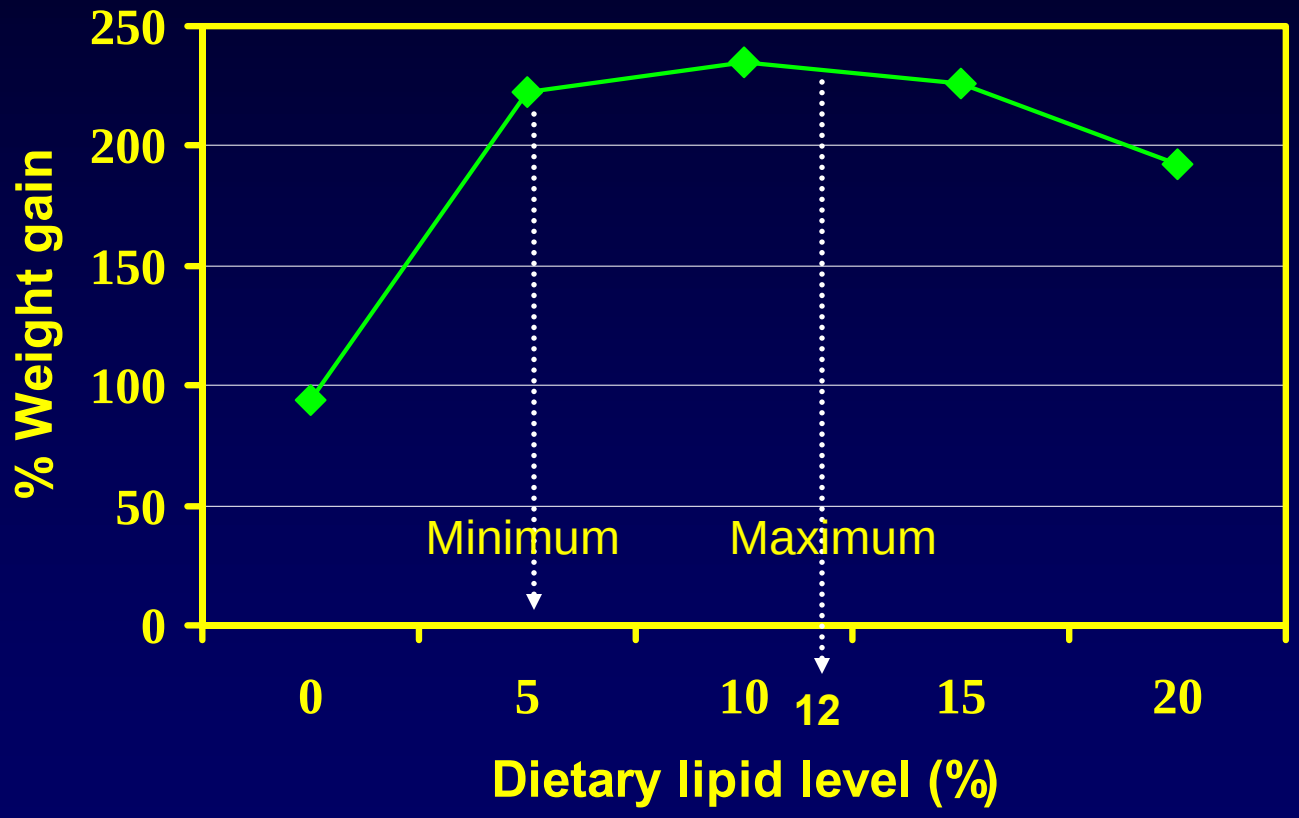
Source: Chawalit et al. 2003 (CP group)

Lipids

- source of energy
- source of essential fatty acids
- absorption of fat-soluble vitamins
- cellular & membrane structures
- precursors of hormones
- imparts flavor to diets
- affects diet texture

Lipid levels in tilapia feeds

Hybrid tilapia (*O. niloticus x O. aureus*)



Corn starch vs. corn oil/ CLO/ lard (1:1:1) *Chou & Shiau, 1996*

Lipid levels in tilapia feeds

Tilapia zillii (El-Sayed & Garling, 1988).

- Dextrin vs. CLO-SBO mix (2, 5, 10, 15% lipid)
- No significant growth increase from 5 -15% lipid

Hybrid tilapia (*O. mossambicus x O.aureus*)
(Fitzsimmons et al., 1997)

- 3, 6, 8% dietary lipids fed for about 3 months
- No significant difference in growth and FCR

Commercial tilapia diets ≤ 5% lipid

Essential Fatty Acids

Contradictory results as to the requirement of tilapia for *n*-3 and *n*-6 PUFA

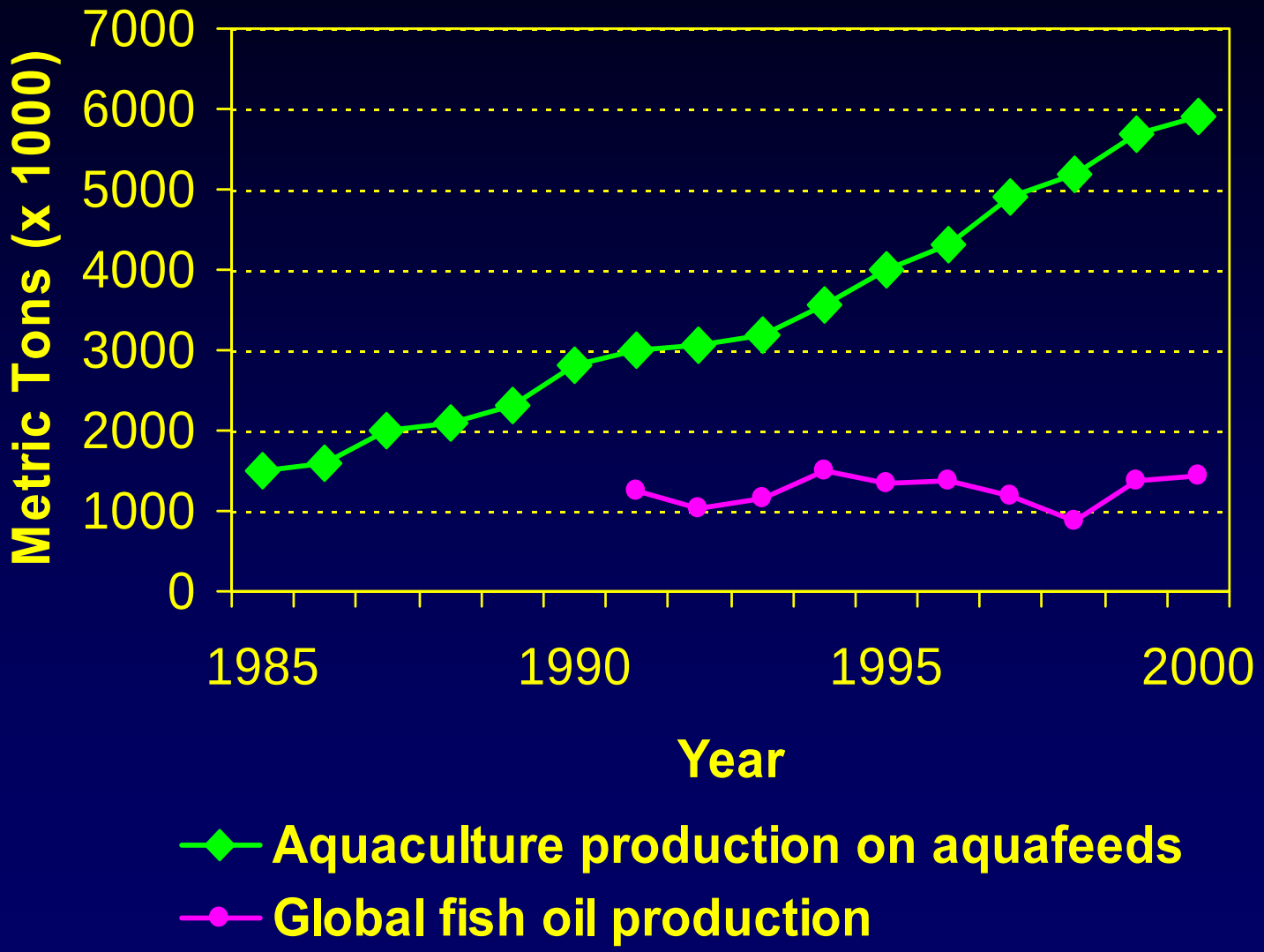
- require only *n*-6 PUFA
- require both *n*-3 and *n*-6 PUFA
- > 1% 18:3*n*-3, DHA or EPA depress growth

0.5 to 1% *n*-3 and *n*-6 PUFA until further research

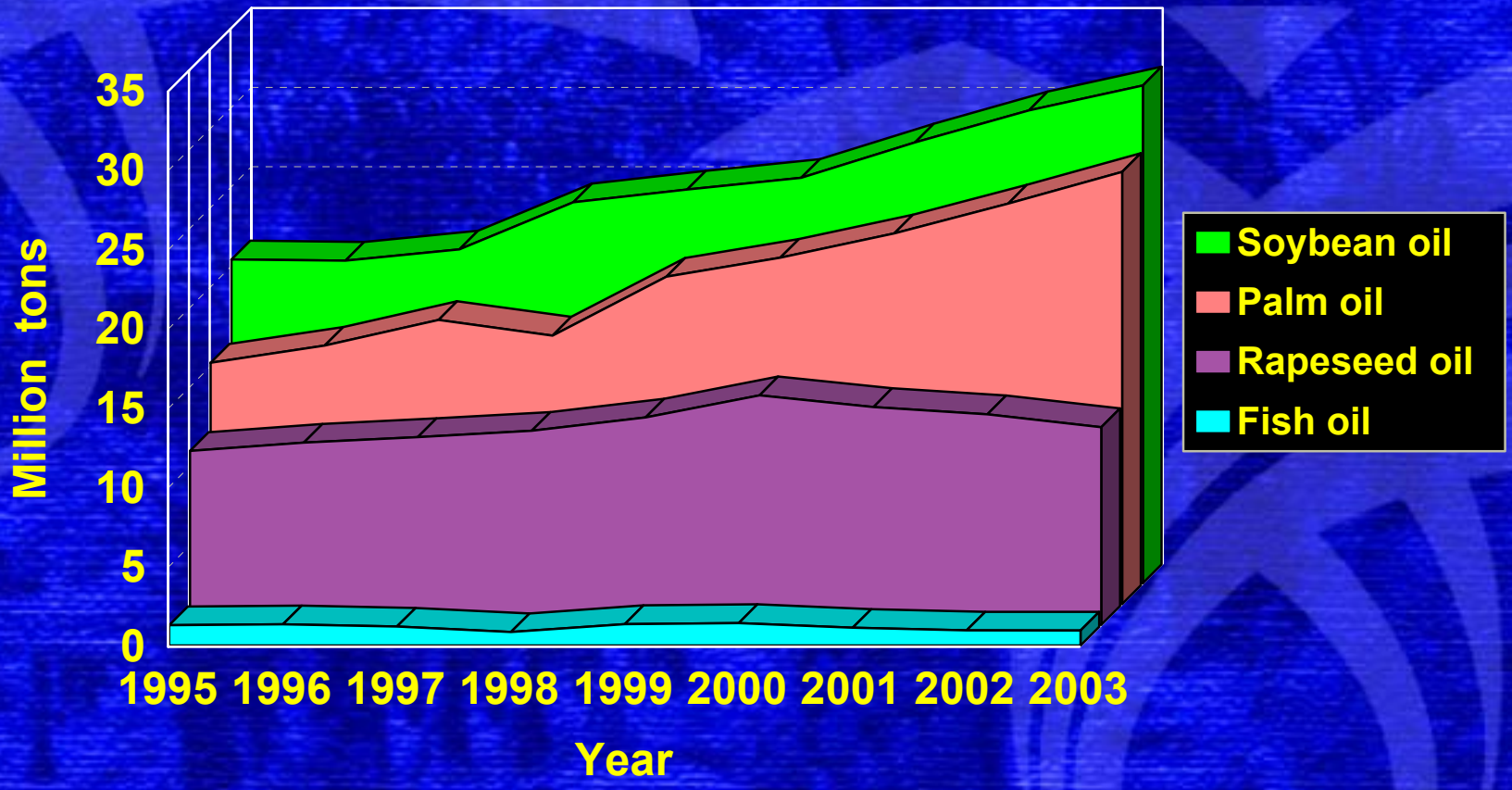
Status of fish oil use in aquafeeds

- Aquaculture consumes 70% of the total global supply of marine fish oil
- Forecasted to use 97% of fish oil supplies by the year 2010
- Cost of fish oils continue to increase due to:
  - stagnation in marine capture fisheries
  - human dietary fish oil supplements
  - animal livestock industry

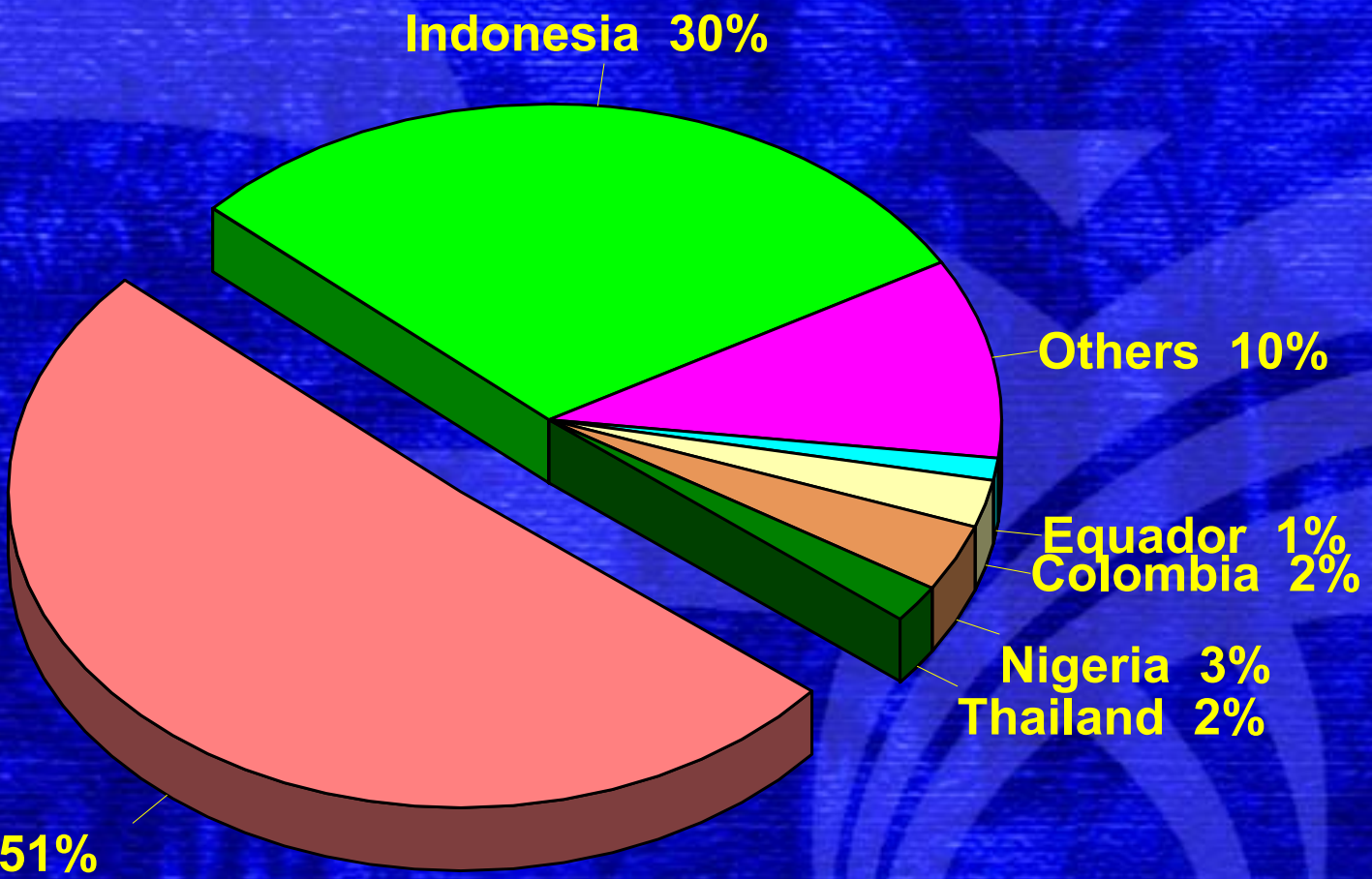
Aquaculture production versus Fish oil production



World production of fish oil, rapeseed oil, palm oil and soybean oil



World Palm Oil Producers



Source: Oil World

Palm Fatty Acid Distillates

Crude Palm Oil

Bleaching

Deodorization

Distillation

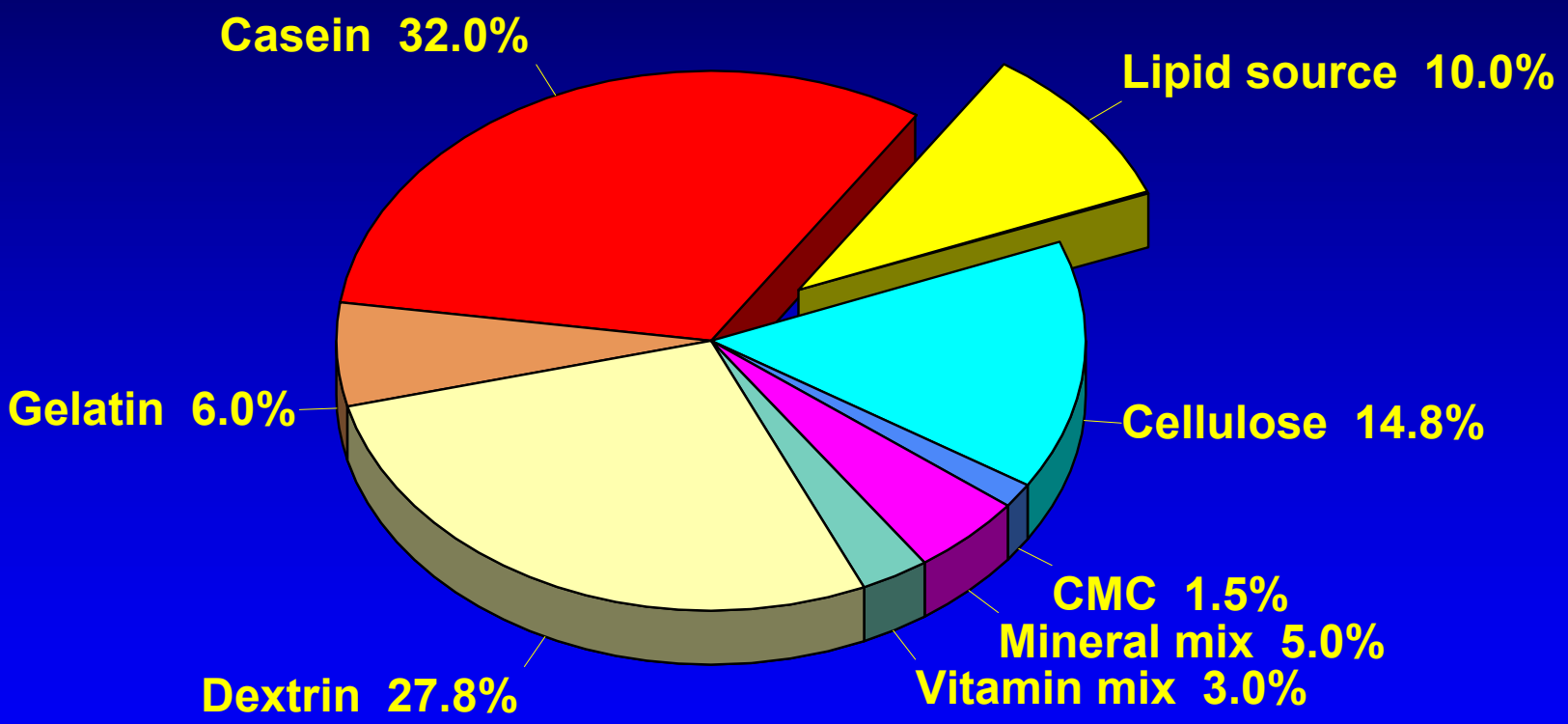
Palm Kernels

RBD Palm Olein

Crude Palm Kernel Oil

Palm Kernel Meal

Composition of Semipurified Diets



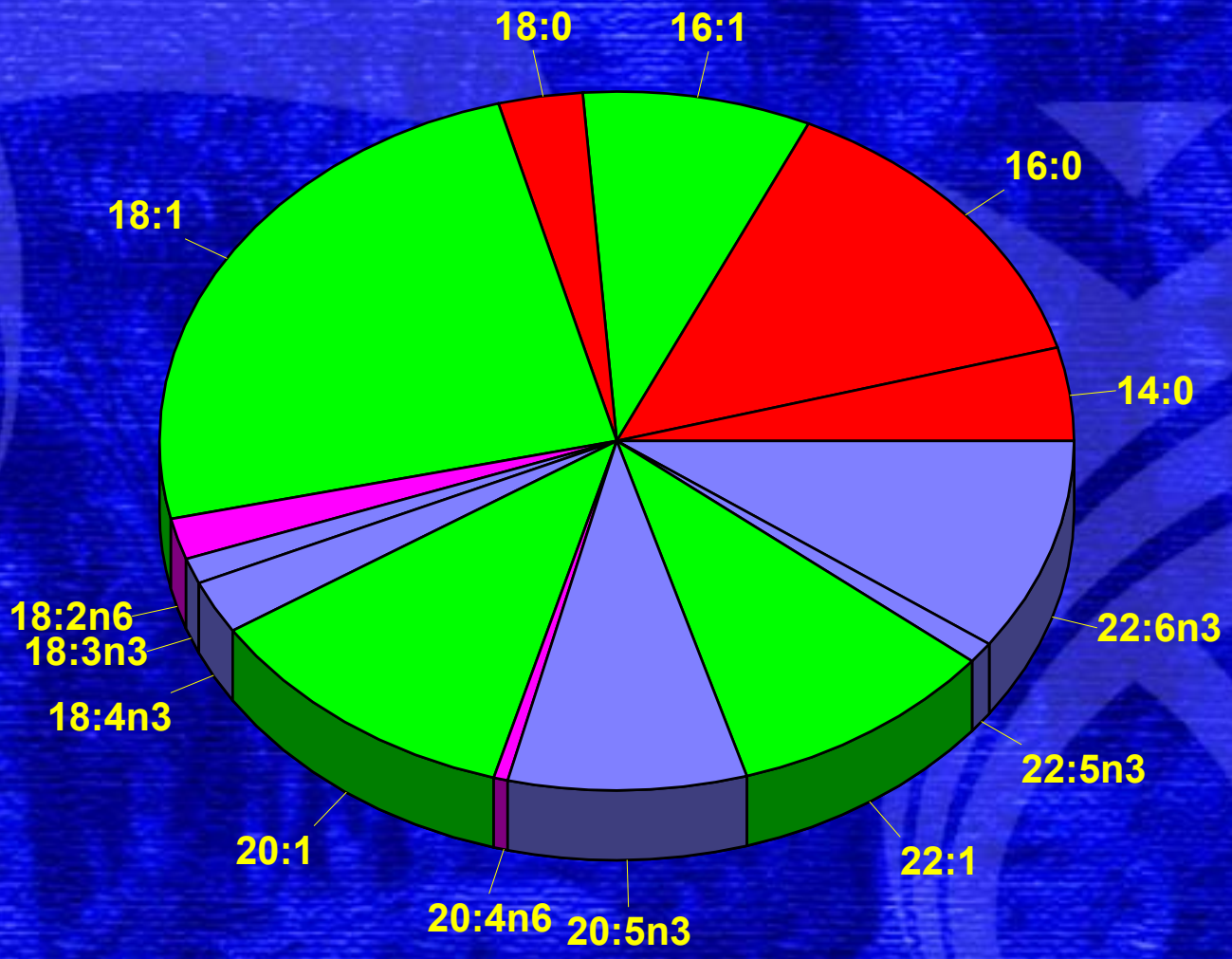
35% protein and 14.6 kJ/g diet

Dietary Lipid Source Tested:

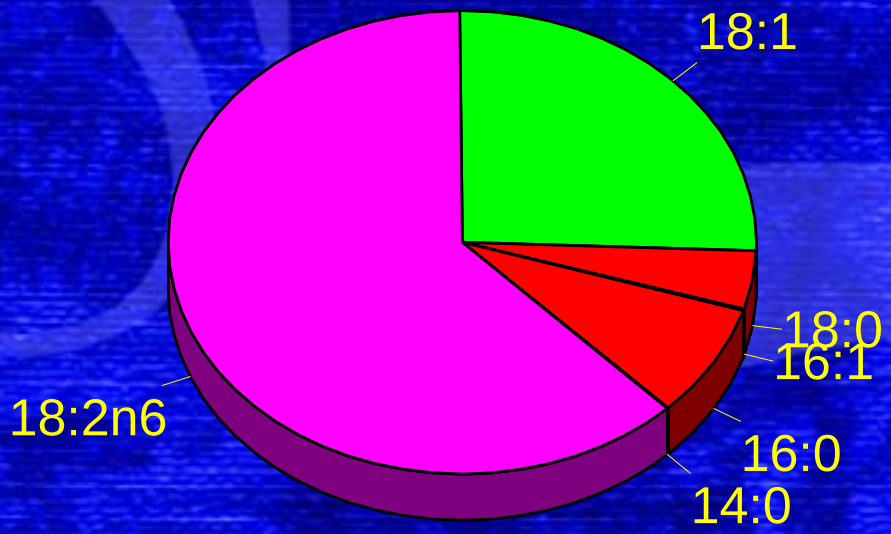
10% Cod liver oil (CLO)
10% Sunflower oil (SFO)
10% RBD palm olein (RBDPO)
10% Crude palm oil (CPO)
10% Crude palm kernel oil (CPKO)
5% CLO + 5% Palm fatty acid distillate (PFAD)

Fatty Acid Composition

Cod liver oil (CLO)

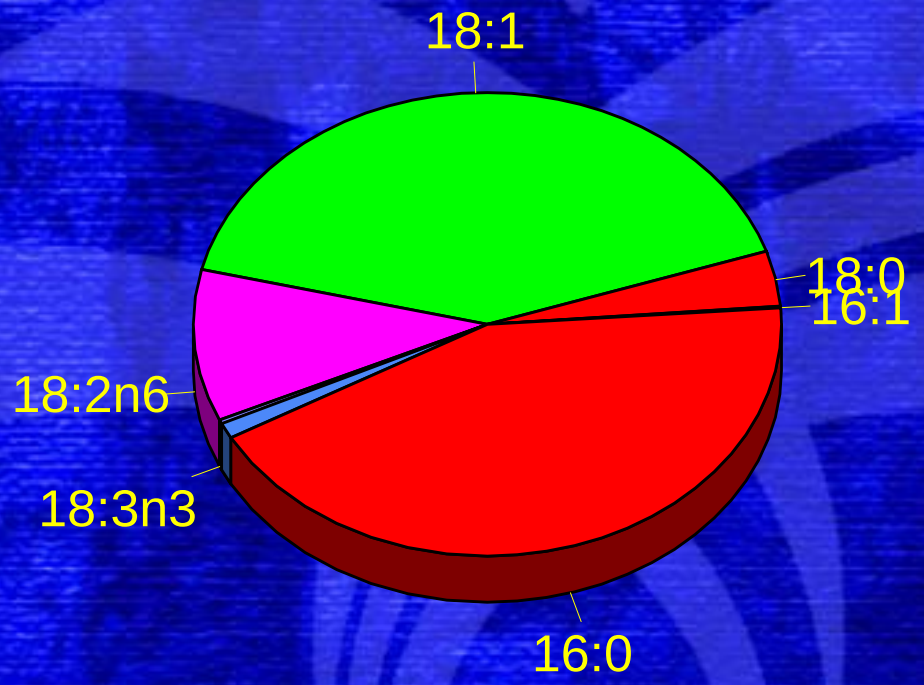


Sunflower Oil (SFO)

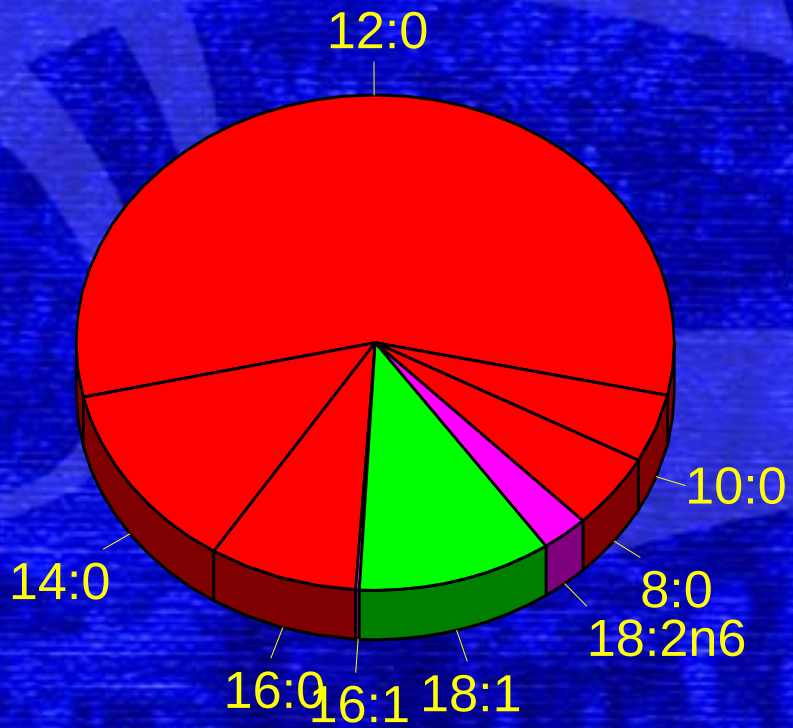


Crude Palm Oil (CPO)

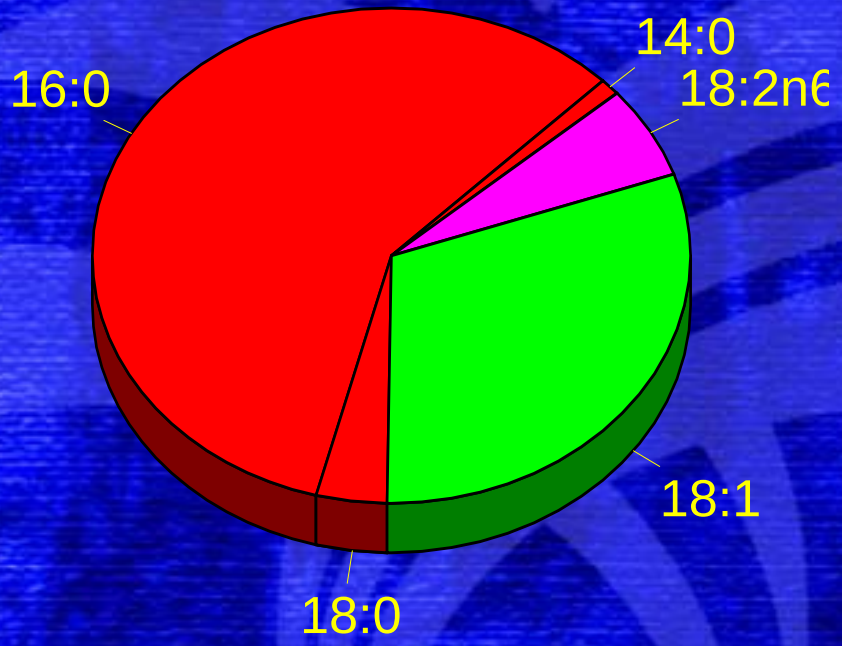
Refined Palm Olein (RBDPO)



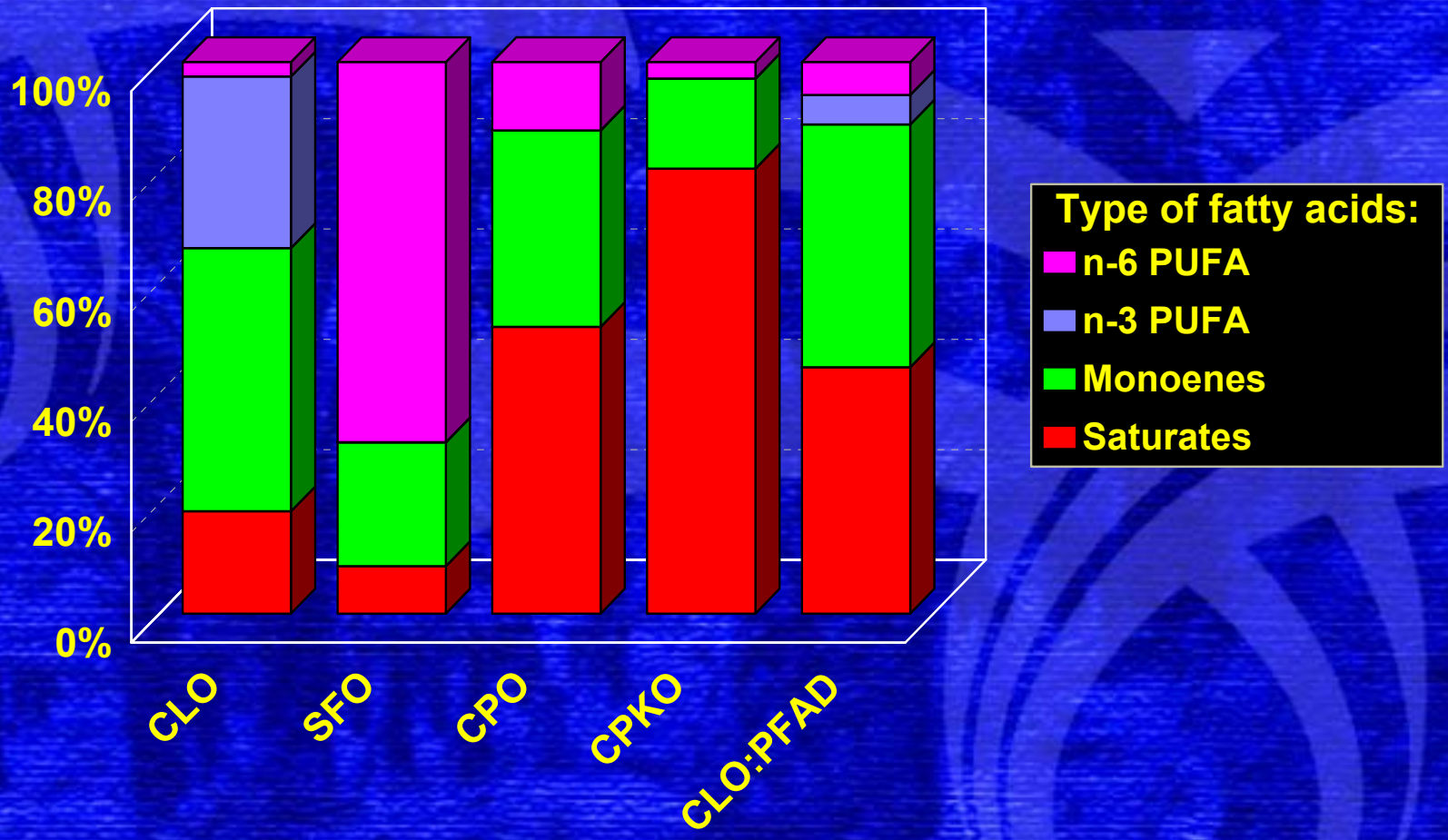
Crude Palm Kernel Oil (CPKO)



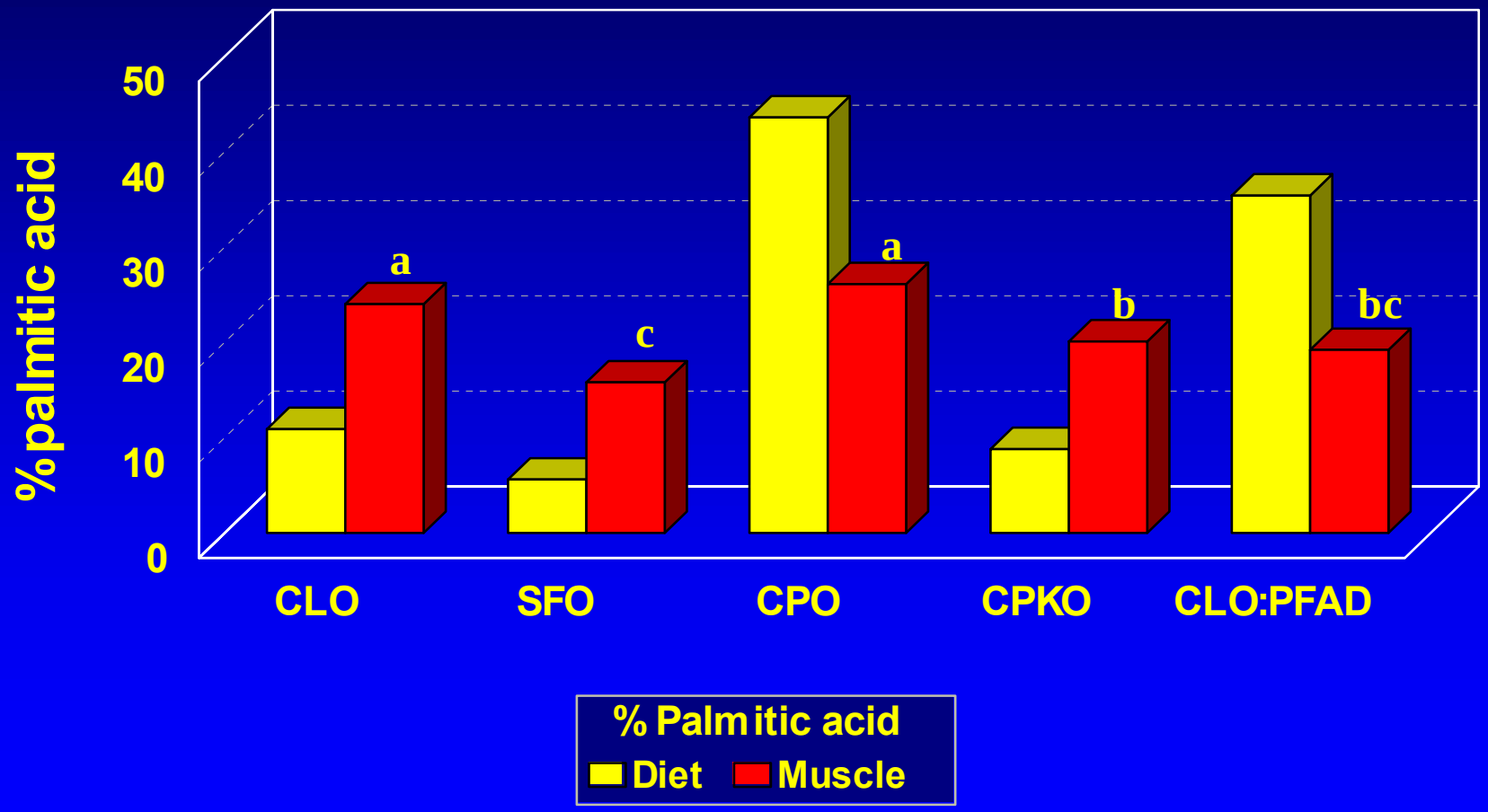
Palm Fatty Acid Distillate (PFAD)



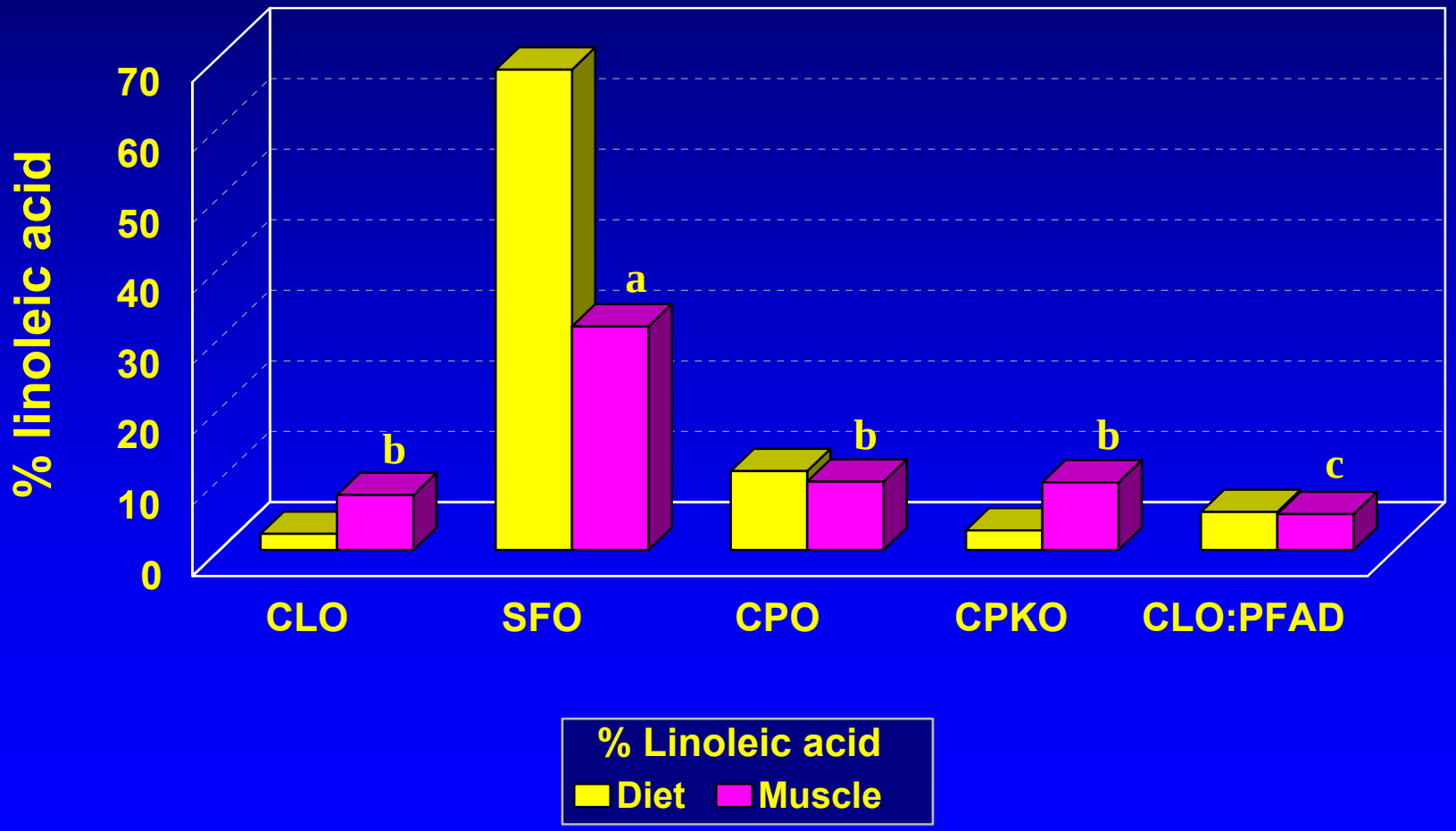
Fatty acid composition of experimental diets



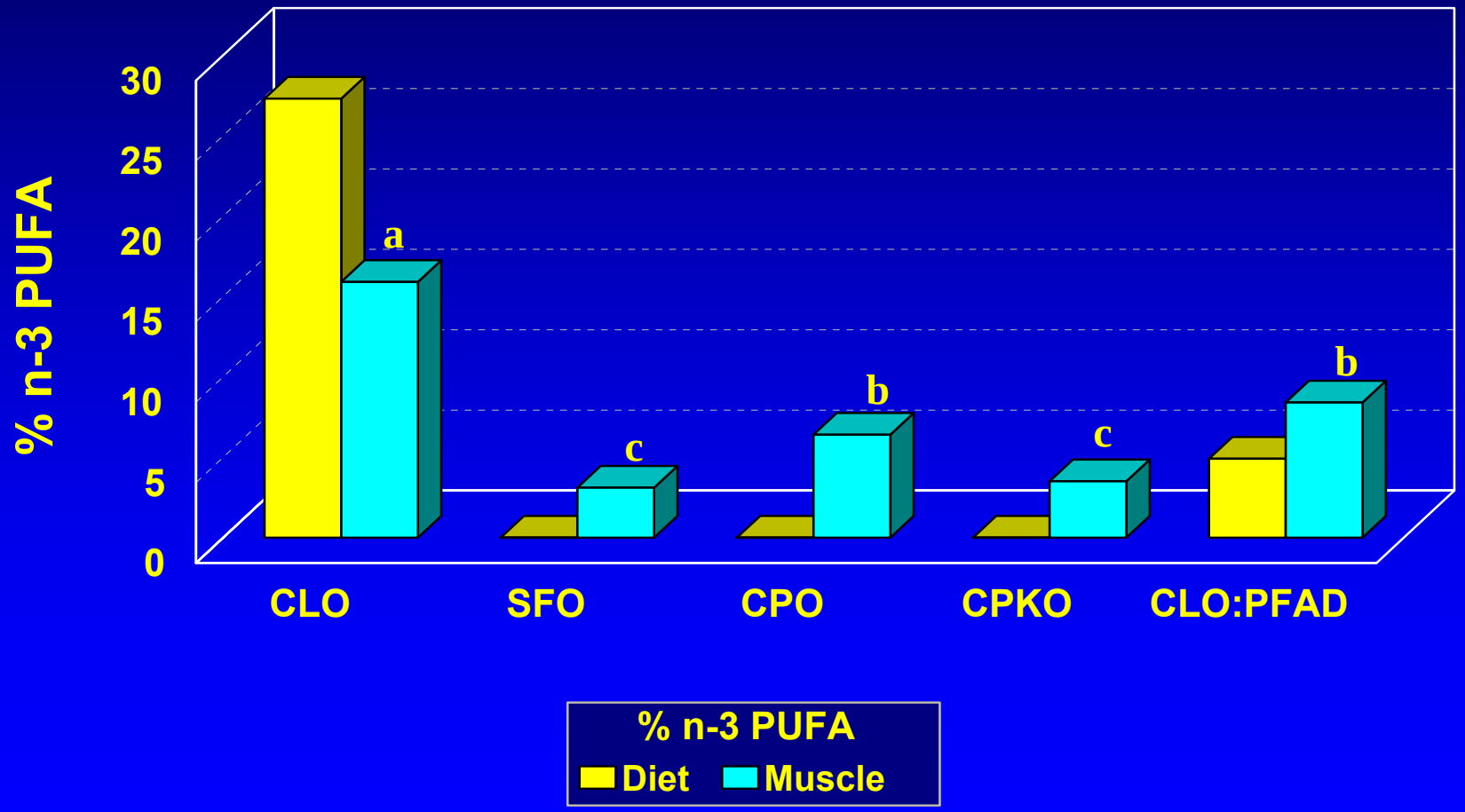
Muscle palmitic acid (16:0) content of hybrid tilapia fed various dietary lipid and palm oil source



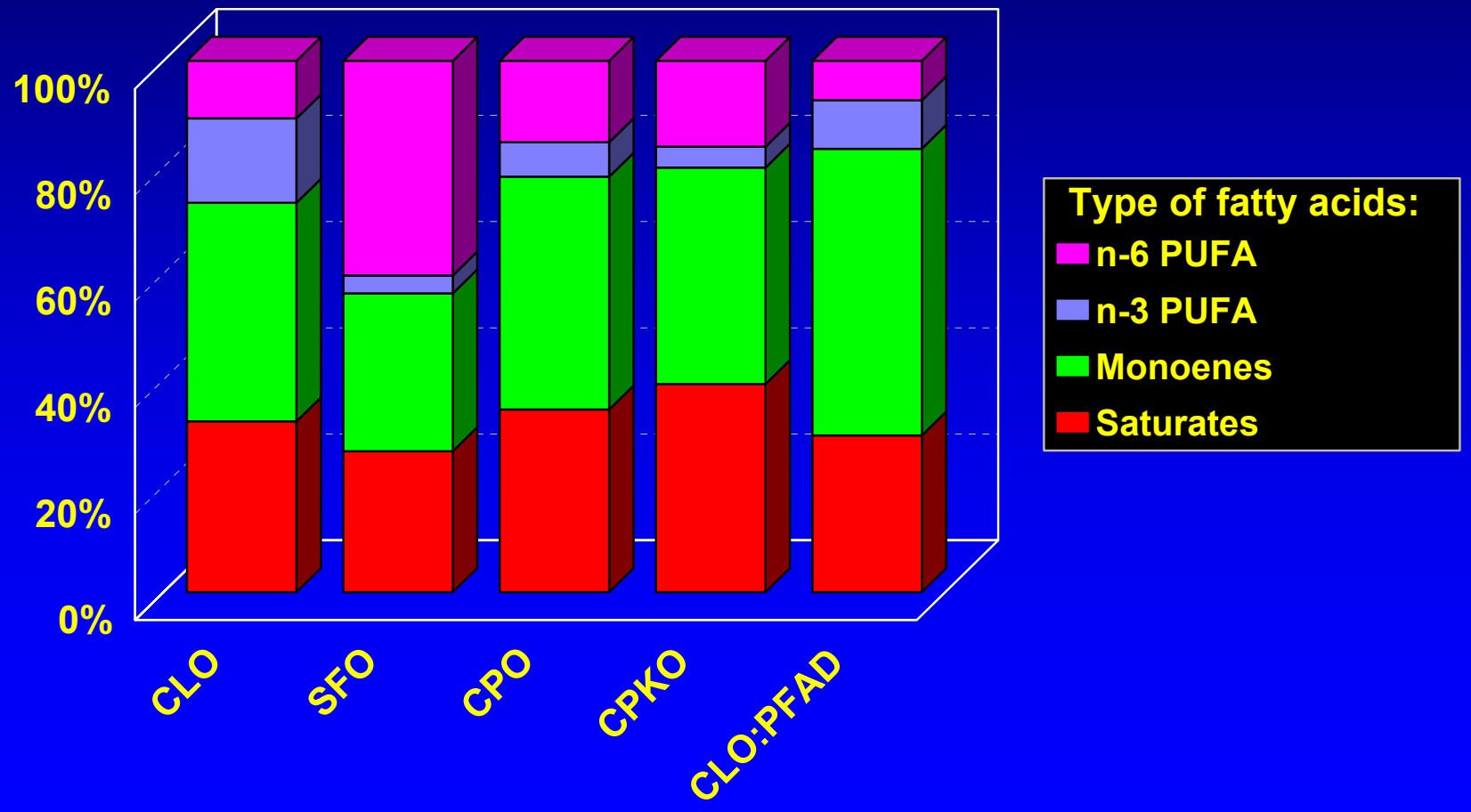
Muscle linoleic (18:2*n*-6) content of hybrid tilapia fed various dietary lipid and palm oil source



Muscle total *n*-3 PUFA content of hybrid tilapia fed various dietary lipid and palm oil source



Muscle fatty acid composition of red hybrid tilapia fed various dietary lipids



Conclusion

Feeding diets containing palm oil have NO negative effects on:

- **growth and feed utilization efficiency**
- **fillet yield and other body/organ indices**
- **fillet and body proximate composition**
- **blood indices such as hematocrits**

Positive aspects of palm oil use in tilapia feeds:

- Lower cost and sustainable production of palm oil.
- High oxidative stability thereby minimizing feed rancidity.
- Does not significantly increase lipid content in tilapia fillets.
- Does not markedly increase the saturated fatty acids in tilapia fillets.

Positive aspects of palm oil use in tilapia feeds:

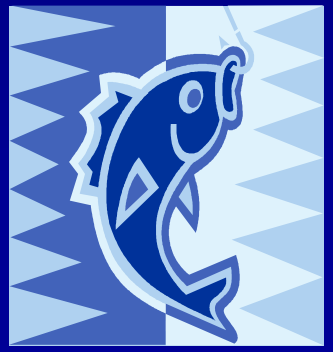
- Limits the deposition of less desirable fatty acids such as linoleic acid (18:2*n*-6)
  - human health concerns.
  - fish health concerns.
- Lower PUFA content in fish fillet minimizes lipid peroxidation of tissue.
- Possible beneficial effects of natural antioxidants in crude palm oil.

Negative aspect of palm oil use in tilapia feeds:

- The deposition of desirable fatty acids such as EPA and DHA is decreased.

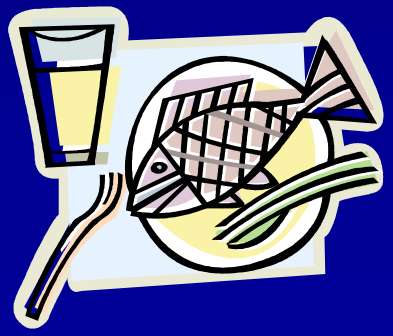
Fish Consumption, Fish Oil, Omega-3 Fatty Acids and Human Health

- There are 2 series of essential fatty acids that cannot be synthesized by animals or humans and must be supplied in the diet.
- n-6 series derived from linoleic acid (18:2n-6) and n-3 series from linolenic acid (18:3n-3).
- Two derivatives of linolenic acid are physiologically important compounds for human health:
  - EPA = eicosapentaenoic acid (20:5n-3)
  - DHA = docosahexaenoic acid (22:6n-3)
- EPA and DHA are abundant in fish oils.



Positive effects of fish and fish oils on cardiovascular diseases

- Death rates from ischemic heart disease (% of all deaths) in the United States, Denmark and Greenland are 40.4, 34.7 and 5.3, respectively (Dyerberg, 1982).
- The American Heart Association strongly endorses the use of omega-3 for cardiovascular disease prevention (AHA, 2002).
- Several countries including the World Health Organization have made formal population-based dietary recommendations:
  - 0.3-0.5 g/day of EPA + DHA
  - 0.8-1.1 g/day of linolenic acid
  - two fatty fish meals per week.

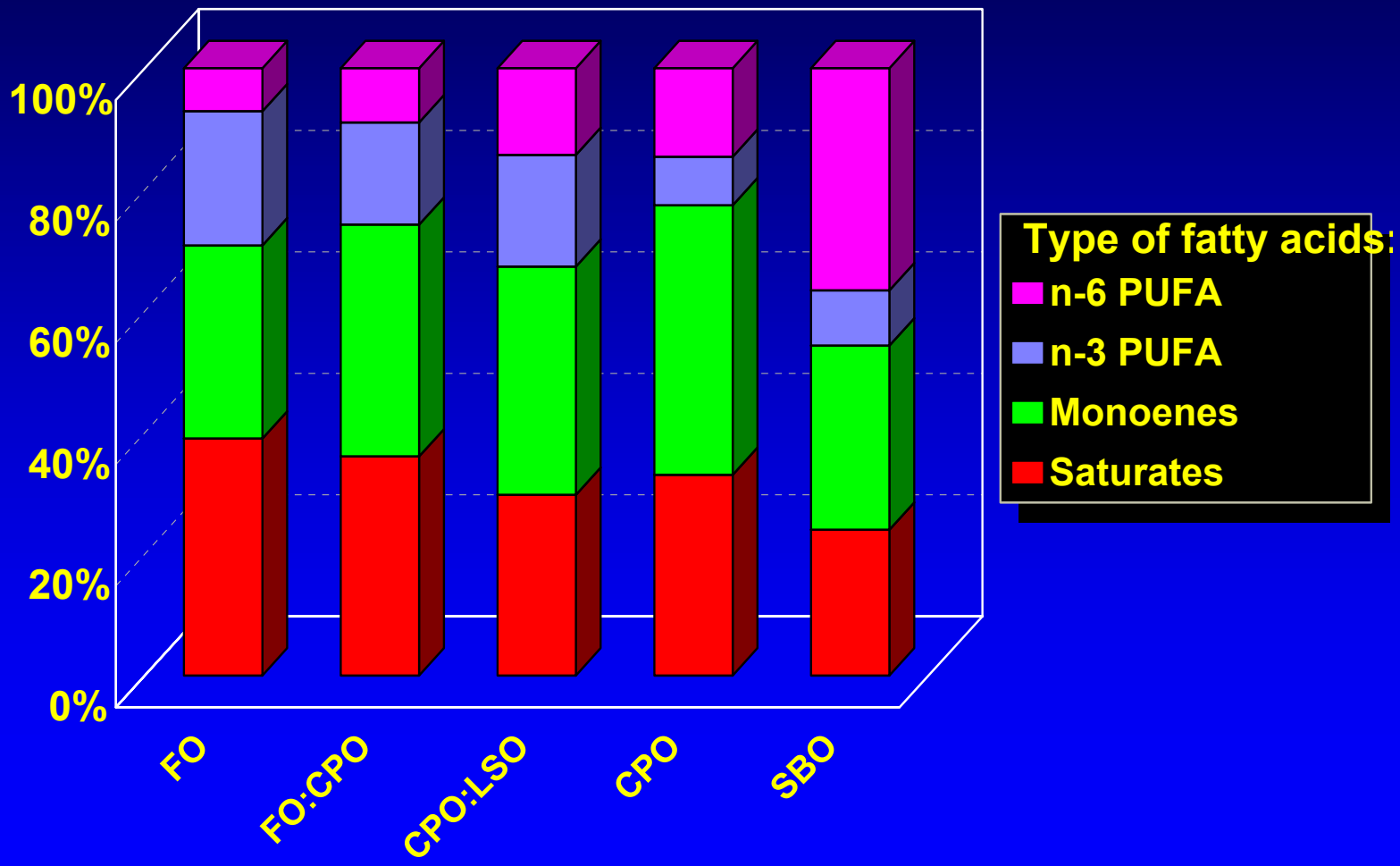


Beneficial Effects of EPA and DHA

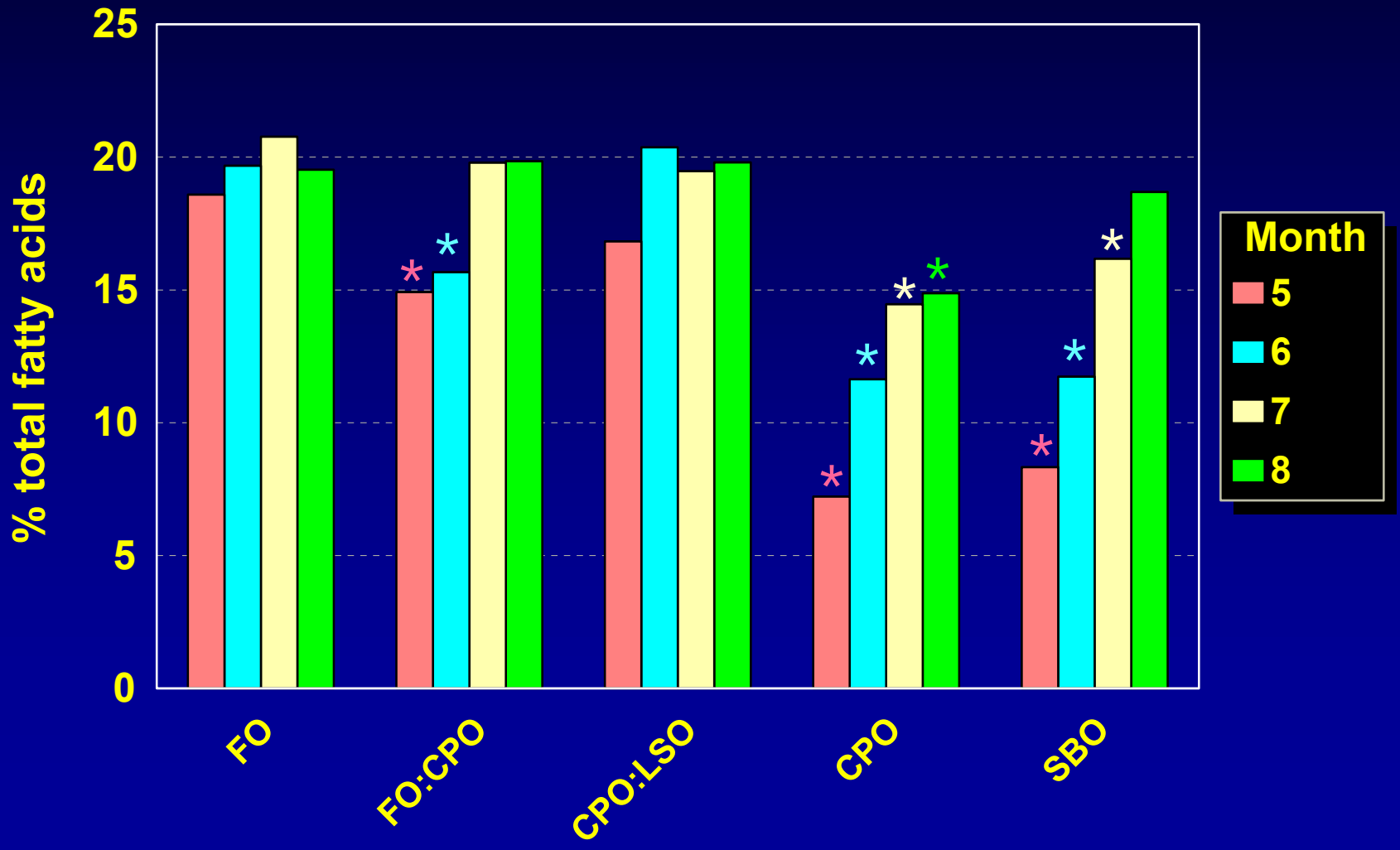
- Cardiovascular diseases
- Inflammatory diseases
- Arthritis
- Multiple sclerosis
- Cancer
- Skin diseases
- Asthma
- Normal brain functions
- Strokes
- Nephritis
- Lupus erythematosis
- Preterm birth
- Diabetes mellitus
- Improves learning ability
- Mood and behavior
- Healthy immune system

Data from various scientific sources

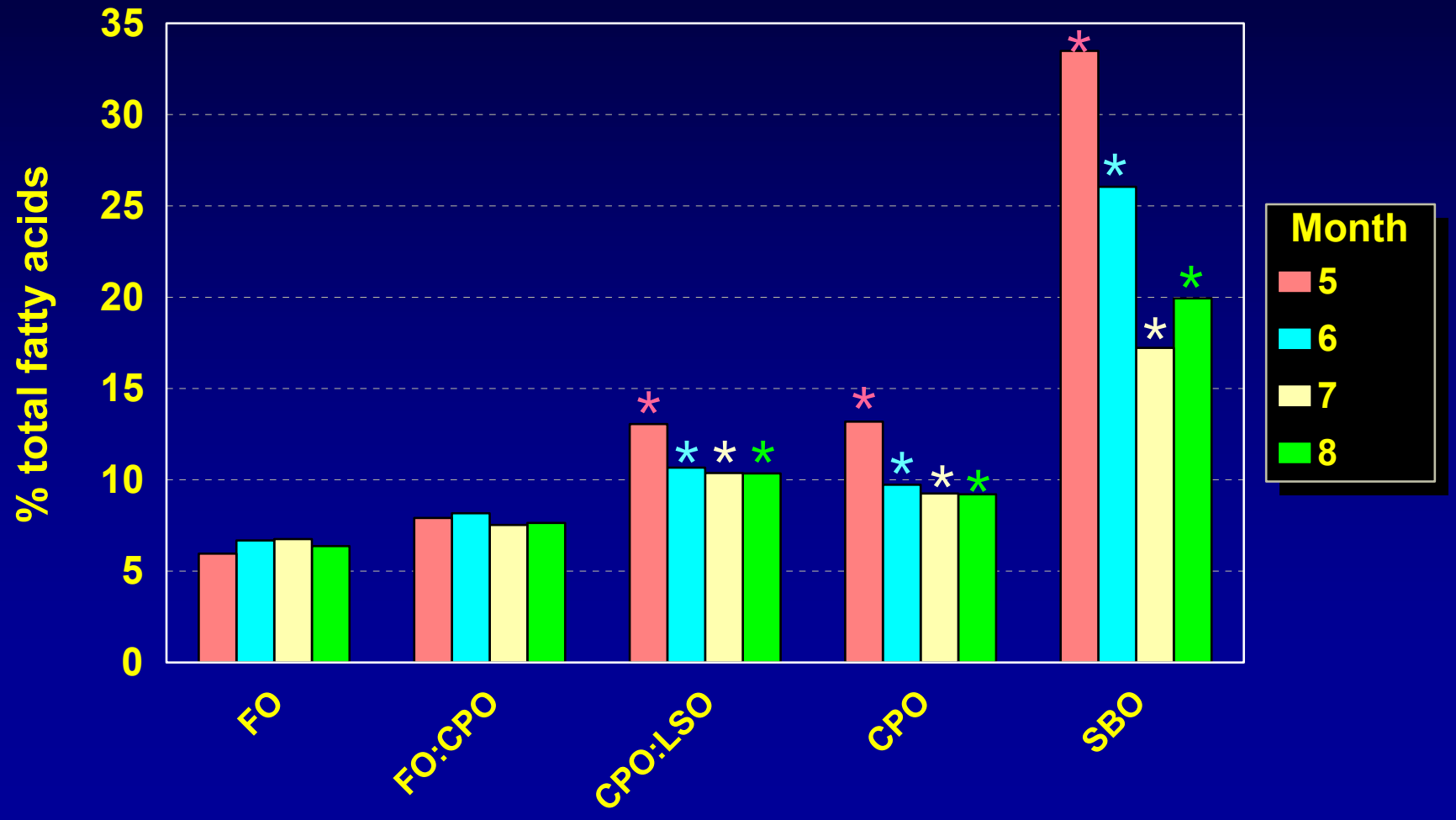
Tilapia fillet fatty acid composition after feeding diets with various oils for 5 months



Total n-3 fatty acids in tilapia fillet after reverting back to a fish oil-based diet for 3 months



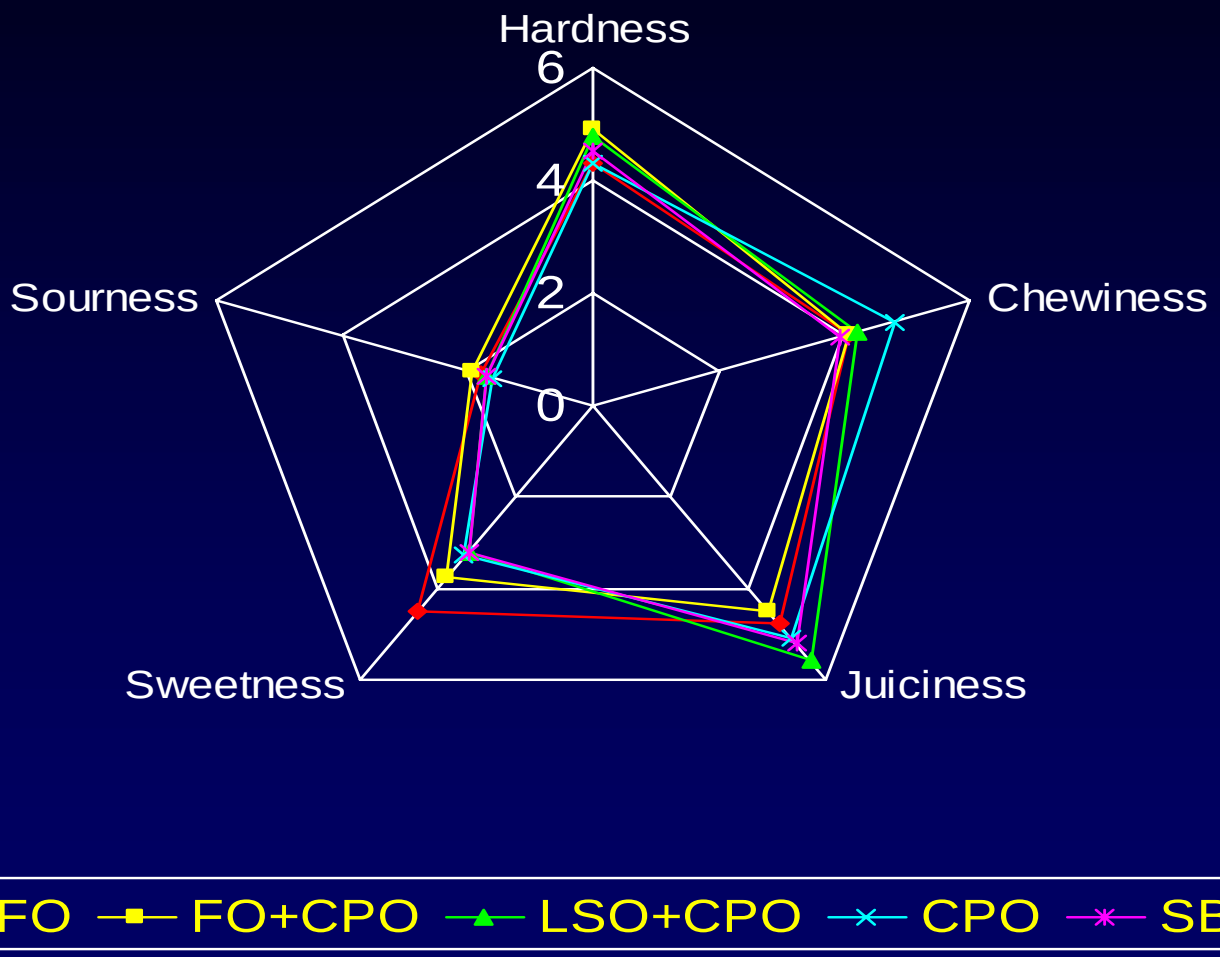
Total n-6 fatty acids in tilapia fillet after reverting back to a fish oil-based diet for 3 months



Conclusions

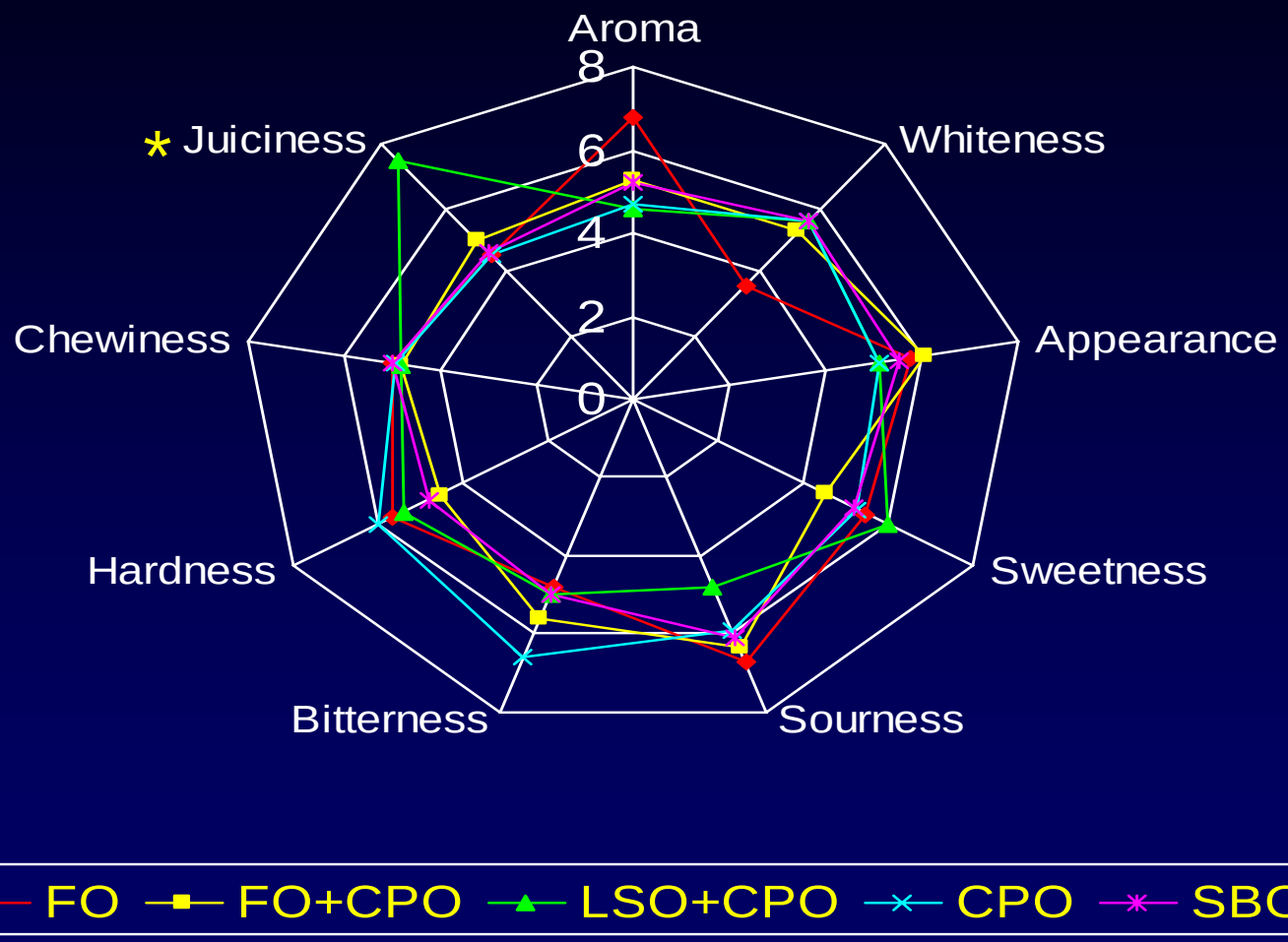
- The total omega-3 fatty acids in tilapia fillet of fish fed palm oil-based diets may be markedly increased by:
  - formulation strategies – blending with fish oil or linseed oil.
  - reverting back to a fish oil-based diet just before harvest to manipulate the fatty acid composition.
- Palm oil is a better fish oil substitute compared to soybean oil as less undesirable omega-6 fatty acids are deposited in fish fillets.

Sensory evaluation of tilapia fillets fed various dietary lipids



Based on 10 trained sensory panelists from SeaPack Food Ltd, a major seafood processing factory in Malaysia.

Sensory evaluation of tilapia fillets fed various dietary lipids and after 6 months frozen storage



Based on 6 trained sensory panelists from Fisheries Research Institute, Malaysia.

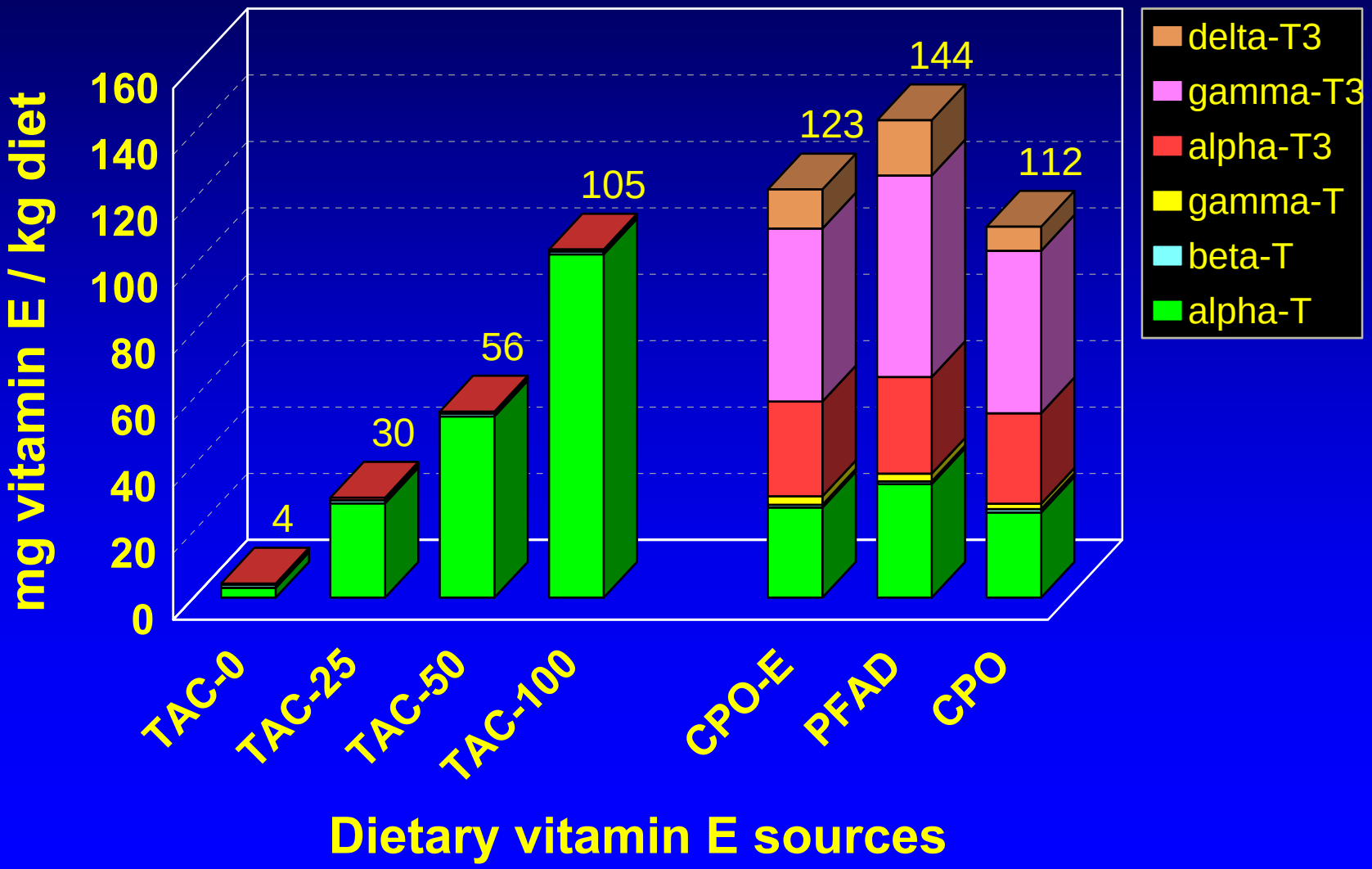
An added human health benefit of using palm oil in tilapia feeds:

- Possible beneficial effects of natural antioxidants such as vitamin E in crude palm oil when deposited in tilapia fillets.

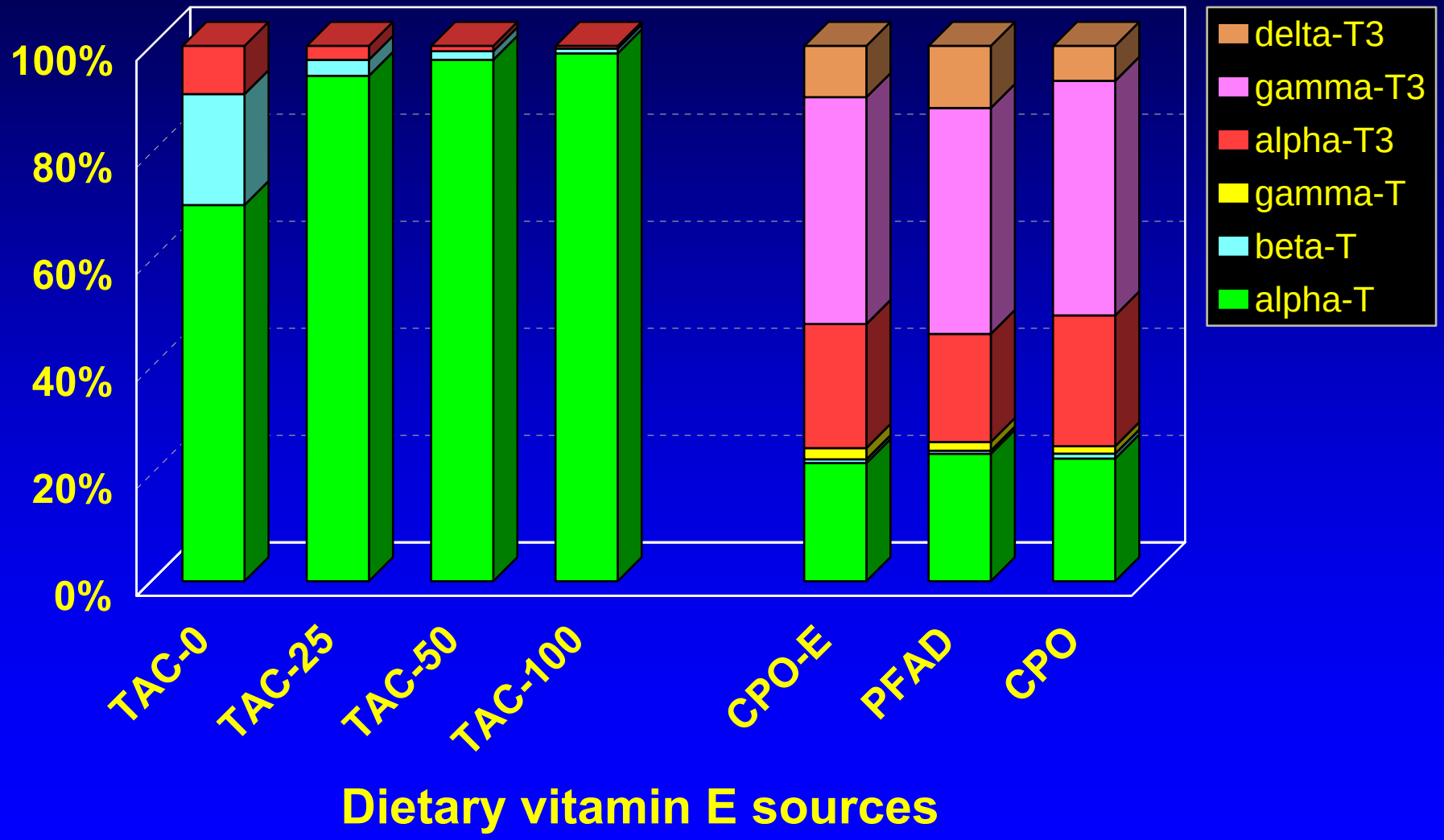
Vit. E	CLO	SFO	CPKO	CPO	PFAD
α-T	96%	88%	7%	18%	21%
β-T	-	3%	-	-	-
γ-T	4%	8%	-	2%	2%
δ-T	-	1%	-	-	-
α-T3	-	-	48%	24%	18%
β-T3	-	-	-	-	-
γ-T3	-	-	45%	46%	42%
δ-T3	-	-	-	10%	17%
Total	235	582	43	983	4054

mg/kg

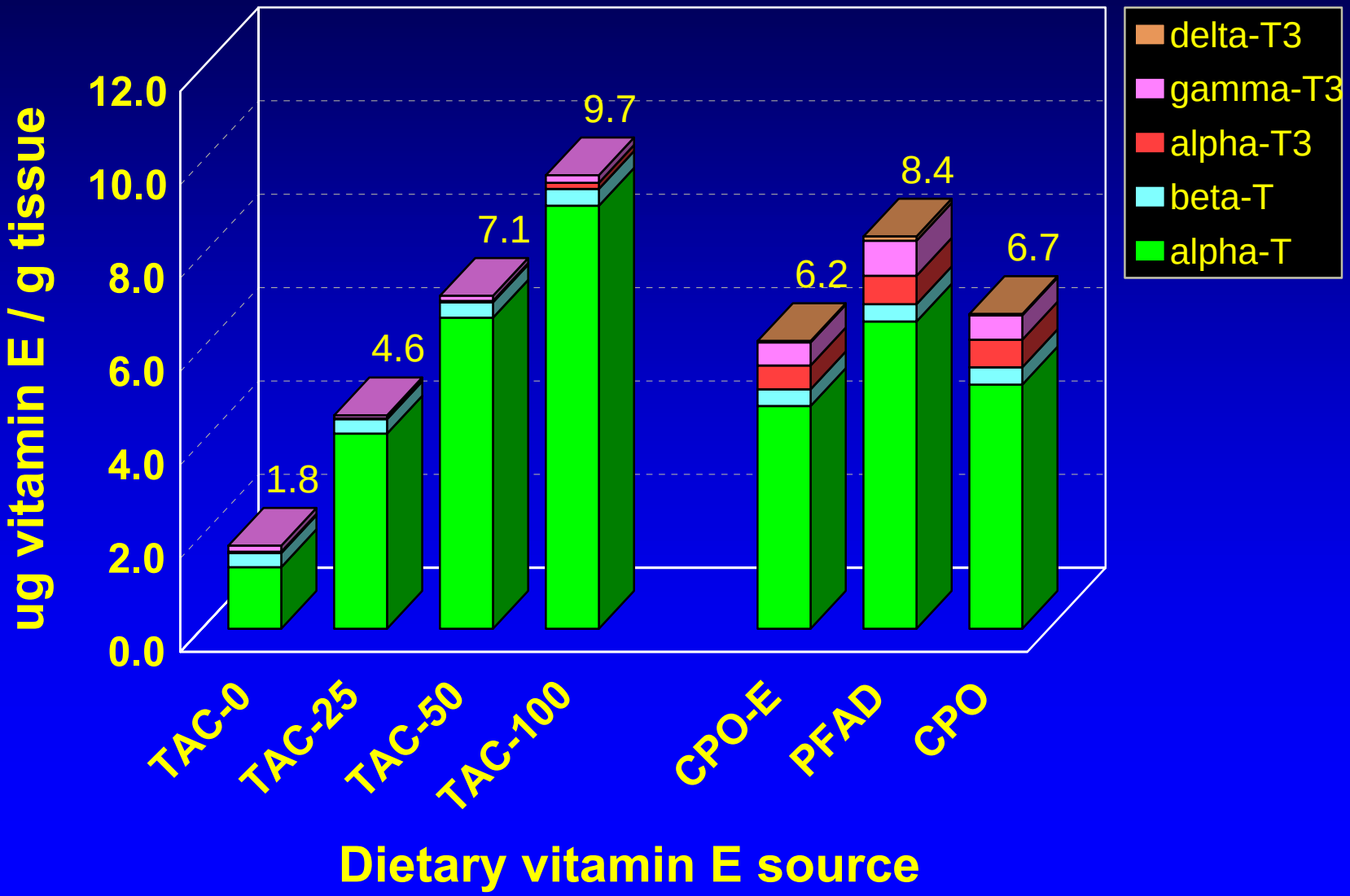
Total tocopherols and tocotrienols in experimental diets



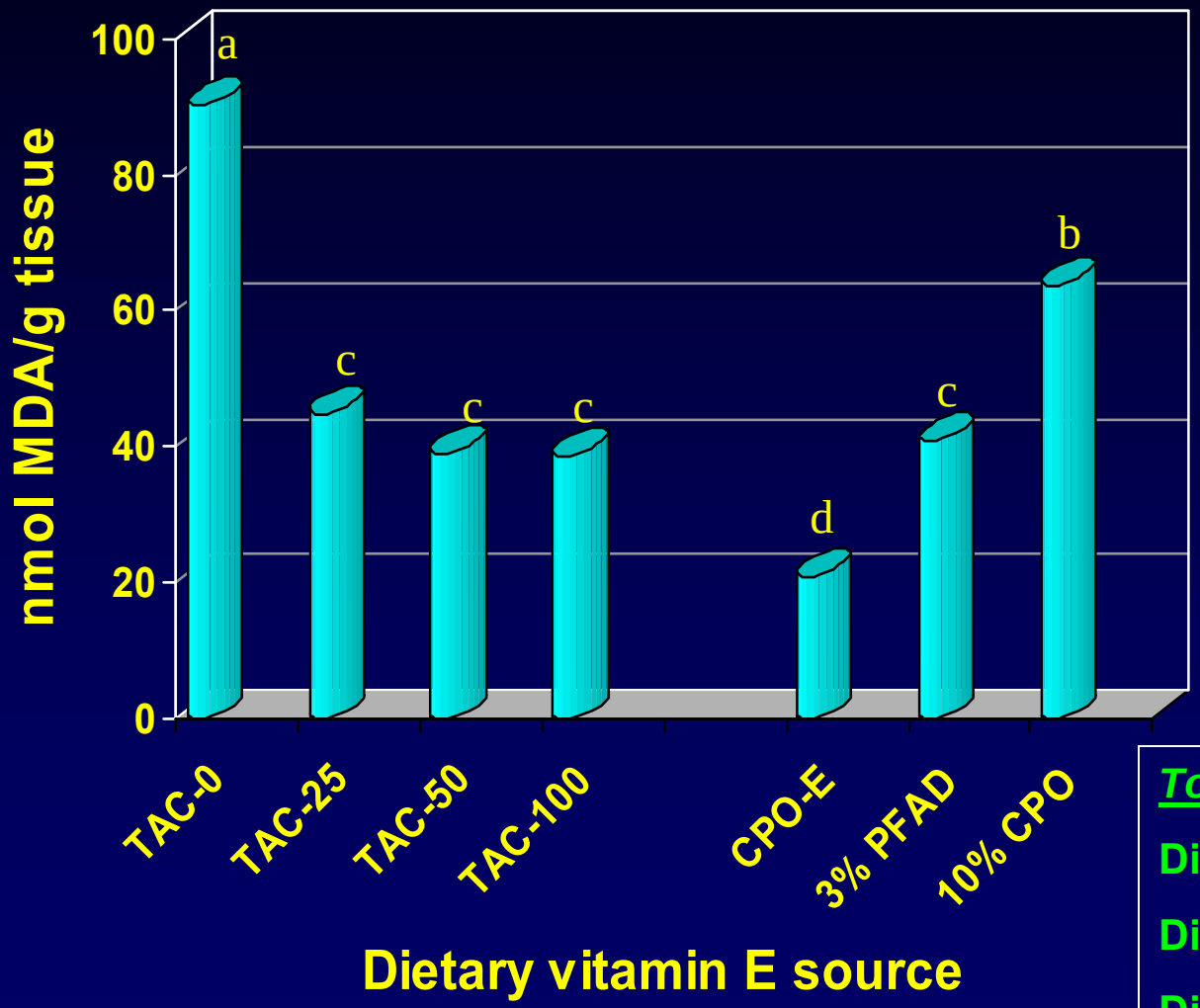
Vitamin E composition in experimental diets



Tocopherol and tocotrienol concentrations in the muscle of tilapia after 8 weeks



TBARS in muscle of tilapia fed various dietary vitamin E source



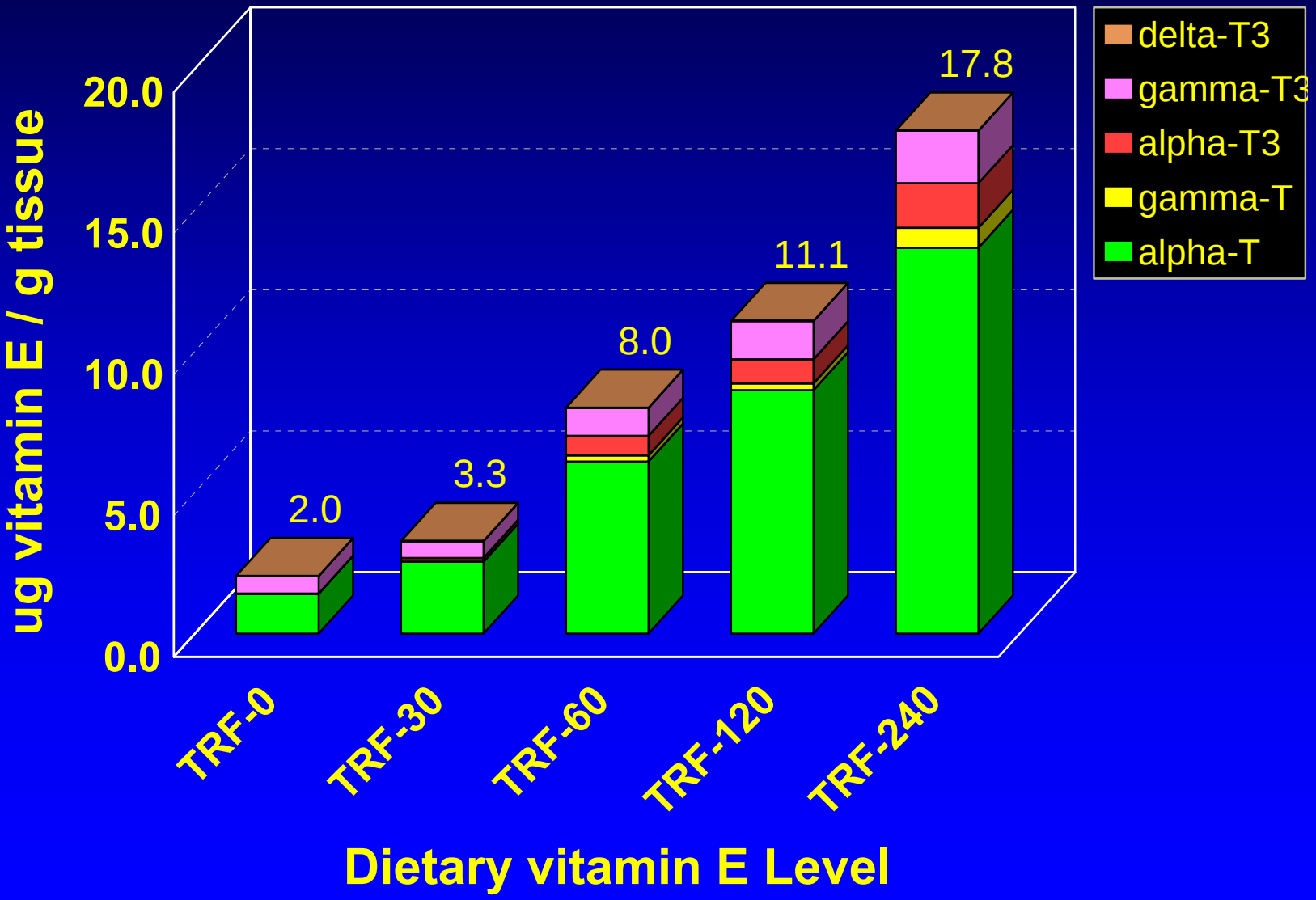
Total PUFA in muscle

Diets 1- 5 = *9.1 to 11.3 %*

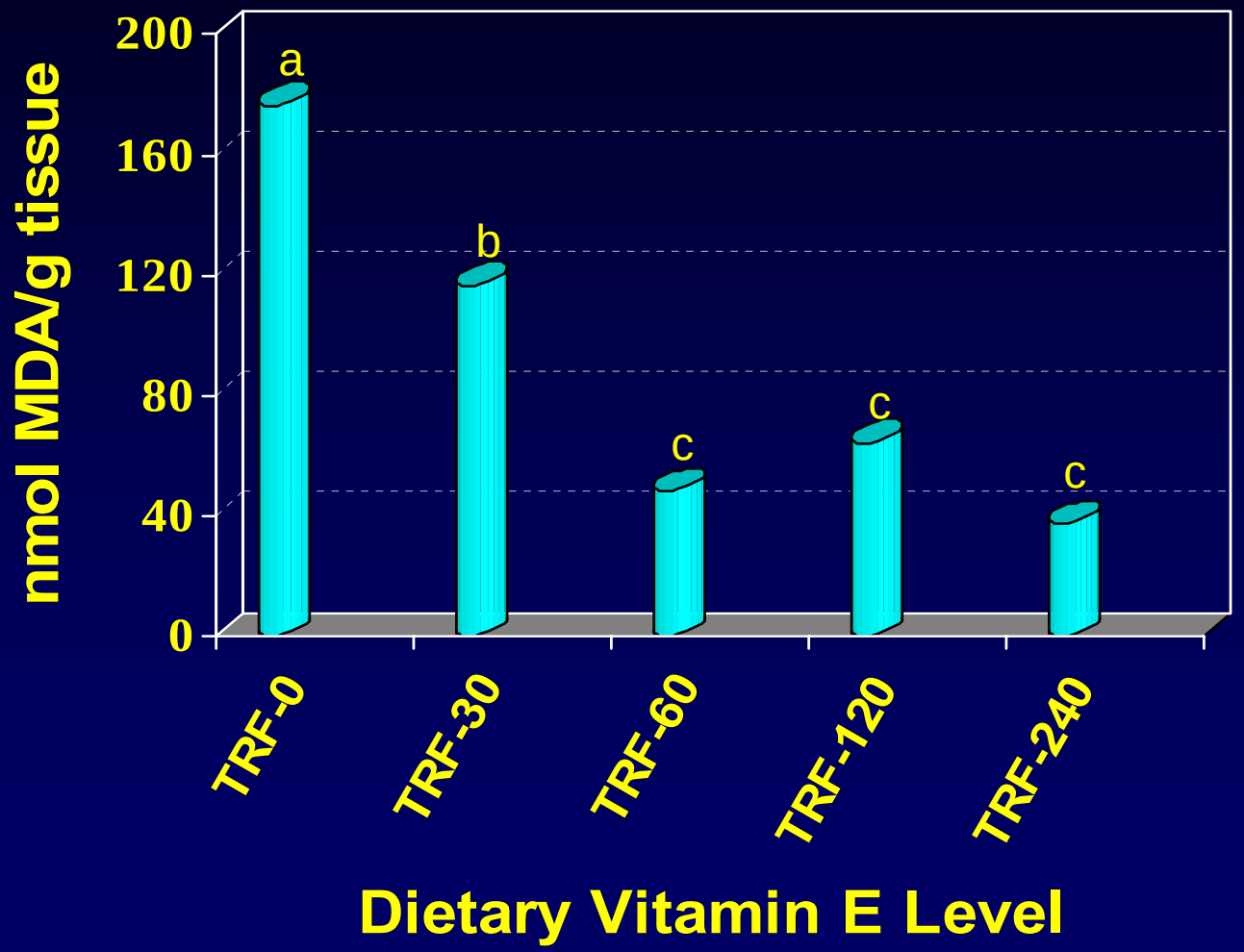
Diet 6 = *12.6 %*

Diet 7 = *17.1 %*

Accumulation of vitamin E in fillet of tilapia fed increasing levels of tocotrienol-rich fraction from palm oil for 9 weeks



TBARS in muscle of tilapia fed increasing levels of a tocotrienol rich fraction from palm oil



Conclusion

✓ Tissue concentrations of tocopherols and tocotrienols increased in response to increasing dietary concentrations.

✓ Antioxidant potency of various vitamin E sources for hybrid tilapia:

palm vitamin E > α-tocopherol acetate.

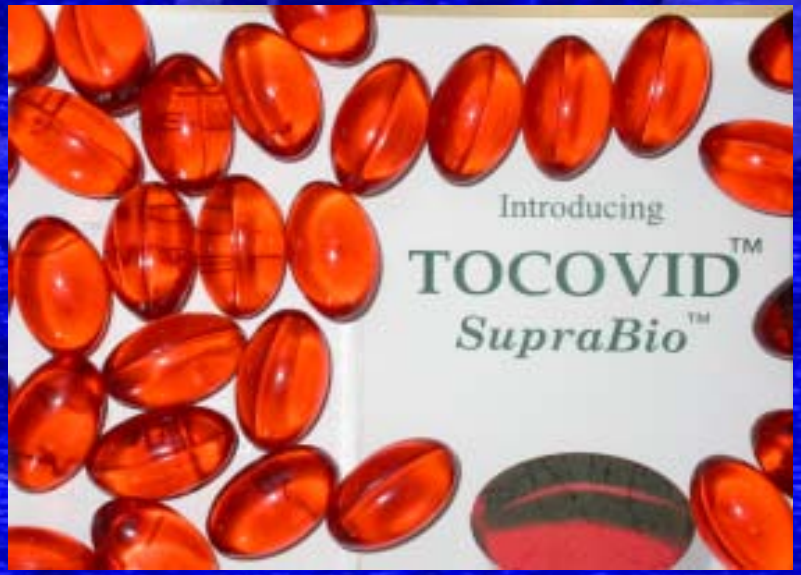
✓ Biodiscrimination mechanism (α-T transfer protein) probably exist in tilapia liver with greater affinity for α-T > α-T3 > γ-T3.

Conclusion

✓ Palm tocopherols and tocotrienols significantly improve oxidative stability of tilapia fillets that will translate to longer shelf life and freshness for seafood products.

Conclusion

✓ Deposition of tocotrienols adds value to tilapia products especially if they are eaten raw as sashimi or sushi.



Human health benefits of palm tocotrienols:

- Higher anti-oxidant potency.
- Hypocholesterolaemic effects.
- Anti-cancer properties.
- Prevention of cardiovascular diseases.

Nutritionally enhanced chicken eggs

It is not inconceivable that one day in the near future, tilapia fillets will also be labeled just like poultry eggs to advertise nutritionally enhanced seafood products at a premium price for the health-conscious consumer.

Bon Apetit !

Recipes for Malaysian White / Red Tilapia


Thank You

An overview of lipid nutrition with emphasis on alternative lipid sources in tilapia feeds

Wing-Keong Ng & Cheong-Yew Chong

Fish Nutrition Laboratory
School of Biological Sciences
Universiti Sains Malaysia
Penang, Malaysia