Final Report

QUALITY AND NUTRITIONAL EVALUATION OF BAITFISH USED FOR SBT FARMING

David Ellis and Kirsten Rough
Tuna Boat Owners Association of South Australia

April 2005
Aquafin CRC Project 1A.2
(FRDC Project No. 2000/221)

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The Tuna Boat Owners Association of South Australia is the body that represents the tuna growers in Port Lincoln.

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1. NON TECHNICAL SUMMARY

OUTCOMES ACHIEVED

The project provided nutritional profiles for all types of baitfish used for feed in the Southern Bluefin Tuna (SBT) (*Thunnus maccoyii)* Aquaculture Industry, as well as for the only available commercially produced compound feed and SBT. Included are values for amino acid and fatty acid profiles for most bait types and proximate analysis for all bait types.

The nutritional profiles have been determined by taking baitfish samples that coincided with major shipments of baitfish in the industry or landings of local pilchards. Weston Food Laboratories, Sydney, Australia undertook all analytical testing.

Often replicate samples were taken and provided to other projects. These included projects researching the development of NIR (Near Infra Red) technology that has the potential to provide a quick screening method for the proximate analysis of baitfish *"2001/249 Aquafin CRC - SBT Aquaculture Subprogram: development and commercial evaluation of manufactured diets"* and investigating the relationship of residues in the flesh of baitfish and wild caught and farmed SBT *"2003/227 Aquafin CRC - SBT Aquaculture Subprogram: development and validation of baitfish sampling methods to address international residue standards for southern bluefin tuna* (*Thunnus maccoyii)"*.

The baitfish profiles produced have been of significant value as they have heightened the understanding of nutrition in SBT farming. This has led to other projects including *"2004/211 Aquafin CRC - FRDC SBT Aquaculture Subprogram: nutritional profiles of baitfish 3: effects of harvest and post-harvest processes on quality of local pilchards for feeding SBT"* and *"2000/221.20 Aquafin CRC - FRDC SBT Aquaculture Subprogram: quality and nutritional evaluation of baitfish used for tuna farming project 2000/221 (extension)".* Both of these projects will significantly enhance the understanding of baitfish feeds used in the SBT industry.

A direct result of this project has been the development of a feed optimisation program "*Formu-Bait".* This software combines the current nutritional understanding of SBT, nutrition and industry feeding strategies with the baitfish database generated by this project.

As part of the original objectives the project sought to determine seasonal variability in the nutritional profiles of key baitfish. This was not achieved due to the seasonal nature of SBT farming (December – September) and the limited period over which most baitfish is purchased or caught. However, there appears to be a seasonal trend in the local caught pilchards (*Sardinops neopilchardus)* which shows a slight increase in fat content of pilchards caught during the summer/autumn months. This trend may be the result of up-wellings that occur in the lower Spencer Gulf and East Great Australian Bight during this time of year providing food to the pilchards.

To take this project further there is a need to test more SBT and baitfish to build on the current database, particularly where gaps exist or unexplained variability is high.

KEYWORDS: **Baitfish profiles, aquaculture, nutrition, SBT farming.**

2. ACKNOWLEDGEMENTS

The authors wish to thank the Aquafin Cooperative Research Centre (CRC), Fisheries Research & Development Corporation (FRDC), Tuna Boat Owners Association of South Australia (TBOASA), baitfish suppliers to the SBT Aquaculture Industry and the SBT Aquaculture Subprogram.

3. BACKGROUND

This study was initiated after meetings with Australian Quarantine & Inspection Service (AQIS) in October 1999, who suggested that strict regulations would be introduced regarding the importation of baitfish. They subsequently identified that imports must be accompanied by a permit certifying catch area, species description and health status. Under this import scenario AQIS can terminate imports of certain species from specific countries at any time should there be a quarantine issue.

The SBT Aquaculture Industry was concerned that if it became heavily reliant on a baitfish source from a certain geographic location and access to the resource was taken away due to health reasons or because the resource failed, that the consequences to SBT farming could be devastating. The loss of a feed source would result in decreased productivity and could lead to urgent harvesting and flooding of the market.

Ironically in 2001, VHSV (Viral Haemorrhagic Septicaemia Virus) was discovered in sardines off the west coast of the United States of America (USA) where sardines are caught and supplied to the SBT Aquaculture Industry. This discovery prompted a scientific investigation into VHSV, but also highlighted the importance of this project in providing sufficient data on baitfish quality from various locations that could be sourced during this time. Currently there are import restrictions on the use of baitfish from the genus *Clupea, Sardinops and Scomber.*

4. NEED

A range of baitfish species are used by the SBT Aquaculture Industry for feeding farmed tuna. Currently the local catch of pilchards cannot meet the volume required for SBT farming and as a result, other sources of baitfish are required to meet the shortfall. Other species of baitfish offer different nutritional profiles which can provide a varied and more complete diet to the SBT.

5. OBJECTIVES

1. In a literature review and through consultation with stakeholders, investigate known information on baitfish supplies and their nutritional profiles.
2. Obtain sample shipments of a variety of products to test their nutritional suitability as a SBT feed.
3. Determine seasonal variation in the profiles obtained.

6. METHODS

The SBT Aquaculture Industry starts to prepare for the upcoming season by importing baitfish used for feeding during the period of September through to February depending on the scheduled time of intake of SBT for farming. When the SBT arrive, large volumes of feed are consumed. The SBT feed at this time is provided by local pilchard fisherman and imported baitfish that is fed fresh or has been stored in freezers owned by SBT farm operators. The feeding of SBT continues throughout the farming season with the volume of feed reducing as the water temperature cools and the SBT reach the optimum desired condition. If possible, SBT farm operators utilise all their baitfish feed holdings to coincide with when the last cage of SBT is harvested.

Sampling for baitfish for this project occurred at peak times for imported baitfish and when local caught pilchards were landed. Most SBT farming companies provided samples for testing which encompasses all of the major baitfish suppliers to the industry. The SBT Aquaculture Industry has also utilised this project framework to test new baitfish that have been identified.

One kilogram samples were collected from SBT farming companies, placed into a plastic sampling bag with waterproof number attached and stored at -18 ^{o}C until a foam 20kg shipping container was full. The box of samples was then sent to Weston Food Laboratories, Sydney for analysis using a direct courier delivery method.

On arrival at Weston Food Laboratories the samples were minced and a representative sample used for analysis. Appendix 3 contains the analytical methods provided by Weston Food Laboratories.

When the results arrived back from analytical testing, each company was provided with their results along with a brief summary of all companies data.

7. RESULTS & DISCUSSION

Nutritional Profiles

The results of the quality and nutritional evaluation of the 23 types of baitfish used for SBT farming were evaluated, along with the only available commercially produced compound feed and SBT. The resulting data is “Commercial in Confidence” and held by the TBOASA, Aquafin CRC and FRDC.

Literature Review

There is little data available on nutritional profiles of baitfish in text, especially for proximate composition. Data when available is incorporated in product quality reports that assess issues such as nutritional composition and lipid oxidation (Hamre et al, 2003) or chilling methods on quality (Garcia and Careche, 2002).

From these reports, Atlantic herring *(Clupea harengus)* were sampled from the beginning of September through to the beginning of March. This period of time reflected a trend in the data showing a change from higher lipid concentration to lower lipid concentration (Hamre et al, 2003). Similarly, (Garcia and Careche, 2002) reported European sardines *(Sardina pilchardus)* caught in March had about half the lipid content of those sardines caught in July and September.

Additional data on nutritional profiles of some baitfish can be found in books by Frimodt (1995) and Bykov (1983) that relate to fishing and processing.

There is some good information on the spotlined sardine *(Sardinops melanostictus)* presented by Nakada (2000). This is a comprehensive reference to the nutritional profile of the spotlined sardine, but unfortunately, the Japanese spotlined sardine in not widely used in the SBT Aquaculture Industry due to price.

Table 1 has been used to crudely assess fat content of spotlined sardines Nakada (2000) and may have some relevance for crudely assessing local caught pilchards for fat content. Genetic research has shown pilchards of genus *Sardinops* merit sub-species recognition and are similar (Grant et al, 1998).

Table 1. Simple estimation methods for fat content in sardines. Reproduced from Nakada (2000).

Classification of Sardines	Subcutaneous Fat	Fat in Abdominal Cavity	Dark Muscle Side Fat	Estimated Crude Fat Content (%)
Small (<39g)	None	None	None	2.0
	None	None	Yes	3.9
	None	Yes	None	5.5
	None	Yes	Yes	7.3
	Yes	None	None	9.0
	Yes	None	Yes	12.0
	Yes	Yes	None	15.0
	Yes	Yes	Yes	18.0
Middle (40-79g)	None	None	None	6.5
	None	None	Yes	9.8
	None	Yes	None	13.0
	None	Yes	Yes	15.3
	Yes	None	None	17.5
	Yes	None	Yes	20.3
	Yes	Yes	None	23.0
	Yes	Yes	Yes	26.0
Large (>80g)	None	None	None	7.5
	None	None	Yes	12.0
	None	Yes	None	16.5
	None	Yes	Yes	19.5
	Yes	None	None	22.5
	Yes	None	Yes	26.3
	Yes	Yes	None	30.0
	Yes	Yes	Yes	34.0

Seasonal Variation

This project sought to address seasonal variation in baitfish feeds used by the industry.

Local caught pilchards were sampled many times during the project. In the past, local pilchards have been caught after the SBT have arrived in tow pontoons and have been transferred into waiting farming pontoons. This coincided with the SBT having a voracious appetite during summer/autumn so that large volumes of local pilchards could be fed. This is reflected in the sampling regime with the majority of samples being taken in summer and autumn (Figure1).

The South Australian Pilchard Industry and SBT Aquaculture Industry is now starting to freeze pilchards using plate, immediate quick freeze (IQF), or block freezing throughout the year. This is a direct result of the increase in the total allowable catch (TAC) permitted in the fishery. Samples taken throughout the season can enhance the knowledge on the seasonal variation in local caught pilchards.

Figure 1 shows the mean lipid results for local caught pilchards throughout the seasons from 1999-2003. There are insufficient samples taken during winter or spring to infer any seasonal variation from these time periods. There was quite a variation in the lipid content of pilchards caught during the summer/autumn period. Anecdotally, this variation can possibly be related to some catches consisting mainly of juveniles, which are low in lipid compared with sub-adults and adults. Furthermore, up-wellings that regularly occur at the bottom end of Eyre Peninsula during summer that supply nutrients that stimulate the food chain are possibly reflected in the lipid composition of local caught pilchards.

Figure 1. Seasonal variation of lipid content of local caught pilchards 1999-2003 (mean +/- standard error).

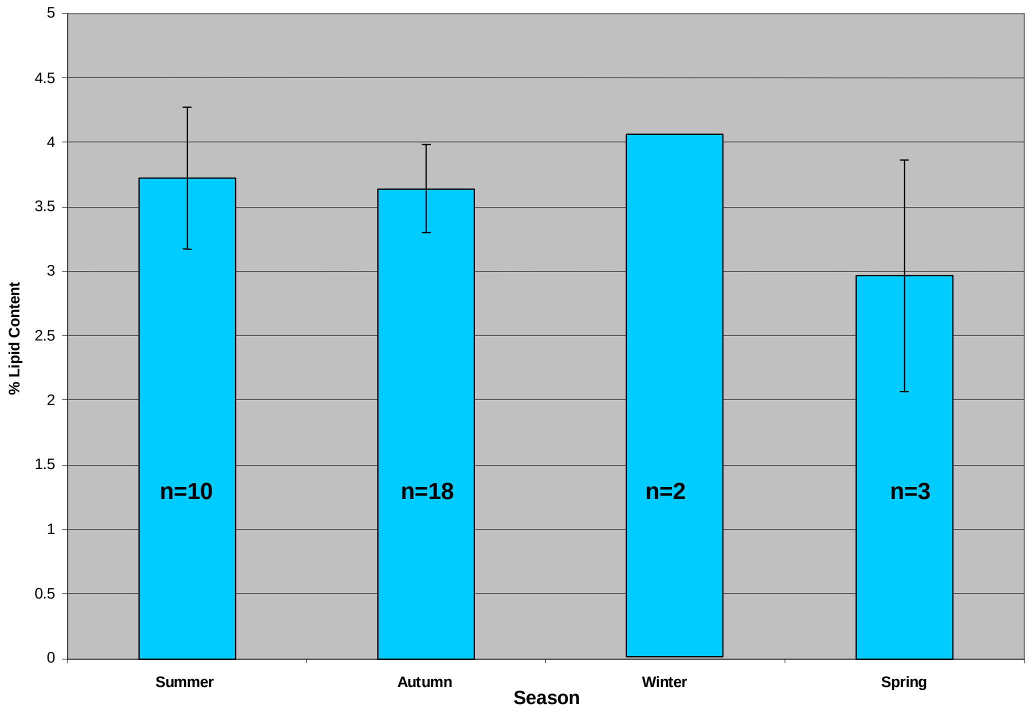

Figure 2. Mean lipid content of all baitfish sampled between 1999-2003 (mean +/- standard error).

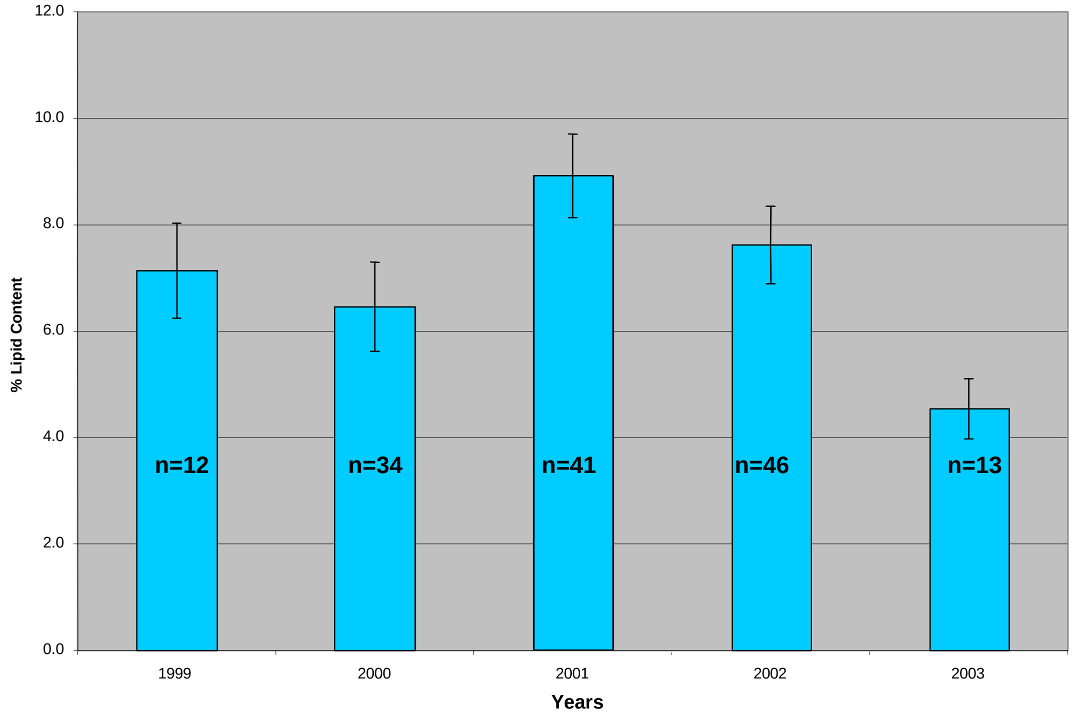

Figure 2 shows mean lipid scores for all baitfish sampled for the duration of this project. This is a qualitative assessment of baitfish sampled but does not reflect the volumes of each type of baitfish fed to SBT.

Obtaining seasonal variation in local caught pilchards should be easier now that fishing vessels are catching pilchards all year round and freezing.

For imported baitfish, based on limited literature and sampling from this project, baitfish caught during late summer and autumn appear to have the highest lipid content.

Tuna Nutrition Concepts

The following text has been provided by Dr Robert van Barneveld of *Barneveld Nutrition Pty Ltd* and Principal Investigator of Project *"2001/249 Aquafin CRC - SBT Aquaculture Subprogram: development and commercial evaluation of manufactured diets".* This text provides a brief overview of the role protein, fat and the other nutritional components of baitfish play in influencing SBT flesh quality.

What are we producing?

SBT muscle tissue = lean meat and fat

SBT muscle tissue consists of:

1. Protein

Protein is a string of amino acids. This string of amino acids is arranged in the same way for all SBT in a set, predetermined sequence such that on analysis, SBT protein has a consistent amino acid profile regardless of diet or origin. It is genetically fixed in the same way as SBT have a dorsal fin and two eyes.

2. Fat

When we feed SBT we try to maximise fat deposition, or fat or oil content, in the final product. This improves the quality of the SBT flesh for premium export markets.

3. Water

SBT muscle tissue consists of approximately 70% water.

4. Bone/Ash

Bone is the frame on which the muscles hang. It consists mainly of calcium and phosphorus.

How is SBT muscle tissue produced?

Having given some thought to what we are producing, we must now consider how it is produced.

Think of the SBT as a factory or a manufacturing plant. Like any factory, we need components or raw materials before we can make a final product. In this case, as our final product is ***SBT flesh*** *which consists mainly of protein, our raw materials are* ***amino acids****.*

As well as the materials, we need labour within the factory to produce the final product. In the SBT the labour is provided in the form of ***dietary energy.*** *We can understand how the SBT produces muscle by considering the basic processes of any factory.*

In any manufacturing process there are fundamental commitments that must be met before we can start to produce the final product. In a factory there are basic running costs such as rent and factory overheads. These expenses must be met independently of the level of production. In SBT, there are some basic running costs such as breathing, swimming, keeping the heart beating, maintaining body temperature, and keeping the digestive tract functioning. These basic running costs in SBT are referred to as ***maintenance costs****.*

After meeting the basic running costs, manufacture can commence. Broadly, manufacture of any product involves marshalling a range of raw materials and the necessary resources required to drive the process (eg labour and power). In SBT, since meat or protein is the main product, the most important raw materials that are required are ***amino acids****. The labour and the power required to make the protein is derived from* ***dietary energy****.*

Gathering raw materials and the labour required to make a final product is not going to make you any money unless you can complete the process ***efficiently.*** *To achieve manufacturing efficiency you must:*

- *Have the factory running at close to full capacity so that there is more output to share the fixed costs.*

We need to ***maximise*** *the* ***protein*** *and* ***fat deposition rates*** *and* ***minimise*** *the proportion of resources directed towards* ***maintenance****.*

To operate a factory at full capacity, you must be able to determine the factors that affect factory capacity. The bigger the factory, the bigger the maintenance costs and the bigger the capacity for raw materials. However, it is the size of the equipment, the ability to supply the raw materials, the working environment and the condition of the equipment that will have the greatest impact on capacity.

Capacity for SBT muscle tissue production is determined genetically and mediated through SBT hormones. SBT are also continually changing in size and changing the composition of the final product. Consequently, there may be a need to continually realign the inputs to the system (ie change the composition of the diet over the course of a season).

- *Labour and power consumption for manufacture must be optimised per unit of output (for example, you don't want five staff doing the job of one).*

In most animals, we need to match the energy inputs to the capacity of the animal to produce protein having first met the maintenance commitments. If we do not supply enough energy, protein manufacture will not be maximised. If we supply too much energy, it will be stored as fat. In SBT, we are trying to produce both fat and protein. The conundrum here is that it is inefficient to make fat compared to lean meat (it takes five times as much energy to make fat compared to lean meat) so identifying the optimum energy inputs and sources to produce SBT muscle tissue is harder.

- *As well as ordering raw materials, the factory manager must order them in the same proportion and at the same rate as they are being used to make the final product.*

In SBT, a fixed proportion of amino acids are required to produce muscle protein. If one amino acid is in short supply, the SBT cannot make the protein and the manufacturing process stops. If amino acids are oversupplied, the SBT has no ability to store them and as a result they are wasted.

- *As well as ensuring the manufacturing process is efficient, the secondary administrative functions must be carefully managed to ensure the whole business runs smoothly.*

As well as meeting the SBT's requirements for protein and energy, there are many other inputs required to facilitate the primary function of the fish. These include minerals and vitamins from the feed and hormones and enzymes from the SBT.

Beyond the factory - the biology of SBT

Although the basic process of meat production is analogous to a factory, the processes that take place in SBT are far more complex due to the fact that a SBT is a biological system rather than a physical process. What SBT producer's need to be able to do is match the nutrients supplied from baitfish with the requirements for muscle tissue production taking the above analogies into consideration.

All of these requirements must be met from the baitfish fed so an understanding of the nutritional composition of baitfish is necessary to produce the desired product in an efficient manner.

8. BENEFITS & ADOPTION

The nutritional profiles of baitfish are used in the SBT Aquaculture Industry to assist farmers with preparing feed programs for farming seasons. It allows farm operators to be discerning with purchases in respect to quality of baitfish offered.

This project provided benefits to other projects performing research within the Aquafin CRC. They involve the characterisation of wastes *"2001/103 Aquafin CRC – SBT Aquaculture Subprogram: tuna environment subproject 2 – evaluation of waste composition and waste mitigation strategies"*, NIR (Near Infra Red) technology that has the potential to provide a quick screening method for baitfish proximate analysis *"2001/249 Aquafin CRC - SBT Aquaculture Subprogram: development and commercial evaluation of manufactured diets"* and investigating the relationship of residues in the flesh of baitfish and wild caught and farmed SBT *"2003/227 Aquafin CRC - SBT Aquaculture Subprogram: development and validation of baitfish sampling methods to address international residue standards for southern bluefin tuna* (*Thunnus maccoyii)"*.

The development of the baitfish optimisation software *"Formu-Bait"* is an important outcome from this project as it can be directly adopted by the SBT Aquaculture Industry and is currently being trialled.

9. FURTHER DEVELOPMENT

1. Completing data sets

To enhance on this project there is a need to further refine some baitfish profiles where there is insufficient samples. For example, the SBT Aquaculture Industry is starting to source more baitfish from the emerging Tasmanian fishing industry that catches red bait (*Emmelichthys nitidus nitidus).* Furthermore, there are some amino acid profiles that are missing and it would be worthwhile completing the data set.

There is currently one nutritional profile for SBT and it would be beneficial to enhance our knowledge through more samples (refer point 5).

2. Understanding natural vitamin levels in baitfish and storage life

There is a perception by the SBT Aquaculture Industry that fresh local pilchards provide "goodness" to the SBT. This needs to be better understood including what happens to natural vitamin levels in baitfish during storage. This will fit well with current flesh quality research on pilchards and vitamin and mineral coatings on pilchards to enhance SBT product quality.

3. Influence of handling methods on baitfish quality

The TAC of local caught (ie South Australian waters) pilchards has increased to approximately 40,000 tonnes. It is almost impossible to deliver this quantity of fresh pilchards for SBT farming. Therefore there is a need to better understand volume freezing methods such as IQF, block and blast freezing, and plate freezing to ensure high quality standards are maintained. This research will possibly allow SBT farm operators to source pilchards out of season or when they are at their peak, store them under the best possible conditions and deliver a premium product to the SBT.

4. Complement previous and current research on pilchard quality

Fitzgerald and Bremer (1994) undertook the initial research that provided the basis for handling pilchards. Another project is currently assessing on-board handling techniques for optimum quality pilchards for human consumption. At the completion of these projects information could be synthesized in a book on baitfish quality.

5. Refinement of baitfish optimisation software using baitfish profiles

The baitfish profiles produced as an outcome of this project have been used as an input to a computer program *"Formu-Bait"* that has the ability to mix and match baitfish to suit SBT requirements based on existing nutritional and industry feed knowledge. This software has the potential to reduce operating costs in respect to purchasing feeds to specification whilst not compromising on quality. To further improve this software program it is necessary to screen more baitfish samples and to obtain more samples from SBT.

10. PLANNED OUTCOMES

The key planned outcome of this project was to deliver nutritional profiles of the baitfish used in the SBT Aquaculture Industry and this was achieved.

To understand seasonal variation is a very big project in itself for all of the bait types. Even to try and determine seasonal variation in the South Australian fishery is difficult but a general rule of thumb would suggest autumn is when the pilchards have the highest lipid levels.

Seasonal variation can also be affected by water temperature and availability of food for the baitfish.

11. CONCLUSION

This project has provided a good knowledge base for understanding basic information of nutrient inputs used in SBT farming.

The specifications provided can be used to enhance other research projects of priority to the SBT Aquaculture Industry.

With this knowledge and based on the results of this project, it is recommended that in general, there is a need to only focus analytical testing of baitfish on three components being protein, fat and free fatty acids to determine the quality of the baitfish to be used for feeding SBT.

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13. APPENDIX ITEMS

APPENDIX 1: Intellectual Property

The information generated from this project has been compiled over four years and provides the South Australian SBT Aquaculture Industry with a database of baitfish nutritional profiles. This information allows SBT farm operators to source products to suit their feeding practices.

APPENDIX 2: Staff

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APPENDIX 3: Analytical Methods

These analytical methods have been provided by Weston Food Laboratories, Enfield, Sydney, New South Wales.

Protein (kjeldahl)	AOAC 988.05
Fat (soxhlet)	AOAC 960.39
Moisture	AOAC 950.46
Ash	AOAC 923.03
Calcium	AOAC 965.09
Phosphorus	AOAC 965.17
Energy	Calculated
Free Fatty Acids	AOCS Aa6-38, Ca5a-40
Peroxide Value	AOCS Cd6-38
Fatty Acid Analysis	AOAC 969.33
Amino Acid Analysis	

The external laboratory performed the amino acids analysis according to Sarwar et al (1988).

AOAC – Association Of Analytical Communities
http://www.aoac.org/

AOCS – American Oil Chemists Society
http://www.aocs.org/