Sustainable Green Biorefineries

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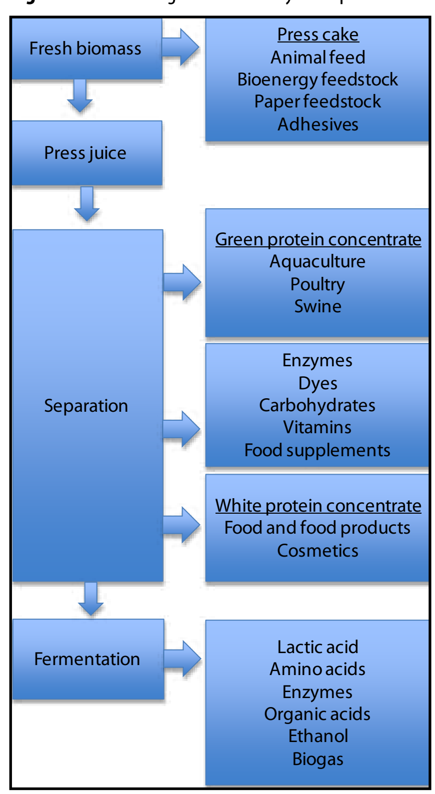
If you track the journey of corn or soybean after harvest, it will lead you to hundreds of different products. Although a major part of the harvest is used as feed for livestock and energy production (ethanol and biodiesel), a significant part is refined into a startling array of commercial and consumer products, with more products being developed every year. Analogous to petroleum refining, almost every major crop in the U.S. is converted from raw plant material into commercial value-added products, except for alfalfa which is used almost exclusively as feed and "refined" by the animal into meat and milk. In Europe, the situation is very different.

In France, the leading producer of alfalfa in the EU, alfalfa refining has occurred for over 30 years. Run by farmer cooperatives, the refineries produce dehydrated alfalfa of a consistent protein content as well as a protein extract. In Havelland, Germany, approximately 50 km from Berlin, a demonstration plant with an annual capacity of 20,000 tons of biomass is in development. This plant will be an integrated system for comprehensive material and energetic use of green alfalfa/grass biomass. In Europe, green biorefineries will be co-located with existing forage dehydrating plants, which will lead to significant energy savings and increase profits from production of high value co-products. In the U.S., alfalfa refineries could be co-located with other biomass refineries, providing plant material during May to October when other biomass sources are not available for processing.

Could alfalfa compete with other plant materials in a biorefinery in the U.S.? Alfalfa has a number of advantages over other plant feedstocks. Alfalfa produces more protein than any other crop. Moreover, protein production is environmentally and economically sustainable because alfalfa requires far less fertilizer and pesticide inputs than other crops, is harvested over multiple years, and provides its own nitrogen as well as increasing overall soil fertility for subsequent crops. Alfalfa has high biomass yield potential. On-farm research shows that under good management, alfalfa can yield 6 tons of dry matter per acre each production year under rain-fed conditions in the Eastern and Midwestern U.S. Additionally, there are new opportunities for increasing total production and harvesting of fresh alfalfa for use in biorefining.

Alfalfa has been proven to be extremely efficient in removing nitrates from surface and ground water. Thus, alfalfa can be used to reduce nitrogen from entering streams and lakes by planting buffer strips near sensitive waterways and planting over tile drains. In addition, alfalfa has been shown to remediate soil and ground water in nitrogen-contaminated sites and to remove nitrogen from wastewater in association with water treatment facilities. In these locations the crop can be managed for maximum yield rather than quality, reducing the number of harvests. Non-lodging cultivars and new harvest machinery that separates fresh protein-rich leaf fractions and cellulose-rich stem fractions in the field are being tested by USDA-ARS and universities in Minnesota, Wisconsin, and Iowa to determine forage yields and plant persistence under different fertility and crop rotation strategies. These plant materials will be ideal feedstocks for an alfalfa biorefinery.

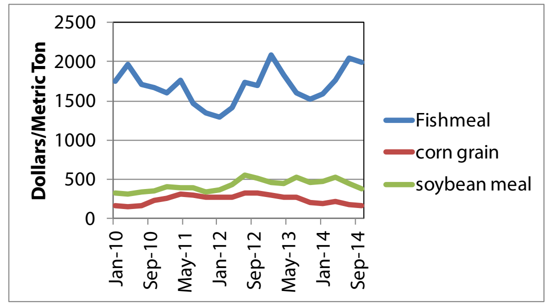
Figure 1. The alfalfa green biorefinery concept.



Research has demonstrated that a number of high value products can be produced from refining alfalfa. The refining process starts with pressing plant material to produce a protein-rich juice and fiber-rich cake (Figure 1). The cake fraction can be used for producing animal feed or as a feedstock for energy production, microbial fermentation, or paper production. Using specific microbes in the fermentation, the alfalfa fiber residue is an effective co-adhesive for forming plywood panels and could replace the phenol-formaldehyde resin currently in use. The juice fraction contains proteins, dyestuffs, vitamins and minerals, and soluble sugars. Importantly, the green protein produced from heat coagulation of the juice has xanthophylls and carotenes, omega-3-fatty acids, and a high lysine amino acid content. These components make it an ideal feed for poultry. Current grain-based diets require lysine and xanthophyll supplements.

The amino acid profile and carotenes make the alfalfa protein highly suited for aquaculture and superior to other plant-based protein sources. It is estimated that an acre of alfalfa can produce 1.5 metric tons of fishmeal-equivalent protein concentrate that at current fishmeal prices would have a value of over $3,400 (Figure 2). The demand for feed to support aquaculture is expected to continue to rise as aquaculture expands globally.

Figure 2. Comparison of commodity pricing of fishmeal, soybean meal, and corn grain from January 2010.



After removal of protein, the alfalfa juice fraction can be used in fermentation to produce lysine or lactic acid, or for biogas production. The protein from the juice fraction can also be separated using membranes to produce a white protein concentrate. Although research is needed to further characterize this product, it has potential as a human foodstuff and for use in food processing and cosmetics. Lastly, past research demonstrated that alfalfa can be genetically modified to produce phytase, an enzyme currently added to poultry and swine feed to aid in absorption of phosphate. It was shown that the phytase produced in alfalfa can be extracted from juice for use as a feed additive or alfalfa meal can be fed directly to animals, eliminating the need for addition of phytase from other sources. Other commercial products can also be produced using alfalfa, including biodegradable plastic and industrial enzymes.