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Use of Fish Waste as Silage - A Review

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ABSTRACT

The use of fish silage as a substitute for protein ingredients in rations for aquatic organisms is an alternative to solve sanitary and environmental problems caused by the lack of adequate disposition for the waste from the fish industry. Besides, it is also a way of decreasing feeding costs, and, consequently, fish production costs, since feeding corresponds to about 60% of the overall expenses with production. The objective of this review was to discuss the use of fish waste, the elaboration of chemical silage and the use of this ingredient in feed for aquaculture.

Key words: Fish waste, chemical silage, feed for aquaculture

INTRODUCTION

Companies that want to be effectively clean must use fish processing waste in the manufacture of new products, not only contributing to environmental preservation, but also increasing their own revenues. The largest benefit, however, is nutritional, since fish waste represents half of the raw material volume of the industry and is a source of low-cost nutrients (Oetterer, 2002). Fish waste from beneficiation and commercialization units can cause serious environmental pollution problems, as their transportation to by-products processing plants is not always a sustainable activity (Nunes, 1999).

There is need for creating systems for the use of waste in industries when it comes to energy savings. The ideal solution would be to use the raw material all along and recover the by-products, avoiding waste production (Maia et al.; 1998). Most of the technologies known for the use of waste in fish industries are not economically attractive due to the high initial investment. Sanitary landings and effluent treatment ponds are not recommendable alternatives due to the unpleasant odor they produce in coastal or interior waters areas, which are almost always used for leisure (Lustosa Neto, 1994).

Every effort must be made to increase human consumption of fish, but there will always be amounts of fish that are considered inadequate or that exceed the processing capacity (Oetterer, 2006).

A way of minimizing the environmental problems generated by the high amount of fish waste is its transformation in a product to be incorporated as ingredient in animal rations (Ristic et al.; 2002). A viable alternative would be the production of fish silage, as it is an easy-to-make product which requires low investments. The product has a good nutritive quality and can, therefore, be very useful in animal feeding (Berenz, 2003). The objective of this review was to discuss the use of fish waste, the elaboration of chemical silage and its use as ingredient of feed for aquaculture.

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Use of fish waste

According to Food and Agriculture Organization (FAO, 2004), the world fish production in 2000 was 130.4 million tons of fish, out of which 94.8 million tons were from fishing and 35.6 million corresponded to aquaculture production. From 1996 to 2000, aquaculture increased from 25.7 to 35.6 million metric tons. The aquaculture production for 2001 was estimated as 37.5 million metric tons.

In 1997, 122 million metric tons of fish were produced in the world, which represented US$ 49 billion in revenues. The Brazilian production of fish was 798,719 metric tons, out of which 115,398 tons came from the national aquaculture production, with consequent revenue of US$ 198,000,200 (Ostrensky et al.; 2000).

The world production of aquatic organisms from aquaculture increased from 28.82 in 1997 to 30.86 million metric tons in 1998. In the same period, there was a reduction of over 7 million metric tons in the production of captured aquatic organisms (FAO, 2000).Sixty percent of the fish captured worldwide are used in the fresh fish market or processed as frozen, canned or cured foods, generating a considerable amount of waste material. The volume of waste produced by processing plants is calculated to be about 50% of the total processed fish. To that, we can add a considerable amount of fishing produce that is considered inadequate for human consumption due to its low commercial value, as well as the amounts discarded and refused by Federal/State Inspections in fresh commercialization markets (Rebeca et al.; 1991).Thus about 50% of the world fish production becomes waste material, which means an expressive amount of 65.2 million metric tons of fish waste (Ferraz de Arruda, 2004).

The largest contributor to the increase in fish production is aquaculture, which is one of the fastest growing agricultural activities in the world. According to Ostrensky et al. (2000), the Brazilian aquacultural production increased from 23,390 metric tons in 1991 to 115,398 metric tons in 1998, an increase of 393%, growing about 26% a year, going up from the 35th position in 1991 to the 26th position in 1997 in the ranking established by FAO.

Over 80% of the Brazilian territory is located in the tropical area drained by the large hydrographical basins, the Amazon and the Parana-Paraguay basins. In the latter, which covers the central part of Brazil, and the San Francisco River basin, which drains the southeast and northeast parts of the country, there are over 100 large reservoirs and dams for purposes of energy production and water storage, with over five million hectares of flooded areas. The exploration potential of this system for semi-intensive of intensive fish farming is large (Castagnolli, 1995).

The processing units of fresh water frozen fish fillets in operation in Brazil has increased, increasing the volume of unused waste (Boscolo et al.; 2005).

Information about these fish processing units in the country is unsatisfactory. For example, in 2000, the Southeast was the area with the largest number of processing units (23), but there were not enough data to quantify the volume which was being currently processed. Another problem is that the amount of fish produced by aquaculture is still small and hardly ever could a medium-sized processing unit operate only with raw material from farming. A positive aspect is that, out of 47 identified units, 32 (68% of the total) are certified by sanitary inspection (Ostrensky et al.; 2000).

As in any animal farming, in aquaculture, feed corresponds to a high percentage of the operational costs, reaching indices ranging from 30 to 60% of the overall (El-Sayed, 1999; Cheng et al.; 2003). Researchers from all over the world have put great efforts in identifying alternative protein sources that would allow a reduction in feeding costs (Portz and Cyrino, 2004).

Fish silage

Fish silage is a liquid product produced from the whole fish or parts of it, to which acids, enzymes or lactic-acid-producing bacteria are added, with the liquefaction of the mass provoked by the action of enzymes from the fish (FAO, 2003). Acid silage was developed in 1920 by A. I. Virtanen, using hydrochloric and sulphuric acid for the conservation of forages. Experiments with fish began in Sweden in 1936, using hydrochloric, sulphuric, and formic acids and sugars (Tatterson and Windsor, 1974).

Organic acids, such as formic acid, are generally more expressive than the mineral ones. However, they produce less acid silages that do not need to be neutralized before being used. The bactericide action must be considered. A mixture of formic and propionic acids has been recommended. If a 1:1 formic-propionic ratio is used as well as the addition of 3% volume/weight to the biomass, the silage obtained is stable, with an acidified aroma

(Kompiang, 1981). The use of formic acid for the preservation of wasted material to be used in rations began after World War II. In the preparation of chemical silage, the choice of preservation reagents is made from inorganic acid, a mixture of acids, organic acids or the mixture of organic and inorganic acids, which, as formic acid, are generally more expansive than common inorganic acids, but produce silages that are not excessively acid, and, therefore, do not need neutralization before being used. Inorganic acids, such as hydrochloric acid and sulphuric acid can be recommended due to their low cost (Oetterer, 2002).

For the preparation of the chemical silage, the raw material must preferably be presented in small pieces or be ground. Afterwards, acid is added to allow for its action until liquefaction takes place. Normally, room temperature is used and the storage provokes the desired biochemical modifications. It is essential that the mixture is stirred so that the raw material can be in contact with the acid, once non-treated parts of the material can putrefy. After the initial mixture, the silage process naturally begins, but occasional stirring helps in obtaining the desired uniformity (Oetterer, 2002).

Use of fish silage

Fish meal is the most abundant animal protein source for the manufacture of rations for domestic animals. The world market has always been looking for an effective alternative to fish meal (Nogueira Junior et al.; 1997). Fish silage is an attractive alternative to fish meal. The advantages in the production of silage, compared to fish meal, are: the process is virtually independent from the scale; the technology is simple; the investment is little, even in large-scale production; reduced effluents and odor problems; the silage process is fast in tropical climates and the product can be used in the place. However, a disadvantage is that the product is voluminous if consumed in its pasty form, implying in an additional drying cost (Kompiang, 1981; Beerli et al.; 2004).

Silage has been produced at commercial scale in Poland and Denmark since the sixties for the production of birds and swine feed or as a protein complement incorporated in rations making feed for domestic animals and fish in aquaculture. In France, a fish Protein Hydrolysate Powder with 90% protein was produced reaching US$ 1,500,00 per ton. In Indonesia, silage was produced at experimental scale and used in rations which substituted fish and soy meals in the feed of swine, fish and birds (Kompiang, 1981).

Fish feeding

The use of fish silage in the feeding of fish has been widely studied. Due to the similarity of this protein source with the raw material and low cost, especially when compared to fish meal, silage has a high potential use in aquaculture. (Hussain and Offer, 1987; Fagbenro et al.; 1994; Vidotti et al.; 2003; Goddard and Perret, 2005). Fagbenro et al. (1994) and Fagbenro and Jauncey (1998) studied the nutritional value of diets containing microbial fish silage partially dehydrated by the addition of soy meal, poultry by-products, or bone and meat powder, and found no significant differences in the performance and protein use when compared to diets based on fish meal. The experiment showed that these diets, especially the ones including silage and soy meal, could be used to feed tilapias, *Oreochromis niloticus* (omnivorous), and the North African catfish, *Clarias gariepinus* (carnivorous), with no changes in its performance, use of protein and carcass composition.

In salmon farming, the search for diets that promote fast growth, favour fish sanitation, result in quality products and have low cost is essential. Some authors, trying to evaluate the use of fish silage in salmon (*Salmo salar*) feeding, concluded that although this silage did not promote a better development, it did not cause a decrease either, and its cost was much lower (Espe et al.; 1994; Heras et al.; 1994).

The natural food for the pink abalone (*Haliotis fulgens*) is microalgae. In the United States, this microalgae is used as the main food. Commercial diets are produced only in Japan and New Zealand, their high cost makes them unviable. Thus, artificial diets are necessary, preferably at low cost. Viana et al. (1999) evaluated the use of silage as an alternative feed. The authors concluded that fish silage was very attractive, but not very palatable. They recommended that it should be used with a more tasteful ingredient, such as corn meal.

Honczaryk and Maeda (1998) studied the use of biological-fish-ensilage-based diets in the feeding of arapaima (*Arapaima gigas*), a very important carnivorous fish from the Amazon area, and concluded that they presented a higher level of ingestion. The most important was that the technology used in the elaboration of biological ensilage was adequate for the production of a product to be used as protein source in the preparation of rations for arapaima, which could be produced at artisanal level, without sophisticated equipment or specialized laborers.

In nutritional terms, the diet given to aquacultured fish can define the fatty acids profile in the fish meat. Thus, for example, the catfish (*Ictalurus punctatus*) diet, supplemented with 2, 4, and 6% of menhaden (*Brevoortia tyrannus*) oil provided 5.7, 8.4 and 10.1% of omega-3 fatty acids, respectively, in the fish muscles. Also, the supplementation of the tilapias (*Oreochromis niloticus*) with sardine (*Sardinella, sp*) oil resulted in a larger proportion of eicosapentaenoic and docosahexanoic acids (Haard, 1992). Lessi et al. (1989) and Ximenes Carneiro et al. (1996) tested biological fish ensilage in the feeding of Black-Finned Pacus (*Colossoma macropomum)* fingerlings and shrimp post-larvae (*Macrobrachium rosembergii)* for the first time in Brazil. Ensilage was found an alternative and a potential substitute for fish meal and meat and bone meal in Black-Finned Pacus rations.

The apparent digestibility is one of the main resources in the evaluation of the potential of the ingredient to be used in fish rations. Borghesi (2004) determined the apparent digestibility coefficient (ADC) of the energy, nutrients and amino-acids of acid silage (AS), biological silage (BS) and enzymatic silage (ES) in Nile tilapias (*Oreochromis niloticus*) weighing on average 94.54 ± 12.66g. The values for digestible energy found were 4041.32; 3663.95 and 3394.20 Kcal/kg for AS, BS and ES, respectively. The ADC values found were: 92.01; 89.09 and 93.66% for crude protein; 89.86, 87.61 and 90.10% for ash; 82.52, 78.98 and 82.96% for dry matter; 81.72, 73.99 and 80.27% for calcium; and 77.86, 79.21 and 81.46 % for phosphor in AS, BS and ES, respectively. The average ADC of amino acids were: 91.83; 90.76 and 94.61% for AS. BS and ES, respectively. These results show the possibility of using AS, BS and ES as proteic ingredient in balanced rations for aquaculture, as partial substitute of fish meal.

Waste recycling for the production of silage and oil

The final composition of silage varies considerably according to the type of raw material used, especially as to the content of lipids, which varies in different fishing seasons (Haard et al.; 1985). The content of lipids is an important point for the investigation of silage quality, as fatty acids which are present in fish oil are highly unsaturated can easily oxidize, affecting the nutritional quality of the product, making proteins and amino acids unavailable or making the product inedible (FAO, 2003).

Fish silage can be used as an alternative protein source in the formulation of rations for monogastrics. However, due to the lipid oxidation that can compromise the nutritional value of the ration, the removal of the lipid fraction during the elaboration of the silage is recommended in order to obtain a uniform and more stable product (Raa and Gilberg, 1982).

The lipid oxidation process results in changes of flavor, color, texture, nutritional value and toxic components production (Sales, 1995). The oxidative process can be accelerated if the fish silage in contact with light and air (FAO, 2003). Lipids oxidation can provoke the formation of peroxides, which form physical and covalent bonds with proteins. Covalent bonds between oxidized products and proteins can destroy amino acids, such as tryptophan, oxidize methionine, and bind lysine to other compounds, making these amino acids unavailable (Nelson and Cox, 2000).

Disney et al. (1977) discussed the changes that occured with lipids during the storage of the silage. They mentioned that the increase in the contents of free fatty acids indicated the hydrolysis of glycerides, whereas oxidative changes caused darkening. The authors recommend that in order to keep the quality of the product there must be a fast fat removal, as most transformations touch place at the beginning of the ensilage process and depended on the temperature. Kompiang (1981) suggested that the nutritional value of ensilage was negatively affected with the increase in the storage time. There was a direct relationship between the darkening provoked by lipids reaction and the loss of the nutritive value.

Most fish species with little amounts of oil are being excessively used in the production of animal feed. For the use of species with larger amounts of oil, techniques must be initially established for the oil to be removed in order to increase the stability of the material and its commercial value (Potter et al.; 1979).

Haard et al. (1985), silage with cod fish (*Gadus morhua*) waste using 3.5% (v/w) of formic acid. The silage obtained became liquid and homogenous in 36 to 48 h at 20^{o}C, although the oil and other protein contents continued to suffer hydrolysis for several months. The maintenance of the lipidic components of the silage to increase the energetic portion in animal ration formulations was undesirable because of the lipidic degradation of this fraction. Ferraz de Arruda (2004) tried to determine the best way for extracting oil from the acid silage of Nile tilapias (*Oreochromis niloticus*) and characterize the oil obtained. The lipidic fraction was extracted in three different ways: centrifugation (3500 x G/30min), Soxhlet (International Union of Pure and Applied Chemistry -IUPAC, 1979) and Bligh and Dyer (1959). The results for the yield and peroxide index were 65.53% and 0.00 mEq/1000 g O_2, 44.27% and 25.00 mEq/1000g O_2, 46.87% and 0.00 mEq/1000g O_2 respectively. Tilapia oil had (mg/100g), 28.60, 16.30 and 3.10 oleic, linoleic and linolenic acids, respectively. Centrifugation was the best extraction method for preserving the physical-chemical characteristics of the oil results in a larger yield. The content of lipids in the tilapia silage, on a dry-matter basis was 3.99g/100g, with the extraction of the lipidic fraction through centrifugation. The sample was left with only 1.54g/100g of lipids, which is considered acceptable for its inclusion in animal feed. The lipid fraction, extracted for the concentration of the protein fraction, could be used as a lipid source after the addition of anti-oxidants in the formulation of rations, or used as a attractive factor in fish rations. However, studies must be carried out on this possibility (Ferraz de Arruda et al.; 2006).

During the “World Aquaculture 97”, it became evident that after 1997, the feeding of water organisms would depend on the production of fish meal and oil (Wiefels, 1998). In Brazil, sardine is the most popular fish, accounting for 50% of the fish commercialization of the Sao Paulo Fresh Products Market, the largest one in the country. In the southeast, the most explored species is *Sardinella brasiliensis*. The composition and production of Brazilian sardine oil has been described (Badolato et al.; 1991).

Fish oil produced in Brazil is normally used in animal consumption or in the production of paint, varnishing and finishing of leather (BRASIL, 1985). However, there are no exact data on the total production of fish oil in Brazil. Fish industry has a wide potential as its discharges can be easily transformed into marketable products. Currently, during the production of fish meal, fish oil is also produced by processes which involve the heating and pressing of waste. Fish oil could be used for pharmaceutical purposes. However, it would be necessary consider how fast this oil oxidizes and the need of extending the stability (Ferraz de Arruda; 2004).

Numerous benefits have been attributed to fish oil, particularly to its EPA and DHA fatty acids (Soccol and Oetterer, 2003). Fish oil normally contain about 30% of the omega-3essential acids, with approximately 18% EPA and 12% DHA. Essential fatty acids are used in several countries to prevent and treat several health problems. They are used in nutritional supplements, children’s nutrition, medicinal and functional foods, parenteral nutrition, and pharmaceutical actives and vehicles. Their prescription by doctors has increased, including in Brazil, and the available products are being improved (Pacchioni, 1999).

Estudies due the scarcity of experimental data on the beneficial and side effects of omega-3 fatty acids, the Food and Drug Administration (FDA) in forbidden the commercialization of fish oil as medicine in the United States, placing them in the category of food supplement (Badolato et al.; 1991)

Fish oil has long been used in the manufacture of food, especially in margarine (Bimbo, 1987), because of its considerable biochemical, metabolic, nutritional and pharmaceutical interest (Stansby, 1969). Scientific studies have intensified in this respect due to the several benefits associated, especially with EPA and DHA fatty acids (Ackman and McLeod,1988). In Brazil, the supply of fish-oil-based food supplements containing pills of EPA and DHA has grown, as well as analyses requests by Adolfo Lutz Institute for purposes of brand registration at the Ministry of Health. According to declarations by interested parties, oil, mostly from sardines, is imported from England and encapsulated in Brazil. The conventional formula guarantees that the product contains 180 mg of EPA and 120 mg of DHA per gram. In some cases, vitamin E or tocoferol is added as anti-oxidant (Badolato et al.; 1991).

FINAL CONSIDERATIONS

The conversion of waste material, with its consequent reutilization, can bring economical advantages for the industry, besides solving a great problem with the discharge of the waste, which is pollutant material. Studies point to a possible use of silage prepared from Nile Tilapia (*Oreochromis niloticus*) waste processing in the formulation of fish rations. Further studies must be carried out in order to evaluate the ideal amount of silage input in the production of fish rations. The use of waste will be an important economic factor for fish industries, as well as for the decrease in the cost of rations (Borghesi, 2004; Ferraz de Arruda, 2006).

There is need for the standardization and the maintenance of the nutritional quality of the silage. The reduction of the lipids content as well as the inclusion of anti-oxidants in the preparation of silage will allow for the production of a more uniform and adequate fish silage for the formulation of rations. Currentily the degree of proteic hydrolysis is considered an index of the silage quality. However, further studies are necessary on lipid oxidation reactions and the possible unavailability of amino acids. Also, the present lipid fraction conditions must be used as a quality parameter. If fish silage can be an alternative for fish meal in the formulation of rations, it would be interesting to investigate if the lipid fraction could have any influence in the taste of the final product, and, as done in fish meal, determine the maximum level of lipids from silage in animal ration.

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RESUMO

A utilização da silagem de pescado como substituto de ingredientes protéicos em rações para organismos aquáticos surge como alternativa para solucionar os problemas de ordem sanitária e ambiental causados pela falta de destino adequado dos resíduos gerados pela indústria do pescado, além de diminuir os custos com alimentação e conseqüentemente os custos de produção do pescado, já que os gastos com a alimentação correspondem a aproximadamente 60% do custo total. Esta revisão teve por objetivo discutir a respeito do aproveitamento do resíduo de pescado, elaboração de silagem química e a utilização desta como ingrediente para ração destinada à aqüicultura.

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