Crops for Biomass and Small Molecule Production

Jim Todd
Transition Crop Specialist
Ontario Ministry of Agriculture, Food and Rural Affairs

Outline

- The Cultivation of Plants for Non-Food Uses.
  - Tobacco as a example.
- A little history
- Why consider alternative uses of tobacco
- Potential challenges
- Research activities

Plants are Great Sources of Renewable Materials

- Corn starch
  - Adhesives, paints, explosives, cosmetics……
- Natural rubber
- Acetylsalicylic acid (aspirin)
- Taxol (anti-cancer drug)

- Not all farming is dedicated to producing food!

Tobacco Production in Ontario

- 30 years ago, ~100 million kg of tobacco was produced annually on ~50k ha in the Norfolk Sand Plains
- 2006: ~24.5 million kg from ~8600 ha
- 2007: ~14.5 million kg from ~5100 ha
- 2008: fewer hectares than in 2007.
- Tobacco growers are looking for alternative crops.

Native Tobacco Protein

- Tobacco protein has many uses:
  - Nutritional supplement
    - Contains all the essential amino acids humans need
    - Easily purified: tasteless, odourless
    - Useful for special needs patients
  - Processed food ingredient, additive in cosmetic and detergent formulations
    - Excellent foaming and emulsifying properties

Small Molecule Production

- Tobacco contains valuable compounds:
  - Solanesol
    - Used in the synthesis of co-enzyme Q9 (a cardiac drug), vitamin K (an anti-hemorrhagic vitamin) and vitamin E
  - Nicotine
    - production of smoking cessation products
    - Excellent insecticide
    - Nicotine drugs for treatment of ADHD, Parkinson's and Alzheimer's diseases?

MACLEAN'S April 3, 2006

7 DAYS

A WEEK IN THE LIFE OF... JOHN GODFREY

The first Liberal MP to declare a candidacy for the federal Liberal leadership, Godfrey came out swinging for environmental sustainability and social issues. He may fade away if heavy hitters such as Belinda Stronach or Michael Ignatieff decide to run when the campaign formally opens April 7. But last week, with Toronto lawyer Martha Hall Findlay and fiddler Ashley MacIsaac the only other declared candidates, Godfrey could take comfort in knowing that, so far, he's way in the lead.

DISCOVERY

Warrior's tomb

Construction workers in Cyprus have stumbled on a 2,500-year-old limestone sarcophagus, apparently that of an unknown warrior. What distinguishes the discovery, archaeologists say, is that the interior has been painted with scenes from the epics of Homer. "The style of the decoration is unique, not from an artistic point of view," says a Cypriot expert, "but the subject and the colours

SARCOPHAGUS: Homeric colour

used." The coffin is decorated with hues of red, blue and black and includes scenes of Ulysses.

Hunch engines

Computer scientist Eric Bonabeau is seeking to marry human intuition with computer number processing in a bid to produce software that boosts the efficiency of human intuition. He calls his software tools a "hunch engine." The software would help users identify what they are looking for even while they're looking for it. It works by providing a user with a "seed" based on an initial inquiry as well as a series of mutations. As the user chooses a mutation, it leads to more mutations, much in the way humans conduct inquiries based on hunches, only far more efficiently.

Twitchless liars

Contrary to popular perception, liars do not twitch, scratch or fiddle with their hair. Such movements, known as "self-adaptor gestures," are believed to comfort an individual under stress. Researchers have found that instead of yielding to such gestures, liars tend to become more still because they're aware of how their gestures and movements may be interpreted.

Long-necked Erketu

Paleontologists report that they've identified what may be a new species of dinosaur with a neck so long—7.5 m—that its vertebrae seem to have contained air sacs to accommodate its long length. The animal's 100 million-year-old fossil was discovered in Mongolia in 2002. Experts have concluded that it belonged to a herbivorous [illegible] called sauropods, and have named the species *Erketu ellisoni*, a name derived from that of the ancient Mongolian god of might.

Poor hosts

Why h[illegible]t avian flu jumped to human[illegible]more readily than it has? Scient[illegible]now say that the H5N1 virus h[illegible] difficult time adhering to mem[illegible]anes in the human nose, throat [illegible]upper respiratory tract. It takes [illegible]ated exposure to infected po[illegible]or other birds to get the virus [illegible]deep in humans' lungs, a Univ[illegible]of Wisconsin-Madison virolo[illegible]ass. Only when it's there does [illegible]hold.

WILD KINGDOM

Maxine and the hawk

Jennifer Rosen of Ladner, B.C., had just let her chihuahua, Maxine, out into the yard recently when she heard a terrible noise. She saw a hawk, its wings spread, trying to drag the one-kilogram dog clear of the porch to carry her off. Maxine broke free of her abductor and hid in the house. Wildlife experts say that hawk attacks on pets are very rare, and that the bird probably mistook Maxine for a rabbit.

Cocoon fat farm

The massive changes a caterpillar goes through to become a butterfly require equally massive amounts of energy. For the first time, science has learned that inside their silky redoubts, caterpillars are burning fat. "It appears as though the larvae is sleeping, and that little energy would be required," says Oregon Health & Science University's William Connor. "But a great deal of metabolic activity is occurring."

Little home wreckers

Female mice like to mate with males who are already taken. Tests [illegible] that males sprayed [illegible] actually attract other females. [illegible]ctory cue was so pronounced [illegible] females would choose a second male infected with parasites over a healthy, uncontested bachelor.

MORTALITY

Meds from cigs

Chinese authorities have been seizing fake cigarettes sold on the streets, crushing them and extracting a compound, solanesol, from the tobacco. In the past, authorities simply burned the counterfeit cigarettes, which are made with a mixture of low-grade tobacco and wood chips. Solanesol is a compound that [illegible]

BUTTERFLY: The heavy demands of chrysalis burn the fat off caterpillar

be used for medicines that treat cardiovascular diseases.

SEIZED CIGARETTES: Extracting a valuable medical compound

Haggis and toddlers

British officials have advised that young children should be restricted in the amount of haggis they eat, owing to its high saturated fat and salt content. Haggis [illegible] a government list of restricted [illegible] that includes "[illegible] and [illegible]. The haggis [illegible]ation is meant to [illegible] a childhood obesity program [illegible] kids under five.

[illegible]wder death

[illegible] winter in France has been [illegible] deadliest in decades for skiers. [illegible]alanches have killed 53 people, many of whom strayed off-piste to experience untouched powder. Without a December

MORTALITY

Meds from cigs

Chinese authorities have been seizing fake cigarettes sold on the streets, crushing them and extracting a compound, solanesol, from the tobacco. In the past, authorities simply burned the counterfeit cigarettes, which are made with a mixture of low-grade tobacco and wood chips. Solanesol is a compound that can be used for medicines that treat cardiovascular diseases.

Small Molecule Production

- Plant Pigments (Xanthophylls)
  - Added to poultry feed to improve skin and egg yolk colouration
  - Lutein is used in the treatment of age-related macular degeneration
    - 6mg/day reduces occurrence of disease by 43%
    - Lutein currently isolated from marigold flowers, yielding 2.8 to 4.5 kg/ha (450-675 kg dry flowers)
    - How much lutein is there in young tobacco?

Production of High Value Proteins

- Genetically engineer tobacco to produce:
  - Pharmaceutical proteins, e.g. herceptin
  - Industrial proteins such as
    - recombinant antibodies for waste purification or protection against food borne pathogens.
    - Industrial enzymes e.g. cellulases, amylases and proteases
  - A U.S. company is in the early stages of producing cancer drugs and vaccines in tobacco.

Tobacco as a Biomass Crop

- Energy production from tobacco waste
  - Ethanol production from cellulose
    - Est. yields of ethanol from tobacco are similar to those from corn, sweet potato, grain millet and switch grass.
  - Anaerobic digesters for biogas production
    - Burn biogas to generate electricity/heat
    - Pump purified gas directly into NG pipelines

Barriers to Economic Feasibility

- Markets
  - Access to existing & development of new markets
- Ability to maximize use of value added traits for economic gain
  - Capitol costs for equipment
- Research is needed to address:
  - New agronomic practices (fertilization, crop cycles, pest management etc.)
  - Variety development (higher density plantings)
  - Handling and processing issues (no curing)

Tobacco as an Industrial Crop

- The key is to produce a lot of biomass by growing the tobacco at high density (247k/ha vs. 17.5k).
- High biomass yields are obtained through multiple harvests, the first done prior to the stretch bud stage.
  - In Delaware, up to 3 harvests of field seeded tobacco yield 9-13.5 dry tonnes/ha

Direct Seeding in Ontario

- Our colder climate limits seeding to mid to late May.
  - 2006 trials yielded very poor plant stands
    - Too much irrigation the likely culprit
  - 2007 trials - stand establishment is much better.

Field Seeded May 28, 2007

August 11, 2006

July 11, 2007

August 21, 2007

Growing tobacco at high density

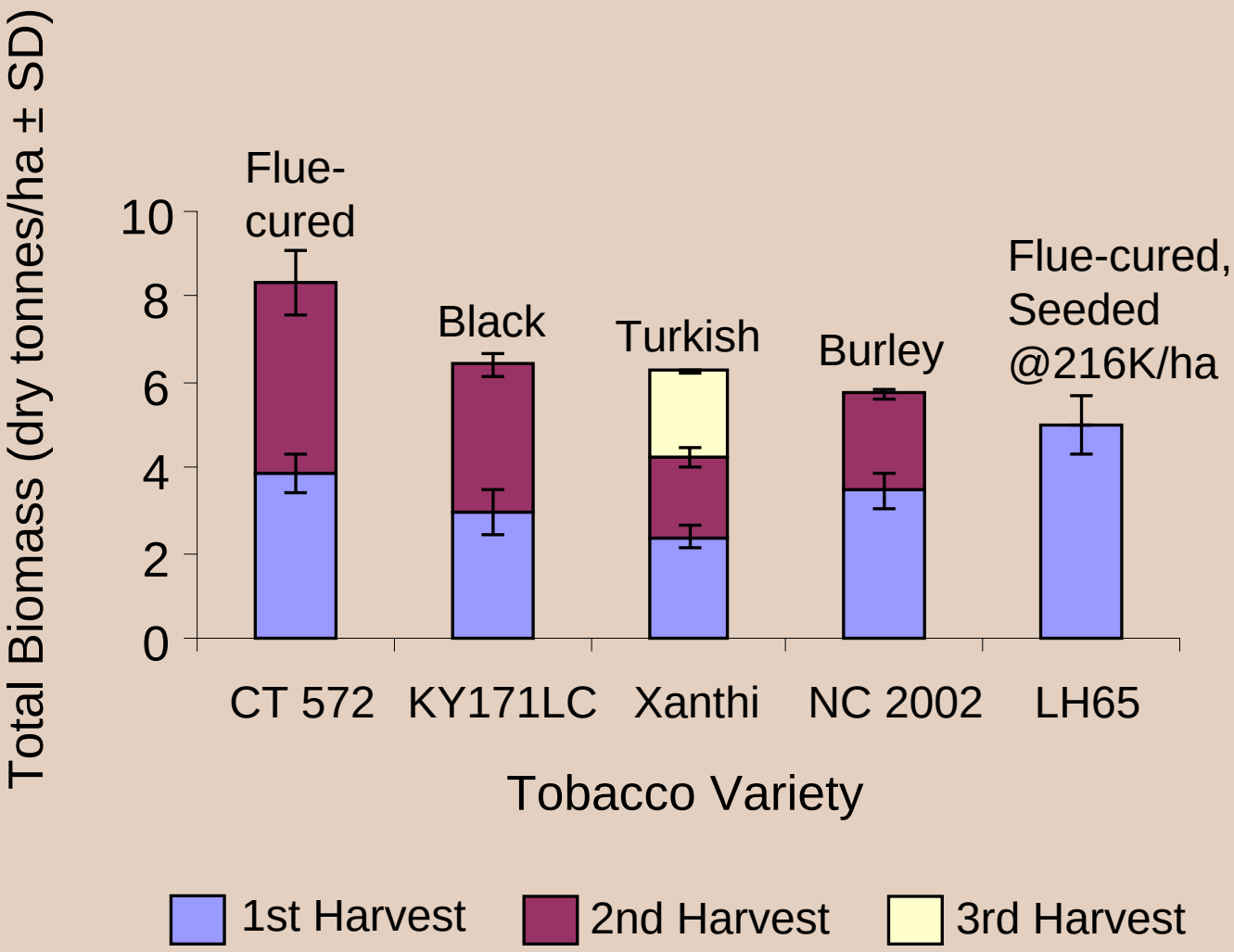
VS.

- Yield vs. cost of production
  - Greenhouse space, transplanting costs etc.

2007 Field Experiments

- 29 different varieties (74k/ha)
  - Burley, Flue-cured, Turkish and Black
- Plant density by nitrogen trials
  - 42K to 125K plants/ha, 40 to 160 kg N/ha
- Tray cell density trials
  - 166, 244 and 488 cell trays
- Fungicide Treatments
- Direct seeding trials
  - Raw, pelletized, pre-germinated seed

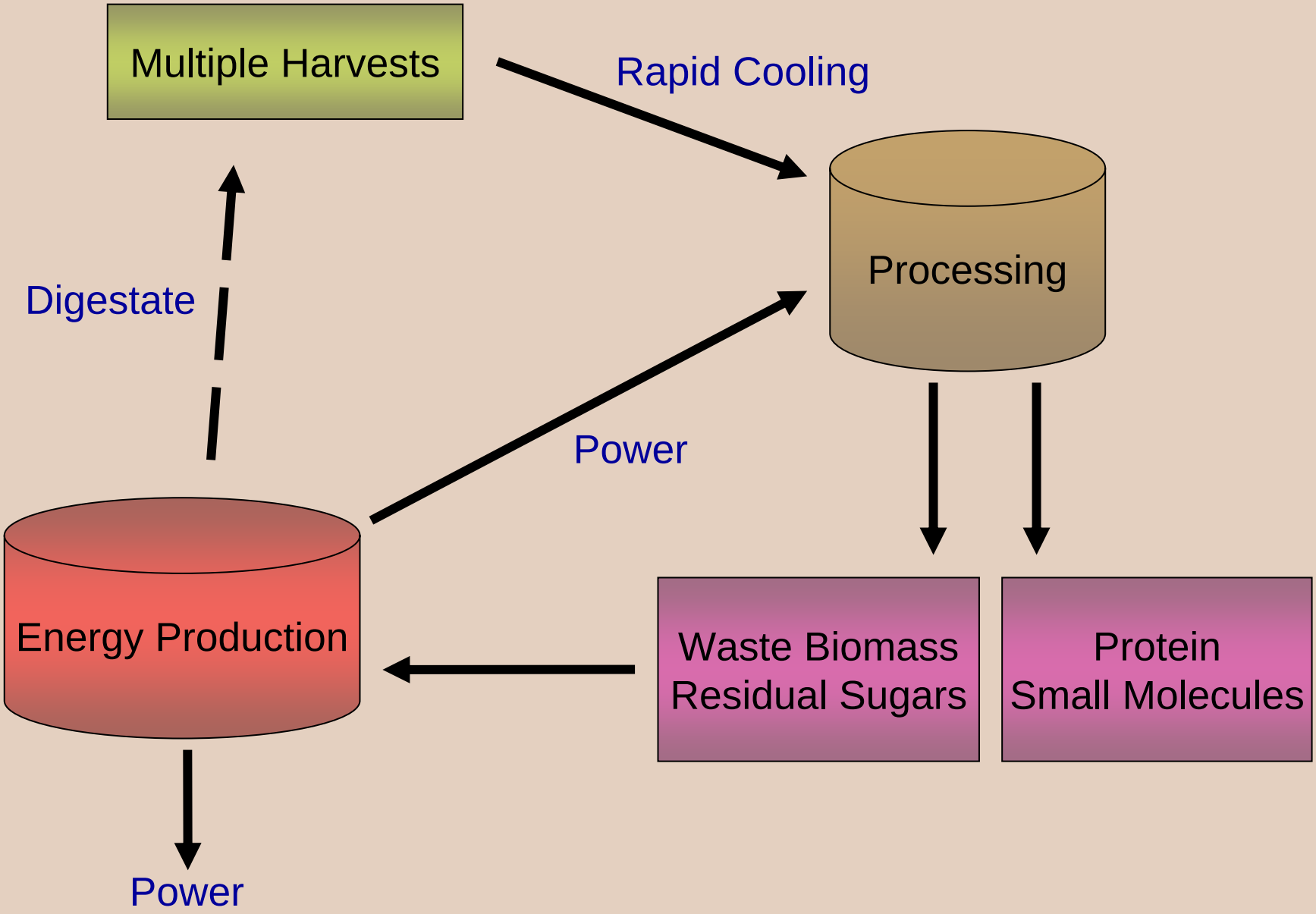
Potential Tobacco Biomass Yields



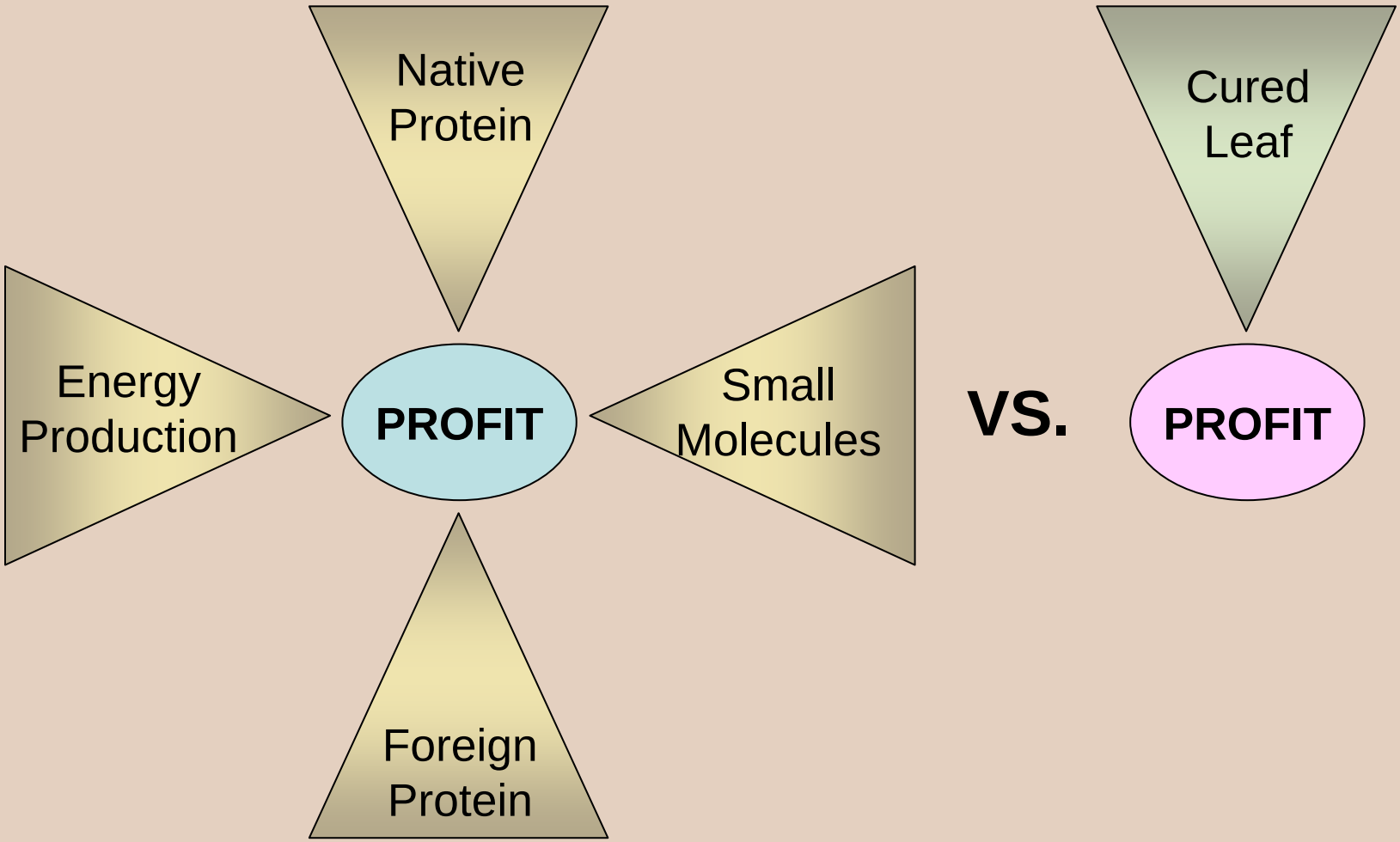
Energy Production From Mature Tobacco Waste

Meher et al, 1995, Envir. Pollution. 90(2):199

- 0.236m^3 biogas/kg total solids/day in a 10m^3 anaerobic digester
- 5 tonnes/ha = 1180 m^3 biogas
- (1180 m^3/ha) ÷ 0.42m^3 biogas/1kw electricity = ~2810 kw total electrical yield
- 2810kw * 12¢/kw = $337 gross income/ha


Multiple Harvests
Rapid Cooling
Processing
Digestate
Power
Energy Production
Waste Biomass
Residual Sugars
Protein
Small Molecules
Power

Revenue Generation



Sponsorship

- Tobacco Research
  - The Ontario Flue-Cured Tobacco Growers Marketing Board (CORD IV Program)
  - OMAFRA, University of Guelph, AAFC
- Anaerobic Digester
  - Ontario Fresh Vegetable Producers (CORD IV Program)
  - OMAFRA
  - University of Guelph
  - AAFC
  - Agricultural Adaptation Council

- Jim.Todd@ontario.ca
  - 519-426-3823