Evaluation of the apparent digestibility (*in vivo*) of different feather meals in Pacific White Shrimp (*Litopenaeus vannamei*)

By Dr. Orapint Jintasataporn[1], Dr. Franz-Peter Rebafka and Julian Hoping[2]

1 Kasetsart Univerity, Department of Aquaculture

2 GEPRO Geflügel-Protein Vertriebsgesellschaft mbH & Co.KG

Million tons of fishmeal are used globally each year in all animal feed, including aquaculture. The proportion of the world's fishmeal used for aquaculture is estimated to be close to 75 % by 2018. The total cumulative fishmeal production in 2020 increased by 11 % compared to 2019 (IFFO, 2020).

If aquaculture is to grow as expected, alternatives must be found due to the limited availability of fishmeal for use in aqua feed. In addition, rising fishmeal prices are forcing the industry to reduce the inclusion of fishmeal in diets in order to increase the use of more economical and sustainable feed ingredients.

Hydrolyzed poultry-based animal proteins - for example hydrolyzed feather meal - are economically interesting protein sources that are used in certain areas of aquaculture. These proteins are less expensive, palatable, have extremely low content of unwanted substances and are free of antibiotic growth promotors. By virtue of their origin, free from any marine-based diseases and hence considered as fully aqua biosecure.

However, the use of hydrolyzed feather meal has been limited for reasons, such as poor digestibility.

Unprocessed feathers are high in crude protein (90 %), but are highly indigestible due to the rigid beta-keratin structure typical of avian tissues, in which protein chains are tightly packed and stabilized through hydrophobic interactions as well as cysteine-disulfide bonds. In order to open the cysteine-disulfide bonds and to make the crude feathers available for digestive systems, feathers have to be processed *(Stiborova et al., 2016)*.

Currently, processing in a continuous hydrolyser is recognized by the rendering industry as the most advanced process resulting in a maximum degree of hydroxylation or so called "cooking". Several factors are known to influence digestibility of protein and amino acids. Among these process conditions, drying conditions in particular seem to play an important role in terms of digestibility and nutritional quality of hydrolyzed feather meal *(GEPRO, Newsletter 3 / GoldMehl)*.

Processing

In the past, drying techniques have been discussed in depth. Whereby, the low temperature (LT) fishmeal technology seems to be the state-of-the-art process.

The LT fishmeal technology imparts minimal denaturing effects on proteins, thus preserving inherent digestibility

and biological value. A comparison regarding specific quality aspects is shown in **Figure 1.**

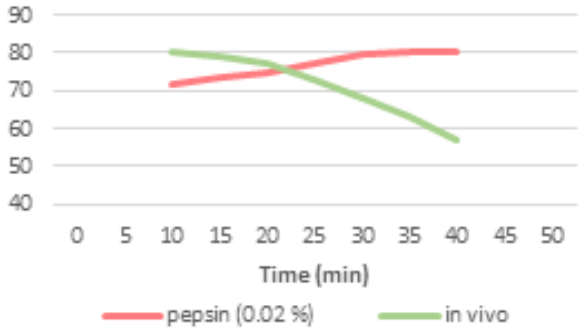

Figure 2: *In vivo* and pepsin (0.02 %) digestibility (2.5 bar)

Figure 1: Protein quality as affected by different drying systems - Low Temperature (LT) fishmeal has been produced with LT fishmeal technology (GEPRO, Newsletter 3/ GoldMehl).

Fishmeal substitute

In addition, mink digestibility evaluations have been extensively discussed as well, indicating the suitable potential of **GoldMehl® FM** as a substitute for unsustainable protein sources.

In this newsletter, we dedicate to another topic the *in vivo* digestibility of feather meals in shrimps. This parameter expresses the real metabolism of nutrients in the animal, which is finally crucial for weight gain.

To better understand the correlation; in a number of studies it has been observed that there are differences in protein quality of processed poultry by-products *(Cho and Slinger, 1979; Cho et al., 1982; Pfeffer et al., 1995; Sugiura et al., 1998, Hajen et al., 1993, Dong et al., 1993)*.

Optimization of cooking and drying conditions are considered to be the main factors contributing to the high digestibility values now observed for poultry by-product meal *(Miller, 1996)*. It is noteworthy that Alterbaum, 2020 indicated that protein meal was almost completely digestible, could also demonstrate the negative correlation between drying conditions and protein quality.

Negative correlation

Papadopoulos, 1987 and Han & Parsons, 1991 observed a poor correlation between the *in vitro* and *in vivo* digestibility of feather meal from broiler chickens. While the *in vitro* digestibility increased with increasing pressure and time of the cooking, the in vivo digestibility decreased with increasing pressure and time **(Figure 2).**

This results in a loss of biological availability of the protein for the targeted species.

As Miller, 1996 mentioned – cooking and drying must be optimized, which means in short – extended hydrolytic processes might increase protein digestibility on the paper, but actually reduce the nutritional value of the product.

This could be illustrated by changes in the amino acid pattern. Amino acids are linked to other substances. They form new crosslinkages within the protein molecules.

Feeding trial – in vivo digestibility

In 2021, a feeding trial was conducted using Pacific Whiteleg Shrimp *(Litopenaeus vannamei)* to evaluate the apparent nutrient digestibility (*in vivo*) of different types of feather meal. As shown in **Table 1**, the trial was carried out with four experimental groups at Kasetsart University, Thailand. Three different types of feather meals, including **GoldMehl® FM** (Group 2), as a partial protein sources, incorporated into a commercial diet and tested against a reference diet without feather meal.

Shrimp (8-10 g weight) were fed assigned diets to excess (4 % of BW) for 15 minutes twice daily. Uneaten pellets were removed after 30 minutes.

Table 1: Description of the feather meals (*analyzed values*)

	CP (%)	CL (%)	CA (%)	Moisture (%)	Digestibility (pepsin 0.02 %)
GoldMehl® FM	89.31	5.24	1.69	5.17	80.59
Feather Meal A	89.07	4.94	1.73	3.89	80.96
Feather Meal B	84.42	4.56	2.74	8.49	87.14

As shown in **Figure 3**, best dry matter, protein and energy digestibility was observed in **GoldMehl® FM** in contrast to the comparable feather meals. Most interesting, the *in vivo* protein digestibility for **GoldMehl® FM** (79.50 %) was much higher than for Feather Meal A (62.55 %) and B (59.91 %).

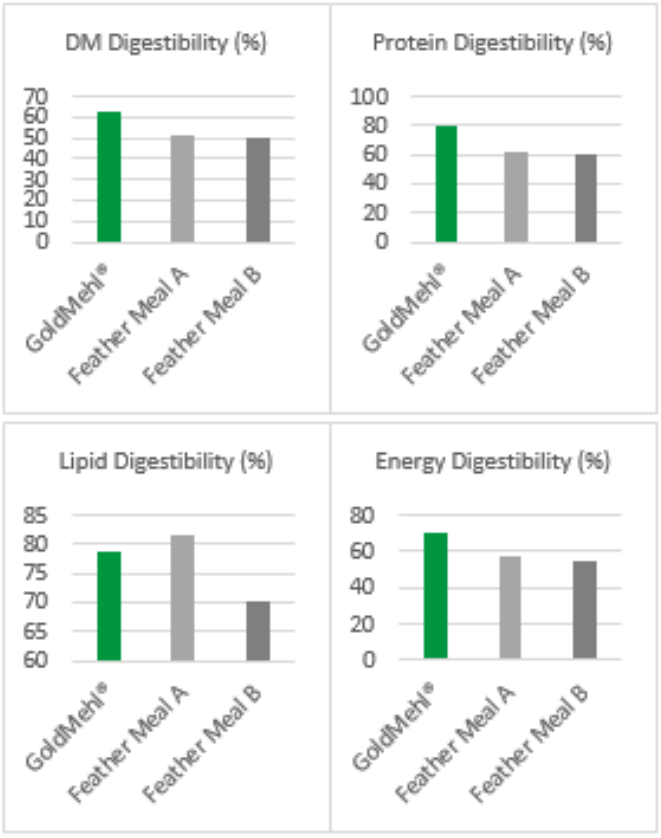

Figure 3: *In vivo* digestibilities of feather meals

In contrast to **Figure 3, Figure 4** shows digestibility of the complete diet between the different types of feather meals and in addition also to fishmeal. It is noteworthy that the diet with **GoldMehl® FM** showed the highest protein digestibility (75.06 %), in contrast to diets with comparable Feather Meal A (69.97 %) and B (69.18 %) and to fishmeal as reference diet (73.15 %). But, as expected, diets with fishmeal showed the highest digestibility for dry matter, lipid and energy. Followed by **GoldMehl® FM** for the dry matter and energy digestibility. In conclusion, the nutrients of **GoldMehl® FM** are more digestible *in vivo* than those of the other feather meals of this trial, and especially for protein the digestibility is superior even compared to the fishmeal.

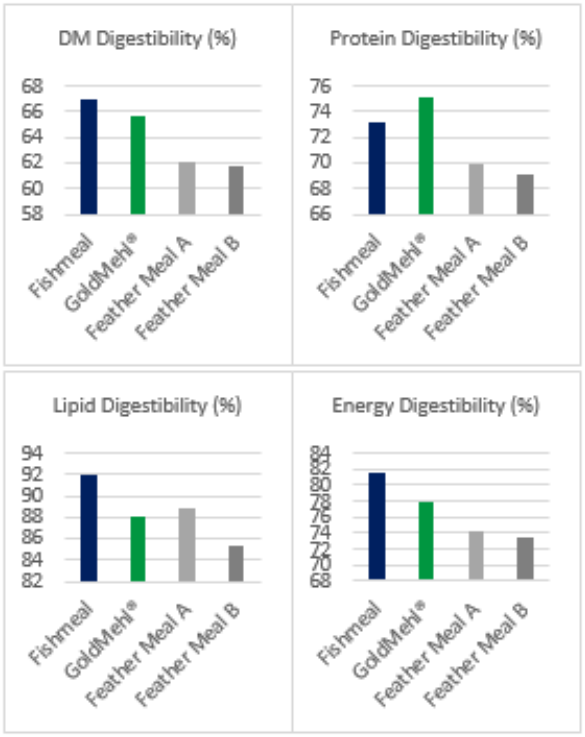

Figure 4: *In vivo* digestibilities of complete diet

In vitro digestibility

In this trial, we also evaluated the in vitro digestibility of soluble protein. This nutrient digestibility measurement was done by using the pepsin (0.02 %) digestibility assay, which is the most common method for the first indication of product quality.

The in vitro digestibility evaluation was tested in the laboratory. **Figure 5** shows that **GoldMehl® FM** (80.59 %) and Feather Meal A (80.96 %) have lower pepsin digestibility values compared to Feather Meal B (87.14 %). However, with regard to the negative correlation of both digestibility parameters shown in **Figure 2**, we can observe for **GoldMehl® FM** that the real (in vivo) digestibility in the animal is relatively high (in contrast to the other feather meal types). This value contrasts with a lower theoretical (in vitro) value of the pepsin analysis shown in **Figure 5**. This could be explained by the short treatment time at low pressure in the **GoldMehl® FM** processing.

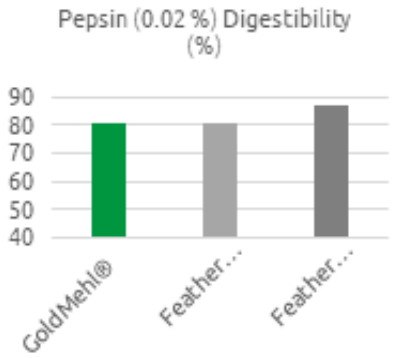

Figure 5: in vitro pepsin (0.02 %) feather meal protein digestibilities

Conclusion

GoldMehl® FM has nutritional composition and feeding values for shrimps similar to those of fishmeal and is better than regular comparable feather meals. Although the raw materials of all feather meals in the experimental groups are poultry feathers, the superiority of **GoldMehl® FM** can be attributed to its special process of manufacturing, which is very similar to the production conditions of high quality LT fishmeal mentioned before in the newsletter. Finally, it is difficult to evaluate the proper interpretation of the *in vitro* digestibility values among feather meals, as each manufacturer has its own process with different settings. We as GEPRO can see a relation for our product on the negative correlation mentioned before, but cannot do this for comparable products. Thus, the conclusion of this study is that to a certain degree we can see that the *in vitro* digestibility values could be misleading, but it always depends on the specific processing settings. To prove this theory, the next step could be to study a change in amino acid pattern between protein meals processed by an extended hydrolytic process and vice versa.

GoldMehl® FM has the potential to partly substitute fishmeal in the diet and thus reduce feed costs. Accordingly, applying a state-of-the-art drying process to the production of feather meal creates an added value to feathers. The recycling of feathers is environmentally friendly and is able to partly relieve pressure on marine raws and unwanted vegetable proteins, such as soybean and palm. Further, it can be regarded as sustainable protein production in the wake of increasing poultry production in all parts of the world.

References

Alterbaum, 2020 - wirkliche und Pepsin Verdaulichkeit - negative Korrelation.

Cho, C.Y. Slinger, S.J. 1979 - Apparent digestibility measurements in feedstuffs for rainbow trout. In: Haiver, J.E, Tiew, K (eds): Finfish nutrition and fish feed technology, Vol. II. Hennemann GmbH & Co. KG, Berlin, pp. 239-247.

Cho, C.Y., Slinger, S.J. Bayley, H.S. 1982 - Bioenergetics of salmonid fishes: Energy intake, expenditure and productivity. Comparative Biochemistry and Physiology B. 73, 25-41.

Dong, F.M. Hardy, R.W. Haard, N.F, Barrows, F.T, Rasco. B.A Fairgrieve, W.T. Forster, I.P. 1993 - Chemical composition and protein digestibility of poultry by-product meals for salmonid diets. Aquaculture 116, (149-158).

GEPRO, Newsletter 3 / GoldMehl.

Hajen, W.E., Higgs, D.A., Beames, R.M., Dosanjih, B.S., 1993 - Digestibility of various feedstuffs by post-juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in seawater. 2. Measurement of digestibility. Aquaculture 112, 333-348.

Han, Y. and Parsons, C.M., 1991 – Protein and Amino Acid Quality of Feather Meals. 1991 Poultry Science 70:812-822.

IFFO, 2020 - IFFO's analysis on market trends: Increased fishmeal production in 2020 with respect to 2019.

Miller, T. 1996 - Utilising rendered products: Petfood. In: Franco, D.A., Swanson W. (Eds.). The original recyclers. The animal protein industry. The fats and proteins research foundation and the national renderers association, Alexandra, pp. 203-223.

Papadopoulos, M.C., 1987 – *In vitro* and *in vivo* Estimation of Protein Quality of Laboratory Treated Feather Meal. Biological Wastes 21 (1987) 143–148.

Pfeffer, E., Kinsinger, S., Rodehutscord, N., 1995 - Influence of the proportion of poultry slaughter by-product and of untreated or hydrothermally treated legume seeds in diets for rainbow trout. *Oncorhynchus mykiss* (Walbaum), on apparent digestibility's of their energy and organic compounds, Aquaculture Nutrition 1, 111-117.

Stiborova, H., Branska, B., Vesela, T., Lovecka, P., Stranska, M., Hajslova, J., Jiru, M., Patakova, P., Demnerova, K., 2016 – Transformation of raw feather waste into digestible peptides and amino acids. Journal Chemical Technology Biotechnology 2016; 91: 1629-1637.

Suigura, S.H., Dong. F.M., Rathbone, C.K., Hardy, R.W., 1998 - Apparent protein digestibility and mineral availabilities in various feed ingredients for salmonid feeds. Aquaculture 159, 177-202.