Sustainable Protein for Aquaculture from Alfalfa

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Alfalfa acres have declined by 33% across the U.S. since 1980. Those acres have been replaced with annual crops, primarily corn and soybean due to changing market demands. Reduction in perennial crops has increased nutrient runoff and soil erosion into water resources, increased issues with insect and weed pests in annual crops, and reduced soil quality, especially when corn is planted continuously with no rotation. Could new uses provide increased demand for alfalfa and increased revenue for farmers? Nutritional components in alfalfa make it an ideal ingredient in diets for a wide range of livestock, including aquaculture.

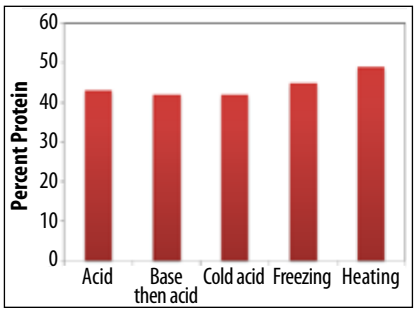
Utilization of alfalfa protein in aquaculture feeds has numerous economic, environmental, and social benefits. Fish and shellfish farmed in marine and urban settings require a protein concentrate as a major diet component. Fishmeal, derived from small forage fish, has historically been the ingredient of choice. However, these fish are over-exploited worldwide and fishmeal cost has been volatile but increasing steadily. Researchers around the globe are pursuing development of sustainable ingredients for aquaculture feeds to find replacements for fishmeal and fish oil in order to decrease the demands on ocean fish. At the same time, the demand for fish in human diets is booming, particularly in China with a rapidly growing middle class. In the U.S., 91% of the seafood we consume originates abroad, half of which is from aquaculture. Driven by imports, the U.S. seafood trade deficit has grown to over $11.2 billion annually.

Although a small producer, the U.S. is a major player in global aquaculture, supplying a variety of advanced technology, feed, equipment, and investment to producers around the world. In particular, there is a burgeoning aquaculture industry taking shape in the Midwest. The main aquaculture feed plant protein is soybean meal, which has limited use due to antinutritional components found in the seeds. In contrast, protein concentrate extracted from "juicing" immature alfalfa forage has a balanced amino acid profile, contains compounds promoting skin and shellfish pigmentation, and does not contain antinutritional factors. An acre of alfalfa can annually produce 1.5 metric tons of fishmeal-equivalent protein concentrate, as well as a press cake of residual protein and fiber having potential use in dairy, beef, or poultry feed. If alfalfa protein concentrate (APC) were to make up just 1% of aquafeed ingredients by 2030, replacing fishmeal (currently at $1,480/ton) or soybean meal (currently at $330/ton), this would require about 4 million acres of alfalfa at 3.2 tons DM/ac/year, the current national average alfalfa yield.

APC technology was developed by the USDA in the 1980s and is straightforward. Fresh alfalfa is put through a screw press to create a protein-rich juice, treated to separate proteins from liquid, and the protein is then concentrated and dried. At present, opportunities for developing APC and related products are wide open. Only one company in France is currently producing APC commercially.

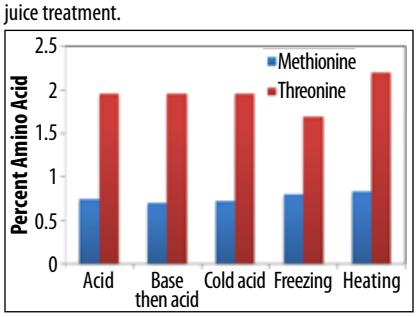
USDA-ARS scientists in St. Paul, MN, in collaboration with students and faculty at the University of Minnesota, are investigating different alfalfa varieties (a non-lodging biomass type developed by JoAnn Lamb of USDA-ARS, reduced lignin types, and conventional alfalfa) and treatments of alfalfa juice affecting APC composition with funding provided by the Minnesota Department of Agriculture. The response of yellow perch and trout to APC aquaculture feeds is also being tested. With the non-lodging type of alfalfa, a novel harvester is being used to preferentially harvest leaves and stem tips with the most protein, allowing older stems to be harvested for a fast drying fiber-rich hay. A major advantage of biomass type alfalfa and a leaf-stripping harvester is the ability to harvest at late maturity stages, reducing labor and harvest cost. In pilot studies, total foliage was harvested and juiced. Protein was coagulated from the juice by freezing, heating to 80°C, acidifying at room temperature, acidifying at 4°C, or alkalization followed by acidification. Although the most material was recovered by the alkalization followed by acidification, the most protein was recovered by the heat treatment (Figure 1). All treatments resulted in low (<1%) fiber. The

Figure 1. Recovery of alfalfa protein concentrate varies by treatment of juice to coagulate proteins.



heat treatment also resulted in the highest recovery of methionine and threonine, key amino acids in fish nutrition (Figure 2). Extraction methods also differed in amount of crude fats, specific fatty acids, and sugar content in the coagulate. Findings show production methods can be adjusted to produce an APC product for specific diets or uses. Amount of APC recovered was greater from juicing leaves or total forage while stems had lower, but significant amounts recovered using the heating method to coagulate proteins.

Figure 2. Yield of methionine and threonine varies by juice treatment.



In a 16-week trial, yellow perch were fed a conventional diet or a diet in which APC replaced fishmeal. Fish were grown in a greenhouse environment and weight was measured every two weeks. Weight gain of individuals varied considerably with both diets. On average, weight of fish receiving the APC diet was lower, but the rate of gain was the same as those fed the conventional diet (Figure 3). This experiment is currently being repeated using a larger number of fish. In addition, a new study in cooperation with the Minnesota Department of Natural Resources is being conducted using rainbow trout to measure weight gain using a feed containing APC compared to conventional feed. Results so far indicate APC can replace fishmeal in aquaculture diets without affecting weight gain. This project is laying groundwork for commercialization of new alfalfa products, increasing use of alfalfa in crop rotations.

Figure 3. Growth rate is equal in yellow perch fed a diet with APC or fishmeal.