Open or closed raceway culturing systems are still the preferred system for the sustainable, large scale cultivation of microalgae despite the rather poor productivity thereof compared to photo-bioreactor systems. In an attempt to improve the productivity of raceway culture systems, two of its major shortcomings were addressed. These include the rather poor volume to surface area ratio, and poor gas-liquid mass transfer characteristics. This was achieved by adding freestanding, interconnected vertical column photo-bioreactors - holding approximately 20% of the total volume of the integrated system - to a traditional raceway system. The growth medium is recycled during photosynthetically active periods through the vertical columns at a rate at which sufficient carbon dioxide could be transferred to the culture system. By adding the vertical columns to the raceway, the effective surface area of the raceway was essentially doubled, which should improve the system’s light harvesting capacity. Results from experiments conducted under various environmental conditions indicate that the modified system outperformed the traditional raceway system by a significant factor. This poster will provide details of the actual integrated raceway/vertical column PBR culture system, its operation, and its performance compared to a traditional raceway system operated under as near as possible identical conditions.

### Advantages
- **Open Raceway Ponds**
  - Low capital investment
  - Low maintenance costs

- **Disadvantages**
  - Large area to volume ratio
  - Poor light utilization
  - Poor mixing
  - Poor gas transfer
  - Low population densities
  - Low harvesting efficiency
  - No temperature control
  - Contamination possible

- **Photo-bioreactors**
  - Small area to volume ratio
  - High population densities
  - High harvesting efficiencies
  - Low contamination risk
  - Effective light utilization
  - Effective gas transfer
  - Temperature control

- **Integrated systems**
  - Large capital investment
  - High maintenance

### Disadvantages
- **Open Raceway Ponds**
  - Poor light utilization
  - Poor mixing
  - Poor gas transfer
  - Low population densities
  - Low harvesting efficiency

- **Photo-bioreactors**
  - Low contamination risk
  - Effective light utilization

- **Integrated systems**
  - High capital investment
  - High maintenance

### Shortcomings addressed
- **Open Raceway Ponds**
  - Poor light utilization
  - Poor mixing
  - Poor gas transfer
  - Low population densities
  - Low harvesting efficiency

- **Photo-bioreactors**
  - Low contamination risk
  - Effective light utilization

- **Integrated systems**
  - High capital investment
  - High maintenance

### Experimental
- **Microalgae**: Mixed culture containing Scenedesmus sp. (dominant), Chlamydomonas sp. and cyanobacteria (low concentrations).
- **Monitored**: pH, light intensity, temperature, nitrate, and phosphate concentrations (IC).
- **Biomass concentration**: Dry weight
- **Feed**: Micro- and macro-nutrients
- **N source**: NaNO₃
- **P source**: NH₄PO₄
- **N/P**: 4:1
- **Carbon**: 5 – 12 Vol % CO₂ (depending upon climatic conditions and culture density)
- **Air flow rate**: 130 – 160 L/columnh
- **Recirculation rate**: 0.5 – 1 complete volume change

### References

### Hypothesis
The addition of multiple freestanding, vertical column photo-bioreactors to a traditional paddle wheel driven open raceway pond will result in increased productivity by addressing the major shortcomings of ORPs, namely poor gaseous transfer and volume to surface area ratio of such systems.

### System Characteristics
- **ORP vs. Integrated raceway system**
  - The addition of 13 vertical column PBRs (ø 0.25 m; liquid height: 1.4 m above liquid height of 0.25 m) to a raceway with a length of 14 m, results in an increase of the surface area exposed to direct sunlight by 95%.
  - Volumetric holding capacity of integrated vertical columns hold 5-30% of the total growth medium volume of the system.
  - Improved CO₂ delivery by increasing the gas hold up time through bubbling CO₂-containing air from the bottom of the 1.6 m high columns relative to the 250-350 mm pond depth of traditional ORPs. Reflected in the control of the pH of the integrated system.
  - Introducing vertical columns enhances mixing by creating regions of high and low liquid pressure bioreactors, and after each vertical column which results in upward movement on the high pressure and downward on the opposite side of each column. This further improves vertical mixing.