Aquaculture and the utilisation of plant wastes in fish feeds

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Outline

- Background

- The technological challenges of using cereal waste to replace fishmeal proteins

- Plant-based fishmeal replacements:
    - Brewers spent grain
    - Soyabean oilcake from biodiesel production

- Maintaining water quality during feeding with replacements

- Outputs (patent and publications)

- Team

Background

- Aquaculture is broadly defined as the production or cultivation of living organisms in an aquatic environment and includes algal cultivation, molluscs, fish and even bacteria
- CSIR, Biosciences focus on the production of marine and freshwater finfish
- Aquaculture is not sustainable if fish has to be fed to fish (estimated 4 kg “trash” fish needed to produce 1 kg salmon)
- resources used worldwide to find cost-effective alternative plant-based feedstuffs with the potential of replacing fishmeal – also locally for developing farmers
- large collaborative international projects such as the Plant Products in Aquafeeds Working Group, NEPAD, FAO,
  EU FP6 project REPRO (contract no. 006922)

Fish feed requirements

- Some fish has special nutritional needs related to **essential highly unsaturated fatty acids** (HUFA's), need for omega-3's, DHA and EPA and **amino acids** e.g. lysine, methionine

- **Feeding habits** will influence need for quality protein; compare for example herbivorous vs. omnivorous vs. carnivorous vs. piscivores. Herbivorous fish have higher tolerance for plant-based feeds

- **Feed palatability** and stability, fish are picky eaters, difficult to change a carnivore into a herbivore! Some fish also prefer to eat on the bottom while others prefer floating feed. Feed shape and size of pellets vary between species and age of the fish

- **Feed management** needs on fish farms, must be convenient, thus feed must be stable, dry, easy to handle, cost-effective

Plant-based feedstuffs to replace fishmeal – Brewery waste (BSG) EU REPRO

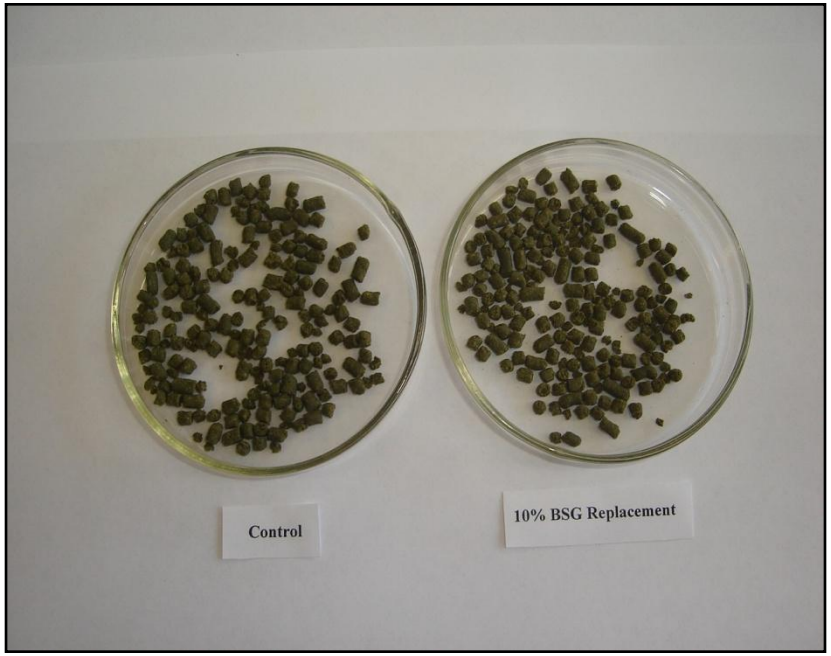
- General problem with wastes especially from cereals: low concentration and quality of protein and high fibre content
- Rhabdosargus globiceps (White stumpnose or sea bream), and Argyrosomus inodorus (Silver cob or mulloway)
- marine finfish, carnivorous by nature, utilise carbohydrates and fibres very poorly
- need 35 - 60% protein in diet with specific amino acids e.g. lysine, depending on fish age and stage in life cycle
- enrichment of BSG with eicosapentaenoic acid (omega-3) by fungal fermentation
- low cost separation of the BSG into two fractions namely a high protein and a high fibre fraction

Composition of raw BSG vs. improved BSG

Nutrient	Analytical method	Percentage (CSIR dried BSG protein concentrate)	Percentage of typical SA BSG stream (dried)
Protein	Protein (Dumas), AACC 46-30, 1999	41.2	21.7
Ash	Ash, In house method	4.1	3.3
Fat	Fat (Soxhlett), AACC 30-25, 1999	12.85	9.0
Carbohydrates	Carbohydrates – by difference	36.34	49.2
Crude Fibre	Fibre (Crude), AACC 32-10, 1999	5.52	16.8

Dried BSG raw material and extruded feed pellets

Dried high protein BSG (1eft) and dried high fibre BSG (right).



Extruded fish feeds made from high protein BSG

Fish feeding trial in tanks, Stumpnose (left) and Silver cob (right)

Results: Performance of Silver cob on BSG replacement

Formulation	Measure 1 (6 weeks)			Measure 2 (10 weeks)			Measure 3 (13 weeks)			Measure 4 (17 weeks)		
	WG %	SGR	FCR	WG %	SGR	FCR	WG %	SGR	FCR	WG%	SGR	FCR
Control	30.4	0.89	1.17	30	0.93	1.09	12	0.6	1.6	24	0.7	1.3
Improved BSG replacement	9.5	0.3	1.87	42	1.26	0.81	16	0.8	0.9	31	0.9	0.9
Control + Fungal material	21	0.64	1.14	29	0.91	1.09	16	0.76	1.2	Feed Depleted		

- No toxicity effects
- Fish ate more of the BSG replacement pellets
- Positive trend in FCR

Plant-based feedstuffs to replace fishmeal – Soyabean oilcake (DST Biodiesel)

- Soyabean oilcake as a by-product from the biodiesel industry have been used extensively to produce fish feeds containing no fish meal for trials at CSIR.
- Both marine (cob) and freshwater (tilapia) species have performed well in these soya-based feeds.
- The unique combination of the preparation of the raw ingredients and the use of twin-screw technology resulted in a feed that is well digested and well tolerated by the fish.
- Fermentation reduced antinutrients (oligosaccharides: stachyose and raffinose)
- A poster on the use of soybean oilcake in Dusky cob feed was presented to the International Aquaculture Symposium in Swakopmund in 2009 and it won the best poster award.

Twin screw extruder used to produce feed pellets

Mozambique tilapia in fish tanks at CSIR

100% plant-based fish feed for tilapia

Larger freshwater indoor tanks at CSIR

Some growth performance data of different soybean oilcake-based feeds fed to Mozambique tilapia.

	Measure 1				Measure 2				Measure 3			
Formulation	WG %	SGR	FCR	FCE	WG %	SGR	FCR	FCE	WG %	SGR	FCR	FCE
Soya	36.8	1.57	0.9	1.2	36.1	1.47	1.3	0.8	12.4	0.73	2.6	0.4
Soya + Amino Acids	37.8	1.6	0.8	1.2	38.8	1.56	1.2	0.8	20.3	1.16	1.5	0.6
Fermented Soya	37.2	1.58	0.9	1.2	34.5	1.41	1.4	0.7	20.7	1.18	1.6	0.6

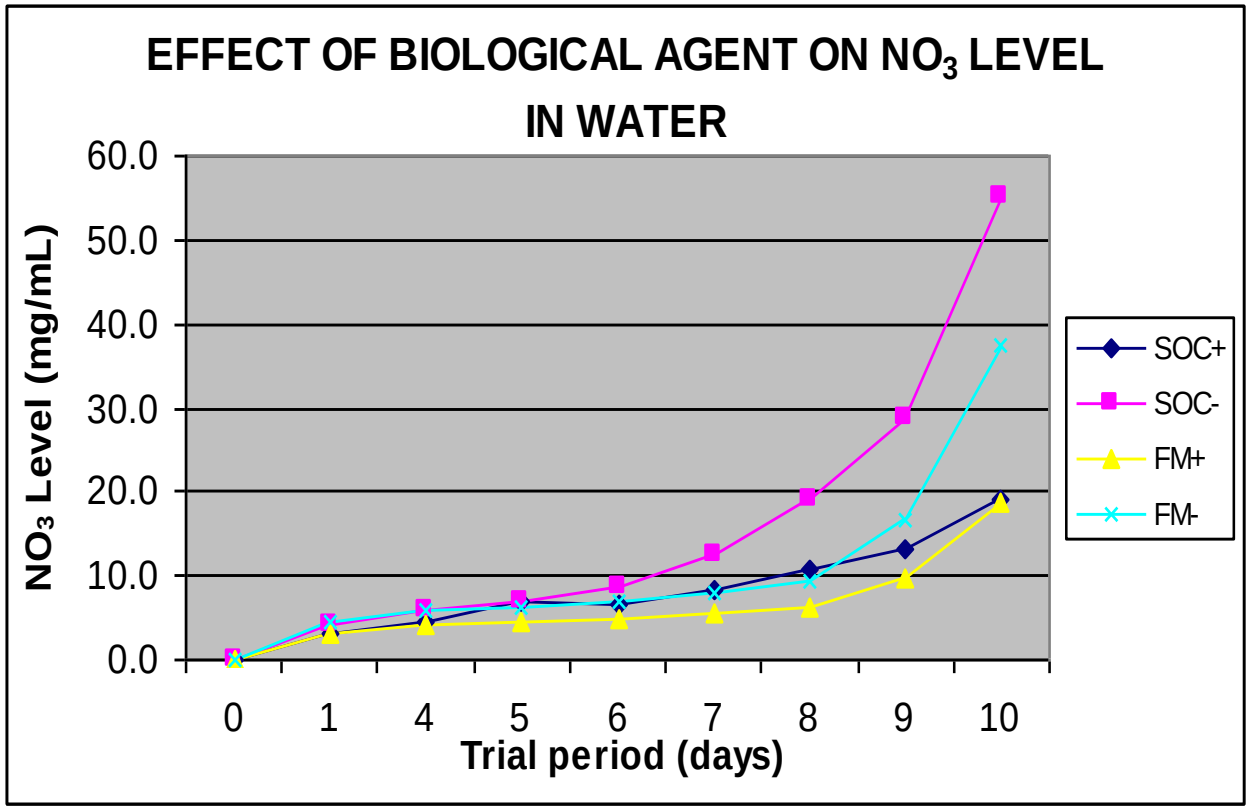
	Measure 4				Measure 5			
Formulation	WG %	SGR	FCR	FCE	WG %	SGR	FCR	FCE
Soya	49.8	0.62	1.9	0.5	16.7	0.74	1.8	0.6
Soya + Amino Acids	65.4	0.77	1.4	0.7	18.3	0.8	1.5	0.7
Fermented Soya	56.1	0.68	1.7	0.6	18.4	0.8	1.6	0.6

The effect of aquaculture biological agents on water quality during feeding trials

- Freshwater finfish *Oreochromis mossambicus* feeding trials in small closed systems with individual filtration
- Accumulation of waste ions (ammonium, nitrate, nitrite, phosphates) due to poorer digestibility of plant based feeds
- alleviated by addition of bacterial agent (probiotic) to water during feeding trial

CSIR infrastructure – small tanks for water quality trials

The effect of aquaculture ‘probiotics’ on water quality during micro-system feeding trials



Conclusion on plant-based fish feeds

- Cereal wastes have challenges of high fibre contents and low protein contents for fish feeds
- Need for innovative solutions to increase protein and lipid (omega-3) contents of plant wastes streams in a cost effective way
- Fish farming is challenging because of popular species being carnivorous and very little understood - especially regarding marine finfish diets
- Fish performed well during these initial trials in terms of consumption response, growth, FCR and mortality rates
- Using high protein BSG or SOC to partially replace fish meal was successful
- Sensory analyses and fish pathology tests did not show any negative effects (results to be published this year)

Some relevant publications on this work:

Erasmus C. 2009. Vegetable and Cereal Protein Exploitation for Fish Feed. Chapter 17, Volume 2. **In**: Waldron, K.W. (Ed.). Handbook of Waste Management and Co-product recovery in Food Processing. Woodhead Publishing

Erasmus C. Patent on separation method “Dietary fibres”, International Publication Number: WO2008/010156 A2

Jacobs A., Botha A. & Van Zyl W.H. 2009. The production of eicosapentaenoic acid by representatives of the genus *Mortierella* grown on brewers' spent grain. *Biologia*. 64(5): 871-876

Jacobs A., Botha A. & Van Zyl W.H. 2010. Adding value to the by-products of cereal processing by fungal production of highly unsaturated fatty acids. CST-SA Conference poster, Pretoria

Jacobs A., Botha A. & Van Zyl W.H. 2010. Sunflower press cake as a substrate for eicosapentaenoic acid production by representatives of the genus *Mortierella*. *Bioresources.* **5 (2):** 1232 – 1243

Timme E., Goodman M., Ginindza J.N., Botha G., Erasmus C. & Lalloo R. 2009. Partial inclusion of a plant-based protein as a fish meal alternative in carnivorous finfish diets – preliminary findings. Aquaculture Conference poster, Swakopmund.

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Thank You

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