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Commentary

Fish silage hydrolysates: Not only a feed nutrient, but also a useful feed additive☆

Ragnar L. Olsen*, [1], Jogeir Toppe

Products, Trade and Marketing Branch (FIAM), Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00153 Rome, Italy

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ABSTRACT

Background: Processing of fish and shellfish may result in substantial amounts of by-products and unless they can be used as food, the most realistic option in most cases is the production of preserved feed nutrients. If large volumes are available, reduction to fishmeal and fish oil is the preferred technology. However, fresh by-products are most often available in insufficient quantities to justify production of fishmeal. Preservation by acid silage is, however, a simple and inexpensive alternative.

Scope and approach: The purpose of this paper is to highlight that silage preservation of by-products using formic acid produces a protein hydrolysate that may function as a useful feed additive and not only an important feed nutrient. The fast growing global aquaculture industry is particularly in need of high quality feed nutrients and the focus in this paper is therefore on including acid protein hydrolysate in diets for fish and shellfish.

Key findings and conclusions: The proteins in acid silage are largely hydrolysed to free amino acids and short-chain peptides. Studies have shown that moderate amounts of protein hydrolysate may successfully be included in fish feed and in some cases this leads to improved performance. In addition, the formic acid in the hydrolysate may contribute to the growth and well-being of fish, in particular under unfavourable microbiological conditions. This may encourage fish processors to preserve by-products using acid silage and feed producers to incorporate the products in the feed.

1. Introduction

In 2012, 76.2% of the 91.3 million tonnes (Mt) wild caught fish and all of the 66.6 Mt fish produced in aquaculture were estimated to have been used for human consumption (FAO, 2014). These figures also include crustaceans and other invertebrates and the word fish in this paper is used in accordance with this. The term "human consumption" is, however, not precise since fish are often processed to different degrees before being sold to wholesalers or retailers. Such processing, which mainly occurs on-board fishing vessels in industrial scale fisheries and in land-based processing facilities, may consist of deshelling, gutting, beheading, filleting, skinning and trimming. The fillet yield is species-dependent and is most often in the range of 30–50% (Rustad, Storro, & Slizyte, 2011). Some of the by-products such as heads and off-cuts, may in certain cases be used for human consumption while the majority has traditionally been regarded to be of low value or as a problem and used as feed for farmed animals, as fertilizers or discarded (Olsen, Toppe, & Karunasagar, 2014). Although it is quite often suggested that by-products may be turned into high-value products we believe that these in most cases are not commercially viable and the most realistic utilization of by-products is to convert them into preserved feed ingredients if they cannot be used directly as food (Olsen et al., 2014). The rapidly growing global aquaculture industries are in particular in need of high quality feed nutrients to reduce the amount fishmeal and fish oil produced from pelagic species in formulated feed (Tacon, Hasan, & Metian, 2011).

By-products from processing of fish deteriorate rapidly and will create unacceptable local pollution if not preserved properly at land-based processing sites. Viscera containing by-products are especially prone to rapid degradation due to high microbial counts in the gastrointestinal tract. In addition, quick preservation is also necessary if the raw materials are going to be used as high quality

☆ Note: The opinion expressed in this article is of the authors, not necessarily of the FAO of the UN.

* Corresponding author.
E-mail address: ragnar.olsen@uit.no (R.L. Olsen).
[1] Permanent address: Norwegian College of Fishery Science, UiT The Arctic University of Norway, N-9037 Tromsø, Norway.

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feed ingredients. Discarding of by-products from processing at sea does not usually create any problems unless it occurs close to land. This should however be avoided since it is a waste of resources. Unfortunately, older fishing vessels processing the catch on-board do not, in most cases, have facilities or space to preserve the by-products. Perhaps on-board processing vessels built in the future should include equipment for preserving all the products, not only those intended for human consumption.

Use of fishmeal and oil technology is the traditional way of producing feed ingredients from pelagic fish and today the products are mainly used in feed for farmed fish. It has been estimated that 35% of the available fishmeal in 2012 was based on fish processing residues (FAO, 2014). This technology is, however, a multistep, energy-demanding process which requires large amounts of fresh raw materials daily over a long period to justify the costs of establishing and running such a factory (Naylor et al., 2009; Raa & Gildberg, 1982; Tatterson, 1982). It has been known for a long time that fresh by-products available in smaller amounts may instead be preserved by silage technology using short-chain organic acids. The proteins present in the silage will, to a large extent, be hydrolysed by endogenous acid proteases to small peptides and free amino acids (Espe et al., 2015). The silage or the separated oil and protein hydrolysate may later be included in feed for farmed animals and fish (Gallardo et al., 2012; Jackson, Kerr, & Bullock, 1984; Petersen, 1953; Raa & Gildberg, 1982; Tatterson, 1982; Whittemore & Taylor, 1976). Published works suggest that short chain organic acids like formic acid and peptides/amino acids when included in the feed may contribute to improved performance and growth of farmed animals, and possibly also of fish and crustaceans (Dibner & Buttin, 2002; Gilbert, Wong, & Webb, 2008; Martinez-Alvarez, Chamorro, & Brenes, 2015; Partanen & Mroz, 1999).

The objective of this commentary article is to draw attention to the fact that protein hydrolysate formed during the formic acid silage process is not only a simple way of providing important feed nutrients, but also that the short-chain organic acid, peptides and free amino acids in the hydrolysate may function as useful feed additives.

2. A brief overview of silage technology

Acid preservation is a simple and inexpensive way to preserve processing by-products and can be carried out virtually at any scale (De Arruda, Borghesi, & Oetterer, 2007; Raa & Gildberg, 1982; Tatterson, 1982). The raw materials are minced and acidified most commonly today with 2–3% formic acid to reduce the pH to 4 or below preventing microbial growth. To stop lipid oxidation, an antioxidant, so far most often ethoxyquin, is mixed in the silage which can then be stored for an extended time (Arason, 1994; Raa & Gildberg, 1982). Combinations of organic acids like propionic acid and formic acid or an organic acid and a mineral acid may also be used (Arason, 1994; Hardy, Shearer, & Spinelli, 1984). However, if only mineral acids are used, the pH has to be around 2 in the silage to stop microbial growth and this requires increasing the pH by adding a base before including it in feed (Arason, 1994; Tatterson, 1982). After acidifying the by-products, a temperature dependent autolytic liquefaction will occur due to the action of endogenous proteolytic enzymes, mainly pepsins, present in the viscera. The amino acids are fairly stable during the acid autolysis. However, some degradation of lysine, methionine and particular tryptophan may occur (Arason, 1994; Gallardo et al., 2012). Without the presence of stomach containing viscera in the by-products, the autolysis will go on at a much slower rate, unless acid proteases are added (Raa & Gildberg, 1982). In 2014, 258,150 tonnes of by-products from processing of farmed and wild fish were preserved by silage technology in Norway (Richardsen, Nystøyl, Strandheim, & Viken, 2015). This silage production using formic acid with added antioxidant is carried out at many local fish processing plants along the coast and subsequently the silages are collected by trucks or boats and transported to a few centralized plants. Here, the volumes are large enough to economically separate the silage into an oil product and an aqueous phase containing hydrolysed proteins. The protein hydrolysate has a high water content and it is therefore evaporated to a dry matter content of 45–50% before it is included in a formulated dry feed. According to one of the producers, about 4–5% formic acid is found in the concentrated protein hydrolysate obtained from salmon by-products using silage technology (B. Dulavik, Hordafor, Norway, per. comm.). The oil and the concentrated protein hydrolysate from Atlantic salmon are used in feed for pigs, poultry and fish other than salmon while the products from wild whitefish by-products are used in feed for salmon (Olsen et al., 2014).

One drawback with fish silage is the high water content which makes it difficult to use directly in dry or moist feed (Madage, Medis, & Sultanbawa, 2015). The silage may however be used locally after drum-drying or co-drying with other feed ingredients like soybean-, feather- or poultry by-products meals or cereal brans (Dong, Fairgrieve, Skonberg, & Rasco, 1993; Goddard & Perret, 2005; Hardy et al., 1984; Madage et al., 2015; Nwanna, Balogun, Ajenifuja, & Enujiugha, 2004).

Fish silage may also be produced by fermentation using lactic acid bacteria like *Lactobacillus plantarum*, as a starter culture. However, since the fish by-products do not contain carbohydrates, a fermentable sugar such as molasses or fruit processing waste must also be added (Bower & Hietala, 2008; Dong et al., 1993; Fagbenro & Jauncey, 1995). The lactic acid produced during the fermentation will reduce the pH in the silage and prevent growth of spoilage bacteria (Faid, Zouiten, Elmarrakchi, & Achkari-Begdouri, 1997). This is a more complicated silage production process than direct acidification since a starter culture must available, but it might be suitable in countries where fermentable sugars are readily available (Hernandez, Olvera-Novoa, Smith, Hardy, & Gonzalez-Rodriguez, 2011; Plascencia-Jatomea, Olvera-Novoa, Arredondo-Figueroa, Hall, & Shirai, 2002). The level of free fatty acids has been reported to be much higher in oil obtained from fermented silage than in oil from acid silage and this may limit the use in feed (Vidotti, Pacheco, & Goncalves, 2011).

3. Use of protein hydrolysate in fish feed

The successful use of fish protein hydrolysates from acid silage in aquaculture feed has been reported in several studies. Espe et al. showed that improved growth was obtained in Atlantic salmon (*Salmo salar*) when 10% of the fishmeal in a fishmeal-based diet was replaced by silage protein hydrolysate. Lower or higher inclusion levels led to reduced growth (Espe, Sveier, Høgøy, & Lied, 1999). Studies on Japanese sea bass (*Lateolabrax japonicus*) also suggested better growth when 15% of fishmeal was substituted with acid silage hydrolysate. Improved nonspecific immunity was also indicated in the same work (Liang, Wang, Chang, & Mai, 2006). More recently, Goosen et al. reported that low amounts of protein hydrolysate from acid silage in feed for Mozambique tilapia (*Oreochromis mossambicus*) resulted in excellent growth and possibly also increased phagocytic activity (Goosen, de Wet, & Gorgens, 2016). In the work of Ridwanudin & Sheen, it was observed that 50% of fishmeal in the feed for orange-spotted grouper (*Epinephelus coioides*) could be substituted with 10 or 20% acid silage protein hydrolysate combined with poultry by-product meal without affecting the growth (Ridwanudin & Sheen, 2014).

Several feeding trials have been carried out substituting