REVIEW OF BIOFLOC TECHNOLOGY OPTIONS FOR SHRIMP CULTURE: BENEFITS, BURDENS, AND NUTRITIONAL CONSIDERATIONS

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What are bioflocs?

- Bioflocs are a conglomerates of
  - Bacteria
  - Protozoa
  - Filamentous organisms
  - Algae
  - Multivalent cations
  - Exocellular polymers (ECP)
    - Polysaccharides
    - Proteins
  - Uneaten feed
  - Feces
  - Etc.

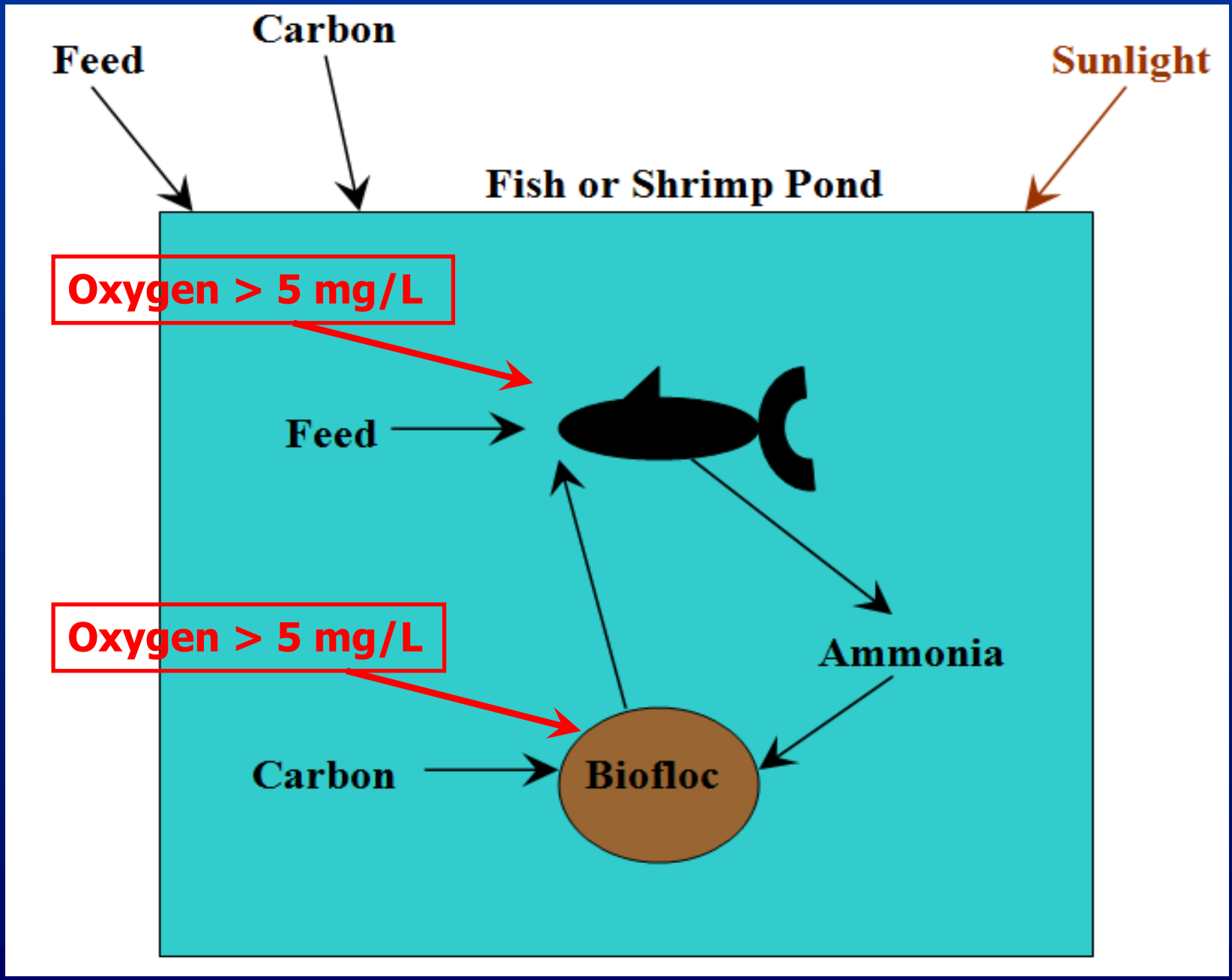
Biofloc Technology

- Bioflocs
  - Remove dissolved nutrients (e.g. nitrogen) from the water
  - Convert dissolved nutrients into bacteria protein
  - Serve as a food source for aquacultured animals

Types of Biofloc Technology

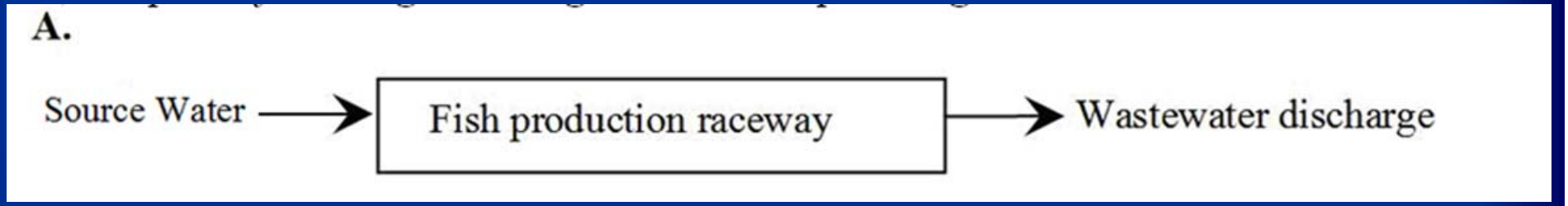
- In-situ biofloc technology
  - Bioflocs are produced in-situ (in water with animals)
  - Carbon source is often added to increase C:N
- Ex-situ biofloc technology
  - Bioflocs are produced ex-situ (externally in bioreactors)
  - Carbon source not necessarily required

In-situ Biofloc Technology

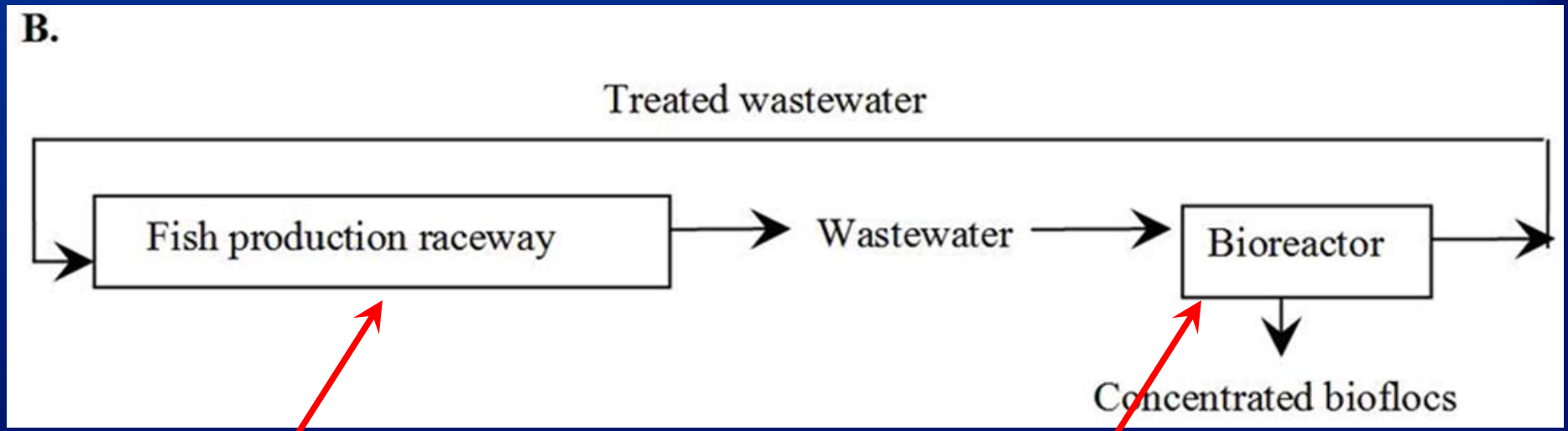


Ex-situ Biofloc Technology

Traditional culture (with nitrification)



Traditional culture w ex-situ biofloc technology



Oxygen > 5 mg/L

Oxygen ≤ 1 mg/L

Ex-situ Biofloc Technology

In fish or shrimp culture system/pond

$$Ammonia + Carbon \xrightarrow{DirectAssimilation} Bioflocs$$

Benefit

In-situ Biofloc Technology

In fish or shrimp culture system

$$Ammonia \xrightarrow{Nitrosomonas} Nitrite \xrightarrow{Nitrobacter} Nitrate$$

In bioreactor

$$Nitrate \xrightarrow{Denitrification} Nitrogen\ Gas$$

Other Advantages and Disadvantages

	In-situ Bioflocs	Ex-situ Bioflocs	Comments
Oxygen Demand	1 to 2	3	In-situ: Bioflocs have a high oxygen demand
			Ex-situ: Bioflocs oxygen demand is external to culture system/pond
Nutrient removal	3	2	In-situ: Directly assimilates ammonia
			Ex-situ: Nitrification and denitrification cycles required
Protein Benefits	1 to 3	3	In-situ: Bioflocs may be high or low in protein, difficult to control
			Ex-situ: Can control biofloc protein content to be consistently high
Fat Benefits	1 to 3	1	In-situ: Bioflocs may be high or low in fats, difficult to control
			Ex-situ: Typically bioflocs are very low in fats
Probiotic Benefits	3	3	In-situ: Good chance bioflocs will have probiotic properties
			Ex-situ: Good chance bioflocs will have probiotic properties

	In-situ Bioflocs	Ex-situ Bioflocs	Comments
Delivery of Biofloc as a Feed	3	1 to 2	In-situ: Bioflocs are mixed with culture species
			Ex-situ: Need to move or process bioflocs to get it to culture species
Controlling How Much Biofloc is Fed	2	3	In-situ: Some control on biofloc levels in system but not how much is consumed
			Ex-situ: Control level on how much biofloc is fed is similar to typical feed
Minimizing Risks - "Bad" Microorganisms	2	3	In-situ: May propagate "bad" microorganisms in water with cultured animals
			Ex-situ: May propagate "bad" microorganisms in bioreactor, external to cultured animals
Minimizing Risks - Culture Crash	2 to 3	3	In-situ: Some instability with biofloc production and consequently water chemistry
			Ex-situ: Issues would be external to cultured animals
Capital Expense	3	1 to 3	In-situ: Inexpensive
			Ex-situ: Can be expensive
Ease of Implementation	2 to 3	1 to 2	In-situ: Easy to implement and some training required
			Ex-situ: Additional equipment and training required

Bioreactor

Controlled system that supports a biologically active environment

Sequencing batch reactors (SBRs)

a suspended growth biological process

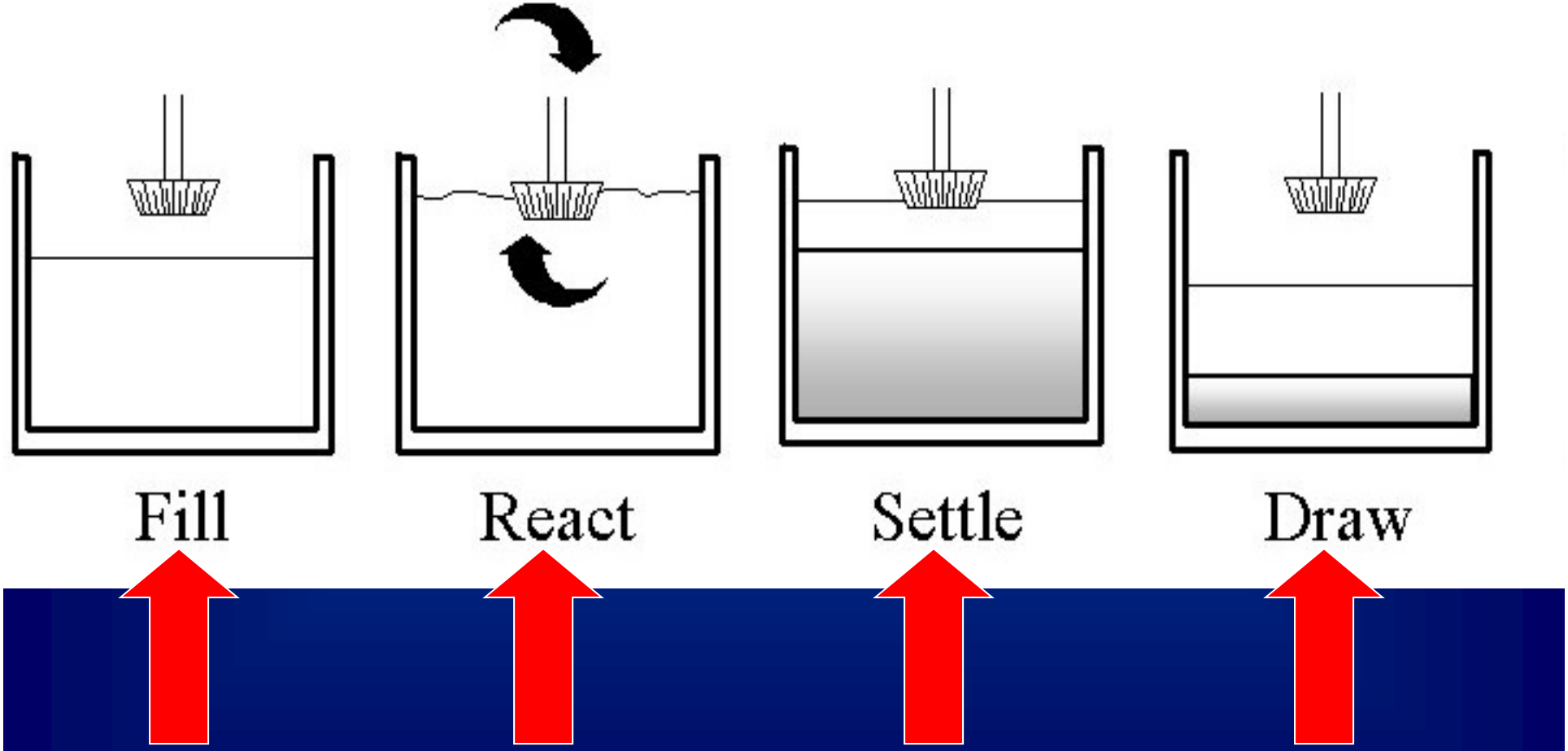
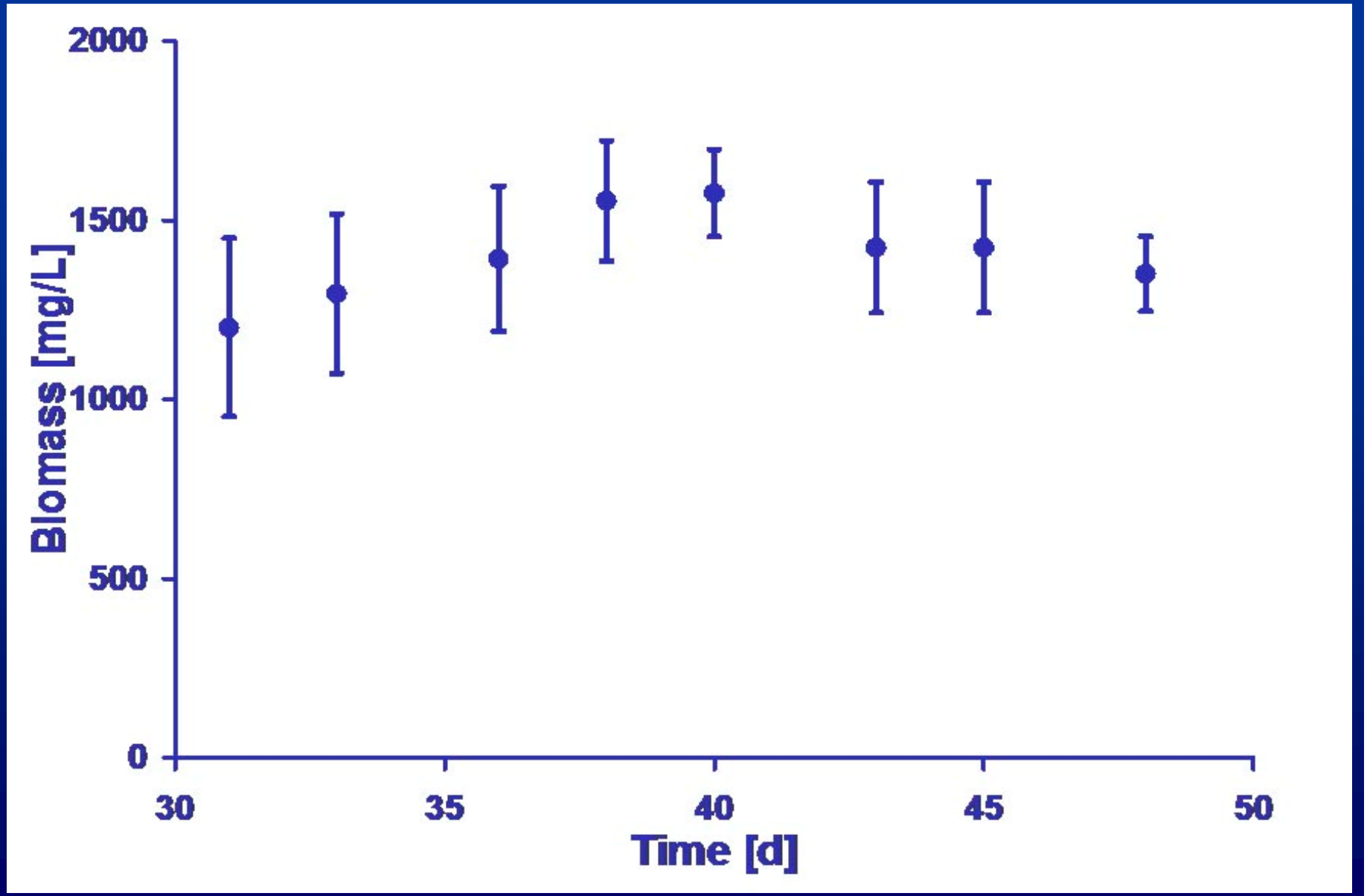


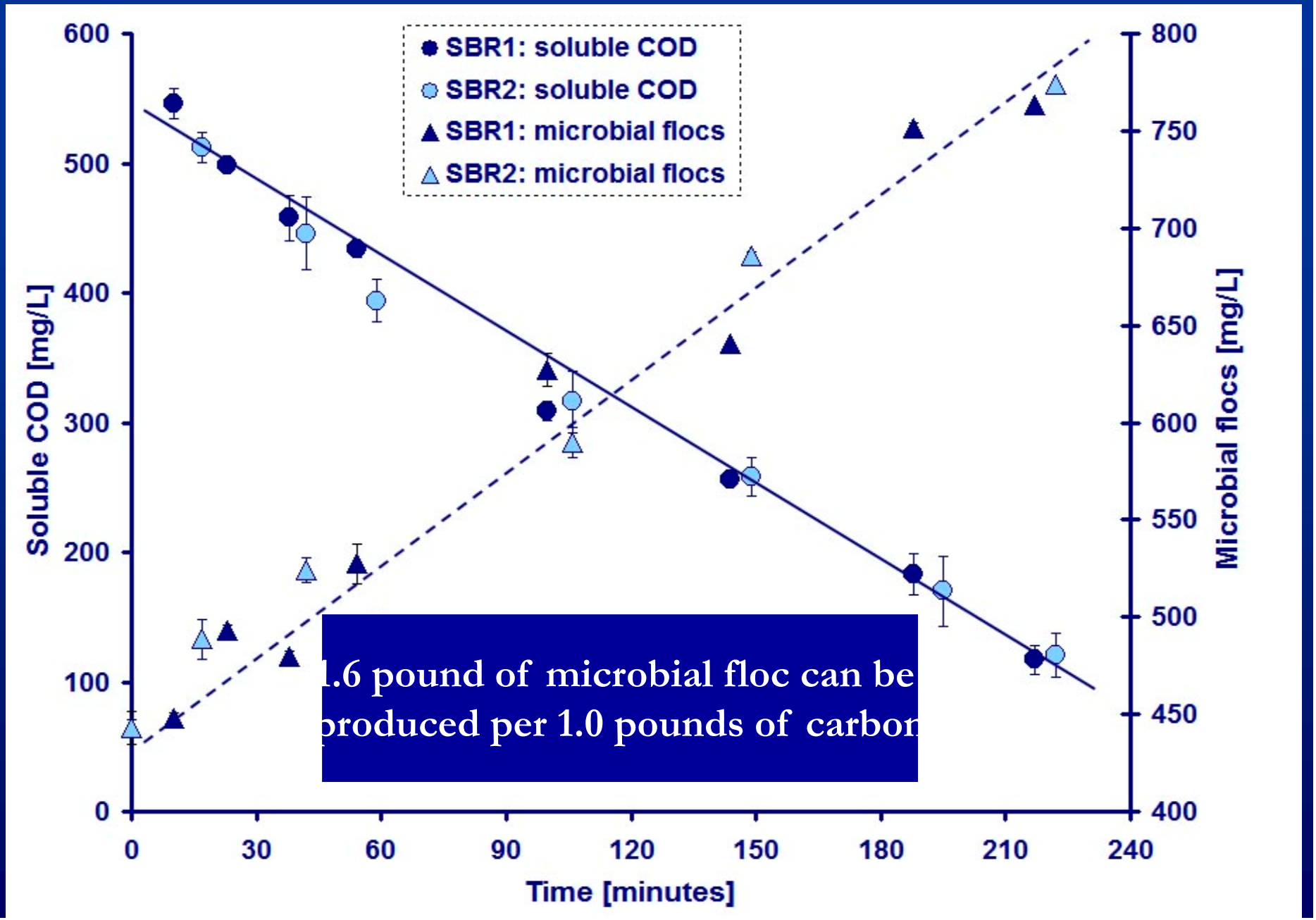
Photo source: http://www.lifesciences.napier.ac.uk/

Three pilot-scale SBRs (5,600 L) onsite at VSF

Representative data set demonstrating stable biomass concentrations in SBRs operated in triplicate

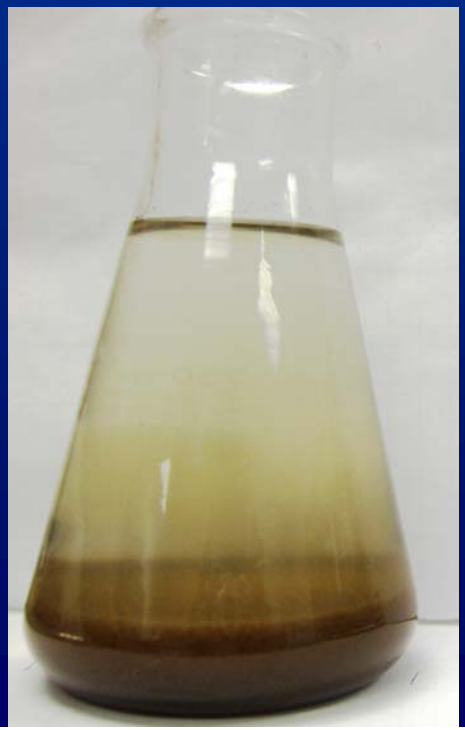


Microbial floc generation as soluble COD is removed



Typical removal rates for SBR vs MBR

Reactor Type	Removal rates			
	Ammonia	Nitrite	Nitrate	Suspended solids
SBR	> 90%	> 90%	0 - 90%	> 95%
MBR	> 90%	> 90%	> 90%	> 99%



Bioreactor Operations

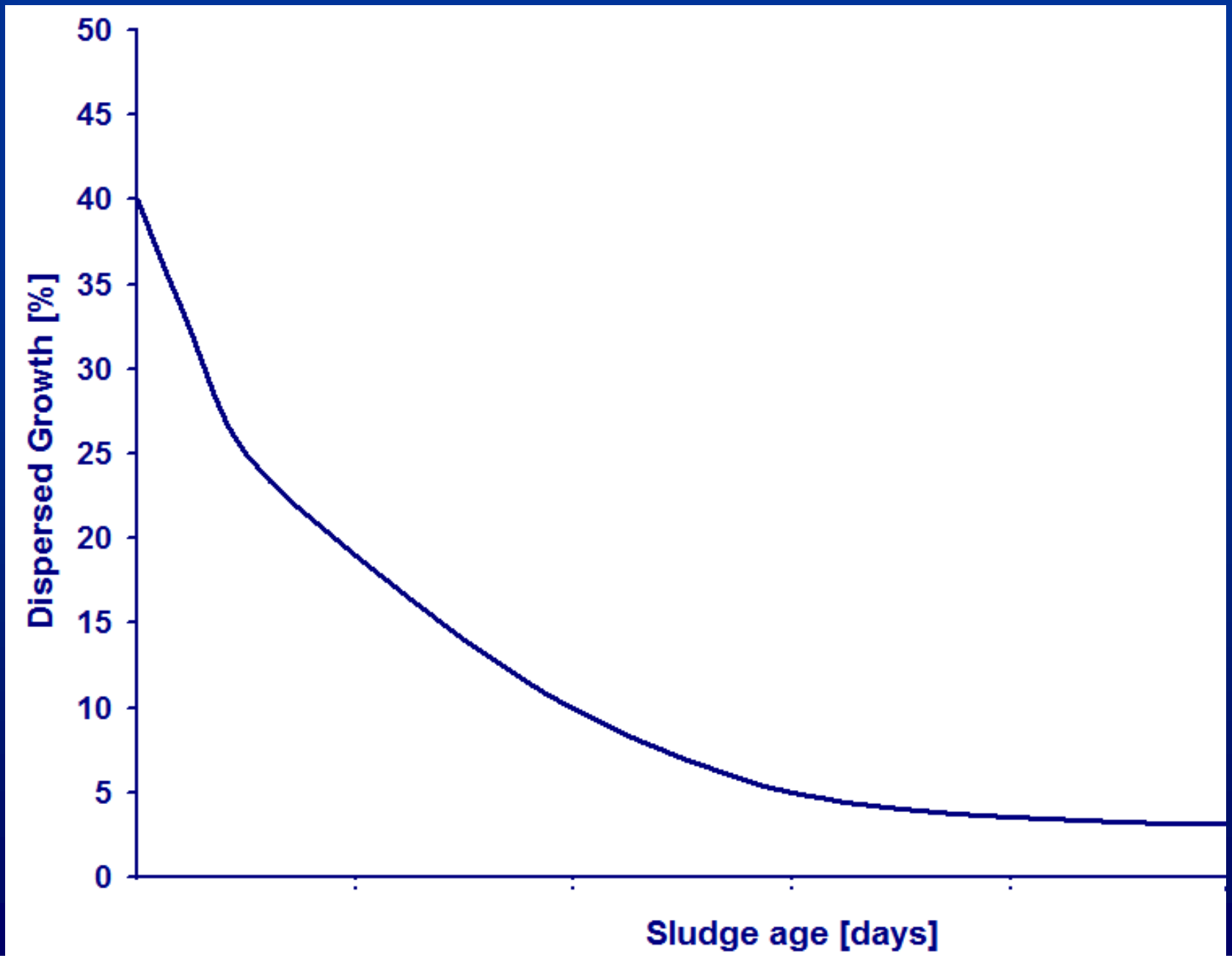
Manipulation of treatability and nutritional properties of bioflocs

- Reactor types
  - SBR
  - MBR
  - CSTR
  - Plug flow
  - etc...
- Supplementation
  - Carbon
  - Acid or bases
  - Flocculants
  - Ions
  - etc...

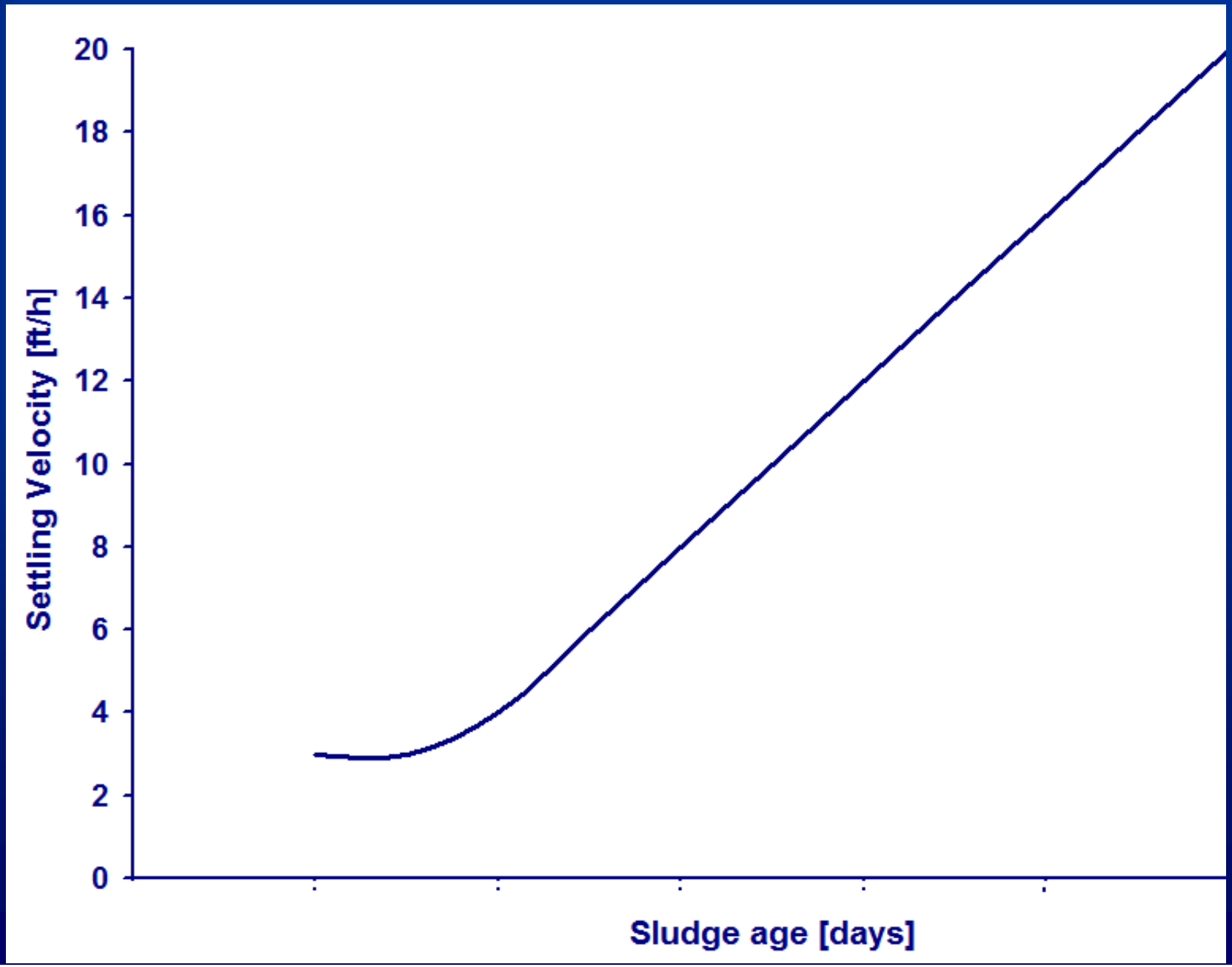
Others

- Mixing rates
- Loading rates
- Food: Microorganism
- Temperature
- Oxygen levels
- pH
- Nutrients
- Micronutrients
- Recycle ratios
- Hydraulic residence time
- Sludge residence time
- etc...

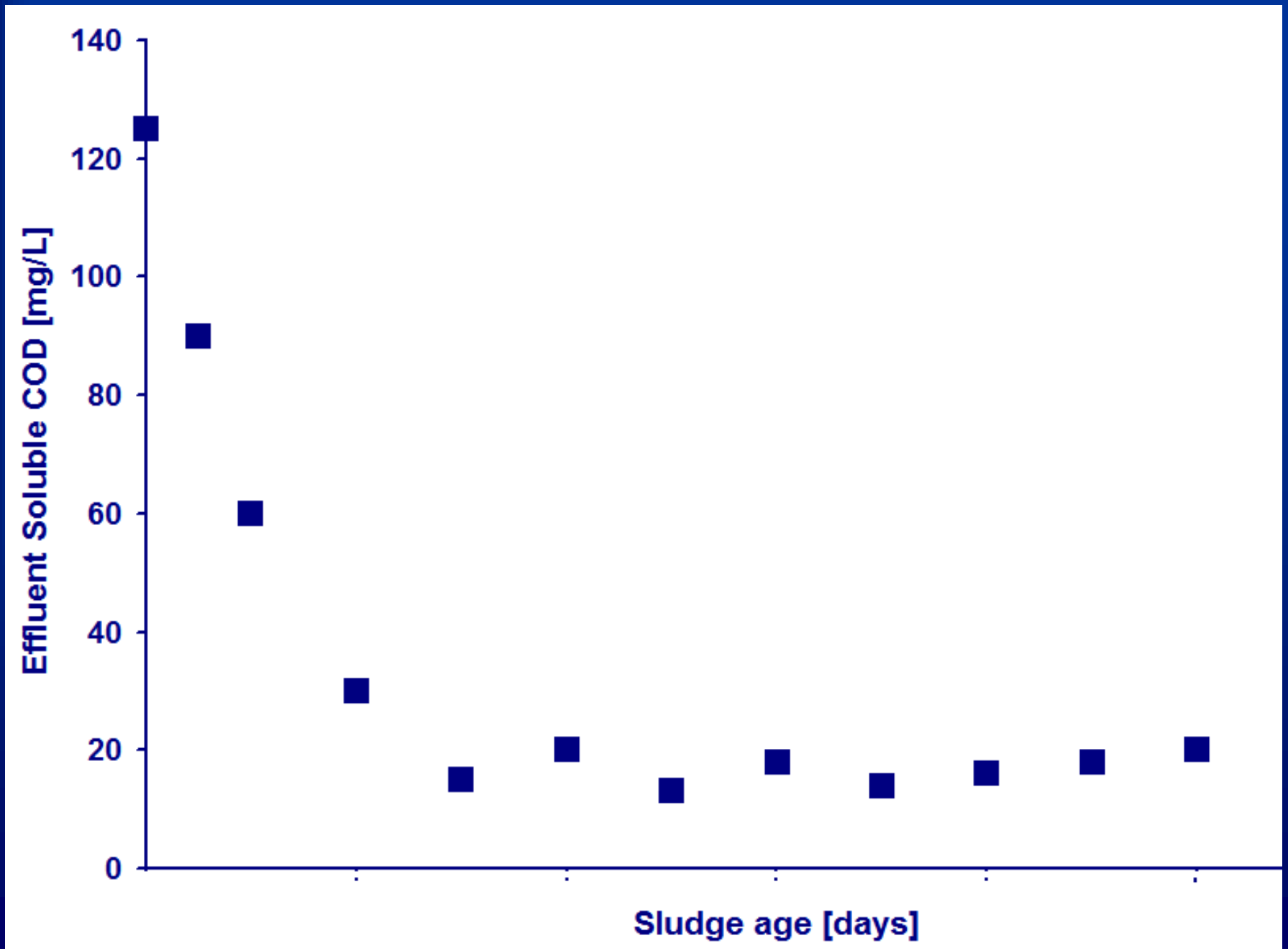
Percent pin flocs



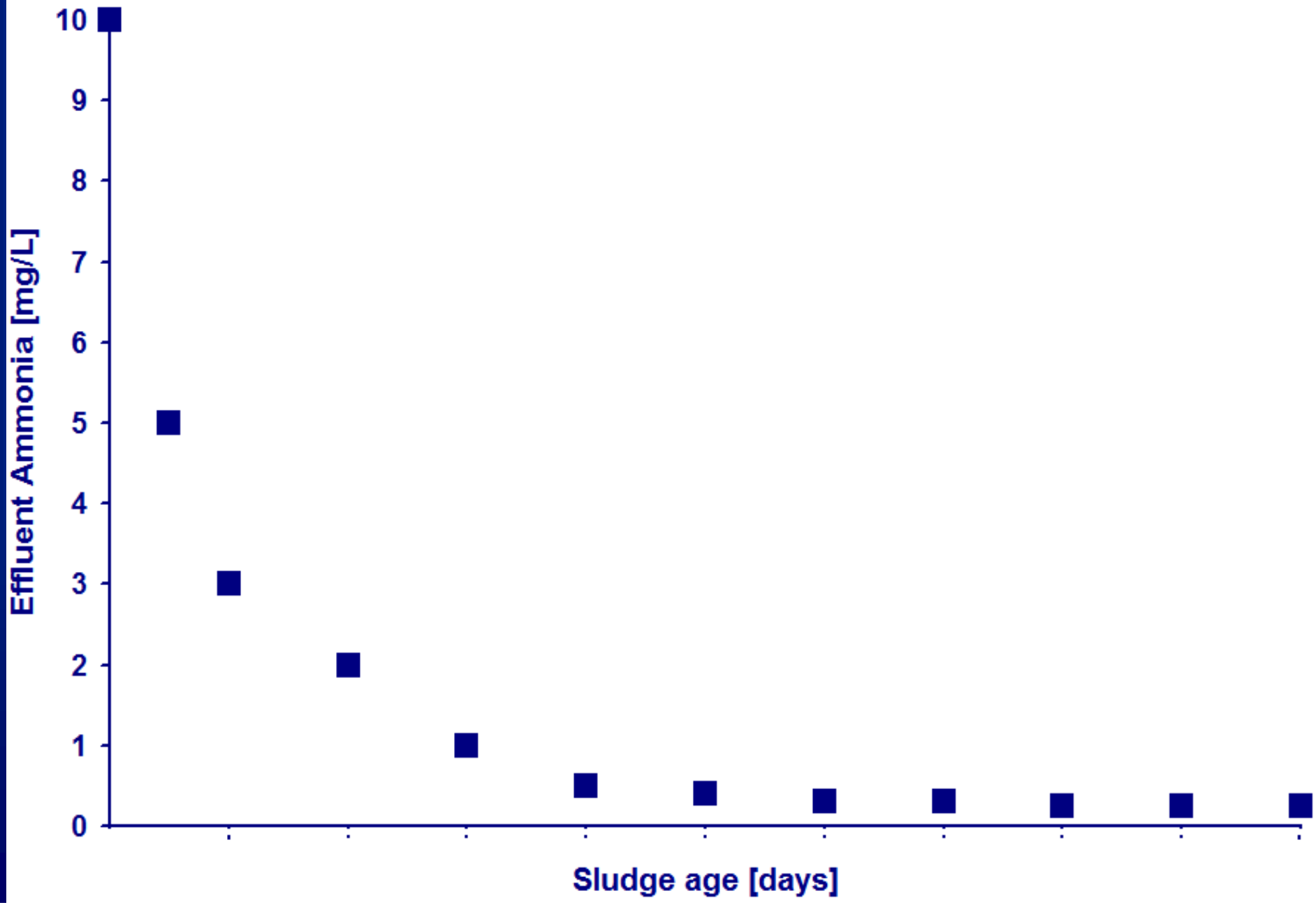
Biofloc settling velocity



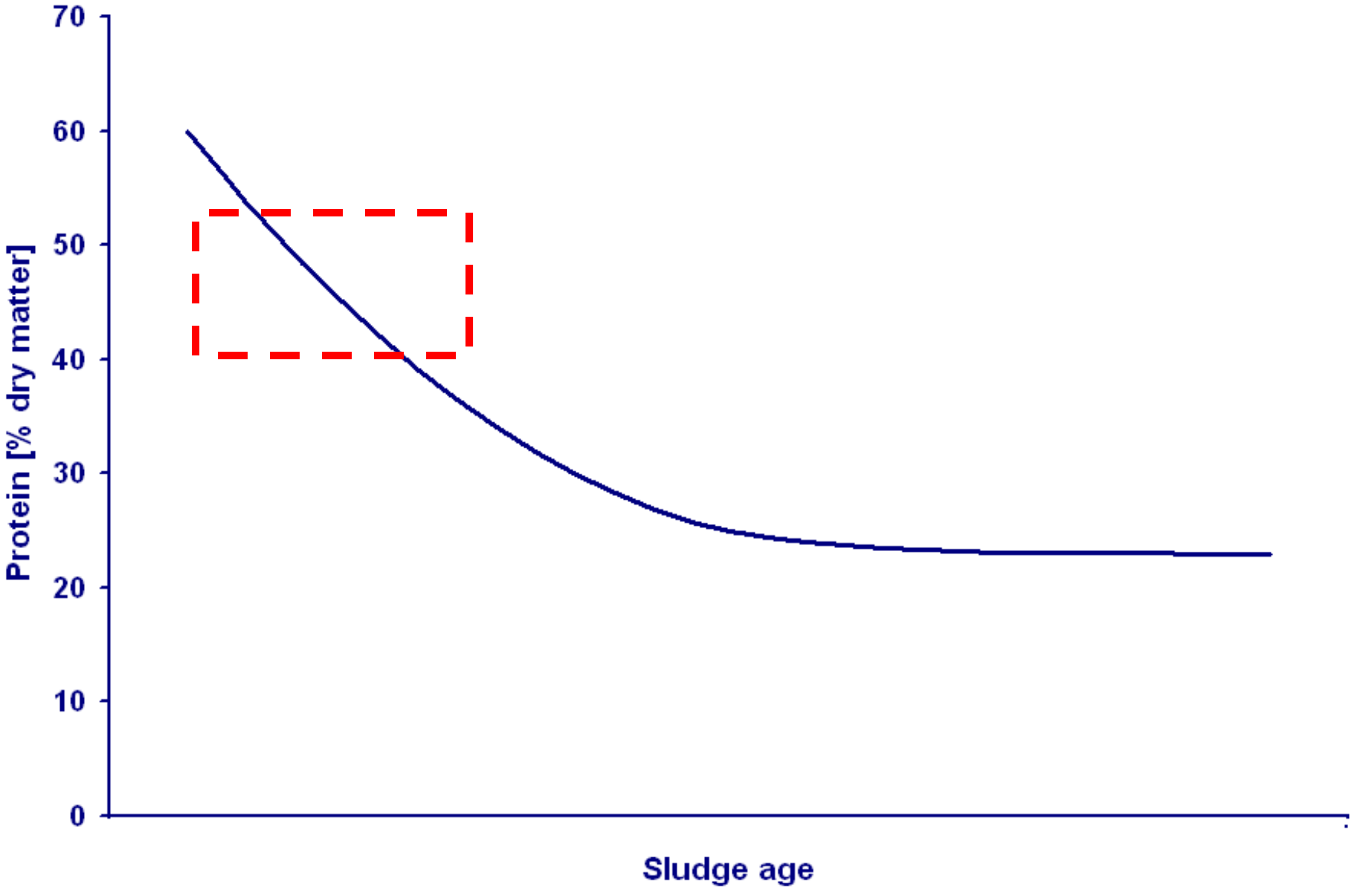
Effluent soluble COD



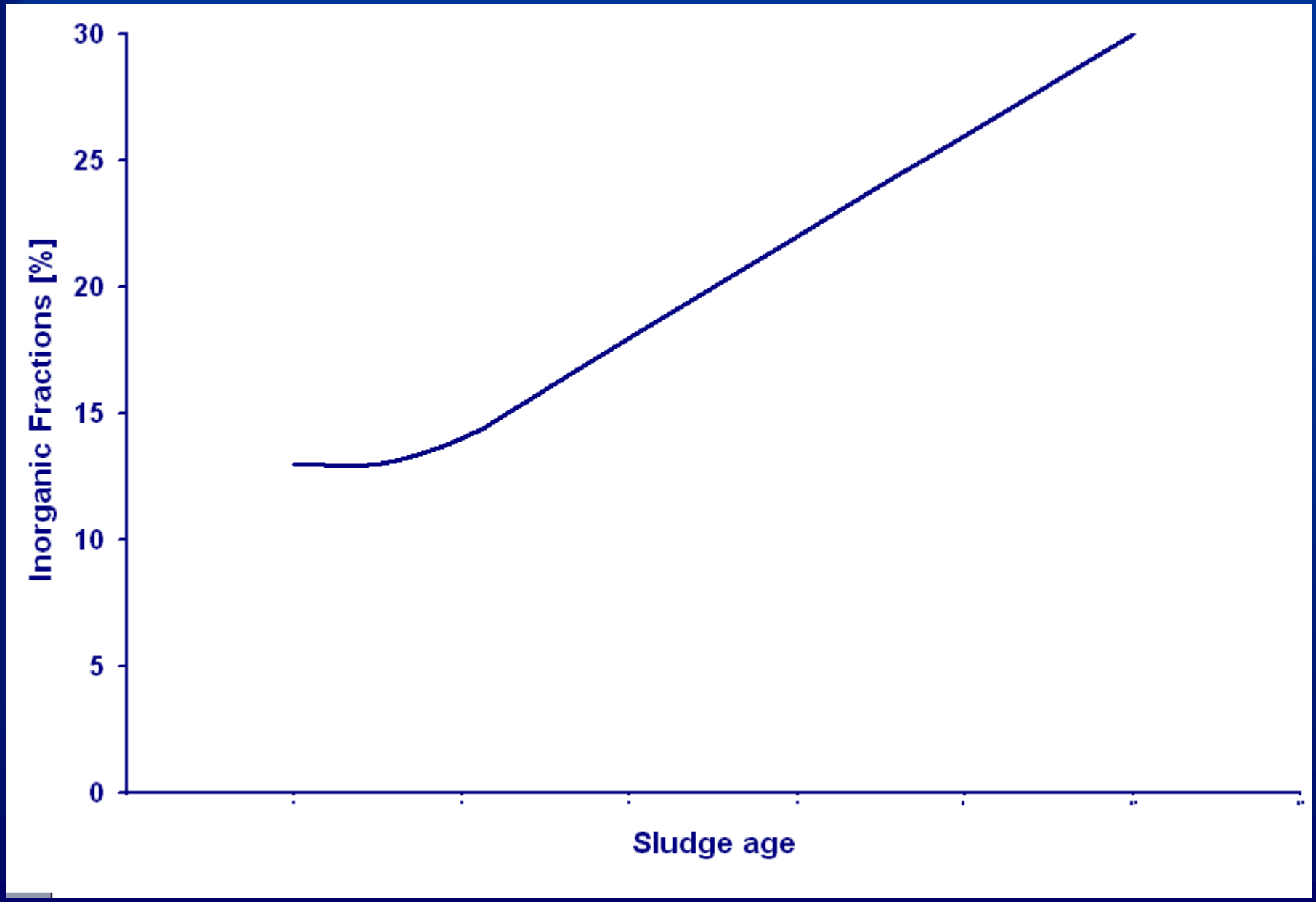
Effluent ammonia



Biofloc protein manipulation



Inorganic fraction of bioflocs



Nutrition Studies Using Bioflocs

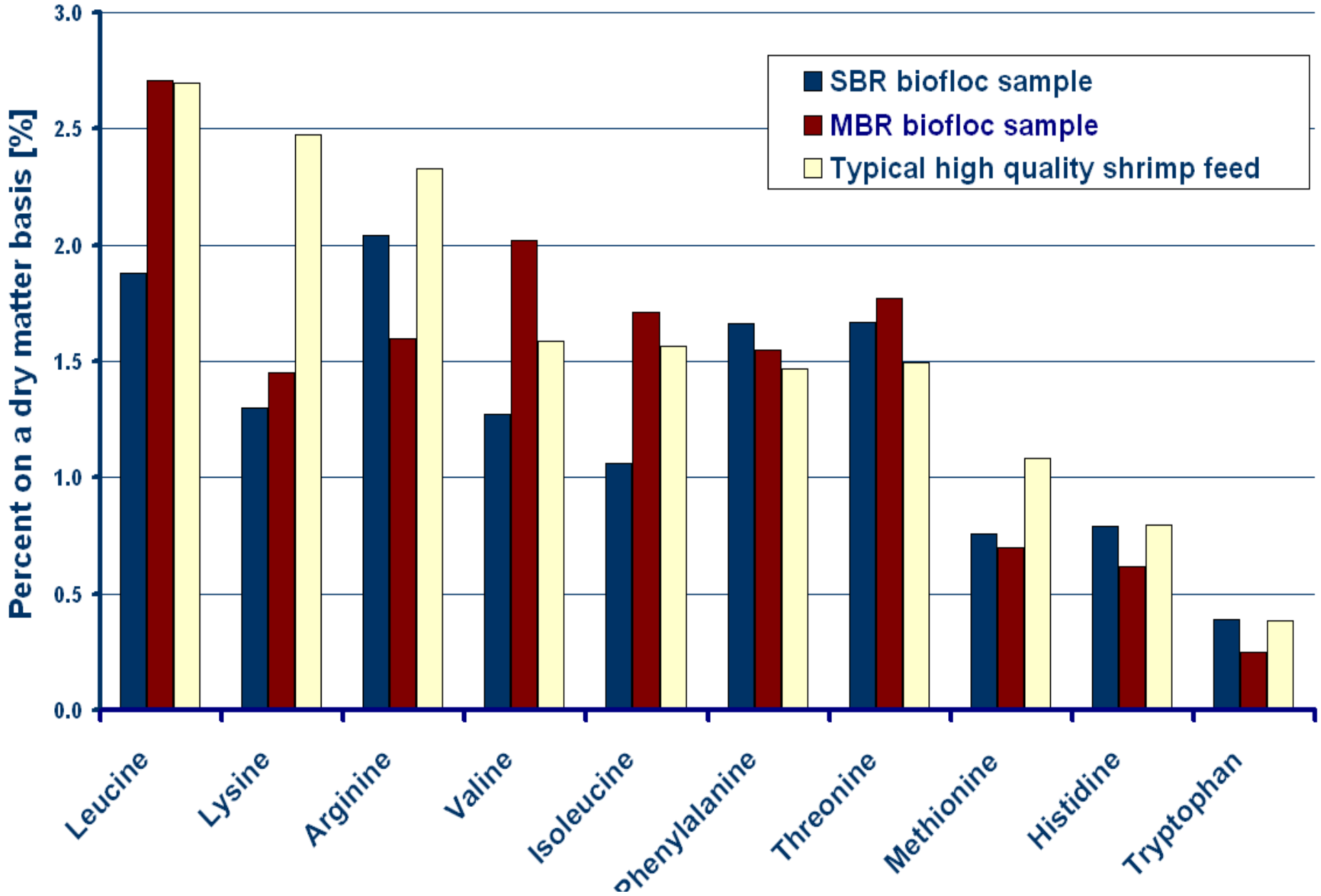
Biofloc Nutritional Properties

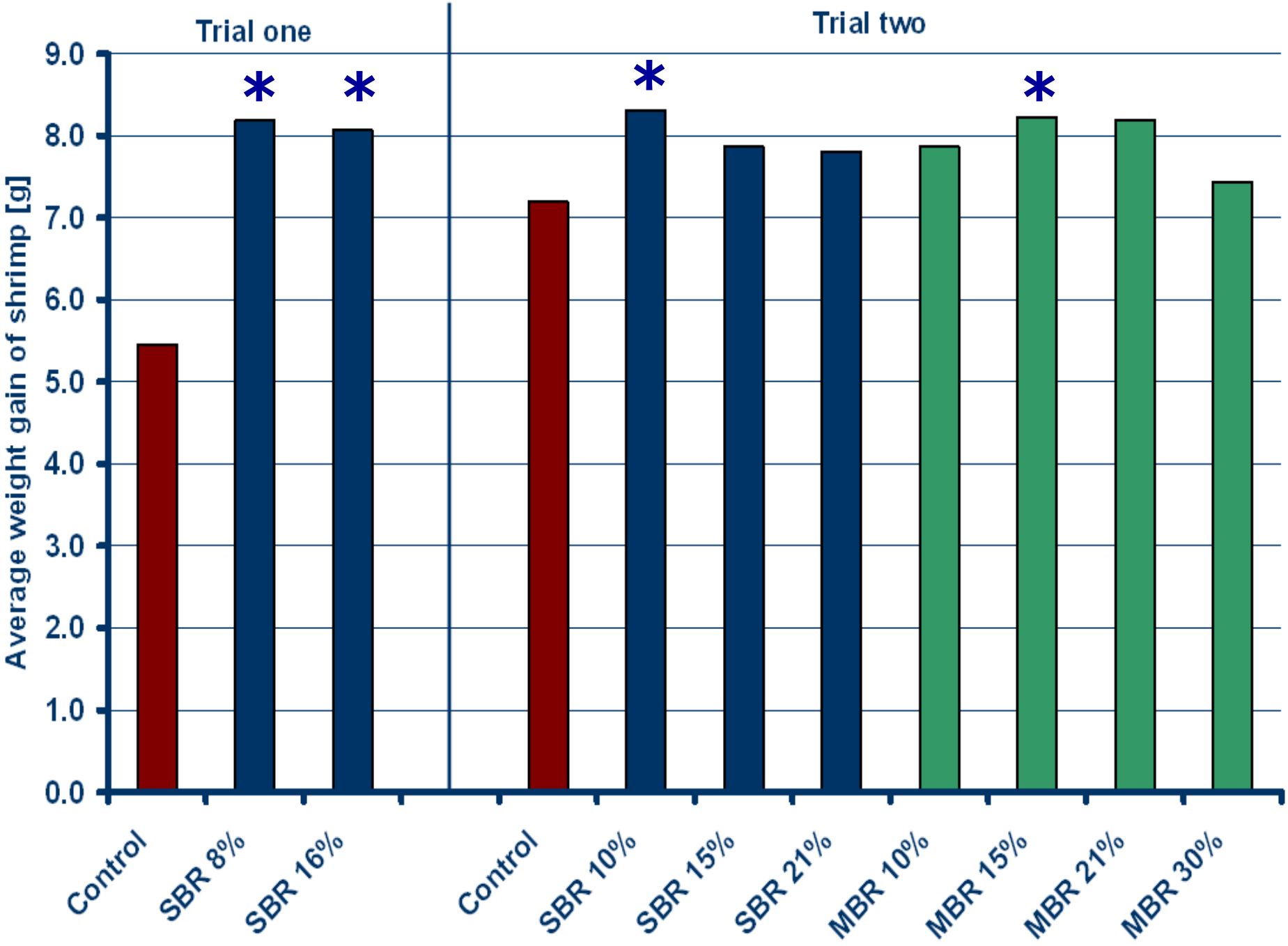
In-situ bioflocs

Ex-situ bioflocs

- Protein: 35-55%
- Lipid: 0-0.2%
- Carbohydrate: 20-36%
- Ash: 12-30%
- Fiber: 13-18%

Essential Amino Acid Profiles for Ex-situ Produced Bioflocs Compared to Shrimp Feed




Trial one
Trial two
Average weight gain of shrimp [g]
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
*
*
*
*
Control
SBR 8%
SBR 16%
Control
SBR 10%
SBR 15%
SBR 21%
MBR 10%
MBR 15%
MBR 21%
MBR 30%

Carbon Sources and Various Types/Sources of Bioflocs

Carbon Sources & Various Types/Sources of Bioflocs

- Carbon sources
  - Sucrose (eventually formed fungii in bioreactors)
  - Glycerol (formed good bioflocs)
  - Acetate (formed best bioflocs)

  Note: not much difference in nutritional content
- Biofloc types/sources
  - Fish wastewater using sequencing batch reactor
  - Fish wastewater using membrane bioreactor
  - Confectionary wastewater using continuously stirred bioreactor

Overall Conclusion

- Biofloc technology benefits:
  - Removes unwanted (toxic) dissolved nutrients from the water
  - Provides a “recycled” feed for the cultured animals
  - Reduce soybean and fishmeal requirements in shrimp and fish feed
  - Reduce overall protein level required in shrimp and fish feed (in-situ bioflocs)
  - Offer a sustainable option for the culture of shrimp and fish

Acknowledgements

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Discussion and Questions?