Refining low grade non-homogeneous biomass feedstocks: Bioenergy and a co-products strategy

Esteban Chornet[1,2], Roger D'Amour[1], Vincent Chornet* and Nicolas Abatzoglou[1]
ENERKEM TECHNOLOGIES Inc.
414 McGill St., Suite 204, Montréal, Qué., Canada H2Y 2G1
Tel: 514 875 0284; Fax: 514 875 0835; email: vchornet@enerkem.com
In partnership with Georges B.B. Lê (Ministère des Ressources Naturelles du Québec); Ed Hogan and Bill Cruickshank (Natural Resources Canada)
[1]Also affiliated with Université de Sherbrooke, Département de génie chimique, Sherbrooke, Qué., Canada J1K 2R1; email: echornet@courrier.usherb.ca
[2]Also affiliated with the National Renewable Energy Laboratory (NREL), 1617 Cole Blvd., Golden, Colorado, USA 80401-3393; email: esteban_chornet@nrel.gov

Low quality lignocellulosic biomass feedstocks comprise: (a) forest and sawmill residues, usually rich in bark; (b) stalks, stover and hulls from agricultural operations; (c) straws and grasses; (d) "urban wood"; and (e) sorted and fractionated municipal solid residues. Such feedstocks are distributed regionally and thus, in principle, are of prime interest for bioenergy. However, only in the case of forest biomass (either thinings or residues from ongoing operations) and large cities (case of urban wood or municipal solid waste) their availability exceeds 100,000 tonnes/y (dry basis) and only exceptionally the feedstock basis reaches 400,000 tonnes/y (dry basis), amount that will result in, typically, a 50 MW bioenergy plant. With a perspective of distributed bioenergy systems, the feedstock base has to be considered as being available at < 100,000 tonnes/y (dry basis) where economies of scale are essentially absent. Since the cost of the biomass feedstocks is, fob plant, anywhere between $20 - $40/tonne (dry basis), direct or indirect bioenergy production via distributed (small) plants requires some sort of carbon credit or subsidy to make economic sense.

The purpose of this paper is to show that fractionation, the key core technology of current chemical pulping, has been, in recent years, adapted to low grade feedstocks making possible their refining. A sequential approach, Feedstock Impregnation and Rapid Steam Treatment (FIRST), successfully handles the complexity of the feedstocks and yields rather homogeneous fractions which are the basis of upgrading strategies to green energy products and green commodities as well as, for specific biomass types, specialty chemicals. The net result is a marked improvement in economics and a more diversified use of the biomass resource base. Enerkem Technologies Inc., a subsidiary of the Kemestrie Group, has been applying the FIRST technology to four categories of biomass sytems:

• Bark-rich residues from thinnings and debarking operations. Such low grade biomass has substantial amounts of extractives (typically 20 wt%, dry basis). In the FIRST process, they are initially removed from the matrix via an aqueous ethanolic treatment, recovered and separated into specific fractions: when working with predominantly coniferous species, we have isolated and purified four families of compounds present in the extractives: hydrophilic oligomeric proanthocyanidins, flavonoids having antioxidant properties and known in the market as OPCs; sterols, hormone precursors and known binders to cholestorol; fatty acids, which can be further separated into individual molecules; and hydrophobic polyphenols. The extractives-free biomass is essentially a matrix composed of hemicelluloses, lignin and cellulose. The matrix is subjected to a sequential treatment that yields a hemicellulose-rich liquor (about 80 wt% of the sugars present in the hemicelluloses are recovered), the lignin (over 80 wt% of the initial Klason lignin is recovered) and the cellulose (essentially 100 wt% of the initial cellulose is recovered).

• Sugar beet pulp, prototype agri-residue. Sequential application of the FIRST process yields a pectin-rich product, which can be further purified to a food grade product; a hemicelluloses-rich fraction which contains predominantly L-arabinose (a recovery of over 80 wt% of the potential has been reached); the lignin (80 wt% recovery with respect to potential); and the cellulose (100 % recovery).
• Corn stover, also a prototype agri-residue. The FIRST process yields a hemicellulose-rich fraction where the pentoses represent over 80 wt% of the potential recovery; a lignin fraction, again with a recovery of 80 wt% of the potential; and a solid residue which contains, essentially, all the cellulose.
• Urban wood. This feedstock, contaminated with preservatives, paints and lacquers, was initially detoxified, via a variation of the FIRST process. The cleaned wood was then subjected to three sequential treatments that yielded a hemicellulose-rich fraction, the lignin and the cellulose. Recoveries were similar as those of previous cases.

Upgrading the different fractions obtained from the FIRST process is a function of markets and technology. The extractives have specific, and often captive, markets that limit their production. A priori knowledge of these markets is essential. The hexoses present in the hemicellulose-rich liquors, are readily fermented to ethanol using known yeasts. The pentoses, can also be fermented to ethanol (with appropriate microorganisms), but Enerkem has an alternate approach: their conversion to methyl-furan, a high octane oxygenate which can be used as an additive to gasoline. The lignin and hydrophobic polyphenols (the latter present in the extractives) have been depolymerized, by Enerkem, to a mixture of monomeric oxyaromatics (20 wt% yields whose composition, a function of severity, is predominant on either guaiacol/syringol, catechols/methylcatechols or vanillin/syringaldehyde) and oligomeric oxyaromatics (over 50 wt% yields). The latter can be converted to gasoline blending compounds (via the strategies being developed by UofUtah/NREL). The cellulose is split into two fractions: fines and fibers. The fines are further hydrolyzed to sugars using methods and models that are based on controlled acid-catalyzed depolymerization. The fibers can be blended with chemical pulps for specific applications. All process wastes are used for bioenergy.

The above described strategy for low grade lignocellulosics can be enhanced by using, in the case of coniferous biomass, the needles and accompanying small branches. Very high value compounds can be isolated, purified and sold in specific markets. Kemestrie has technology for isolation of maltol, a flavor and fragrance component, and taxans, whose three constitutive taxol molecules are currently being marketed as anticancer drugs.