“HANDBOOK on BIOACTIVE COMPOUNDS from TOMATO PROCESSING RESIDUES”

Assessment and dissemination of strategies for the extraction of bioactive compounds from tomato, olive and grape processing residues

BIOACTIVE-NET

BIOACTIVE-NET MANUAL

HANDBOOK on BIOACTIVE COMPOUNDS from TOMATO PROCESSING RESIDUES

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The aim of this handbook is to provide an overview about the bioactive compounds in tomato processing residues, the extraction techniques and the application possibilities in the food and cosmetic industries.

The Bioactive-net manual is a collection of three publications as part of the project BIOACTIVE-NET. The aim of this project is to collect the most relevant knowledge and technology concerning bioactive compounds in tomato, olive and grape processing residues, from techniques of extraction, to application fields and economic feasibility of the extraction, and at the same time make it accessible to the public.

This publication has been carried out with the support of the European Commission, priority 5 (food quality and safety): contract number FOOD-CT-2006-43035, Specific Support Action (SSA) "Assessment and dissemination of strategies for the extraction of bioactive compounds from tomato, olive and grape processing residues". It does not necessarily reflect the views of the Commission and in no way anticipates the Commission's future policy on this area.

Additionally, BIOACTIVE-NET anticipates dissemination workshops aimed at tomato processors, olive oil mills and wine producers in Southern European countries. The Bioactive-net manual constitutes a key part of this dissemination action and will be available on the project website and upon request.

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BIOACTIVE-NET

The BIOACTIVE-NET project is a Specific Support Action (SSA) funded by the European Commission under the 6th Framework Programme.

The primary objective of bioactive-net is to assess and disseminate strategies for the extraction of bioactive compounds from tomato, olive, and grape processing residues to SME processors, and therefore allow the:

- Creation of a broad information platform regarding the extraction of bioactive compounds from tomato, olive, and grape processing residues as well as their application in the food and cosmetic industry.
- Implementation of dissemination workshops in the southern European countries (Spain, Italy, Greece and France) aimed at transferring know-how and evaluating the economic feasibility of extracting bioactive compounds for the residue generating companies (SMEs), the technology providers, the industrial residue extractors and the end-users of the respective natural ingredients.
- Strengthening the European market for natural ingredients which has enormous economic potential due to high availability of the raw materials.
- Increased competitiveness of the European food industry by pre-empting the competition in the use of bio-active compounds derived from natural, renewable and economic source processing residues.
- Increased use of bio-active compounds in the European diet.

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BIOACTIVE-NET members:

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- ainia centro tecnológico (Spain).
- CCAE - Confederación de Cooperativas Agrarias de España (Spain).
- AMITOM - Mediterranean International Association of the Processing Tomato (France).
- Vignaioli Piemontesi S.C.A (Italy).
- Union of Agricultural Cooperatives in Peza (Greece).
- ANFOVI - L'organisme de formation des Vignerons Indépendants (France).
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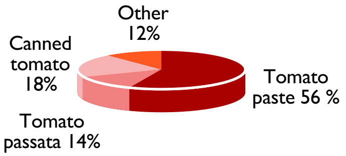
TABLE of content

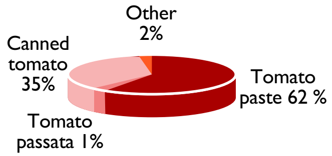
1.INTRODUCTION

The total tomato production in the EU was estimated at more than 16 million metric tons in 2005 [AMITOM]. The demand for tomato processing arises from a need to preserve the product for cooking purposes out of season. Traditionally, the most important tomato processed products are tomato concentrates: passata, puree, paste.

Italian tomato product repartition



Spanish tomato product repartition



In 2005 in Europe, 10 million tons tomatoes were processed into tomato paste and ketchup, leading to more than 200 000 tons solid tomato residues (peels and seeds), also called pomace, and a large volume of wastewater.

Following the General EU Legislation on wastes (Directive 2006/12/EC), Member States shall take the necessary measures to ensure that waste is recovered or disposed of without endangering human health and without using processes or methods which could harm the environment.

The by-products produced during the tomato transformation process are defined as Secondary Raw Materials. Council Directive 96/25/EC, legislates the re-use in particular of "tomato pulp obtained by pressing tomatoes Solanum lycopersicum Karst. during the production of tomato juice" for animal feeding. Currently the pomace is sold, transferred to other companies without financial exchange or removed with payment from the tomato processors.

Is it possible to gain more added value from tomato processing residues for businesses? Can the health benefits from tomatoes be obtained from tomato residues? Existing research has identified that tomato pomace still constitutes an excellent source of nutrients such as carotenoids, proteins, sugars, fibres, waxes and oils (75 % unsaturated fatty acids) which might then be used in food applications and in the cosmetic industry.

2. BIOACTIVE COMPOUNDS in TOMATO processing residues

The main bioactive compounds extractable from tomato processing residues are: Lycopene, Tomato fibre, Tomato seed oil and Enzymes.

2.1. Lycopene

Ingredient description

Lycopene is a bright red carotenoid pigment found in tomatoes and other red fruits such as watermelon, pink grapefruit, pink guava, papaya and rosehip. Lycopene is the most common carotenoid in the human body and is one of the most potent carotenoid antioxidants. Its name is derived from the tomato's species classification, *Solanum lycopersicum* (formerly *Lycopersicon esculentum*).

Known metabolic known effects

Lycopene has an effect as an antioxidant and protects against degenerative diseases. Moreover it decreases the risk of cardiovascular diseases and that of cancer (mainly prostate cancer). Lycopene also has an immune-stimulant effect and boosts skin health by protection from UV induced damage.

Studies are underway to investigate other potential benefits of lycopene (the H.J. Heinz Company sponsored research at the University of Toronto and at the American Health Foundation). These studies will focus on lycopene's possible role in the fight against cancers of the digestive tract, breast and prostate cancer.

Amount of extractable molecule

The lycopene extractable from raw processing tomatoes varies from 80 to 150 mg/kg. Through genetic improvement a maximum of 200 mg lycopene/kg can be reached.

Lycopene is present in different concentrations in the different tomato parts:

- 11mg/100g in the tomato pulp.
- 54mg/100g in the tomato peel.

Nevertheless the difference is not so important when the dry weight of the tomato parts is considered.

Unlike other fruits and vegetables, where nutritional content such as vitamin C is diminished upon cooking, processing of tomatoes increases the concentration of bioavailable lycopene. Lycopene in tomato paste is four times more bioavailable than in fresh tomatoes. Thus processed tomato products such as pasteurised tomato juice, soup, sauce, and ketchup contain the highest concentrations of bioavailable lycopene.

2.2. Tomato Fibre

Ingredient description

Dietary fibres are the indigestible portion of plant foods that move food through the digestive system, absorbing water. Dietary fibres consist of non-starch polysaccharides and several other plant components such as cellulose, dextrins, inulin, lignin, waxes, chitins, pectins, beta-glucans and oligosaccharides.

Known metabolic effects

Tomato fibres present the typical beneficial health effects of other dietary fibres.

- Positive effects during the mastication mechanisms.
- Reduce the caloric contribution of foods.
- Induce satiety sensation.
- Reduce blood sugar.
- Reduce cholesterol.
- Tie toxic substances
- Stimulate the digestive processes.
- Increase the time of intestinal transit.
- Favour fermentative processes in the colon.

Current recommendations from the United States National Academy of Sciences, Institute of Medicine, suggest that adults should consume 20-35 grams of dietary fibre per day.

Amount of extractable molecule

As determined during the TOM project, around 75% dietetic fibres can be extracted from tomato processing residues[1].

[1] Results raised during the European Project TOM "Development of new food additives extracted from the solid residue of the tomato processing industry", contract number. QLK1-CT-2002-71361.

2.3. Tomato Seed Oil

Ingredient description

Tomato seed oil consists of approximately 75% of unsaturated fatty acids and would therefore be a very healthy food. Tomato seed oil is a good source of the essential linoleic fatty acid.

Known metabolic effects

Tomato seeds oil acts as vascular protector and emollient.

Amount of extractable molecule

Around 4% oil and 3% waxes can be extracted from tomato processing residues[1]. Vegetable fats and oils are substances derived from plants that are composed of triglycerides. Normally, oils are liquid at room temperature and fats are solid. A dense brittle fat is called a wax.

3. Best Available TECHNIQUES for the extraction and purification of BIOACTIVE COMPOUNDS from TOMATO processing residues

To extract bioactive compounds from tomato processing residues, different steps must be followed:

- Pre-treatment of tomato processing residues.
- Extraction of dried and homogeneous tomato processing residues.
- Purification of extracts.
- Drying of purified extracts.

3.1. Pre-treatment of the tomato processing residues

Tomato processing residues contain a lot of water. Depending on the extraction process it may be necessary to dewater the samples before the extraction process. For example, for supercritical fluid extraction, dewatering of the tomato residues is necessary. Moreover, the drying of tomato residues facilitates the transport and storage of bioactive rich residues. To enable efficient extraction, the dried residues must be milled in order to guarantee the homogeneity of the extractor feed.

Several techniques and equipments may be applied in order to prepare tomato processing residues. Some of the most common drying and milling techniques are presented here.

3.1.1. Tray dryer

Tomato residues are spread out thinly on trays, inside a cabin which is connected to a source of air heated by gas diesel or biomass to remove the moist vapours. Depending on the cabinet design, there are batch tray dryers, semi-continuous tray dryers and cross flow chambers.

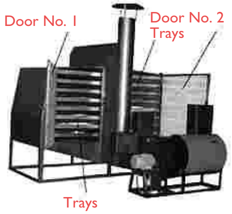


Figure 1: Tray dryer.

3.1.2. Drum dryer

Tomato residues are spread over the surface of a heated drum. The drum rotates and the residues remain on the drum surface during the major part of the rotation while the drying process takes place and are then scraped off.

The following table compares tray drying and drum drying processes used with tomato processing residues:

Technique	Initial investment	Energy consumption	Ease of operation	Drying time
Tray drying	+	+	easy	long
Drum drying	++	++	easy	long

3.1.3. Fluid bed dryer

The feed of wet material is dried by close contact with hot air when the material is in a fluidised state.

The dryer comprises:

- A top fluidising chamber.
- A bottom air distribution chamber.
- A specially designed perforated plate.

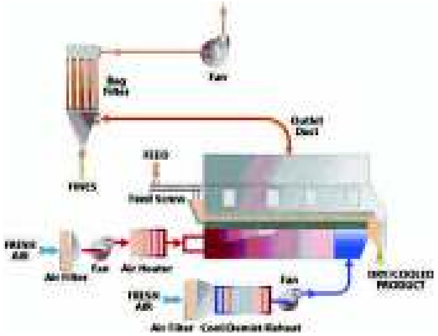


Figure 2: Fluid-bed drying process.

3.1.4. Milling and Homogenisation of the tomato processing residues

Sometimes it may be necessary to reduce the size of the particles (by milling) and to mix the residues by a homogenisation process in order to improve the extraction process.

Milling of the dried tomato processing residues

Milling is used to convert the shredded material into fine particles. One possible milling technique for the pre-treatment of the tomato processing residues is the hammermill.

Figure 3: Hammermill

A hammermill is essentially a steel drum containing a vertical or horizontal cross-shaped rotor on which pivoting hammers are mounted (see figure 3). The hammers are free to swing on the ends of the cross. The rotor is spun at a high speed inside the drum while material is fed into a feed hopper. The material is impacted by the hammers on the ends of the rotating cross and thereby is shredded and expelled through screens in the drum.

Homogenisation of the dried tomato processing residues

Homogenisation is a process that makes a mixture the same throughout the entire substance. A mixing phase is required and sufficient in order to homogenise the dried and milled residues.

3.2. Extraction of the dried and homogeneous tomato processing residues

The operation of extraction consists of separating one or more species from a solid or liquid matrix based on the different relative solubility that such substance or substances present in a certain solvent with respect to the rest of the components of the matrix. In other words, extraction works according to the principle that soluble components can be separated from insoluble or less soluble components by dissolving them in a suitable solvent. Raw materials that are suitable for extraction may contain solids only, solids and a solution, or solids and a liquid.

3.2.1. Solvent extraction

Conventional solid-liquid extraction

This technique implies the contact of the plant solid matrix with a liquid solvent. The selection of the solvent will be determined by the chemical and physical properties of the target substances. In particular, the thermal stability and the polar character of the substance have special relevance. The solvent temperature must be chosen accurately depending on the raw material and on the thermal resistance of the solutes we want to recover. In order to facilitate the transfer of the target substances to the liquid, the plant feedstock is normally treated mechanically.

This process is used to extract oils. It is not suitable for thermolabile substances. Some organic solvents that may be used as extraction agent are toxic and can leave traces in the end product. Ethanol can be used to replace some toxic or dangerous organic solvents. In addition, all the solvent extraction requires a purification stage after extraction, such as filtration or centrifugation. Ultrasound and microwave assisted extraction are similar to conventional extraction, with the addition of ultrasound or microwave in order to increase the yields, reduce the volume of solvent and reduce the working time.

Sonicated-assisted extraction (ultrasound)

Sound waves with frequencies higher than 20 kHz can improve the extraction yield of plant material because they involve alternative expansions and compressions of matter inducing the creation of bubbles in liquids.

The most relevant parameter to control in sonicated assisted extraction is frequency, because small changes of this parameter can affect dramatically the yield of extraction. Ultrasounds cause a greater penetration of solvent into cellular matrices improving mass transfer.

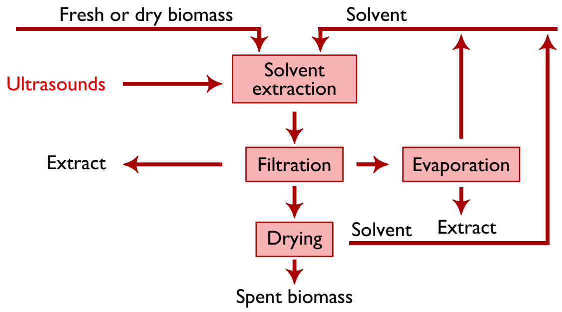


Figure 4: Sonicated-assisted extraction process diagram.

Ultrasound-assisted extraction has been used to extract nutraceutical such as essential oils, lipids, antioxidants, steroids and terpenoids. It allows process conditions to be milder compared to traditional solvent extraction, so it is therefore recommended for thermolabile substances.

Microwave-assisted extraction (MAE)

Microwaves are electromagnetic waves that interact with matter, particularly with polar molecules to generate heat. They can therefore, penetrate water and biological matrices heating up the whole at a homogeneous rate. Radiation produces superheating of water within plant cells and causes the rupture of the cellular wall facilitating the transfer of interesting substances to the bulk phase inside the extraction vessel and the penetration of the solvent into the plant matrix. Microwaves can therefore improve the extraction yields of nutraceuticals. The volume of solvent needed and the extraction time are reduced.

The effectiveness of MAE depends strongly on the polarity of the solvent, the particle size and distribution of the vegetable material. It can be applied to extract polar components but it is not suitable for dry materials or very wet matrices using non-polar solvents. (Water, methanol and ethanol are polar enough to be employed). In addition, MAE requires a purification stage after extraction, such as filtration or centrifugation.

Accelerated solvent extraction (ASE)

Accelerated solvent extraction is a solid-liquid extraction carried out at high temperatures (that improve the diffusivity of the solvent accelerating the extraction) and pressures (to maintain the solvent in liquid phase), below the critical point of the solvent. Most of the solvents used in conventional solid-liquid extraction are suited to ASE (including water) to recover polar compounds from plant material.

3.2.2. Supercritical Fluid Extraction (SFE) SC-CO_2 extraction

The supercritical state is reached by bringing the fluid to a temperature and pressure beyond its critical point. Supercritical fluids present characteristics of both gases and liquids, properties that make them especially suitable for extraction processes.

Supercritical fluids have higher diffusion coefficients as well as lower viscosity and surface tension than conventional solvents. The dissolving capacity of supercritical fluids depends on its density, so the selectivity of extraction can be changed by adjusting the temperature and/or the pressure of extraction. After the extraction phase, pressure is reduced or temperature is increased, so that the solubility of the extract decreases and it can be separated.

The most used solvent is CO_2, which is cheap, safe, non-toxic and its supercritical conditions may be fairly easily reached. It can be used to extract polyphenols such as resveratrol and other natural antioxidants from grape peels and stalks. It is suitable for thermolabile substances and it can be also used for polar substances if some modifiers are added to it (methanol, ethanol, water, acetone...). The following table compares the different extraction techniques exposed.

Extraction method	Compounds extracted	Humidity tolerance	Purification requirements
Conventional	Polar & Non-polar	+	High
Ultrasound	Polar & Non-polar	+	High
Microwave	Polar	+	High
SC-CO_2	Non-polar	-	Low
Subcritical	Polar	++	Medium-high

3.3. Purification of the extracts

After the extraction processes, the recovery of a biological product from the interferences and the impurities requires some purification steps to obtain the product consistent with the final specifications. The purification simply aims at obtaining a satisfactorily pure molecule in the shortest possible time.

3.3.1. Chromatographic techniques

Chromatography is a very special purification process because, it can separate complex mixtures with great precision (even very similar components can be separated).

In fact, chromatography can purify basically any soluble or volatile substance. It can be used to separate delicate products because the conditions are not typically hard. For these reasons, it can be used to separate mixtures of tomato bioactive compounds.

Another advantage of these techniques is that the separated compounds are immediately available for identification or quantification. On the other hand, some instrumentation is expensive and not easily portable and some work is needed to avoid the contamination of the column.

Separation by chromatography depends on the differential partition of compounds between a stationary phase (the adsorbent) and a mobile phase (the buffer solution). Normally, the stationary phase is packed into a vertical column of plastic, glass or stainless steel, and the buffer is pumped through this column. The sample to be fractionated is pumped in at the top of the column and the various sample components travel with different velocities through the column and are subsequently detected and collected at the bottom of the column. In general, bio-molecules are purified using purification techniques that separate them according to differences in their specific properties, as shown in following table.

Molecular property exploited	Type of chromatography
Size	Gel filtration (sometimes called size-exclusion)
Charge	Ion exchange chromatography
Ligand specificity	Adsorption chromatography

Partition chromatography

The stationary phase is usually a liquid which can be mechanically coated or chemically bonded on a comparatively inert solid support. The molecules which need separated are held in this stationary phase (shown in figure 5). When the stationary phase is less polar than the mobile phase, reverse phase (RP) chromatography is a good example of liquid-liquid chromatography.

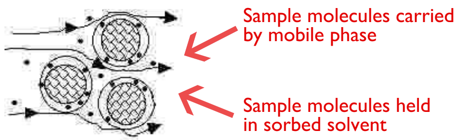


Figure 5: Partition chromatography.

The advantages of this technique are the high recovery, the large volumes and the easiness to scale-up.

Size-exclusion or gel filtration

The separation in gel filtration depends on the different abilities of the sample molecules to enter inside the pores which contain the stationary phase. Very large molecules do not enter and move through the chromatographic bed faster. Smaller molecules, which can enter inside the gel pores, move more slowly through the column, because they spend a part of their time in the stationary phase. Molecules are eluted according to their decreasing molecular size.

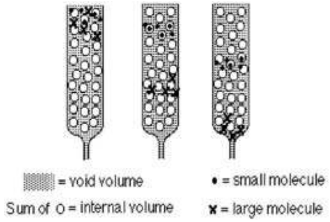


Figure 6: Size-exclusion chromatography mechanism

The disadvantage of this simple and effective method is its low capacity coupled with the fact that it does not work very well for crude mixtures. Consequently, this process can be applied in the final 'polishing' step.

Ion exchange chromatography

The basis for ion exchange chromatography is the competitive binding of compounds with differences in charge, to an oppositely charged chromatographic medium, the ion exchanger.

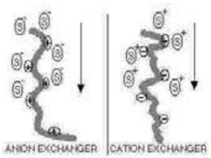


Figure 7: Ion-exchange chromatography mechanism.

Large volumes can be processed using this technology.

Adsorption chromatography

A bio specific adsorbent is prepared by coupling a specific ligand on a solid surface that will only interact with the molecules which can selectively bind to it (the ones that must be separated).

Molecules that are not bound elute unretained. The retained compound can later be released in a purified state. This kind of technique is used in Fine Chemistry. The following table compares the main characteristics of the different chromatography technologies that have been explained above.

Technique	Partition chromatography	Size-exclusion chromatography	Ion exchange chromatography	Adsorption chromatography
Laboratory scale	X	X	X	X
Large scale	X	X	X	X
Selectivity	High	Low	High	High
Resolution	High	Low	High	High
Capacity	High	Low	High	High
Recovery yields	High (close to 100%)	High	Low (50-60%)	High
Operating easiness	Easy	Simple, fast	Lengthy procedure	Easy
Costs	++	+	++	++
Fine chemistry application	X	NO	X	X
Industrial chemistry applications	X	X	X	X

3.3.2. Membranes filtration techniques

Membranes selectively filter gases or liquids in solutions or mixtures into their different components. The membrane micropores are sized to allow some molecules and particles to go through and block others. Thus membranes are very specific, with their molecular structure tailored according to the particular species to be separated.

Membrane filtration is regarded as BAT in the BREF (Best Available Techniques Reference Document) for the Food, Drink and Milk Industries because of the reduced water consumption and wastewater pollution that its use entails. There are three main technological processes depending on the size of the components to be retained: microfiltration, ultrafiltration and reverse osmosis.

Microfiltration

Microfiltration is a low-pressure cross-flow membrane process for separating colloidal and suspended particles in the diameter range 0.1-10 µm. Microfiltration is a purely physical process in which particles are captured on the surface on the membrane.

Any particle larger than the pore size of the membrane cannot squeeze through. Membrane filters are widely used in biotechnology and food and beverage applications where a sterile product is required.

Ultrafiltration

Ultrafiltration membranes retain particles in the range 0.01-0.1 µm and operate in a pressure range 0.5-10 bars. It has become the best method to concentrate, largely replacing size-exclusion chromatography in these applications. UF membranes are commonly used in biopharmaceutical applications.

The major advantages of ultrafiltration over competing purification techniques such as chromatography are:

- High throughput of product.
- Relative easiness to scale-up.
- The equipment is easy to clean and sanitise.

Reverse osmosis

Osmosis explains the phenomenon whereby if a semi-permeable membrane separates two salt solutions of different concentration, water will migrate from the weaker solution, through the membrane, to the more concentrated solution, until the solutions have the same salt concentration. Reverse osmosis involves applying pressure to reverse the natural flow of water, forcing the water to move from the more concentrated solution to the weaker. The semi-permeable membrane is porous and allows water to pass through but blocks the passage of the bulkier salt molecules. The result is water without salt on one side of the membrane.

Reverse osmosis will generally remove any molecular compounds smaller in size than water molecules. It is non-selective in its removal of both dangerous and beneficial minerals. Reverse osmosis is a highly efficient technique for concentrating/separating low-molecular-weight substances in solution. For this purpose, it requires an energy source and is fairly expensive.

3.3.3. Crystallization

Crystallization is a technique used to purify solid compounds. It is based on the principles of solubility. As a general rule, compounds (solutes) tend to be more soluble in hot liquids (solvents) than they are in cold liquids. If a saturated hot solution is allowed to cool, the solute is no longer soluble in the solvent and it forms crystals of pure compound. Impurities are excluded from the growing crystals and the pure solid crystals can be separated from the dissolved impurities by filtration. High purity products are obtained so, this process is commonly employed at pharmaceutical level.

The following table compares the purification techniques explained in the present chapter.

Technique	Partition chromato	Size-exclusion chromato	Ion exchange chromato	Adsorption chromato	Micro-filtration	Ultra-filtration	Reverse osmosis	Crysta-llization
Scale-up	Relatively easy	More difficult	More difficult	More difficult	Relatively easy	Relatively easy	Relatively easy	Used
Equipment	Flexible	Relatively inexpensive	Expensive	Complex and expensive	Simple, reliable, easy to maintain	Simple, reliable, easy to maintain	Simple, reliable, easy to maintain	
Pressure sensitive compounds	Suitable	Suitable	Suitable	Suitable	Not suitable	Not suitable	Not suitable	Suitable
Temperature sensitive compounds	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Selectivity	High	Low	High	High	Low	Low	Low	High
Particle size	Independent	Dependent	Independent	Independent	Dependent (0,1-10µm)	Dependent (0,01-0,1µm)	Dependent	Independent
Purification time	Fast	Fast	Low		Long	Long	Long	Long
Costs	++	+	++	++	+	+	Fairly costly	++
Energy requirements	Low	Low	Low	Low	Quite low	Quite low	High	Low
Efficiency	High	Low	High	High			High	Medium

3.4. Drying of the purified bioactive extracts

The bioactive compounds need to be sufficiently dried to be safely stored until they are required for further processing. The whole drying process must be gentle to reduce the risk of bioactive compounds degradation. Different drying methods can be used.

3.4.1. Freeze Drying

Also known as lyophilization, freeze-drying is used to preserve a perishable material or to make it easier to transport. Freeze-dried products can be rehydrated quickly and easily.

This process includes the following steps:

- Freezing the material.
- Reducing the surrounding pressure.
- Adding enough heat to allow the frozen water in the material to sublime directly from the solid phase to gas.

3.4.2. Spray Drying

Spray drying is the most widely used industrial process, involving particle formation and drying. It is highly suited to the continuous production of dry solids from a liquid feedstock in powder, granulated or agglomerated form. It is an ideal process when the final product must comply with precise quality standards regarding particle size distribution, residual moisture content, bulk density and particle shape.

Spray drying involves the atomisation of a liquid feedstock into a spray of droplets and contacting the droplets with hot air in a drying chamber. Evaporation of moisture from the droplets and formation of dry particles proceed under controlled temperature and airflow conditions (shown in the following diagram).

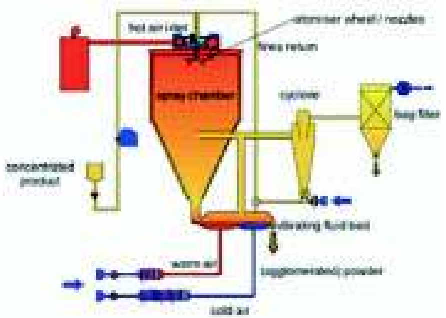


Figure 8: Spray drying process

Drying occurs very quickly so this process is very useful for materials that can be damaged by long time exposure to heat. Spray drying has been identified in the Best Available Techniques Reference Document for the Food, Drink and Milk Sectors as the best available technique for drying because of its reduced energy, water consumption and its reduced emissions of dust.

3.4.3. Rotary Vacuum Drying

Wet feed is loaded as a batch and is heated indirectly under agitation by paddle mixing. The operation is normally carried out in a vacuum. Recovery of solvent is possible by condensing the vapours generated during the drying operation.

Other advantages of this process are:

- Granular / pasty wet materials can be handled.
- Low temperature operation is possible: it is ideal for materials that would be damaged or changed if exposed to high temperatures. The vacuum removes moisture while preventing the oxidation or explosions that can happen when some materials are mixed with air.
- Mode of heating is indirect.
- High energy efficiency.
- Closed operation: solvents can be recovered, it is safer and minimizes the product loss caused by atmospheric contaminants, dusting, oxidation, discoloration, and chemical change.

4. Application fields for BIOACTIVE COMPOUNDS In FOOD and COSMETIC products.

4.1. Legislation

From a legislative point of view, natural ingredients are regulated as Food additives and/or Cosmetic products.

Food additives

Food additives used as ingredients during the manufacture or preparation of food and which are part of the finished product are covered by the scope of the Directive 89/107/EEC. Prior to their authorisation, food additives are evaluated for their safety by the Scientific Committee on Food. This is an expert panel that advises the European Commission on questions relating to food.

All authorised food additives have to fulfil purity criteria which are set out in detail in three Commission Directives:

- Commission Directive 95/45/EC laying down specific purity criteria concerning colours for use in foodstuffs.
- Commission Directive 95/31/EC laying down specific criteria of purity concerning sweeteners for use in foodstuffs.
- Commission Directive 96/77/EC laying down specific purity criteria on food additives other than colours and sweeteners.

Cosmetic products

Council Directive 76/768 of 27 July 1976 on the approximation of the laws of the Member States relating to cosmetic products.

Restrictions and prohibitions on ingredients that can be used in cosmetics are included in various lists under the EU Cosmetics Directive.

Decision 96/335/EC updated by Commission Decision 2006/257/EC, establish an inventory and a common nomenclature of ingredients employed in cosmetic products. The inventory is purely indicative and shall not constitute a list of substances authorized for use in cosmetic products.

4.2. Lycopene

State of the competition

An investigation of lycopene suppliers gave the following results.

Product	Company	Origin of lycopene	Purity	Price per kg
Tomate Lyco 160	Obipektin	Tomatoes	0,16%	12.23$/kg
NutriPhy Lycopene 100, GIN601841	Chr Hansen	Tomatoes	3.8-4.2%	635.83$/kg
Lycopene	Abl biotechnologies	Ripe tomatoes	6%	286.28$/kg
Lycopene	Abl biotechnologies	Ripe tomatoes	8%	374.55$/kg
Lycopene	Abl biotechnologies	Ripe tomatoes	10%	465.21$/kg
Lyc-O-Red® 10% CWD	Buckton Scott Limited	Selected, non GMO, ripe tomatoes	>10%	489.10$/kg
Lyc O Mato®	LycoRed Natural Products Industries Ltd.	Tomatoes	15%	6 000.00$/kg
Natural Lycopene Beadlet 5% CWS	Vita-solarbio	*Blakeslea trispora* (fungi)	5%	115.00$/kg
Lycopene	AHD International		5%	163.00$/kg
Natural Lycopene Beadlet 5% TAB	Vita-solarbio	*Blakeslea trispora* (fungi)	10%	185.00$/kg
Natural Lycopene Beadlet 10% CWS	Vita-solarbio	*Blakeslea trispora* (fungi)	10%	195.00$/kg

The strong price divergences from 12 to 6 000$/kg can be explained by the difference of origin of the natural lycopene (tomato or fungi) and the difference in purity.

Lycored is the only company which produces natural pure lycopene: Lyc O Mato ®. The tomatoes are cultivated with the only purpose of lycopene production and show a lycopene content which lies well over that of "normal" tomatoes. The enterprise offers lycopene in form of oleoresins of pure lycopene.

BioLyco an Italian start-up is planning to introduce, by the end of 2008, lycopene extracted from waste products from tomato processing industries.

Lycopene prices vary depending on customer, quantity ordered and packaging, but sources cite an on-the-spot figure of over US$6 000 per kg (c. ¤4 600). While cheaper lycopene is available from Chinese suppliers, this tends to be from genetically modified tomatoes, to which consumers in the Europe and the US are generally unreceptive.

Synthetic lycopene is available from chemical companies as well but is not allowed for food applications yet. Thus, it is only applied in cosmetic as well as nutraceutical applications at the moment. Furthermore, the high free radical scavenging effect of the natural lycopene containing extracts could not be found in-vitro in the synthetic molecule.

Possible application

Lycopene from tomatoes was approved for use as a colouring in 1997. This means that the ingredient can be listed on labels as E160d, but the companies have not been able to flag up “contains lycopene” to draw attention to its health benefits.

Novel food approval granted by the UK’s Food Standards Agency in 2005 gave the go-ahead for the use of lycopene in foods amounts of 5mg per serving, thought to be the dose required to produce a health benefit. Prior to this it felt under the legislation for additives, since it was more commonly used as food colour.

Lycopene is to be classified as safe with regard to the amount with the taking. The ADI (acceptable daily intake) was evaluated and approved by 0-0.5mg/kg by JECFA.

Lycopene can be used as a food colouring in food and beverages, giving a strong red or orange colour. However, its use pure as a colour would be very expensive, because its price remains very high.

Because of its many positive qualities as an active substance, lycopene is potentially interesting for application by the food industry as a food supplement. It could be used, not only on its own but also in combination with other carotenoids like beta-carotene and lutein.

In addition, the health-promoting effects of lycopene are important for the application in the medicine industry. Lycopene acts as an antioxidant, as a scavenger of free radicals and its potential role in the prevention of cancer and cardiovascular diseases are very promising.

Lycopene also offers potentials to be used in cosmetics against the premature aging process of the skin. In the cosmetics industry, lycopene is used in skin-maintaining products.

Existing and potential markets

The market for lycopene as an ingredient has been valued at ¤27million in 2003 (Frost and Sullivan) with growing demand. The growth is forecast at over 100%.

In September 2004 LycoRed filed for novel foods approval to market its lycopene oleoresin from tomatoes for food products including yoghurts, cheese, bread sausages and cereal bars.

The European market for lycopene as a functional food ingredient looks to be opening up, since the company Vitatene gained novel foods approval for its ingredient derived from the *Blakeslae trispora* fungus in 2006.

4.3. Tomato Fibres

State of the competition

So far only the company LycoRed has been identified as natural tomato fibres supplier. They are supplying dietary tomato fibbers for 3.50 – 4.70$/kg.

Possible application

Tomato fibres are roughage and result as a by-product of the lycopene extraction. The production of the fibres as a "waste product" is consequently very good value.

The fibres can find an application as a food supplement, for example, in fitness snacks and other functional food.

Tomato fibres are mainly used in the food industry as a viscosity modifier in soups and sauces. They are a functional ingredient for the food industry, used to regulate viscosity and to prevent syneresis.

There are many types of soluble fibre supplements available to consumers for nutritional purposes, treatment of various gastrointestinal disorders, and for such possible health benefits as lowering cholesterol levels, reducing risk of colon cancer, and losing weight.

Existing and potential markets

Up to now only few offers in the market have been identified. Therefore, the application of the tomato fibres would be innovative and create a new market. The communication and penetration of any new product would require another study with regard to the consumer's acceptance to be expected and determine price levels.

4.4. Tomato Seed Oil

State of the competition

Tomato seed oil is not available so far on the market as a single product. Most of the time tomato seed oil is integrated in the oleoresin from tomato sold for its lycopene content but including also tomato seeds oil as whole tomatoes are used as raw material for the extraction process.

Nevertheless an Italian start-up Biolyco is planning to start the industrial production of low cost tomato seed oil from tomato processing residues. The plant is scheduled to start production by the end of 2008 [2].

The consumer's price of comparable oils lies between 6.80 and 27.00$/kg.

Possible application

Tomato seed oil can be used as: a food additive rich in poly-unsaturated fatty acids and as a cosmetic ingredient.

Existing and potential markets

Tomato seed oil, extracted from the tomato residue by means of solvents cannot be considered as food. Unless extracted mechanically, extracts dedicated for food applications have to be officially tested and registered within the EU with "E" numbers. The immediate admittance would assume, as for example with olive oil, require mechanical pressure as the only process.

Tomato seed oil could be produced at the same time as lycopene is extracted with CO_2 application. The Lycopene extracted by mean of supercritical CO_2 is already registered as food additive with the E160d.

Therefore, the application of the tomato seeds oil would be, lie for tomato fibres, innovative and create a new market. The communication and penetration of any new product would require another study with regard to the consumer's acceptance to be expected and determine price levels.

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[2] http://www.nutraingredients.com/news-by-health/news.asp?id=73851&idCat=125&pff=1

5. Assessment of the ECONOMIC feasibility for the extraction of TOMATO BIOACTIVE COMPOUNDS from processing residues

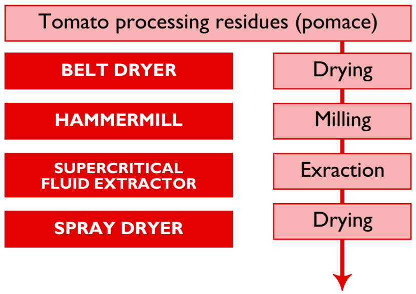
The objective of this chapter is to demonstrate the net benefit of the extraction of bioactive compounds from tomato processing residues in light of the costs for the industrial extraction of bioactive compounds and the revenues deriving from their selling.

Two extraction processes have been used as calculation example to determine the economic feasibility of the extraction of bioactive compounds from tomato processing residues:

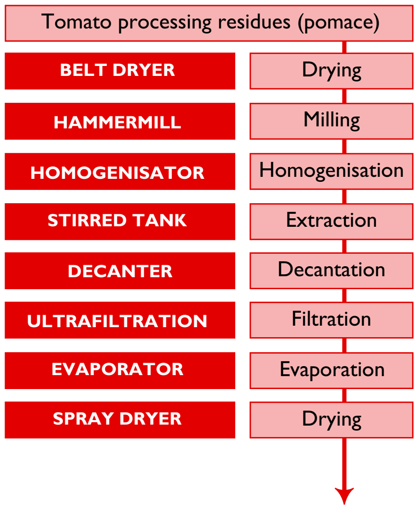
- Example 1: Supercritical Fluid Extraction (SFE)/SC-CO_2 extraction.
- Example 2: Solvent extraction.

Considering the SFE and Solvent extraction, the following flow-charts show the process steps required to extract compounds and the necessary equipments.

Example 1:
SUPERCRITICAL FLUID EXTRACTION



Example 2:
SOLVENT EXTRACTION



It is interesting to underline that while the pre-treatment (draining, drying, milling of the pomace) must necessarily be carried out during the harvesting season to preserve the processing residues (from July to September, 3 months), the extraction and the drying are two operations that can be done all year round (either 60 days in the minimum hypothesis; 200 days in the intermediate hypothesis or 330 days in the maximum hypothesis; 24 hours a day), reducing in this way the effort during the short and hard period of the tomato harvesting and partially cancelling the problem of the seasonality of the extracts obtainable from tomato.

It is also very important to note that the calculations developed in this chapter include only labour, energy, maintenance, quality control and consumable costs. Costs such as costs of sales and marketing, shipping, handling and storing, recovery costs of solvent have not been considered. However, even if not exhaustive, the following evaluations give a good idea of the economic feasibility of two different extraction methods.

5.1. Extraction of bioactive compounds from tomato processing residues.

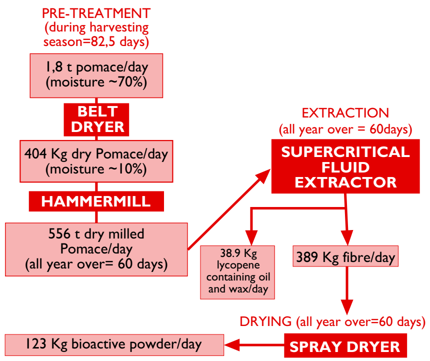
Starting from the production data of tomato processing residues provided by the European Industrial Associations of the tomato sector participating to the project, three hypothesis have been chosen (minimum, intermediate and maximum) to provide more adapted information to companies with different production sizes.

5.1.1. Minimum Hypothesis

The minimum hypothesis considers the case of small tomato companies processing around 20 000 tons of tomato/year. Small tomato processors are concentrating their yearly work during a total of 60 days during the harvesting season.

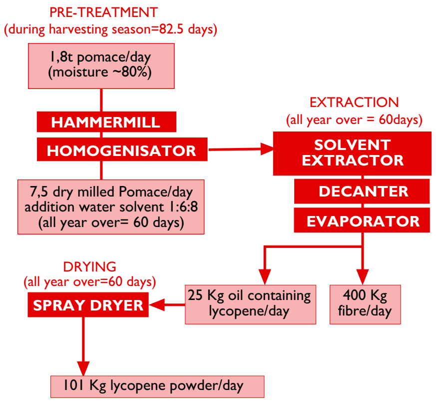
Pomace represents around 3% of the quantity processed. In other words, the minimum hypothesis considers a quantity of 150 tons/year of tomato processing residues to treat in single tomato processing companies during the harvesting season. The harvesting season is lasting an average of 82.5 days from July to September. The small tomato processors therefore have to treat 1.8 tons pomace every day during the harvest.

Example 1:
SUPERCRITICAL FLUID EXTRACTION



With SFE it is possible to extract, during the 60 days of yearly production, around 39kg of oil and wax containing 1 and 0.5% lycopene and 389kg of fibre per day. The oil and wax can be sold as such or further processed into lycopene powder (0.25%) yielding 123kg/day.

Example 2:
SOLVENT EXTRACTION



With solvent extraction it is possible to extract, during the 60 days of yearly production, around 25kg of oil containing lycopene and 400kg of fibre per day. The oil can be sold as such or further processed into lycopene powder yielding 101kg/day.

5.1.2. Intermediate Hypothesis

Middle size tomato processing companies are working yearly 200 days and process around 100 000 tons of tomato/year. The intermediate hypothesis therefore considers an amount of 750 tons tomato processing residues per year (3% of the amount processed). In this intermediate hypothesis around 9 tons tomato pomace a day have to be pre-treated in single cooperatives during the 3 months harvesting season (82,5 days) before extraction which can be performed during the 200 days of yearly work.

Example 1:
SUPERCRITICAL FLUID EXTRACTION

With SFE it is possible to extract, during the 200 days of yearly production, around 58kg of oil and wax containing lycopene and 583kg of fibre per day. The oil and wax can be sold as such or further processed into lycopene powder yielding 184kg/day.

Example 2:
SOLVENT EXTRACTION

With solvent extraction it is possible to extract, during the 200 days of yearly production, around 42kg of oil containing lycopene and 666kg of fibre per day. The oil can be sold as such or further processed into lycopene powder yielding 168kg/day.

5.1.3. Maximum Hypothesis

The total amount of tomato processing residues produced yearly during 330 days in the North of Italy (first production worldwide) reach 1 500 000 tons. The maximum hypothesis for the cost calculation considers that the extraction of bioactive compounds is performed by a big and centralized extractor for the processing residues of the whole region which would treat 136 tons tomato pomace per day during the harvesting season (82,5 days) before extraction which can be performed during the 330 days of yearly work.

Example 1:
SUPERCRITICAL FLUID EXTRACTION

With SFE it is possible to extract, during the 330 days of yearly production, around 530kg of oil and wax containing lycopene and 5 303kg of fibre per day. The oil and wax can be sold as such or further processed into lycopene powder yielding 1 675kg/day.

Example 2:
SOLVENT EXTRACTION

With solvent extraction it is possible to extract, during the 330 days of yearly production, around 383kg of oil containing lycopene and 6t of fibre per day. The oil can be sold as such or further processed into lycopene powder yielding 1 531kg/day.

5.2 Economic analysis of the extraction of bioactive compounds from tomato processing residues

5.2.1. Extraction of lycopene containing oil and wax and tomato fibres

5.2.1.1. Cost analysis

The costs of the different treatment steps have been evaluated.

Drying costs

The drying phase is the same in both processes (SFE and solvent). The production costs have been calculated using belt dryers of different capacities depending on the hypothesis considered. The labour costs, the energy costs and the quality control analysis costs are proportional to the tomato residues amount to treat annually.

Example 1: SUPERCRITICAL FLUID EXTRACTION

Yearly DRYING costs (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11250 t/year)
8.458	34.378	114.020

Minimum and Intermediate Hypothesis	
Capacityof the Dryer: 20 000kg/day	
Initial Investment: 80 000¤	
Maximum Hypothesis	
Capacity of the Dryer: 2x100.000 kg/day	
Initial Investment for the Dryer : 440.000¤	

Example 2: SOLVENT EXTRACTION

Yearly DRYING costs (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
not necessary	34.378	114.020

Intermediate Hypothesis	
Capacity of the Dryer: 20.000 kg/day	
Initial Investment: 80.000 ¤	
Maximum Hypothesis	
Capacity of the Dryer: 2x100.000 kg/day	
Initial Investment: 440.000 ¤	

Milling costs

The milling phase is the same in both processes (SFE and solvent) and requires the investment in a Hammermill.

Example 1: SUPERCRITICAL FLUID EXTRACTION

Yearly MILLING costs (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11.250 t/year)
4.756	23.160	35.750

Minimum and Intermediate Hypothesis	
Capacity of the Mill: 5 000 kg/day	
Initial Investment: : 20 000 ¤	
Maximum Hypothesis	
Capacity of the Mill: 50 000 kg/day	
Initial Investment: : 50 000 ¤	

Example 2: SOLVENT EXTRACTION

Yearly MILLING costs (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11.250 t/year)
18.352	23.160	35.750

Minimum Hypothesis	
Capacity of the Mill: 2 x 5 000 kg/day	
Initial Investment: : 40 000 ¤	
Intermediate Hypothesis	
Capacity of the Mill: 2 x 5 000 kg/day	
Initial Investment: : 20 000 ¤	
Maximum Hypothesis	
Capacity of the Mill: 50 000 kg/day	
Initial Investment: : 50 000 ¤	

Homogenisation costs

The homogenisation is a phase necessary only in the solvent extraction process.

Example 1: SUPERCRITICAL FLUID EXTRACTION

No homogenisation necessary!!

Example 2: SOLVENT EXTRACTION

Yearly HOMOGENIZING costs (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11.250 t/year)
21 307	65 374	856 935

Minimum and Intermediate Hypothesis	
Capacity of the Homogenisator: 24 000 kg/day	
Initial Investment:	20 000 ¤
Maximum Hypothesis	
Capacity of the Homogenisator: 5x24 000 kg/day	
Initial Investment:	100 000 ¤

Extraction costs

The initial investment of the two extraction processes is extremely different: 40 000 ¤ to 160 000 ¤ for the solvent extraction; and 4 000 000 to 14 000 000 ¤ for the SFE extraction. Besides, the solvent consumption is higher for the non-supercritical extraction. A ratio of 30 from CO_2 consumed toward sample extracted and a CO_2 recycling of 80% have been considered. For the solvent extraction a solvent recovery of 90% has been considered.

Example 1: SUPERCRITICAL FLUID EXTRACTION

Yearly EXTRACTION costs (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11.250 t/year)
198 634	469 919	3 853 298

Minimum Hypothesis
Capacity of the SFE Extractor: 2 x 1320
Initial investment: 4 000 000 ¤

Intermediate Hypothesis
Capacity of the SFE Extractor: 3x 1 320 kg/day
Initial investment: 6 000 000 ¤

Maximum Hypothesis
Capacity of the SFE Extractor: 7x1 320 kg/day
Initial investment: 14 000 000 ¤

Example 2: SOLVENT EXTRACTION

Yearly EXTRACTION costs (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11.250 t/year)
18 925	48 460	659 428

Minimum Hypothesis
Capacity of the Extractor: 35 000 kg/day
Initial investment: 40 000 ¤

Intermediate Hypothesis
Capacity of the Extractor:100 000 kg/day
Initial Investment for the extractor: 80 000 ¤

Maximum Hypothesis
Capacity of the Extractor: 2x100 000 kg/day
Initial investment: 160 000 ¤

Decantation costs

The decantation is a phase necessary only in the solvent extraction process.

Example 1: SUPERCRITICAL FLUID EXTRACTION

No decantation necessary!!

Example 2: SOLVENT EXTRACTION

Yearly DECANTATION costs (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
15 619	99 440	1 044 372

Minimum and Intermediate Hypothesis
Capacity of the Decanter : 25 000 kg/day
Initial Investment: 180 000 ¤

Maximum Hypothesis
Capacity of the Decanter : 3 x 50 000 kg/day
Initial Investment: 750 000 ¤

Evaporation costs

The evaporation is a phase necessary only in the solvent extraction process.

Example 1: SUPERCRITICAL FLUID EXTRACTION

No evaporation necessary!!

Example 2: SOLVENT EXTRACTION

Yearly DECANTATION costs (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
47 568	85 360	721 848

Minimum Hypothesis
Capacity of the Evaporator : 2x25 000 kg/day
Initial Investment: 360 000 ¤

Intermediate and Maximum Hypotesis
Capacity of the Evaporator : 150 000 kg/day
Initial Investment: 600 000 ¤

Intermediate and Maximum Hypotesis
Capacity of the Evaporator : 2 x 150 000 kg/day
Initial Investment: 1 200 000 ¤

Other costs

Supervisory control and transport over an average distance of 15km for the maximum hypothesis have been considered.

Example 1: SUPERCRITICAL FLUID EXTRACTION

Yearly OTHER costs (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750 t/year)	Maximum Hypothesis (11 250 t/year)
559	2 794	76 319

Example 2: SOLVENT EXTRACTION

Yearly OTHER costs (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250 t/year)
1 587	4 555	98 564

Total investment and production costs

By summing the pre-treatment, the extraction and the purification costs, the following investment in equipments and yearly operation costs are required.

Example 1: SUPERCRITICAL FLUID EXTRACTION

TOTAL yearly cost (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
212 407	530 250	4 079 387

TOTAL initial investment (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
4 117 333	6 126 000	14 726 364

Example 2: SOLVENT EXTRACTION

TOTAL yearly cost (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
136 958	388 313	3 992 157

TOTAL initial investment (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
719 778	1 154 667	3 478 788

5.2.1.2. Benefit analysis

The process provides different kinds of natural extracts which can be sold in raw state as food integrator or for cosmetic formulations. The selling prices depend on the content of lycopene. A good enrichment can lead to 1% lycopene. Considering the current prices of the products on the market an average oil price of 50.00¤/kg and a fibre average price of 1.00¤/kg can be considered.

Example 1: SUPERCRITICAL FLUID EXTRACTION

Products of the extraction (kg)

	Lycopene oil and wax	Fibres
Minimum Hypothesis (150 t/year)	2 333	23 333
Intermediate Hypothesis (750 t/year)	11 667	116 667
Maximum Hypothesis (11 250 t/year)	175 000	1 750 000

Yearly revenue (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
140 000	700 000	10 500 000

Example 2: SOLVENT EXTRACTION

Products of the extraction (kg)

	Lycopene oil	Fibres
Minimum Hypothesis (150 t/year)	1 516	24 000
Intermediate Hypothesis (750 t/year)	8 421	133 333
Maximum Hypothesis (11 250 t/year)	126 316	2 000 000

Yearly revenue (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
99 789	554 386	8 315 789

5.2.2. Extraction of Lycopene powder and tomato fibres

To obtain lycopene powder, the lycopene containing oil and wax have to be further processed. The tomato fibres obtained from SFE or solvent extraction can be sold as such.

5.2.2.1. Cost analysis

The costs related to a further drying phase were estimated.

Drying costs

A carrier is needed to spray dry an oil.

Example 1: SUPERCRITICAL FLUID EXTRACTION

Yearly SPRAY DRYING costs (¤)

Minimum Hypothesis (150t/year)	Intermediate Hypothesis (750 t/year)	Maximum Hypothesis (11 250 t/year)
30 847	102 200	1 318 310

All Hypothesis

Capacity of the Spray Dryer : 3000 kg/day

Initial Investment: 350 000 ¤

Example 2: SOLVENT EXTRACTION

Yearly SPRAY DRYING costs (¤)

Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750 t/year)	Maximum Hypothesis (11 250 t/year)
16 199	72 120	578 710

Minimum and Intermediate Hypotesis

Capacity of the Spray Dryer : 500 kg/day

Initial Investment: 100 000 ¤

Maximum Hypotesis

Capacity of the Spray Dryer : 3 000 kg/day

Initial Investment: 350 000 ¤

Total investment and production costs

By summing the pre-treatment, the extraction, the purification costs and the further drying costs, the following investment in equipments production costs are required.

Example 1: SUPERCRITICAL FLUID EXTRACTION

TOTAL yearly cost (¤)

Minimum Hypothesis (150/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250 t/year)
243 253	632 450	5 397 697

TOTAL initial investment (¤)

Minimum Hypothesis (150/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
4 467 333	6 476 000	15 076 364

Example 2: SOLVENT EXTRACTION

TOTAL yearly cost (¤)

Minimum Hypothesis (150/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250/year)
153 157	460 433	4 570 867

TOTAL initial investment (¤)

Minimum Hypothesis (150/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
819 778	1 254 667	3 828 788

5.2.2.2. Benefits analysis

Considering an average price of about 20.00 ¤/kg for lycopene powder and the described income related to the selling of tomato fibres, following annual revenue can be estimated.

Example 1: SUPERCRITICAL FLUID EXTRACTION

Products of the extraction (kg)

	Lycopene oil	Fibres
Minimum Hypothesis (150 t/year)	7 368	23 333
Intermediate Hypothesis (750 t/year)	36 842	116 667
Maximum Hypothesis (11 250 t/year)	552 632	1 750 000

Yearly revenue (¤)

Minimum Hypothesis (150/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
170 702	853 509	12 802 632

Example 2: SOLVENT EXTRACTION

Products of the extraction (kg)

	Lycopene oil	Fibres
Minimum Hypothesis (150 t/year)	6 063	24 000
Intermediate Hypothesis (750 t/year)	33 684	133 333
Maximum Hypothesis (11 250 t/year)	505 263	2 000 000

Yearly revenue (¤)

Minimum Hypothesis (150/year)	Intermediate Hypothesis (750t/year)	Maximum Hypothesis (11 250t/year)
145 263	807 018	12 105 263

5.3. Yearly profit and break-even point

			Minimum Hypothesis (150 t/year)	Intermediate Hypothesis (750 t/year)	Maximum Hypothesis (11 250 t/year)
Example 1: SUPERCRITICAL FLUID EXTRACTION	Lycopene containing oil; Tomato fibres	Yearly profit (¤) without amortization	-72 407	169 750	6 420 614
		Yearly profit (¤) including a 5 years amortization	-892 407	-1 050 250	3 522 614
	Lycopene containing powder; Tomato fibres	Yearly profit (¤) without amortization	-72 551	221 059	7 404 935
		Yearly profit (¤) including a 5 years amortization	-962 551	-1 068 941	4 436 935
Example 2: SOLVENT EXTRACTION	Lycopene containing oil; Tomato fibres	Yearly profit (¤) without amortization	-37 169	166 073	4 323 633
		Yearly profit (¤) including a 5 years amortization	-171 169	-49 927	3 763 633
	Lycopene containing powder; Tomato fibres	Yearly profit (¤) without amortization	-7 894	346 585	7 534 397
		Yearly profit (¤) including a 5 years amortization	-161 894	110 585	6 904 397

The financial loss for the minimum hypotheses for the supercritical fluid extraction and the solvent extraction demonstrate the non-feasibility of the treatment of 150 tons residues a year.

The drying of the lycopene oil is not economically interesting except for the treatment of 11 250 tons residues a year, due to the required use of a large amount of carrier and the subsequent diminution of the lycopene content in the powder.

The maximum hypothesis proves to be economically feasible. However, the advantage of SFE over solvent extraction in term of residual solvent in the end product and also the cost of building the treatment centre, the transport for conveyance of the by-products, the packaging, and the environment also have to be considered.

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8. Other related PROJECTS and LINKS

TOM "Development of new food additives extracted from the solid residue of the tomato processing industry for application in functional foods" was funded under the 5th FP. This project aimed at developing a profitable and new process for the reduction of the amount of tomato residue by means of the total utilisation of the tomato waste. On the other hand, the project's aim was the specific purification of valuable substances to be used as food additives and also for the cosmetic and pharmaceutical industry with innovative as well as already established methods.
(Project number: QLK1-CT-2002-71361)

- Gateway to the European Union.
  www.europa.eu
- Community Research & Development Information Service.
  www.cordis.europa.eu
- ttz Bremerhaven
  www.ttz-bremerhaven.de
- ainia centro tecnológico.
  www.ainia.es
- Confederación de Cooperativas Agrarias de España.
  www.ccae.es
- AMITOM - Mediterranean International Association of the Processing Tomato.
  www.amitom.com
- VIGNAIOLI PIEMONTESI S.C.A (Italy).
  www.vignaioli.it
- Union of Agricultural Cooperatives in Peza (Greece).
  www.pezaunion.gr
- ANFOVI - L'organisme de formation des Vignerons Indépendants (France).
  www.anfovi.com
- Tecnoalimenti S.C.p.A. (Italy).
  www.tecnoalimenti.com