Krill Meal and Krill Oil

How price and tonnage competitive are they with other fishmeals and oils?

By Dimitri Sclabos Katevas, General Manager Tharos Ltd., Chile.

Krill are swarming pelagic euphausiids, similar in appearance to shrimp, and are an important member of the food chain and polar waters. They are relatively low in the trophic food web and form an essential part of the diet of diverse species such as fish, seabirds and whales. There are currently six krill species that are fished (Nicol and Endo 1997) particularly Antarctic krill *Euphausia suberba*.

The Antarctic krill fishery is the largest extending to annual 10-year avg. of 145,000 tons. This catch represents only 1/50th of the total allowable catch where the standing stock is estimated between 55 and 160 million tons (Nicol and Foster, 2003).

The development of the market for krill meal and oil as an aquaculture ingredient is limited by technical difficulties, associated with catching and processing, and issues pertaining to its suitability of inclusion in the human food chain. Astaxanthin (Storebakken

1988), proteins and lipids that are present in high concentrations in krill, degrade rapidly once captured meaning that krill must be immediately processed once on board. The extreme environment characteristics of a majority of oceans where krill are found increase the cost of exploiting this resource limiting future growth.

Although krill has been successfully cultured in extensive ponds (Hirano et al. 2003) there is currently no research suggesting that intensive culturing methods may serve as a potential source of protein and-or oil for aquaculture feeds.

Krill meal, and krill oil more specifically, are considered a rather new ingredient, although in the 70s the former Soviet Union krill fishing fleet was manufacturing both.

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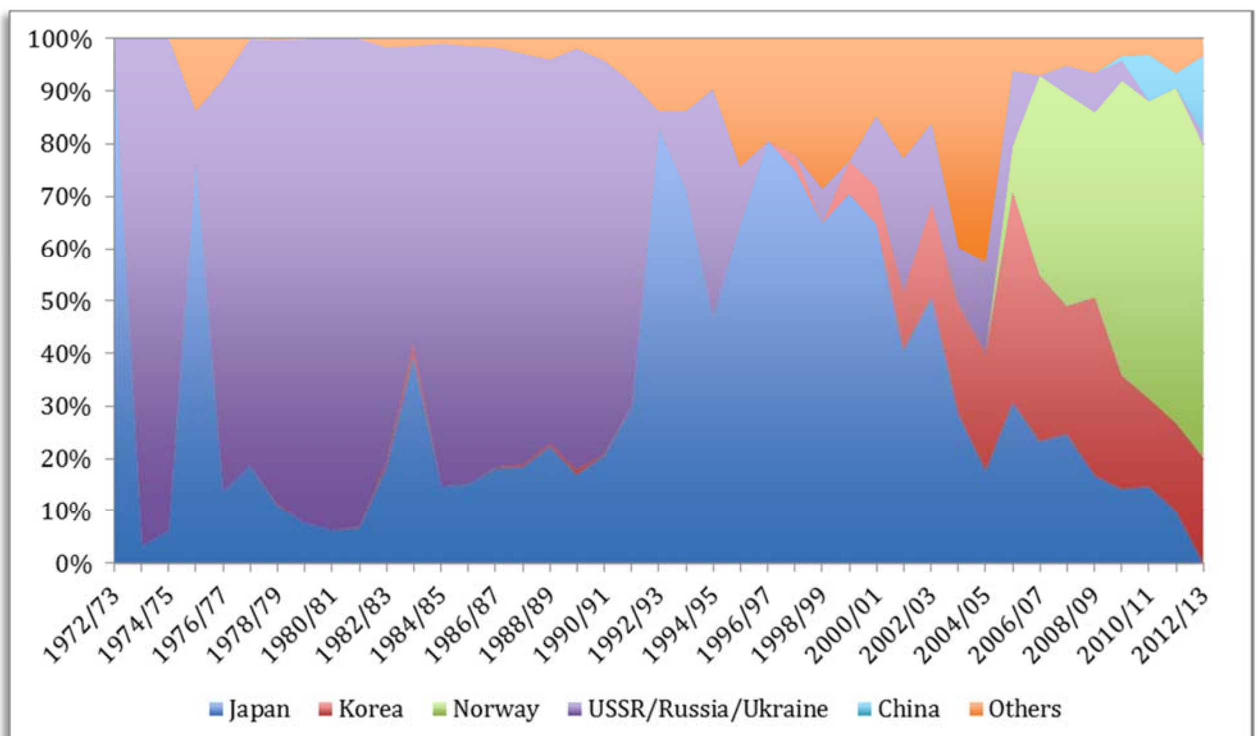
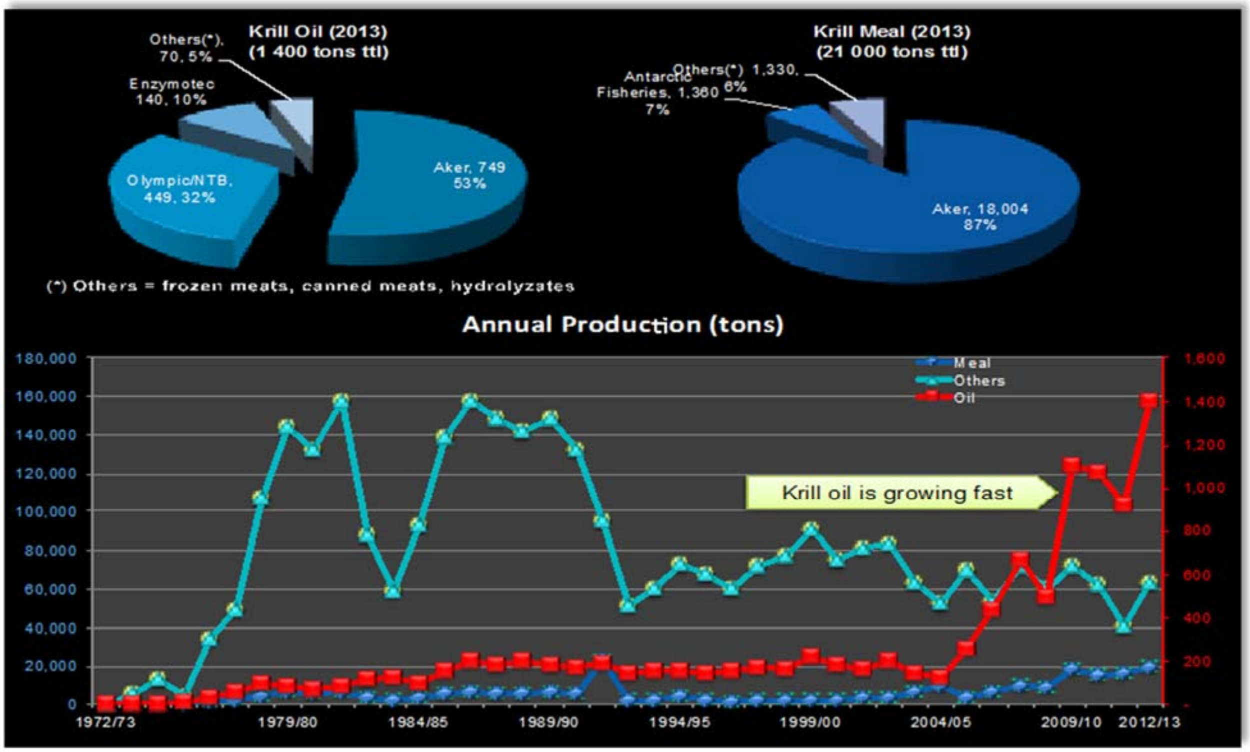
Whole fresh frozen, meats and feed-grade meals are major krill products with an annual 10-yr avg. of 70,000, 750 and 9,750 tons, respectively. In the same period, krill oil was close to 450 tons per/yr., triglycerides (TG) and phospholipids (PL) enriched oils.

If current world production plans are fully accomplished, it will increase dried meal tonnage twofold and krill oils three times in the coming three to four years, a tonnage that will not ease shortages of other marine-origin meals and oils, particularly for oils as the primary target is pricy human-grade applications, predominantly the human health and supplement category. Nor is feed-grade TG-enriched krill oil is a target, unless blended with phospholipids-enriched krill oils to help improve viscosity, and hence, ease of encapsulation.

South Antarctic Krill Fishing Effort





Krill Meal as a Feed Ingredient

Several of Aquafeed.com's publications and articles have addressed Tharos research regarding protein, palatability, pigment, heavy metals, dioxins and other important krill meal compounds and their impact on aquafeeds.

Although pelagic meals and oils are getting scarcer, hence, expensive, krill meal is not called to become the main relevant protein source, rather one that allow vegetable proteins to take a leading share in the feed. Krill meals' negligible amount of dioxins, PCB's and heavy metals help this goal.

Krill meal is an excellent source of **protein** (avg. 60% dry basis] with the highest biological value.

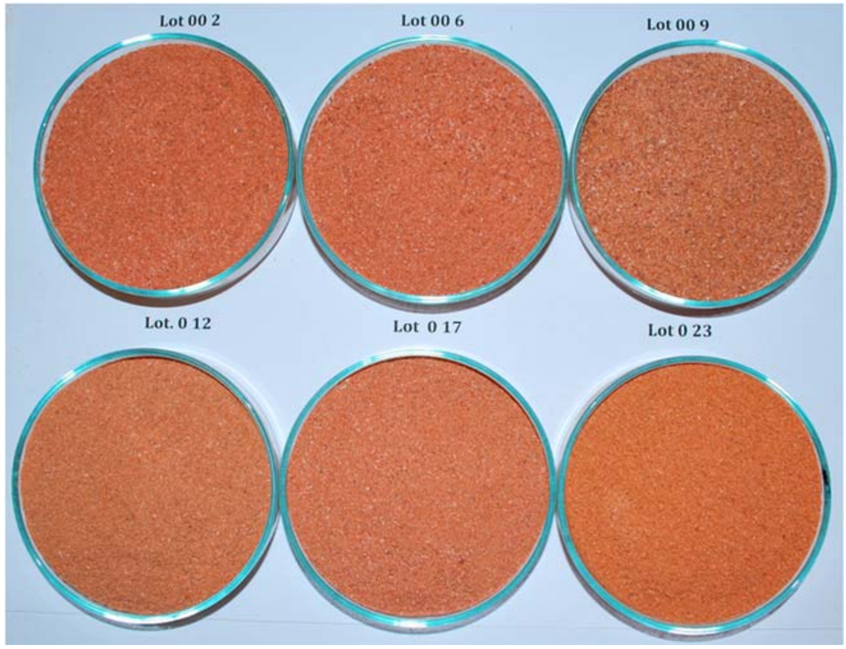
Regarding **palatability**, krill meal has a low molecular weight of soluble compounds such as nucleotides, amino acids and high levels of trimethyl amine oxide, TMAO (190 MgN/100 g sample), all acting together as an effective attractant and flavoring agent. (*Allahpichay and Shimizu 1984; Storbakken, 1988; Shimizu, et al., 1990; Ogle and Beaugz, 1991*).

Arnd et al. (1999) show that a 5% inclusion increased palatability of highly fish oil/meal substituted feeds to levels comparable with traditional diets while *Suontama et al. (2005*) demonstrated excellent performance of both salmon and halibut fed diets based on krill protein and copepod oil.

The inclusion in feed formulations of ingredients that act as attractants has been proposed as a means of increasing feed consumption, hence, growth of farmed shrimp. Given a choice between a base feed and one containing krill meal for example, *P. monodon* show a significantly greater preference for feeds containing krill meal. (*The efficacy of ingredients included in shrimp feeds to stimulate intake. D.M. Smith, S.J. Tabrett, M.C. Barclay & S.J. Irvin. CSIRO Marine Research, Cleveland, Queensland, Australia. November 10th 2010.)*

In one research from the

Institute of Marine Research and the National Institute of Nutrition and Seafood Research (NIFES) in Bergen, Norway, using proteins from Northern krill (*Thysanoessa inermis*), Antarctic krill and Arctic amphipod (*Themisto libellula*), concluded that krill meal could successfully replace fishmeal up to 60%. (*Institute of Marine Research, Bergen, Norway; Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway; Aquaculture Protein Centre, Ås, Norway; 4National Institute of Nutrition and Seafood Research (NIFES), Bergen, Norway).*



Not all krill Meals are the same—although the may look the same.

South Antarctic krill meal natural **pigment** (in the form of Astaxanthin) has a typical range of 115-175ppm dry basis, depending in processing, resource and fishing conditions. The end product contains the same type and coloring agent as naturally fed wild caught salmon adding a strong selling argument for feed manufacturers focused on natural or organic conscious buyers.

When Tharos Ltd introduced to the market, in the early 90s, krill meal sales separated by pigment content, it was a time when Japanese krill meals prevailed in the market sold primarily by protein content.

Tharos' pigment segmentation lapses each 50ppm, 100ppm onwards for feed-grade meals. Less than 100ppm pigment meals are currently sourced off processes that extract oils from the meal, oils used in human health applications. Tharos' selling principle stands for krill meal prices varying in a ratio of US$50 per ton for every 50ppm pigment difference.

Krill meal **fat content,** in an average of 15% (8 – 18%, up to 26-27% if used for human-grade krill oil extraction), depends on fishing season and processing conditions. For traditional krill meal-processing layouts, around 70% of raw krill original fat content remains bonded to krill meal protein. This fat contains high Omega-3 concentrations linked to phospholipids, whereas EPA & DHA are found in the range of 19 to 24%, or higher (as part of lipids). The fat has a high content of phospholipids (30-50% of lipids). Fish fed with diets containing krill meal increase their natural Omega 3 and natural astaxanthin content.

Krill meal is added in aquaculture feed diets in a range of 1 to 8% *(Dimitri Sclabos unpublished reports 2001 and 2005),* used at pre-harvest or throughout the whole rearing and growth phase, depending on diet's target. Markets for these feeds include shrimp, trout and salmon-feed manufacturers.

Best krill meals are a result of fresh and whole raw krill processed on board (at-sea) factory trawlers within the first two hours after the krill has been captured, allowing the highest freshness expressed in a very low TVN value in the range of 5 – 20 (mgN/100g). *(Raul Toro, Mr. Dimitri Sclabos, independent report 1999-2003, unpublished data).* One recent publication expands on this concept.

Krill Meal shows a remarkably low content of undesirable substances such as heavy metals and dioxins, closely related to the unpolluted waters where it is captured and processed *(Dimitri Sclabos & Raul Toro Aquafeed.com report June 2003).*

Arsenic inorganic form is found in krill in an amount of less than 0,01ppm while fish have 1-10ppm of As/kg (wet weight). In whole krill, Arsenic level reaches 3 ppm As/Kg *(Deheyn, D. et al, 2000).*

Methyl mercury found in fish feeds is accumulated in fish's flesh and slowly eliminated. Tuna, halibut, sharks, and other predatory species accumulate higher mercury concentrations (0.5 – 1 ppm wet weight). The opposite is valid for species found at the beginning of the food chain, such as Antarctic krill that fed from plankton. It accumulates mercury at less than 0.1 ppm (wet weight).

The Fluoride Question

Soevik & Breakkan, 1979, first indicated the high fluoride content of the exoskeleton of krill for *E. superba* but all other krill species so far examined have similar high levels *(Sands et al., 1998).* It seems that high exoskeleton fluoride concentration is a general feature of euphasids, hence, feed users have to take this feature into account when assessing potential products.

Aquafeed.com has published Tharos research about krill Fluoride.

All krill species contain high levels of natural organic fluorine in their shells *(Nicol & Stolp 1991; Soevik & Breakkan 1979; Virtue et al., 1995).* However, South Antarctic krill is a key food source for a huge number of predators, fluoride being involved in the synthesis of bones and scales *(Steffens, W. & lbrecht, M., 1982).* Despite the high fluoride level of whole raw fresh krill, they are, however, suitable for aquaculture feed *(Storbakken 1988).*

Krill contain high concentrations of fluoride (up to 6,000 mg/kg dry-weight). However, krill derived fluoride has been shown to have a very low retention in salmon and cod *(Moren et al. 2005)* and, when retained, it is largely stored in

the fish skeleton *(Virtue et al. 1995).*

Using a typical processing layout, with fresh raw krill, (including the exoskeleton), the resulting krill meal has natural organic fluorine content in a range of 1,000-3,000 ppm.

Many surveys have demonstrated that the use in aquaculture of crustacean meals, despite its high fluoride content, poses no risk to the animal's health. Fish don't accumulate fluoride in their fillets, so is not harmful for human consumption.

Since Soevik and Braekkan (1979) found high concentrations of fluoride in krill (1,300-2,400 ppm DW in whole krill), the problem in using Antarctic krill for human nutrition increased. Krill fluoride shows good bioavailability and high amounts of fluoride are toxic. Less than 4 mg F- daily is considered harmless to humans. In the long term, higher amounts lead to fluorosis with symptoms such as changes in bone structure and enzyme inhibition (Eagers, 1969).

A December 2006 study carried out at Kochi University (Japan) by Bunji Yoshitomi, Masatoshi Aoki and Syunichirou Oshima looked to totally replace fishmeal (FM) in diets by low fluoride krill (*Euphausia superba*) meal (LFK). The Yoshitomi, B. et al., study replaced fishmeal with LFK in experimental diets at the replacement proportion of 0.0%, 7.7%, 15.4%, 30.8%, 46.2% and 100.0%, fed to groups of rainbow trout (*Oncorhynchus mykiss*). In all experimental groups, feed intake, feed efficiency, specific growth rate and hepatosomatic index were unchanged compared with fish fed the control diet. After 95 days, the fluoride concentration in dorsal muscles of the fish of each experimental group, except LFK100, was below the detectable limit (1 mg/kg). The total replacement of fishmeal by LFK in aqua diets was successful, with no defects in growth performance.

Krill Meal Lipids

Is there a standard fat content in krill meal? Is the fat content stable throughout the entire season?

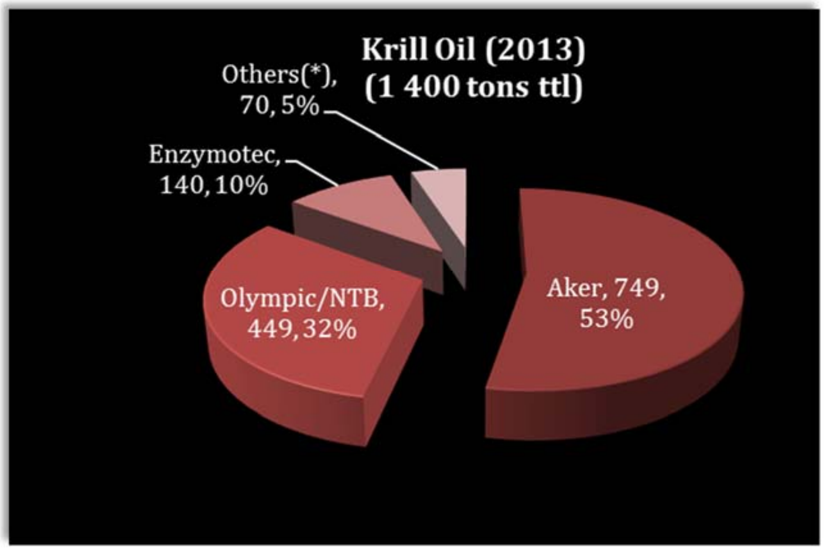
South Antarctic krill contains 4 to 5% of its natural weight composed of extractable lipids, more than half of which are in the form of phospholipids (PL) — phosphatidylcholine (PC) (33–36% of the sum of the lipids), phosphatidylethanolamine (15–17%), lysophosphatidylcholine (3–4%), and others (2–3%). Among phosphorus-free components, triacylglycerols predominate (32–35%). Among other factors, krill meal lipid content is related to the lipid content of raw fresh krill and size of each specimen.

Month	Lipids Content Raw krill (%) Wet Base (Range)	Fishing ground
Jan	2.0 – 3.0	North Antarctic Peninsula, Bransfield Straight
Feb	2.0 – 3.0	Orkney/Elephants Islands
Mar	3.0 – 4.0	Orkney/Elephants Islands
Apr	4.0 – 6.0	Orkney/Elephants Islands
May	4.0 – 6.0	Orkney/Elephants Islands
Jun	3.0 – 4.0	Orkney/Elephants/South Georgia Islands
Jul	2.0 – 3.0	South Georgia Island
Aug	2.0 – 3.0	South Georgia Island
Sep	2.0 – 3.0	South Georgia Island, North Antarctic Peninsula
Oct	2.0 – 3.0	North Antarctic Peninsula
Nov	2.0 – 3.0	North Antarctic Peninsula
Dec	2.0 – 3.0	North Antarctic Peninsula

Lipid Content in South Antarctic Fresh Raw Krill

South Antarctic raw krill lipid content also varies on seasonality and fishing ground. It is not possible to secure a stable one-single fat content level for aqua-grade krill meals, rather min - max levels.

Valuable krill meal lipids are used by several current krill operators to extract pricy supplement and pharma-grade krill oil. This oil is entirely extracted onshore from krill meal previously manufactured at sea and transported to onshore extraction facilities. Such extraction processes use chemical sol-



vents (e.g. acetone, ethanol) at one point of the manufacturing steps, a model that prevents valuable biological and chemical raw krill compounds from remaining in the oil. More at WorldFishing.net. Tharos' newly patented process gets rid of all solvents, and extracts pure 100% solvent-free krill oil directly at sea.

Current Antarctic krill fishing operation models do not allow krill oil to become a competitively priced feed-ingredient. It will remain a niche food, supplement and pharma ingredient with the USA as its biggest market (43% of world krill oil sales) and Asia in second place, for now.

Krill oil production (2013) is in the vicinity of 1,400 tons (PL-enriched krill oil) from which 65-75% was sold in the same year valued at US$105-135MM with a market potential of US$500MM within the coming three to four years.

Krill oil key players are Norwegians Aker and Olympic, Canadian Neptune Technologies and Israeli Enzymotec, Aker being the sole fully vertically integrated company. Several Chinese krill oil manufactures have entered the market.

In terms of raw fresh krill, 1,400 tons krill oil equals approximately 50,000 tons, or 16% of 2014 raw fresh krill capture.

Current prices limit krill oil from expaning to the feed category, in the vicinity of US$125 per kilo FOB bulk for supplement/pharma grade krill oils. Prices will drop once new processing technologies go commercial and planned new krill operations enter the fishery (2015-2016).

Triglycerides-enriched krill oil prices were in the low US$1 per kilo range (early 2000s) up to US$7-23 per kilo range (early 2010s) subject to quality, used as a blender for phospholipids-enriched krill oils.

Krill Meal Pricing

Has krill meal price a direct relationship with fishmeal prices?

Krill meal can be sourced as a direct-target product (from raw krill), as a co-product of tail meat production (waste + raw) or as a by-product of oil production (waste from oil extracted from meal).

Krill meal prices have remained above US$1.5 per kilo FOB in the least 10-years and almost always above fishmeal prices.

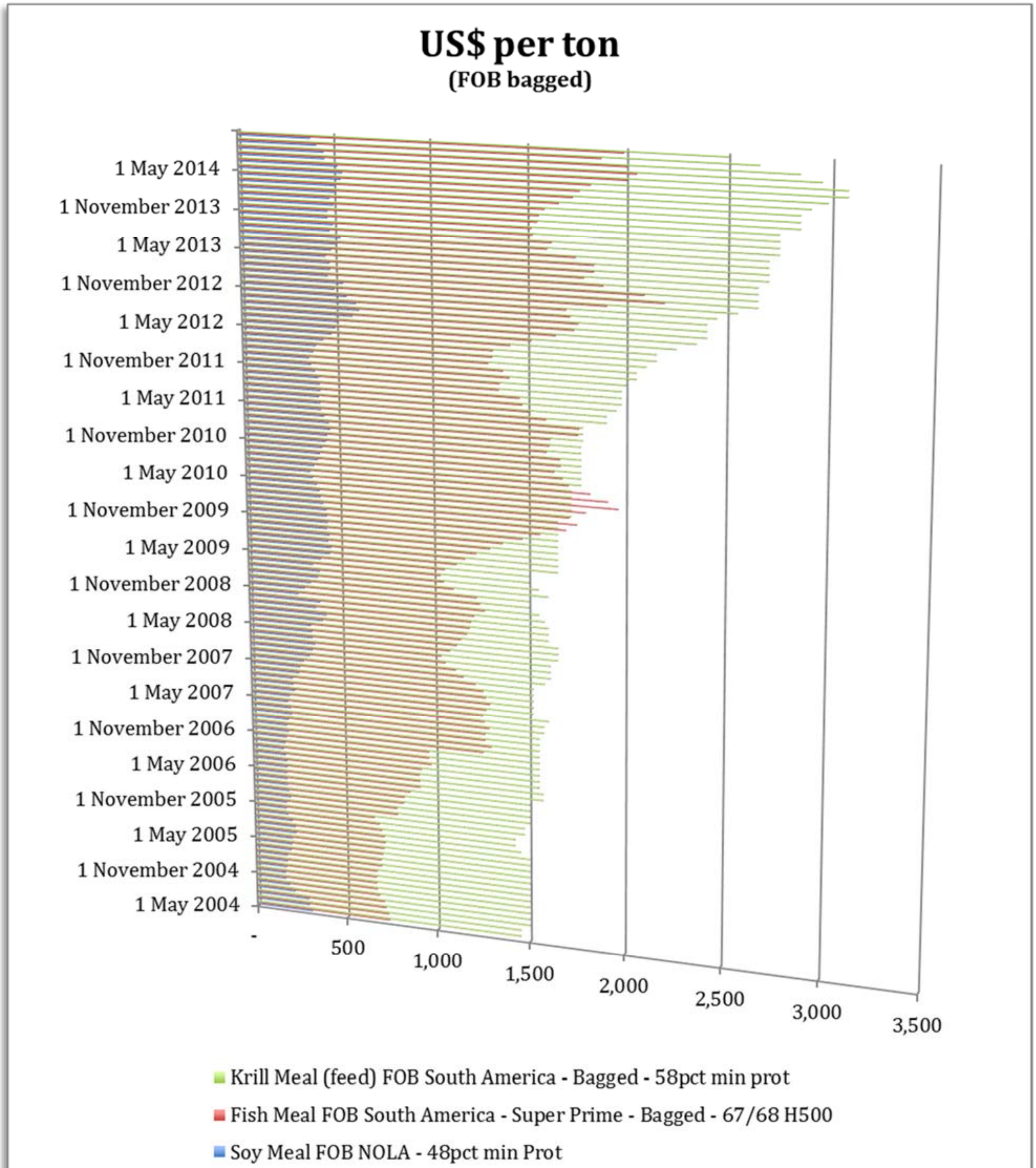
Given the main krill meal characteristics, the following products are relevant krill meal substitutes, either combined or independently; (a) Pigment (as astaxanthin), (b) fish and vegetable proteins, (c) lipids and (d) attractants. These components have seen significant ups and downs in the same period, although krill meal prices still show a rather stable trend.

Tharos' mid 2000 market research estimated krill meal potential annual demand of around 117,000 tons of mid-high quality krill meal mostly for aqua-feeds for salmonids and farmed shrimp.

Late 2000s Tharos developed a krill meal and oil econometric price predictive model whose key influencing variables, in different proportions, proved to be rapeseed oil, soy oil, sunflower oil, fish oil, soy meal and fishmeal.

10-yr. avg. prices shown below apply to high-quality krill meals traded in the open market and through Tharos' world channels. The same model predicted the 4 to 6% price decrease seen since the end of Q3.'14, price expected to stabilize until Q2.2015 shipments in the range of US$2.45 to US$2.85 per kilo FOB for meal 58% prot min, moisture 10% max, 18% max fat and 13% max ash content.

Future krill meal prices will be impacted by (a) feed sub-



stitutes prices and (b) krill meal demand used for krill oil extraction. The effect in krill meal prices might show a different path. FAO food price index on the downturn and expanded krill fishing operations and larger Chinese krill oil extraction facilities will impact krill meal prices in opposite directions.

More about krill end-products at Aquafeed.com publication October 6,2003.

Raw Krill (Tharos trials at-sea 2013)

	KRILL MEAL	FISHMEAL
Palatability	Low molecular weight compounds that act as an effective attractant and flavoring agent.	Less effective.
Antioxidant Properties	It has a high carotene (Asthaxanthin) content and natural tocopherols.	None.
Fluoride	High contents of natural organic fluorine.	Low content.
Natural pigments	Increases flesh pigmentation of farmed species. Acts as a powerful antioxidant.	None.
Steroidal components	Growth promoting agent.	None.
Chitin	Immune system stimulant for some fish species.	None.
Lipids	Sufficient Omega3 fatty acids content. Fatty acids in the form of phospholipids (good bio-availability).	Sufficient Omega3 fatty acids content. Fatty acids in the form of triglycerides (poor availability).
Undesirable substances	Low contents of Dioxins, PCB's and heavy metals.	Risk of high contents of Dioxins, PCB's and heavy metals.

More information

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