Report on Credit Seminar entitled

RECENT DEVELOPMENT IN
AQUAFEED EXTRUSION TECHNOLOGY

Submitted By

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INTRODUCTION

WORLD FISH PRODUCTION

Fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world. World per capita fish supply reached a new record high of 20 kg in 2014, thanks to vigorous growth in aquaculture, which now provides half of all fish for human consumption, and to a slight improvement in the state of certain fish stocks due to improved fisheries management. Moreover, fish continues to be one of the most traded food commodities worldwide, with more than half of fish exports by value originating in developing countries. Recent reports by high-level experts, international organizations, industry and civil society representatives all highlight the tremendous potential of the oceans and inland waters to now, and even more so in the future, contribute significantly to food security and adequate nutrition for a global population expected to reach 9.7 billion by 2050.

Global total capture fishery production in 2014 was 93.4 million tonnes, of which 81.5 million tonnes from marine waters and 11.9 million tonnes from inland waters. China remained the major producer followed by Indonesia, the United States of America and the Russian Federation.

World catches in inland waters were about 11.9 million tonnes in 2014, continuing a positive trend that has resulted in a 37% increase in the last decade. Sixteen countries have annual inland water catches exceeding 200 000 tonnes, and together they represent 80% of the world total.

Aquaculture has been responsible for the impressive growth in the supply of fish for human consumption. Whereas aquaculture provided only 7% of fish for human consumption in 1974, this share had increased to 26% in 1994 and 39% in 2004.
Indian Aquaculture Production

India offers a huge potential for aquaculture development. The country has a coastline of 7,517 km and an extensive river and canal system of about 195,210 km, consisting of 14 major rivers, 44 medium rivers and numerous small rivers and streams. In addition, pond and tank resources are estimated at 2.36 million ha. In India, the annual fisheries and aquaculture production increased from 0.75 million tonnes in 1950-51 to 9.6 million tonnes in 2013-2014. Globally the country now takes the second position, after China, with regard to annual fisheries and aquaculture production. The total aquaculture production in 2012-2013 was 4.21 million tonnes.

This constituted over a third of the country’s total fish production. This quantity is almost fully consumed on the domestic market, except for shrimps and freshwater prawns, which are mainly exported. India is the largest exporter of shrimps to the Netherlands. Specifically freshwater aquaculture experienced over a tenfold growth in the past three decades, 0.37 million tonnes in 1980 to 4.03 million tonnes in 2010. Over ten percent of the global fish diversity can be found on or near the Indian subcontinent and more than 14.5 million people depend on fisheries activities. Nevertheless, the national average annual consumption of fish and fish products in 2010 was 2.85 kg/capita.

In the coastal state of Kerala, fish is consumed the most, with 22.7 kg/per capita and in the mountainous state of Himachal Pradesh consumption is with 0.03 kg/capita relatively low. About 40% of the Indian population does not eat fish since they are vegetarian and the remaining 60% only occasionally consumes fish. Lower income and rural families consume less fish than higher incomes or urban families.
FRESHWATER AQUACULTURE

The freshwater aquaculture production in India comprises about 2.36 million ha of ponds and tanks and accounts for nearly 55% of the total fish production in India. Currently, only an estimated 40% of the available area is in use because of technical and market access issues. Additionally, freshwater aquaculture is undertaken in lakes, irrigation canals, reservoirs and paddy fields. It is often combined with the production of shrimps in traditional low-brackish water ponds. Aquaculture production is mainly of a low quality which requires low levels of inputs. More intensive high-quality aquaculture has received more attention in recent years however. Freshwater aquaculture in Eastern India mainly consists of ponds and tanks of less than 1 ha. In Western India aquaculture is operated on a larger scale, with watersheds of 15-25 ha. In Northern India more use is made of open waters for aquaculture and in the South, ponds for crop irrigation are used in aquaculture. Different species of Indian carps (catla (catla catla), roho (labeo rohita) and mrigal (cirrhinus mrigala)) contribute between 70% and 75% of the total freshwater fish production, while silver carp, grass carp, common carp and catfish make up 25% to 30% of the production. Production is mainly destined for the domestic market and processing of freshwater aquaculture produce is rare. This is caused by the high demand (West-Bengal, a large fish producing state imports for instance 30% of its consumption form neighbouring states). Cold chain is non-existent for similar reasons. In addition, the giant river prawn (scampi) is produced in freshwater ponds.

INPUTS

Feed is provided through farm produced oil cake, rice bran, snail, clam or mussel meat and buffalo meat. When looking at specific states, Andhra Pradesh, followed by West Bengal and Uttar Pradesh are the main producers of freshwater aquaculture. For feed however, producers depend on these agricultural byproducts. The production of feed specifically for freshwater aquaculture experienced a growth in the 2010s. Additional feed is imported from Thailand, Chile, Peru, Myanmar and Taiwan. In West-Bengal a large untapped market for freshwater aquaculture feed exists.
Freshwater aquaculture production is however scattered and awareness of farmers is low. In order to overcome these hurdles, foreign companies might need to tie up with local actors. As in the other aquaculture sectors, there exists a need for high-quality feed to increase production. Indian feed plants are available to take this opportunity. Dutch companies may nevertheless become involved through initiating production or supporting the production of higher quality feed by existing producers. Moreover, the aquaculture industry requires quality fish seed, preferably from disease resistant species that grow fast, and quality hatcheries. The feed consists 60 to 70 percent of the production costs. Enabling a reduction in feed costs, for instance through high-quality feed, while stimulating a good growth will increase margins for farmers.

**BRACKISH WATER AQUACULTURE**

In the domain of brackish water aquaculture it is worth mentioning that a scientific approach to the traditional practice of trapping naturally bred fish and shrimps in coastal wetlands or manmade impounds was carried out. Initiatives of the Indian government, demonstration projects of the Marine Products Export Development Authority (MPEDA) in combination with credit facilities provided by commercial banks enabled the establishment of several shrimp hatcheries. Between 1989 and 2007, the shrimp farming experienced a fivefold increase to 144,346 tonnes per year. Production is decreasing again however and 90% of the shrimp farmers in India are small scale farmers which own less than 2 ha of land. Some species of shrimps are more sensitive to production relate risks and diseases than others.

The whiteleg shrimp (Litopenaeus vannamei) is produced inland and is mainly destined for export. This species rapidly replaces the black tiger shrimp (Penaeus monodon). In addition to the production of shrimps, also seabass, milkfish and other freshwater species are produced in (low) brackish water aquaculture. The production of shrimps takes place in different ways. Either after the harvest of rice (polyculture), such as in central Kerala, Odisha, Karnataka, Goa and parts of West Bengal, combined with the growing of rice, which is mainly practiced in Goa and West
Bengal, or in dedicated ponds using scientific methods, such as in Andhra Pradesh and parts of West-Bengal.

As for freshwater aquaculture, the Seafood Trade Intelligence Portal indicates that Andhra Pradesh is a major player. Production has been developed here however and new development opportunities for shrimp production exist in West Bengal, Odisha and Gujarat.

**INPUTS**

Like in the freshwater aquaculture sector, a shortage of hatcheries and cost-efficient feed exist exists and the brackish water aquaculture industry requires the introduction of better techniques and management practices. However, techniques should be adapted to the Indian situation and financial circumstances. Seed is mainly produced in the Chennai region (Tamil Nadu). In West-Bengal the environmental circumstances are not favourable for shrimp hatcheries.

In the Bhimavaram and Visakhapatnam area in Andhra Pradesh hatcheries breed mainly Vannamei shrimp, but also produce small quantities of rohu, tilapia, bas and catla. Important local producers of feed for shrimp farming are CP, Avanti and BMR. Fingerling food is however still imported. Dutch companies can take up the opportunities in feed, feed formulation and feed additives (pre-mixes). Some Dutch companies are already exploring market opportunities in the feed sector. One Dutch feed company is initiating a pilot project for which it imports feed to explore market opportunities.

Depending on the market situation, future plans may include taking over an Indian feed factory. In brackish water aquaculture, as in the other aquaculture sectors, there is a need for high-quality feed to increase production. Indian feed plants are available to take this opportunity. They are however mainly located in Andhra Pradesh. Opportunities for shrimp feed producers may exist in Orissa and West-Bengal, states where the shrimp sector is developing. Different actors in the West-Bengal aquaculture sector indicate that the feed market has been divided amongst the major companies, but that foreign companies with high-quality feed can attempt to conquer a market share. They do need to tie up however with a local partner to obtain essential market insights. Anmol Feeds, IFB Agro and Elque Group all have indicated their interest in possible cooperation to exchange knowledge and technical expertise. Anmol Feeds will initiate its own production in West-Bengal in
2018. Dutch companies may also become involved through initiating production or supporting the production of higher quality feed by existing producers.

The West-Bengal Secretary of Fisheries expressed his interest in starting feed production in his state. It is important to realise however that the majority of farms in West-Bengal are of a traditional nature and do not use feed because of the size of the ponds and the feed prices. Some farms however combine the use of probiotics with rice bran. This is for instance the case for farms tied to S.A. Exports in West-Bengal. In Andhra Pradesh the sector is more advanced and shrimp farmers use feed specific for the cultivated species instead of generic feed.

UPCOMING AQUAFEED DEMAND IN INDIA

As per an estimate, currently, India’s aqua feed consumption is around 1 million tonnes and assuming on an average 1.5 feed conversion ratio (industry standards), the demand for aqua feed comes to around 7 million tonnes by 2017-18. India’s seafood production was recorded at 9 million tonnes in 2012-13 and due to rapid changes in shrimp and fish farming, production capacities for modern feed has gradually gone up to 2.88 million tonnes during 2013-14. India has around 26 aqua feed mills spread across the country.

However, their production capacities are only 43.4 per cent with a total production of 1.25 million tonnes. To meet the requirement, India imports more than half of the requirements from other countries, so there is huge scope in aqua feed. With the introduction of vannamei shrimp, the cultured shrimp production is growing at 16 per cent. The demand from shrimp will drive the growth of the aqua feed industry at five to six per cent annually. The feed demand only from shrimp and fresh water shrimp is around 1 million tonnes. India currently has 13 feed mills that can produce modern feed for the shrimp sector with a production capacity of 1.33 million tonnes. On fish feed, the current installed capacity is 1.55 million tonnes.

The total feed production for shrimp and fish stands at 572,000 tonnes and 684,000 tonnes respectively, the report adds. Shrimp production growth has driven consumption growth by 13 per cent between 2007-08 and 2012-13 reaching almost 300,000 tonnes in 2013-14. Disease outbreaks remain one of the major risks affecting the growth of the aquaculture feed industry. Freshwater fish feed demand has grown rapidly, driven by the growth in the freshwater fish segment in India.
Current freshwater fish feed production is estimated at 0.7 million tonnes and significant investment has gone into the creation of capacities.

It is expected that the demand for fresh water fish feed is expected to grow at five to six per cent in the near term. Emphasising on emerging markets for aqua feed, the report said that current market players and feed mill investors are looking for market diversification options to increase feed capacity utilization. Currently, Andhra Pradesh constitutes the major share in the domestic market, accounting for feed sales at almost 60,000 tonnes per month followed by other states with below 5000 tonnes sale a month.

After 2008 many aqua feed mills have started manufacturing floating/pellet feeds for the farming of freshwater fish. Cheaper feed ingredients like deoiled rice bran, wheat bran, cottonseed cake and groundnut cake are extensively used in freshwater aquaculture. Both conventional and non-conventional feed ingredients are used in feed formulation for shrimps. Feed ingredients like fishmeal, squid meal, lecithin, cereal flour and other essential and propriety additives and fish oil are also used in prawn and shrimp feed formulations. Freshwater fish are fed with farm made feeds which consists of a mixture of rice bran, wheat bran and oilseed cakes, the report said.

Globally, the aqua feed market has witnessed an exponential growth owing to factors such as growing consumption of seafood and growth of the aquaculture industry as a whole. India along with US, China and Brazil are the leading aqua feed producers across the world. The report also said that Asia Pacific is the largest market for aqua feed consumption, contributing to over 70 per cent of the overall consumption. An Altech-2015 Global Feed survey stated that the world has produced an estimated 41 million tonnes of aqua feed during the last year. With Asia Pacific and China as one of the leading consumer and producers of aqua feed.

**Extrusion-Definition**

Extrusion, one of the most important innovations of the 20th century, is often presented as a model of scientific and technology transfer between different processing industries, such as the polymer and plastics, food and feed and paper-milling industries in particular.

Although the first technical designs of screw extruders were introduced in the latter years of the 19th century, extrusion processing really established itself
approximately 60 years later, with the development in the plastics industry of polymer-based materials. It was later successfully exploited by the industries that processed plant biopolymers and has developed into a widespread extrusion processing culture over the past 80 years.

Extrusion is commonly defined as the operation of forming and shaping a molten or dough-like material by forcing it through a restriction, or die. This operation is extensively applied in many processes as a batch or continuous operation. While adhering strictly to this definition, the understanding and analysis of extrusion are quite simple and straightforward. Extrusion processing technology relies on a continuous process operation which uses extruders to handle process functions such as the transport and compression of particulate components, melting of polymers, mixing of viscous media, cooking of polymeric or biopolymeric materials, product texturization and shaping, defibering and chemical impregnation of fibrous materials, reactive extrusion, fractionation of solid–liquid media, etc.

Extrusion processing technology is highly complex and in depth descriptions and discussions are required in order to provide complete understanding and analysis of this subject. Extrusion processing technology uses two different equipment designs: the single screw extruder and the twin screw extruder. Within each design, there are various engineering options, which depend upon the equipment manufacturers and/or the processing requirements.

HISTORY OF THE EXTRUDERS

Single screw and intermeshing co-rotating twin screw extruders appeared over the last 30 years of the 19th century. An 1871 US patent to Sturges (1871) presents a single screw machine for pumping and forming soap. Gray (1879) developed a single screw extruder for processing and extruding gutta percha with specific application to wire coating. In fact, the rubber industry was an early user of screw extrusion machinery for the continuous compounding of rubber.

Throughout the period from 1880 to 1930, though no notable industrial application emerged, there was significant mechanical engineering activity that brought remarkable improvements to the designs of the single screw extruder (segmented screws, threaded and grooved liners, pin barrel designs, steam heated barrels, etc.).
In 1869, the first patent for a fully intermeshing corotating twin screw extruder was
granted to Coignet (1869). This patent described a machine called malaxator, which
pumped and processed artificial stone paste.

There was real development of the intermeshing co-rotating twin screw
extruder design in the late 1930s, when Colombo (1939) proposed an advanced
design which was manufactured by the Italian company Lavorazione Materie
Plastiche (LMP). LMP machines were deployed extensively to the polymer industry
over the period between 1940 and 1956, through manufacturing licenses (to Clextral,
formerly CAFL and then Creusot-Loire in France, to R.H. Windsor in England and to
Ikegai Iron Works in Japan), and through exportation sales, to IG Farben industrie in
Germany, for example. The introduction of thermoplastics in the 1930s gave a boost
to the development of extrusion processing technology.

In Germany in 1939, Paul Troester Maschinen fabrick (PTM) built an
electrically heated, air-cooled single screw extruder, with automatic temperature
control and variable screw speed. This was the precursor to modern automated
extrusion technology for the emerging plastics industry. In following years, various
ancillary equipment was introduced to meet the process requirements of the
polymer-processing industry (venting, breaker plates, screen packs, co-extrusion
dies, film blowing, etc.).

As the polymer industry burgeoned, along with the complexity of polymer
formulations, single screw extruders showed real processing limitations in their
ability to efficiently mix, compound and pump polymer melts of specific
characteristics. Then, following World War II and at the request of plastics
manufacturers, twin screw extrusion technology was introduced, adding
significant value to the process.

For example, in July 1956 CAFL delivered its first intermeshing co-rotating
twin screw extruder (72.5mm inter axis) to the French Pechiney company (Pennaroya factory of Noyelles-Godault in France),
for manufacturing plastic pipes. At the same time, at the request of Bayer, the
German company Werner and Pfleiderer made the first prototype of the ZSK 83 intermeshing co-rotating twin screw extruder. Figure 1.1 shows a vertical intermeshing co-rotating twin screw machine supplied by CAFL in 1963, for nylon and tergal spinning. It must be noted that screw extruders played a determinant role in the spectacular growth of the polymer processing industry (plastics and rubber) between 1940 and 1960, when world production of plastics exploded from 300,000 to 12 million metric tonnes per year (Utracki, 1995).

And extrusion technology really established its processing potential with the development of the polymer-processing industry, where, together with the availability of reliable machinery, flexible and productive processing could be carried out at a competitive cost-to-performance ratio.

THE KINEMATICS OF EXTRUDERS

The kinematics of extruders is composed of a motor drive system and a gear reducer, the designs of which determine the torque-speed domain covered by the extrusion equipment. The torque-speed domain is fundamental to defining the extruder’s performance in terms of process productivity and product conversion. The gear reducer transmits the power supplied by the motor to the shank of the screw, the screw shaft for single screw extruders, or the two screw shafts for intermeshing co-rotating twin screw extruders. The gear reducer also has to match the relatively low speed of the screw(s) to the high speed of the motor drive. The mechanical design of the gear reducers defines the torque-speed domain of the extruder and therefore, the maximum torque and screw speed available for extrusion processing. It should be noted that the efficiency of gear reducers is high, generally greater than 95%.

The design of a twin screw extruder gear reducer is more complex, as it must symmetrically divide the torque between each screw. It is composed of two stages: the first stage reduces the speed of the motor drive (1200 to 2000 rpm) to the final speed of the screws (generally 100 to 1200rpm for modern intermeshing co-rotating twin screw extruders), while the second stage distributes torque between the two screw shafts. The design and manufacturing of high-performance gear reducers require a high level of expertise due to the tightness of the interaxis of the exit shafts. Manufacturers have tremendously improved the design and performance of gear
reducers over the past 30 years. This is clearly illustrated by the development of the standard maximum torque density-speed characteristics of intermeshing co-rotating twin screw extruders, which progressed from about 2.5N.m/cm3-250rpm in the 1970s, to 12N.m/cm3-1200 rpm in the 1990s. This allowed end-users to significantly improve the competitiveness of extrusion processes through process productivity and product functionalities.

Over the same period of time, gear reducers have achieved a high level of reliability which today ensures long lifetimes, over 50,000 hours for most extrusion applications, provided end-users rigorously adhere to the appropriate maintenance and lubrication procedures.

PARTS OF THE EXTRUDER

The first section, called the feed section, has deep flights, in order to offer a high transportation capacity for solid and particulate raw material (solid powders and particulates). Its function is to convey the material down the screw. The following section, called the compression section, is where the material is compressed under the compressive effect of the screw (in a channel of decreasing depth). At the same time, the material is heated by interparticular friction and conductive heat transfer until melting occurs. In this section, the material changes from a solid particulate state into a melt state (viscous fluid). This is the longest section, and is essential for correct
operation of the extruder, as it must be designed in such a way as to completely melt polymeric materials.

The melting mechanism of polymeric materials is analyzed in the third section, called the metering section, is where the material is ideally in a molten state. This is a pumping section in which the pressure needed to convey and feed the molten material through the die opening is built up. But it can also be used to fine-tune conversion of the material. In fact, the metering section is characterized by shallow flights which generate high shearing conditions. The mechanical energy dissipated allows the material to be converted into a rheological state which is compatible with satisfactory processing and forming.

The barrel is the cylinder that surrounds the screw. It has a feed throat in the feed section, where the material is introduced into the screw channel. The feed throat is generally water cooled, to prevent the temperature of the material from rising too soon, thereby preventing material from sticking to the barrel wall and causing restriction of the flow into the extruder. Thus, an effective cooling capacity and efficient thermal barrier between the feed throat section and the downstream barrel are important requirements for optimizing the output of the screw-barrel assembly in the feed section.

Some examples of high quality pelleted feeds
COMPARISON BETWEEN EXTRUSION AND PELLETING

<table>
<thead>
<tr>
<th>EXTRUSION</th>
<th>PELLETING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Versatility (Float, Sink, Sink Slowly)</td>
<td>Hard to produce floating feed or slow sinking</td>
</tr>
<tr>
<td>2. Utilize wet waste in final feed or ingredients processing. High Moisture quantity can be used.</td>
<td>Minimum utilization of wet wastes. Moisture contents up to 17% maximum.</td>
</tr>
<tr>
<td>3. Feed cook 90% or higher.</td>
<td>Feed cook only 50% with pre-conditioners.</td>
</tr>
<tr>
<td>4. Highly water stable with flexibility in formulation.</td>
<td>Difficult to produce water stable pellets and inflexible formulation.</td>
</tr>
<tr>
<td>5. High product durability</td>
<td>Lower product durability</td>
</tr>
<tr>
<td>6. Fat levels up to 22% in the formulation</td>
<td>Fat levels limit only up to 6% in the formulation</td>
</tr>
<tr>
<td>7. May be able to bind coarser ground ingredients</td>
<td>Requires finely ground ingredients</td>
</tr>
<tr>
<td>8. Higher Capital &amp; Production cost</td>
<td>Lower Capital &amp; Production cost</td>
</tr>
</tbody>
</table>

EXTRUDER MANUFACTURING COMPANIES

<table>
<thead>
<tr>
<th>Companies</th>
<th>Country</th>
<th>Models</th>
<th>Capacity (tonn/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLEXTRAL</td>
<td>France</td>
<td>EVOLUM PLUS</td>
<td>10-50</td>
</tr>
<tr>
<td>ZCME</td>
<td>China</td>
<td>SPHS218</td>
<td>6.0-10</td>
</tr>
<tr>
<td>ZHOUHENG</td>
<td>China</td>
<td>ZH65, ZH70, ZH85, ZH95, ZH135</td>
<td>2.0-5.0</td>
</tr>
<tr>
<td>ANDRITZ</td>
<td>Austria</td>
<td>EX1250</td>
<td>10-20</td>
</tr>
<tr>
<td>WENGER</td>
<td>USA</td>
<td>X-165, X-185, X-235</td>
<td>3.75 - 5.0, 7.5 - 10.0, 11.25 - 15.0</td>
</tr>
<tr>
<td>ZHONGTIAN</td>
<td>China</td>
<td>SPHG</td>
<td>3.0 - 7.0</td>
</tr>
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CONCLUSIONS

- Standardisation of extrusion processing parameters for alternative feed ingredients to be established
- Trainings on basic of aquafeed extrusion technologies has to be conducted
- More studies on feed formulations for extruded products
REFERENCES


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