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Nutritional management and development of manufactured feeds for tuna aquaculture

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SUMMARY – At present, all tuna farming is based on wild capture and feed lotting. The impounded tuna are fed on a diet of small pelagic fish such as sardines, mackerel and herring. The manufactured feeds developed thus far have focused on moist and semi-moist feeds, which produce a soft-textured product, however dry feeds have also been trialed. Farmed tuna are generally fed for 3-6 months before harvest. Feed intake can start at >10% of body weight per day (bw/d) for raw fish feeds, stabilising to <5% bw/d nearer to harvest. FCR (dry feed weight) values range from 3-6:1. Cumulative SGR's of 0.5-0.6 have been achieved.

Key words: Manufactured feeds, proximate composition, feed intake, feedback loops, FCR, SGR.

RESUME – *"Gestion nutritionnelle et développement d'aliments manufacturés pour l'aquaculture du thon". Actuellement, tout l'élevage du thon est fondé sur la capture de poissons sauvages et l'engraissement par lots. Les thons confinés reçoivent une alimentation de petits poissons pélagiques tels que sardines, maquereaux et harengs. Les aliments manufacturés mis au point jusqu'à présent sont des aliments humides et semi-humides, qui donnent un produit à texture douce, bien que des aliments secs aient également été testés. Les thons à l'embouche sont généralement alimentés pendant 3-6 mois avant la récolte. L'ingestion d'aliment peut commencer à plus de 10% de poids corporel par jour pour les aliments à base de poisson cru, en se stabilisant à moins de 5% de poids corporel par jour à l'approche de la récolte. Les taux de conversion alimentaire (en poids sec de l'aliment) vont de 3-6:1. Des taux de croissance spécifiques cumulés de 0,5-0,6 ont été atteints.*

Mots-clés : *Aliments manufacturés, composition approximative, ingestion alimentaire, boucles de rétroaction, taux de conversion alimentaire, taux de croissance spécifique.*

Background

The high value of tuna on the predominantly Japanese market is largely attributed to the red colour and firm but tender texture of the thin pieces of raw flesh served as sushi or sashimi. Northern bluefin tuna (*Thunnus thynnus*) is the most highly regarded and farmed fish average between 4000-6000 ¥/kg depending on size, condition and quality factors. Farmed southern bluefin tuna (*T. maccoyii*) from Australia are the next most valuable tuna species averaging around 2800-3200 ¥/kg over a season. Other tuna species with aquaculture potential are the warmer water bigeye tuna (*T. obesus*), and yellowfin tuna (*T. albacares*), however these have only recently been trialed in farms in Mexico and the Canary Islands. At present, all tuna farming is based on wild capture and feed lotting and is centred in Australia and the Mediterranean (Fig. 1).

Feed development

The impounded wild-caught tuna are fed on a diet of small pelagic fish such as sardines, mackerel and herring. Local sources of these small pelagics are not always available or in sufficient quantities for farmers and therefore importing frozen stocks is often required. Also, they are expensive to use in terms of labour costs and freezer facilities for storage (Fitz-Gerald and Bremner, 1994). There are a number of other feed management issues associated with raw fish diets. For instance, they carry an increased risk of disease transmission (Wee and Tacon, 1992) and thawed fish have associated fragments of blood and scales, etc. which are released into the water column leading to poor water quality and pollution (Watanabe, 1991). In addition, improper storage techniques can bring about the destruction of certain vitamins and fats affecting fish health and growth (Roessink, 1989).

In order to combat the problems associated with trash fish feeds and to maximise production yields

at the lowest cost, manufactured feeds were developed for the Australian tuna farming industry (Smart, 1996). Manufactured feeds have less bulk to store, are of uniform quality, and allow control over feed formulation (Lovell, 1993). The diets developed thus far have focussed on moist and semi-moist feeds, which produce a soft-textured product, however dry feeds have also been well accepted. Diet formulation development has largely taken place in Australia and has been based on the composition of southern bluefin tuna muscle and natural prey species (Clarke *et al.,* 1997). These analyses indicated a high energy, high protein, diet typical of an opportunistic carnivore was most suitable. Analysis of amino acid profile (Table 1) was used to help formulate early manufactured feeds trialed with tuna (van Barneveld *et al*., 1997). In addition, a range of experiments were conducted to assess the *in vivo* and *in vitro* digestibility and transit time of feed ingredients, manufactured diets and pilchards fed to farmed tuna (van Barneveld *et al.,* 1997; Carter *et al.,* 1997; Clarke *et al.,* 1997).

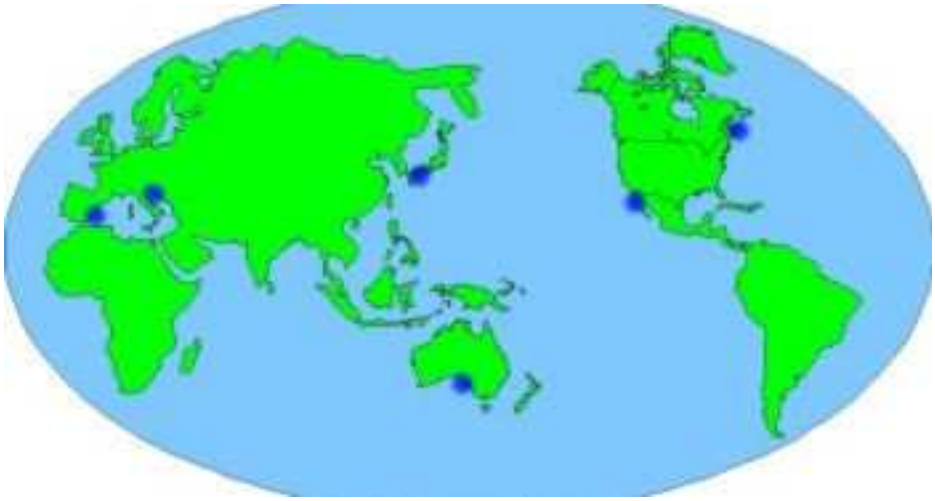

Fig. 1. Map of world showing the main tuna farming locations.

Table 1. Essential amino acid content of red and white muscle in SBT (g/kg, dry matter), dietary amino acid balance (used prior to 1997) and proposed ideal amino acid balance (from van Barneveld, 1997)

Amino acid	Red muscle	White muscle	Dietary balance	Ideal balance
Methionine	11.0	10.9	49	35
Threonine	18.2	17.2	56	56
Valine	20.4	19.2	74	63
Isoleucine	18.7	17.1	61	57
Leucine	29.3	27.6	110	90
Phenylalanine	15.1	14.9	63	47
Lysine	32.5	30.7	100	100
Histidine	30.5	30.3	37	96
Arginine	23.9	22.3	93	73

Performance of farmed tuna

Feed intake

Tuna have sensitive sensory systems, including their visual acuity (Dickson, 1995) and well developed olfactory systems (Atema *et al.,* 1980). The rapid training of a wild tuna to eat manufactured feeds requires a suitable weaning program that makes a transition to the intended feed. Learned behaviour is important in this process along with fish condition (health status) and hunger level.

Farmed tuna are regarded as being in marketable condition after about 3-6 months of feeding and the premiums achieved are generally based on freshness, high condition index, and fat content (Goodrick *et al.,* 1999). The first month of feeding can see feed intake rise above 10% of body weight per day (bw/d) for raw fish feeds and feeding behaviour is initially very active. These levels stabilise to less than 5% bw/d nearer to harvest (Sylvia *et al*., 1999).

Growth, FCR and condition factor

The logistics of managing the feeding of such large quantities of sardines pose a significant challenge. The nutritional quality of small pelagics rapidly decreases over time and oxidation is a major concern, especially when uneaten feed is retained for feeding the following day. The raw fish diets are broadcast by means of hand, shovel, and various pumps. Some feeds are added to the water frozen in 10-20 kg blocks inside small floating enclosures within the cages and as they thaw, they sink to the tuna below. The use of feedback loops is quite limited with some companies using cameras or divers and this area needs attention to avoid overfeeding. Recorded FCR values range from 3-6:1 (dry weight feeds:wet weight tuna) for pilchards and moist pellets (Smart, 1998). Cumulative SGR's of 0.6 for *T. thynnus*, 0.5 for *T. obesus*, and 0.45 for *T. albacares* have been achieved over a 4 month feeding period (Sylvia *et al*., 1999), with rapid growth in the first month after capture which is typically at higher water temperatures. The industry has dramatically improved FCR over time and this evolution will continue with the introduction of extruded diets and feedback mechanisms. The condition factor of farmed tuna typically increases from 1.9 to 2.5 over the 3-6 month fattening period. The shape of the tuna is another important factor for the Japanese marketplace.

This summary attempts to give a general global overview of tuna feed management, however it must be recognised that the scientific literature is typically well behind the rapidly evolving finfish aquaculture industry.

Conclusions

There have been some highly successful recent commercial trials with extruded feeds, which produced good fish performance and market acceptance (G. Bayly, Skretting, Australia, pers. comm.) but these have not been covered in this review. As the tuna industry moves forward with manufactured feeds, the key issue now will be managing the replacement of the raw fish diets with pelleted feeds.

A quantum leap will be achieved once hatchery culture of tuna juveniles is established and this will enable feed development to move more rapidly into the area of drier extruded diets, following a similar evolution to the Atlantic salmon (*Salmo salar*) industry. However, this is likely to be a different product to the current feed-lotted tuna as it may not be economic to on-grow propagated tuna juveniles to the size of wild caught fish. As a result, in the future we may see a farm-reared tuna industry producing fish of 5-15 kg for a new "farmed" market sector that may expand significantly outside Japan.

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