Utilisation of Agro-Industrial Solid Wastes for high added value products by recycling Bio-technologies

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Director of the Institute of Technology of Agricultural Products
Hellenic Agricultural Organization DEMETER

2–4 July 2015
3rd INTERNATIONAL CONFERENCE on Sustainable Solid Waste Management, Tinos island, Greece
The waste world in one place

Global waste generation

1.9 billion tons equal to 25% of the shipments traded in 2011

Global Generation Per capita

One generates annually waste equal to 3-4 times his weight

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>3.48%</td>
</tr>
<tr>
<td>Paper Cardboard</td>
<td>16.26%</td>
</tr>
<tr>
<td>Plastic</td>
<td>10.47%</td>
</tr>
<tr>
<td>Glass</td>
<td>3.78%</td>
</tr>
<tr>
<td>Organic matter</td>
<td>45.34%</td>
</tr>
<tr>
<td>Other</td>
<td>20.66%</td>
</tr>
</tbody>
</table>
SOLID WASTE AND ITS MANAGEMENT

It is defined as:

“Non-liquid, non-soluble materials ranging from municipal garbage to industrial wastes that contain complex and sometimes hazardous substances”
Source of Solid Wastes

- Mining waste consist mainly of rock and soil overburden from mining operations – an earth moving project
- Agricultural wastes are typically organic residuals – biodegradable and recyclable
- Industrial wastes are widely varied – have the potential of being hazardous
- Municipal solid wastes (MSW) vary greatly in quantity and composition
- We will focus on the management of Agricultural wastes
The global issue of food waste

• Worldwide about one-third of all food produced – equivalent to 1.3 billion tonnes – gets lost or wasted in the food production and consumption systems, source: FAO
1/3 OF THE FOOD WE BUY WE THROW AWAY!
The average household throws away more food than packaging.
COMPOSTING

• Composting, often described as nature’s way of recycling, is the biological process of breaking up of organic waste such as food waste, manure, leaves, grass trimmings, paper, worms, and coffee grounds, etc., into an extremely useful humus-like substance by various micro-organisms including bacteria, fungi and actinomycetes in the presence of oxygen.
“Messieurs, c’est les microbes que auront le dernier mot”
Louis Pasteur
<table>
<thead>
<tr>
<th>Organism</th>
<th>Time for One Mass Doubling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria and yeast</td>
<td>10-120 Min</td>
</tr>
<tr>
<td>Mold and algae</td>
<td>2-6 h</td>
</tr>
<tr>
<td>Grass and some plants</td>
<td>1-2 wk</td>
</tr>
<tr>
<td>Chickens</td>
<td>2-4 wk</td>
</tr>
<tr>
<td>Pigs</td>
<td>4-6 wk</td>
</tr>
<tr>
<td>Cattle</td>
<td>1-2 mo</td>
</tr>
<tr>
<td>People</td>
<td>0.2 - 0.5 yr</td>
</tr>
</tbody>
</table>
### TABLE 3

**EFFICIENCY OF PROTEIN PRODUCTION OF SEVERAL PROTEIN SOURCES IN 24 HOURS (5)**

<table>
<thead>
<tr>
<th>Organism (1,000 lbs)</th>
<th>Amount of Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullock</td>
<td>0.9 lb</td>
</tr>
<tr>
<td>Soybeans</td>
<td>82.0 lbs</td>
</tr>
<tr>
<td>Yeast</td>
<td>50 tons</td>
</tr>
</tbody>
</table>
ADVANTAGE OF SCP OVER CONVENTIONAL PROTEIN

1. PRODUCTIVITY
2. INDEPENDENT OF LAND AND CLIMATE
3. CONTROLABILITY
4. LESS POLLUTION
Εικ. 15.1.β: Βιοαντιδραστήρας παραγωγής μονοκυτταρικής πρωτεϊνής από βακτήρια.
SCP as Meat Substitute

- Protein..........................50%
- Fat...............................13%
- Fiber..............................25%
- Minerals.......................great spectrum
- Vitamins.......................Full B complex
- Nucleic Acids ..........< 15%
Fig. 7.11 Mycoprotein before processing. Left “beef”, right “chicken”.
Fig. 7.12 First trial meals with “refined” mycoprotein.
Fig. 7.13  *Quorn* products made of *Fusarium*: meatballs and sausages without meat.
SUGAR PRODUCTION BY-PRODUCTS

- **Molasses**  
  *(cane & sugar beet)*
  - Animal feed
  - C source in Fermentation
  - Citric acid, L-Lysine, L-glutamate
  - Fuel (pentosans) → furfurals

- **Bagasse**

- **Beet pulp**
  - Animal feed
  - Ferulic acid → vanillin
  - Arabinan
  - Ethanol
  - Acetic acid (Ca, Mg, Acetate)
  - n-Butanol
  - Acetone, Glycerol, Citric acid, Polylactate (PLA)

- **Biomass**
AgroVanillin: enzymatic step

FAIR2-CT95-1099: Enzymatic step in the production of natural vanillin from agricultural by-products

AgroVanillin: bioconversion step

FAIR2-CT95-1099: Bioconversion step in the production of natural vanillin from agricultural by-products
FERMENTABILITY OF SUGAR BEET PULP AND ITS ACCEPTABILITY IN MICE

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(Received 2 May 1993; revised version received 29 May 1993; accepted 1 June 1993)
Table 1. Chemical compositions (% dry matter) of un-fermented and fermented sugar-beet pulp (USBP and FSBP)

<table>
<thead>
<tr>
<th></th>
<th>USBP</th>
<th>FSBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>7.00 ± 0.20</td>
<td>7.01 ± 0.20</td>
</tr>
<tr>
<td>Crude protein</td>
<td>9.60 ± 0.20</td>
<td>19.50 ± 0.30</td>
</tr>
<tr>
<td>Fat</td>
<td>1.60 ± 0.30</td>
<td>2.30 ± 0.10</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>23.35 ± 0.20</td>
<td>18.04 ± 0.20</td>
</tr>
<tr>
<td>Cellulose</td>
<td>24.80 ± 0.40</td>
<td>18.40 ± 0.10</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>27.90 ± 0.30</td>
<td>12.90 ± 0.30</td>
</tr>
<tr>
<td>Lignin</td>
<td>2.60 ± 0.20</td>
<td>3.50 ± 0.30</td>
</tr>
<tr>
<td>Ash</td>
<td>3.50 ± 0.20</td>
<td>3.24 ± 0.30</td>
</tr>
</tbody>
</table>

*a* Soxhlet, in AOAC (1984).
Fig. 2. Body weight gain of SWR mice on diets containing 15% and 30% fermented sugar-beet pulp plus control. ■, Diet C (control); ▲, diet A1 (15%); ●, diet A2 (30%).
Protein enhancement of sugar beet pulp by fermentation and estimation of protein degradability in the rumen of sheep

D. Iconomou a, K. Kandylis b, C. Israelides a,*, P. Nikokyris b

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b Agricultural University of Athens, Department of Animal Nutrition, 118 55 Votanikos, Athens, Greece

Accepted 14 January 1997
DVDディスク
(試作品）～
日本ビクター株式会社
原料：トウモロコシ
Samsung ECO E200
Ενα κινητό με οικολογική συνείδηση!
*FAIR4-CT96-3039*: Olives (left) and a traditional olive oil mill (right)
Η Άμμος Ολέα

Οργανικό - Χομικό
Εδαφοφυτευτικό

Προϊόν κατάλληλο για κηπευτικά, ελιές, αμπέλια, εσπεριδοειδή, οπωροφόρα, γκαζόν, ανθοκομικά και μεταφυτεύσεις

100% Από Παραπρόσωπα Ελίας

Προέρχεται αποκλειστικά από παραπρόσωπα επιζητήσεως έλαιοκάρπου (πλατύφυλλα, ελαιοπετρέντα, φυτικά υγρά ελίας)

Ιδανικό Για Βιολογικές Καλλιεργήσεις

Προϊόν σύμφωνα με τους κανονισμούς 2092/91, 2381/94, 834/07 της ΕΕ για τη βιολογική γεωργία
1st Year

<table>
<thead>
<tr>
<th>0%</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>10%</td>
<td>25%</td>
<td>50%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>------</td>
</tr>
</tbody>
</table>

3rd Year
<table>
<thead>
<tr>
<th>0%</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
</tr>
</thead>
</table>

4th Year
CITRUS FRUITS BY-PRODUCTS

- Peels & Rugs
  - Pectin
  - Cattle feed (dried)
  - Essential oils
- Pulp
  - Animal Feed (SSF)
- Seeds
  - Citrus flavonoids
- Citrus molasses
  - Fermentation products
- Colourings
  - Natural clouding agents
Table 1: Chemical composition* % of dry matter (DM) of unfermented (CP) and fermented citrus pulp (FECP) with the fungi *T. reesei* and *T. viride* in solid-state fermentation (SSF) on bioclimatic chamber for 7 days of culture.

<table>
<thead>
<tr>
<th>Component</th>
<th>%DM</th>
<th>CP</th>
<th>FECP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>90.4 ± 0.28</td>
<td>91.0 ± 0.25</td>
<td></td>
</tr>
<tr>
<td>Crude Protein (Cr.Prot): N×6.25</td>
<td>6.78 ± 0.26</td>
<td>21.90 ± 0.15</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>3.01 ± 0.23</td>
<td>1.34 ± 0.18</td>
<td></td>
</tr>
<tr>
<td>Crude Fibre (CF)</td>
<td>14.75 ± 1.08</td>
<td>12.19 ± 0.40</td>
<td></td>
</tr>
<tr>
<td>NDF</td>
<td>36.54 ± 1.55</td>
<td>24.35 ± 0.85</td>
<td></td>
</tr>
<tr>
<td>ADF</td>
<td>30.98 ± 0.29</td>
<td>23.80 ± 0.80</td>
<td></td>
</tr>
<tr>
<td>Cellulose</td>
<td>24.34 ± 1.26</td>
<td>17.50 ± 0.90</td>
<td></td>
</tr>
<tr>
<td>Hemicelluloses</td>
<td>5.56 ± 0.29</td>
<td>0.54 ± 0.10</td>
<td></td>
</tr>
<tr>
<td>Lignin</td>
<td>6.26 ± 1.48</td>
<td>5.95 ± 0.10</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>0.38 ± 0.26</td>
<td>0.45 ± 0.50</td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Dry matter (DM) and crude protein (Cr.Prot.) degradability of concentrate feeds of rations’ nutrient of sheep.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Concentrate</th>
<th>SEM</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Dry matter</td>
<td>81.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>84.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>86.6&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crude protein</td>
<td>92.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>95.2&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

***: P<0.001
Figure 3: 1. fats: 10%; 2. fibers – polysaccharides 50%; 3. Lycopene and β-carotene 0.3%; 4. water 22%; 5. proteins 18%
Walker’s Crisps
POTATO INDUSTRY WASTES

**PEELS (15-40%)**

a) Animal Feed  
b) Ethanol  
c) Compost  
d) Energy (Pyrolysis)  
e) Biogas  
f) Antioxidants  
g) Solanin

**STARCH**

a) Food grade starch  
b) High value compounds by fermentation (e.g. Pullulan)
- Glucose residue
- Glucose with reducing end
- $\alpha$ 1-4 glucosidic linkage
- $\alpha$ 1-6 glucosidic linkage

G - Glucoamylase
Iso - Isopullulanase
Neo - Neopullulanase
P - Pullulanase
2. Character–printed Pullulan film

3. Same as above 2, character–printed Pullulan film is inserted in a fancy candy
8. Seasoning (pepper) incorporated Pullulan film is used to wrap the ham.

11. Table sugar wrapped with edible Pullulan film.
AIR-CT96-1184. Conversion of environmentally-unfriendly onion waste into food ingredients.
• What is a Fructooligosaccharide?
  A fructooligosaccharide (also written fructooligosaccharide) is a carbohydrate, which is made out of a short chain of fructose molecules. It is also classed as an oligosaccharide; oligo meaning few and saccharide, sugar. Fructooligosaccharides are also sometimes called oligofructose. Often the term is abbreviated to the letters FOS.
• Together with inulin fiber, fructooligosaccharides are probably most recognized for their prebiotic qualities
CELLULOSE STRUCTURE SHOWING CRYSTALLINE AND AMORPHOUS COMPONENTS

Διάγραμμα 3
Cellobiose

Cellulose

Branch

Branch point $\alpha(1 \rightarrow 6)$ linkage

Main $\alpha(1 \rightarrow 4)$ chain
Figure 5. Alternative Products from Salvage of Cellulosic Wastes
STRAW UTILIZATION (method)

1. Direct Uses:
   Fuel, Mulch, Fertilizer, Soil Conditioner, etc.

2. Mechanical Conversion:
   Densification, Pulping, Defibrizing, Cubing, Pelleting,

3. Chemical Conversion:
   Sugar, Alcohol, Furfural, Xylitol, etc.

4. Biological Conversion:
   Ensiling, Composting, SCP, Enzymes, Fermented feed.
SHORTCOMINGS OF STRAW AS ANIMAL FEED

1. DIGESTIBILITY
2. PROTEIN
3. PALATABILITY
4. BULKINESS
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Protein (mg)</th>
<th>(% dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain straw</td>
<td>2.54</td>
<td>3.3</td>
</tr>
<tr>
<td>HCl/H$_3$PO$_4$ treated and fermented</td>
<td>4.60</td>
<td>6.1</td>
</tr>
<tr>
<td>HCl/H$_3$PO$_4$ treated and ammoniated</td>
<td>2.62</td>
<td>3.5</td>
</tr>
<tr>
<td>HCl/H$_3$PO$_4$ treated, not ammoniated</td>
<td>1.24</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Acceptability by voles of 30% straw diets treated with different acids

- HCl
- H₃PO₄
- Fermented
ΔΙΑΤΡΟΦΑΦΑΡΜΑΚΕΥΤΙΚΑ

NUTRACEUTICALS,
Functional Foods
Fig. 1 Three mushrooms from which the antitumour polysaccharide agents have been developed in Japan and China. A: Krestin (PSK) from *Trametes versicolor* (mycelium); B: Lentinan from *Lentinus edodes* (fruit body); and C: Schizophyllan from *Schizophyllum commune* (medium product) (Mizuno, 1999).
Fig. 10 *Trametes versicolor* growing naturally on fallen timber
Krestin Capsules

0.37g x 40粒

Action and Indications: This drug is an immunomodulator. It is indicated for chronic infectious hepatitis and cancers as an adjuvant treatment to radiotherapy and chemotherapy.

Dosage and Administration: 2 capsules each time, 2 or 3 times daily orally.

Packing: 0.37g in a capsule. 40 capsules in a bottle.

Storage: Keep in a tightly closed container store in a cool and dry place.

Researched by Institute of Edible Fungi, Shanghai Academy of Agricultural Sciences.

Produced by Shanghai Life Pharmaceuticals Ltd.
Lentinan—an extract of the shiitake Mushroom is approved as an anti-cancer drug in Japan
Fig. 2a *Lentinus edodes* growing naturally on fallen timber
LENTINAN

Lentinan—an extract of the shiitake Mushroom is approved as an anti-cancer drug in Japan.

**Figure 1:** Primary Structure: $(1 \rightarrow 6)$: $(1 \rightarrow 3)$-\(\beta\)-D-glucan$^3$
ANTITUMOR ACTIVITY OF LENTINAN

1. Increase of macrophage production of cytokines (IL-1, TNF-α, IL-12 etc.)
2. Induction of T-helper cells to proliferate and differentiate
3. Restoration of the suppressed activity of T-helper cells to produce IL-2, INF-γ, TNF-β
4. Increase of NK activities
5. Activation complement
6. Lead the cancer to apoptosis
7. Increase of NK activities
8. Increase of cytotoxic activity of CTL, LAK to tumor cells
9. Activation complement
10. Lead the cancer to apoptosis

Tumor antigen peptide
Macrophages
Activated Macrophages
Complement C3
Tumor
THANK YOU