Cost-Effective Utilization Of Agro-Food Processing Waste

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EXECUTIVE SUMMARY

Food canning industries represent an important area of the Italian economy, in particular the industrial conversion of tomato in tomato purée, pulp and tomato minced from seed-firms.

One of the most important problem of food industry is the management of waste and their conversion in products of higher value. Modern eco-compatible technologies, promote the use of food waste to obtain biopolymers that can be re-used in the same sector of the raw materials.

The project’s objects are:
- The adjustment of extraction and purification procedures of the cellulose and wooden based material coming from products and by-products of farm and food production, and finally their physical and chemical characterization.
- The achievement of biodegradable and thermoplastic materials by using chemical and enzymatic/biochemical processes from polysaccharides, proteins and resins obtained in the previous activity.
- The individuation and the use of additives for the injection moulding or thermo moulding for the obtained materials.
- The realization of three and more manufactured articles, for example flowerpots or rigid packing vases, HDPE film for agriculture use and ensiling film.

The project’s phases are:
- From tomato production waste it is possible to re-use up to 20 % of polysaccharides with gel and film-structured remarkable properties.
- These biopolymers can interact with others polymers as proteins, lipids and polysaccharides and modify their properties. Straw fibers, dust from hazelnut shells, exhausted fibers coming from tomato production will be considered.
- After the raw materials identification, it is planned an extracting phase of the cellulose and wooden based material that will be mixed with plastics. Two different ways will be followed. The traditional extracting process of cellulose with soda, or the steam
explosion, an innovative and cleaner process. The latest technique allows to obtain good 
quality fibers with adjustable characteristics due to the need; moreover this process is a 
cleaner technology because it doesn’t make use of chemical reagents. The steam 
treatment consists in keeping in contact the wood-cellulose material with steam at high 
temperature (200-250°C) and pressure (16-40 atm) for a few minutes. This treatment 
destroys the composite nature of the material by the elimination of undesired compounds, 
increasing the cellulose fibers anisotropy and their reactivity. In this way exploded fibers 
can be re-used as reinforcement for polymeric materials because they have an excellent 
resistance at molecular level.

Characterized and extracted products represent the starting point for the realization 
of innovative packing.

The research has already provided important results:
- The realization of aqueous dispersions of polysaccharides and fibers that can 
be used for biodegradable roofs.
- The realization of thermo moulding biodegradable articles of simple structure 
for nursery pots.

In the near future, techniques as injection moulding and extrusion can be used to 
obtain manufactured articles used in the eco-sustainable packing sector.

These products, for their characteristics, will be re-used in the same sector of raw 
materials.

In this way a functional connection between production, recycling and re-using can 
be created.

INTRODUCTION

New methods of extraction and purification of polysaccharides obtained from tomato 
processing waste. Production, testing and optimization of biodegradable films and 
thermoplastic materials.

Recovery of Lycopene and carotene from waste by means of a new method of 
extraction driven by activity assessment tests.

Tomato is a plant belonging to the family of Solanaceae (Solanum Lycopersicum). 
It is a very adaptable plant. It likes deep, cool, well-drained, mixed soils. It is a typical 
annual cultivation. In Italy it is grown in the fields in the regions of Apulia, Campania, 
Emilia Romagna and Sicily. It is low in calories and helps digesting starches. It contains 
vitamins, minerals, micronutrients and anti-oxidants. As an example, 100 grams of fresh 
tomatoes contain 13% of vitamin A, 5% of folic acids, 8% of vitamin B and 33% of vitamin 
C necessary for an adult individual on a daily basis.

Figure 1: Chemical composition of 100 grams of fresh tomatoes

- 95.2% water
- 1.0% proteins
- 3.5% carbohydrates
- 0.2% lipids
Table 1 Chemical composition of 100 grams of fresh tomatoes

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<td>Vitamin C</td>
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WASTE PRODUCTION AND MANAGEMENT

Italy ranks third in the world for tomato processing and export. In 2004, 200 commercial plants processed 6,300,000 tons of tomatoes. 126,000 tons of waste were disposed of. Industrial processing accounts for 70% of food industry. Waste production causes damage to tourism and environment. Thanks to modern biotechnologies this type of waste may be manipulated and transformed into a potentially high value-added resource.

Solid waste is made up of processing residues, fibrous parts, seeds and skins (2% of the total production). Its disposal costs about 4.65 €/QUINTAL. Disposing of this fraction is very expensive and has a strong environmental impact. Environment-friendly technologies utilize and exploit agro-food waste as a source of alternative products. Tomato processing waste is already exploited in animal breeding, feeding and in the production of simple fodders. 50,000 tons of processed tomato waste contain 5 tons of Lycopene. It is worth underlining that Lycopene costs 50,000 euro/Kg.
COMPOSITION OF A TYPICAL WASTE

The typical waste is made up of the outer tegument of the berry (epicarp) and of seeds. Humidity accounts for more than 50%. The presence of polysaccharides is marked. Cellulose, pectin, emi-cellulose and starch are polysaccharides with emulsifying, stabilizing, gelatinizing, condensing, rheological structural properties. They interact with other polymers by modifying their properties. The electric charge, the linear or branched structure, the chain replacements determine their chemical and physical properties. The content in pectin, cellulose and emi-cellulose defines texture, viscosity and degree of cross-linking. Polysaccharides are successfully employed in food industry for their physical and chemical properties (as supports for resins and components of artificial plasma) and in the pharmaceutical industry because of their antigenic properties. Given the source of these polysaccharides it is difficult to produce them industrially. Hence recovering them from surplus biomass is highly cost-effective.

Recently plastic materials have been more and more used for soil mulching and solarization. They are oil-derived products and are usually abandoned in the fields or burned since their recovery is not cost-effective. These problems in their disposal explain why natural products or biodegradable artificial products are worth using. The basic concept is that of conceiving new plastic materials based on biopolymers that can be used by the micro-organisms in the soil. The production of biodegradable products requires the use of new polymers that can be degraded by micro-organisms in the right environmental conditions and over a controlled life-cycle. Therefore they must:

- stay stable over a given time period
- play the role they have been designed for
- degrade in the expected conditions and time.
BIODEGRADATION

It is the enzymatic and chemical transformation mediated by bacteria and fungi. It takes:
- A vulnerable substrate (bonds prone to hydrolysis or oxidation)
- Suitable organisms
- Suitable environment

Proteins and polysaccharides are easily biodegraded by micro-organisms. Temperature, humidity, salt concentration, oxygen and pH are key factors to biodegradation. Environmental conditions affect biodegradation speed since many polymers become bio-resistant. The factors favoring biodegradation are:
- Soluble polymer chains
- Suitable humidity
- Proper nutrient substrate
- High surface/volume ratio

The effect of temperature, pH and O2 varies in each single micro-organism. Bacteria grow at neutral pH values, fungi grow also at acid pH values.

The chemical nature, the structure and morphology of polymer system affect biodegradation. The speed of biodegradation is inversely proportional to molecular weight. Biodegradation is favored by polymers with:
- Low molecular weight
- No ramifications
- No crystal structure
- Prevalence of polar groups

BIODEGRADABLE POLYMERS AND POLYMER-BASED SYSTEMS IN AGRICULTURE

Over the years alternative polymer materials have replaced oil-derived products in agriculture. They can be classified as cellulose-base materials and polysaccharide-containing polymer matrix composite materials. In order to utilize tomato processing by-products, our research work has focused on the following aspects:

1. activity test-driven extraction of antioxidants from waste
2. working out a method to extract polysaccharides from industrial waste
3. chemical and physical characterization of extracted polysaccharides
4. possible biotechnological applications

RESULTS

Waste has been previously frozen in liquid nitrogen and then lyophilized. Then the relevant protocols of extraction have been applied. The most promising method from the point of view of process ecology and yields consists in a series of low environmental impact closed-loop steps using potassium carbonate and alcohol combined with some physical processes. The polysaccharide extraction yield is 7.5% with this method. The product obtained is 100% pure.

Figure 4: Thermus thermopilus growth on culture medium with the polysaccharide C (●) and on the complex culture medium TH (♦) at 75°C and pH 7.2. The polysaccharide C 1g/l was added as only source of carbon in a liter of M162 culture medium with 2g/l of NaCl. The inoculum has been added to 10% (v/v). The decrease of the polysaccharides (▲) has been drawn as g/l using the essay of Dubois.

MOLECULAR WEIGHT DETERMINATION

- **Column Chromatography Sepharose CL 6B**
  - Sample B: > 1.000.000 Da
  - Sample C: > 1.000.000 Da

- **Ultracentrifugtion**
  - Sample B: > 1.000.000 Da
  - Sample C: > 1.000.000 Da

OPTIC ROTATORY POWER

- Sample B: \([\alpha]^{25}_D = -0.154\)
- Sample C: \([\alpha]^{25}_D = -0.189\)

Figure 5: Molecular weight determination
TECHNOLOGICAL APPLICATIONS: FILMS

The polysaccharide fraction has been employed in order to obtain stress-resistant and flexible films. In the presence of suitable plasticizing agents, the film proves resistant. Films are made starting from 2% aqueous solutions. The water insoluble cellulose fraction is re-added to the polysaccharide fraction in order to make the film resistant and long-lasting. As a function of type and amount of fibers added, aqueous dispersions are obtained that can be sprayed or mixed in order to obtain items such as pots and containers. This material will be used for soil mulching as well as to make nursery pots for transplants (flower-growing) and semi-rigid packages for selling fresh vegetables and fruits (“IV range” products) thus promoting the concept of natural closed-loop by means of a biodegradable container.

Figure 6: Treading film of average resistance made of tomato wastes treated with KOH and mixed with alginate

Figure 7: Container of average resistance made of tomato wastes treated with alginate in H$_2$O grid with CaCl$_2$

CONCLUSIONS
The re-use of anti-oxidants recovered from tomato waste contributes to the qualitative improvement of food and cosmetics. This idea, if extended to the whole vegetal world, allows to identify and quantify substances that could be extracted and have high nutritional and functional values.

Biopolymers obtained from tomato processing waste, because of their primary structure, play an interesting role in some biotechnological applications. The polysaccharide film-generating capacity allows the production of bio-films that can be used for solarization and mulching in agriculture. The results obtained that may be of a technological interest are as follows:

- production of aqueous polysaccharides and fibers dispersions to make biodegradable covers for agriculture
- production of thermo-formed items to employ as biodegradable containers (nursery pots).

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