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Deliverable 1.2	**Mapping of AFPW and their characteristics**
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Contents

Executive summary

The deliverable D.1.2 “Mapping of AFPW and their characteristics” concerns the task 1.1 “Update review of the state-of- the-art and waste inventory” and task 1.2 “Definition of requirements of bio-waste derived compounds for the target applications”, within the Work Package 1 “Inventory and Specifications of the waste processing & derived biocompounds”. The main target of this deliverable is to map under-valorised waste streams of the agricultural production and food supply chain across Europe in terms of composition and volume for the selected agricultural food processing wastes (AFPW), namely tomato, cereals, olive and potato. With this aim, a survey involving stakeholders and a literature review data have been conducted and deeply studied and investigated, in order to have a complete characterization of all the waste that will be valorized in the Agrimax project.

Database consulted

To trace all the data regarding the agricultural and food process waste relatively to tomato, cereals, olive and potato cultivation and production and their relatively deriving waste, the following databases have been consulted:

- FAOSTAT, for the global data
- EUROSTAT, for the European data

These open-data sources are the official database respectively of the FAO Organization (Food and Agriculture Organization Corporate Statistical Database) and of the European Union (EUROSTAT is the statistical office of the European Union), therefore the data published in these sources are the official data.

1. Introduction

Tomato, cereals, olive and potato are some major agricultural products in the world. They are cultivated and processed all over the world, especially in Europe. Waste generated by the agricultural industry are diversified and in large quantities. In the European Union every year about 700 million tons of agricultural waste are generated [1]. Agricultural and Food Processing Waste (AFPW) have an extremely varied composition which is highly affected by seasonal variation and farming practices across Europe. Also the use and storage conditions of these wastes could be very different and several, as it will be described in the following paragraph.

This deliverable present a complete mapping of agricultural and food processing waste derived by the cultivation and production of tomato, cereals, olive and potato, with a general presentation of the starting product from which the waste derive and their transformation processes, successively with a detailed survey on the waste and in particular their composition, actual use, storage conditions. The data collected about the feedstocks residues have been found both in reviewing literature and with a specific survey, preparing ad-hoc questionnaires which have been sent among associations, SME and RTDs involved in the Agrimax project.

2. General mapping of the volumes, of the European geographical areas of cultivation and production and of seasonal availability of the starting vegetable products from which AFPW derive.

World vegetable production has experienced a remarkable increase in the last decades. Globally, vegetable production has grown intensively especially on a per capita basis, which has increased 60 percent over the last 20 years. This trend is particularly strong in developing countries.

Vegetables cover 1.1 percent of the world's total agricultural area, with the region of Europe and Central Asia contributing with 12 percent of the total global area, and with 14 percent of global production (2010 data). [2]

The region of Europe and Central Asia produced 136 million tonnes of vegetables in 2010. The four main producers; namely, Turkey, Italy, the Russian Federation and Spain, produced almost half of the total regional output. [2]

Globally, average vegetable production between 2001 and 2010 was 54 percent higher than the average of the preceding decade 1991-2000. [3].

In 2011, more than 1 billion tonnes of vegetables were gathered throughout the world. [2]. According to data on production and trade in fruit and vegetables, presented during the International Fair Fruit Logistica 2015, in Berlin (04-06.02.2015), and based on a survey of the German Agricultural Market Information Company (AMI), in 2014, a total of 970 million tonnes of vegetables were produced worldwide. [4]

In Europe, the vegetable sector is a key sector in EU agriculture, weighting 13.6 % of EU agricultural output. Netherlands (17.8 %), Spain (16.7 %) and Italy (16.5 %) were the most important producers, in terms of economic value, accounting for over 50 % of vegetable output in 2015. Tomatoes, carrots and onions were the most important vegetables in 2015. At European level, the production of vegetables amounted to 63 million tonnes in 2014, an increase of 4% compared to 2013. [5].

Cereals occupy more than half of the world's harvested area and are the most important food source for human consumption. Of the 2.3 billion tonnes of cereals produced each year, 1 billion are destined for human consumption, 750 million tonnes are used as animal feed and 500 million tonnes are either processed by industry, used as seed, or wasted. [2].

World production of cereals increased from 1966 to 1990, representing an average annual growth rate of 3.9 percent during the period. Although the developed market economies produced the bulk of world cereals, their share decreased from 54 percent in 1966 to 46 percent by 1990. At the same time, the developing countries' share in total production increased, primarily in Asia, which is the major contributor to cereal production. Paddy rice, 90 percent of which came from Asia, accounted for most of this gain. The shares of many other developing countries rose slightly, except Sub-Saharan African countries, which maintained a 3 percent share throughout the period [6].

Tomato

The **tomato** is the edible, often red fruit/berry of the nightshade Solanum lycopersicum, commonly known as a tomato plant. Tomato is one of the most important vegetable plants in the world. It is the world's third largest vegetable crop after potato and sweet potato. It originated in western South America, and domestication is thought to have occurred in Central America. Tomato is a widely distributed annual vegetable crop, which is consumed fresh, cooked or after processing. Tomato crop is adapted to a wide variety of climates.

Tomatoes are available in a wide variety of shapes, sizes, and colors. While red tomatoes are the most common, yellow, orange, and pink tomatoes are sometimes grown. Tomatoes may be round, slightly flattened, or pear-like in shape. Sizes range from the bite-size cherry types to the giant beefsteak tomatoes.

New cultivars appear on the market each year, expanding selection and improving disease resistance. At present, there exist a large number of tomato cultivars with a wide range of morphological and sensorial characteristics which determine their use. There are around 7,500 tomato varieties grown for various purposes [7].

Tomatoes are an important component within vegetable production, with a share of 16%. Between 2000 and 2013 the production of tomatoes increased by 49%. [8]. Between 2002 and 2012, global tomato production rose by 38% from 116 to 161 million tonnes.

Global tomato production is currently around 170 million tons [9], of which 130 million are destined for the fresh market and 40 million are processed. The top 5 largest tomato producers are: China, EU, India, US and Turkey. They account for 70% of global production.

China increased its production from 27 to 50 million tonnes and thus accounted for 50% of the overall production increase until 2012. In 2014 China produced an impressive 40.5 million tons of tomatoes, representing almost a third of global production. Almost all of Chinese tomato production is for domestic use. About 1.5% (still 597,000 tons) is exported, of which over 60% is destined for Russia.

India even more than doubled its production from 7.5 to 17.5 milllion tonnes. Turkey is a strong tomato producer and realized a 16% increase during the last 10 years. Europe's production remained rather stable and ranges between 15 and 20 million tonnes. USA production is fluctuating between 11 and 14 million tonnes [10].

In the European Union, the tomato also holds the number one position among vegetables, with a 19% share as the largest fresh vegetable crop. In the EU-28, the most important vegetables in terms of the level of production were tomatoes, onions and carrots.

In 2014, the European Union's countries produced 16.6 million tons, representing 12% of global production. Of these, 6.8 million tons went to the fresh market and 9.8 million were earmarked for processing [11]. In 2015, The EU-28 produced an estimated 17.6 million tonnes of tomatoes, of which approximately two thirds came from Italy and Spain (11.2 million tonnes). In fact Italy and Spain were the largest producers among the EU Member States, with a combined share of 64.0 % of the EU-28's production.

	Tomatoes	Carrots	Onions	Apples	Peaches	Oranges
EU-28	17 562.2	5 087.3	6 109.4	12 698.1	2 540.0	5 961.2
Belgium	253.1	245.4	108.3	284.2	0.0	0.0
Bulgaria	121.7	7.9	8.9	58.4	34.4	0.0
Czech Republic	5.6	23.5	27.2	155.4	1.6	0.0
Denmark	10.6	89.2	53.4	35.7	0.0	0.0
Germany	80.9	526.9	563.3	973.5	0.0	0.0
Estonia	0.9	18.1	0.2	1.6	0.0	0.0
Ireland	4.4	40.2	4.6	18.8	0.0	0.0
Greece	995.1	32.5	211.0	278.5	626.6	909.7
Spain	4 832.7	410.9	1 247.6	598.2	720.9	3 098.3
France	787.9	560.0	368.7	1 967.1	114.7	3.7
Croatia	36.3	10.9	29.4	96.2	3.7	0.2
Italy(*)	6 410.3	533.0	378.3	2 441.6	921.2	1 668.7
Cyprus	16.1	2.3	7.0	4.9	2.3	32.8
Latvia	6.1	8.8	5.7	7.8	0.0	:
Lithuania	7.7	38.0	22.2	65.0	0.0	0.0
Luxembourg	0.1	1.0	0.1	2.4	0.0	0.0
Hungary	200.4	78.2	60.3	511.5	37.4	0.0
Malta	12.0	1.3	8.1	0.0	0.7	1.2
Netherlands	890.0	563.4	1 504.1	335.9	0.0	0.0
Austria	55.7	66.8	168.1	287.6	2.9	0.0
Poland	789.6	677.7	548.4	3 168.8	9.9	0.0
Portugal	1 407.0	97.5	59.4	325.0	35.6	246.6
Romania	464.8	122.1	218.2	459.1	20.5	0.0
Slovenia	5.7	3.4	7.2	83.9	5.6	0.0
Slovakia	19.5	10.1	16.9	46.3	2.1	:
Finland	36.5	72.0	20.2	6.0	0.0	0.0
Sweden	14.8	115.6	64.6	25.4	0.0	0.0
United Kingdom	97.2	731.0	408.1	459.6	0.0	0.0
Iceland	0.1	0.6	0.0	0.0	0.0	0.0
Switzerland	45.7	71.6	41.2	141.7	0.0	0.0
Montenegro	2.7	0.0	1.0	2.8	0.0	0.0
FYR of Macedonia	173.4	4.3	59.5	136.9	12.0	:
Albania	256.5	6.9	90.5	91.8	:	8.4
Turkey	12 615.0	535.0	2 021.0	2 570.0	561.0	1 817.0
Bosnia and Herzegovina	41.2	17.1	37.7	91.5	9.2	0.0

(:) not available
(*) Data referred to 2014.

Table 1 Production of fruit and vegetables in 2015 in EU

Together, **Italy** (36.3% of total EU production) and **Spain** (27.4%) supplied in 2015 almost two thirds of tomatoes produced in the EU. They were followed by **Portugal** (8.0%), **Greece** (6.2%), the **Netherlands** (5.0%), **France** and **Poland** (both 4.5%), as it can be seen in the table n. 1 over reported and in graph reported in figure n.1 below. [12]

Tomato is a rapidly growing crop with a growing period of 90 to 150 days. It is a day length neutral plant. Optimum mean daily temperature for growth is 18 to 25ºC with night temperatures between 10 and 20ºC. Larger differences between day and night temperatures, however, adversely affect yield. The crop is very sensitive to frost. Temperatures above 25ºC, when accompanied by high humidity and strong wind, result in reduced yield. Night temperatures above 20ºC, accompanied by high humidity and low sunshine lead to excessive vegetative growth and poor fruit production. High humidity leads to a greater incidence of pests and diseases and fruit rotting. Dry climates are therefore preferred for tomato production.

Tomato can be grown on a wide range of soils but a well-drained, light loam soil with pH of 5 to 7 is preferred. Waterlogging results in an increased incidence of diseases such as bacterial wilt. For high producing varieties the fertilizer requirements amount to 100 to 150 kg/ha N, 65 to 110 kg/ha P and 160 to 240 kg/ha K.

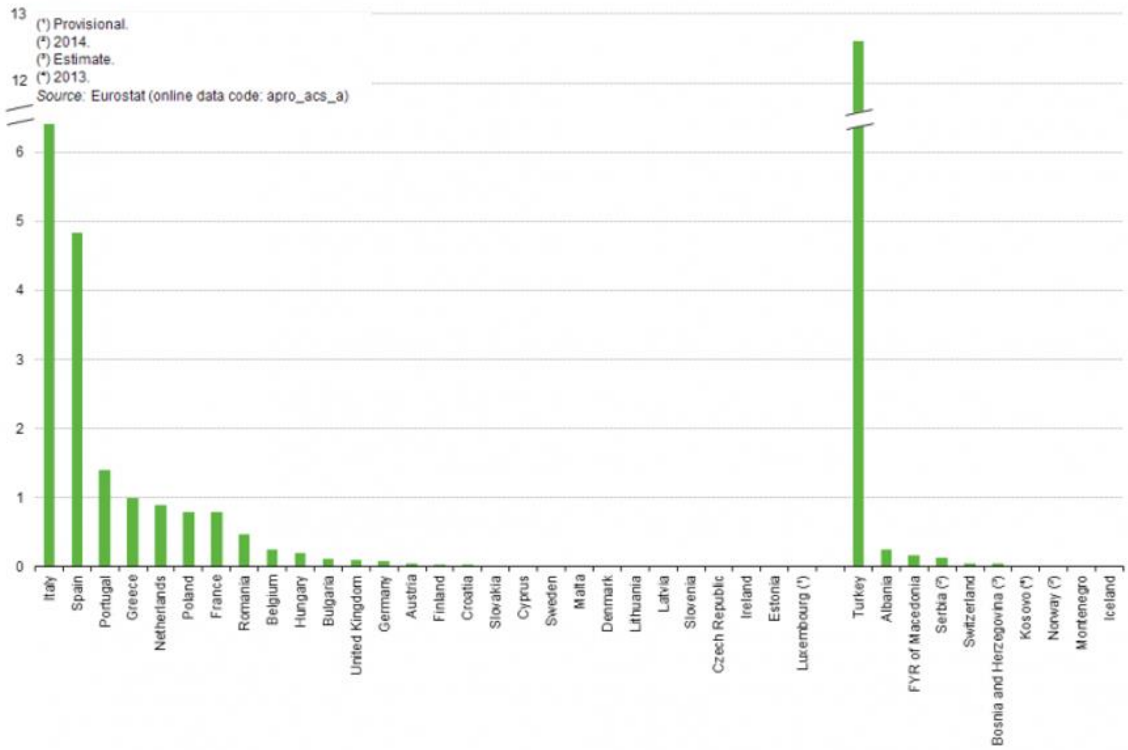

Figure 1 Production of tomatoes - 2015 [12].

The seed is generally sown in nursery plots and emergence is within 10 days. Seedlings are transplanted in the field after 25 to 35 days. In the nursery the row distance is about 10 cm. In the field spacing ranges from 0.3/0.6 x 0.6/1 m with a population of about 40,000 plants per ha. The crop should be grown in a rotation with crops such as maize, cabbage, cowpea, to reduce pests and disease infestations.
The crop is moderately sensitive to soil salinity. The most sensitive period to salinity is during germination and early plant development, and necessary leaching of salts is therefore frequently practised during pre-irrigation or by over-watering during the initial irrigation application.

	Stages of Development					Plant date	Region
Crop characteristic	Initial	Crop Development	Mid-season	Late	Total		
Stage length, days	30	40	40	25	135	Jan	Arid Region
	35	40	50	30	155	Apr/May	Calif., USA
	25	40	60	30	155	Jan	Calif. Desert, USA
	35	45	70	30	180	Oct/Nov	Arid Region
	30	40	45	30	145	Apr/May	Mediterranean

Table 2 Periodicity of tomato [13 http://www.fao.org/nr/water/cropinfo_tomato.html]

Cereal

According to Chapman and Carter (1976), "a **cereal** is generally defined as a grass grown for its small, edible seed" [14]. They also explained that all cereals are angiosperms, monocots, and members of the grass family *Gramineae*.

Similarly, Lantican [15] defines cereal or grain crops as agronomic crops belonging to the grass family Gramineae, which are utilized as staples; the word "cereal" is derived from the most important grain deity, the Roman Goddess Ceres.

FAO's definition of cereals also describes these plants as annual plants (including rice, canary grass, buckwheat and triticale) which generally belong to the gramineous family, producing grains that are used for food, feed, seed and production of industrial products like ethanol.

In their natural form (as in *whole grain*), they are a rich source of vitamins, minerals, carbohydrates and protein. When refined by the removal of the bran and germ minor changes in the composition of the biomass can occur, but usually the remaining endosperm is mostly composed by carbohydrates. In some developing nations, grain in the form of rice, wheat, millet, or maize constitutes a majority of daily sustenance. In developed nations, cereal consumption is moderate and varied but still substantial.

According to FAOSTAT the world cereal production has increased from 2,292.8 in 2012/2013 to 2,563.5 million tonnes in 2014/2015.

The European Union is one of the world's biggest cereals producers and an important cereals trader. Occupying 58 million hectares, cereals were the main crops grown in the EU-28 in 2014. The harvested cereal production amounted to nearly 334 million tonnes, of which 150 million tonnes was common wheat, as it is illustrated in the graph reported in figure n. 2. This made wheat by far the most important cereal grown (44.9 % of EU-28 cereal production). On a global level wheat is the third largest crop after corn and rice. Wheat production in Europe is representing 25% of the global wheat area and 29% of global wheat production. [16].

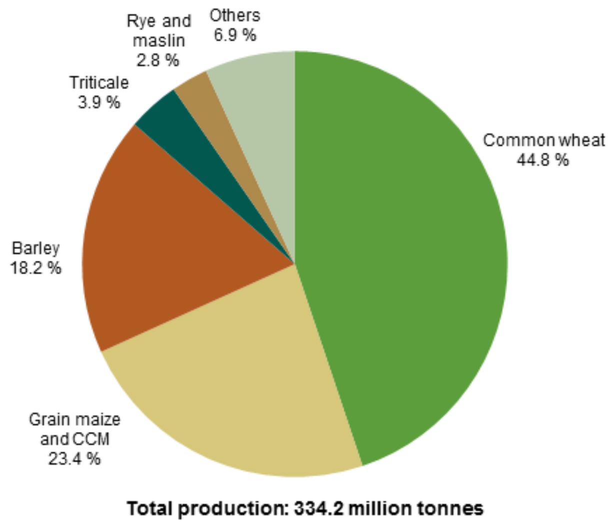

Figure 2 Production of cereals EU-28, 2014

In terms of quantity and area, wheat is by far the most popular cereal grown in the EU, making up nearly half the total. Of the remaining 50%, the second largest harvested quantity was maize (78 million tonnes or 23.4 % of total cereal production), followed closely by barley (61 million tonnes or 18.2 % of total cereal production). The production of other cereals (consisting of triticale, rye, oats and spelt) had together a share of 12.7 %, in particular the oat production is around 15 mln tons per year and only around 0.9 % of total EU production consisted of rice (around 3 million tonnes). Nearly two-thirds of the EU's cereals are used for animal feed, with around one-third for human consumption. Only 3% is used for biofuels. [17]. Cereal production was concentrated in a limited number of Member States with just three Member States accounting for half of total EU-28 production in 2014: France (21.8 %), Germany (15.5 %) and Poland (9.6%). Unsurprisingly, France and Germany were also the largest producers of wheat and barley. Together they accounted for nearly half (43.5 %) of total EU-28 wheat production and 38.4 % of total barley production. Other major producers of barley included Spain and the United Kingdom (both 11.4 %). France was also the largest grain maize producer, accounting for 23.7 % of total maize production in the EU-28. Together with Romania (15.4 %), Italy (11.8 %) and Hungary (11.7 %) four Member States covered 62.7 % of the total EU-28 grain maize production in 2014, as it can be seen from the graph reported in figure n. 3 below [18].

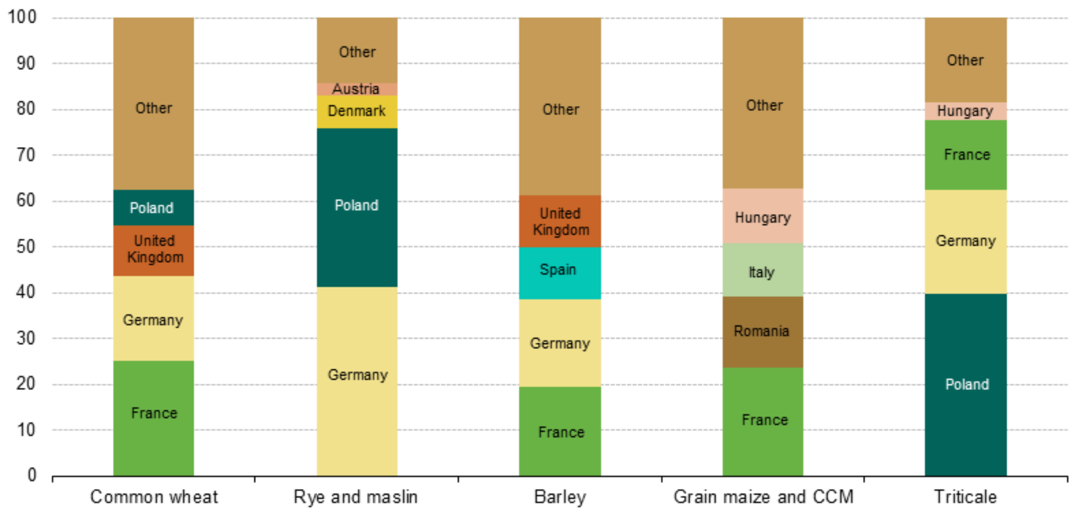

Figure 3 Production of cereals by main producing EU Member States.

Most locations in Europe can benefit from two harvests. In fact the cultivation of all cereal crops is similar and most of them are annual plants. Wheat, rye, triticale, oats, barley, and spelt are the "cool-season" cereals. These are hardy plants that grow well in moderate weather and cease to grow in hot weather (approximately 30 °C, but this varies by species and variety). The "warm-season" cereals are tender and prefer hot weather. Barley and rye are the hardiest cereals, able to overwinter in the subarctic and Siberia [19]. Winter grains (winter wheat, winter barley, and rye) are planted September through October and harvested mid-June through August of the next year, and spring grains (maize, spring barley, and most oats) are planted April through May and harvested September through October of the same year [20]. Wheat is cultivated across the entire European continent, except for the Iberian Peninsula, Belarus, and the Baltic Republics. Throughout southern Europe, spanning France, Italy, Hungary, Moldova, and all countries south of there, the secondary crop is maize. To the north, in Croatia, Bosnia and Herzegovina, northern Serbia, and Romania, can be found a maize-wheat belt. In Poland, the much more cold-tolerant rye can be found as the secondary crop. In this northern sub-region, barley and rye are also found. Second in size in Europe is the area of barley cultivation [21].

As regarding oat cereals, these are best grown in temperate regions. They have a lower summer heat requirement and greater tolerance of rain than other cereals, such as wheat, rye or barley, so are particularly important in areas with cool, wet summers, such as Northwest Europe. Oats are an annual plant, and can be planted either in autumn (for late summer harvest) or in the spring (for early autumn harvest) [22]. The six major European oat producing countries are Poland, Spain, Finland, Sweden, Great Britain and Germany [23].

Olive

The **olive** tree (*Olea europaea*) is a small evergreen and long-lived species that averages from 3 to 5m in height, cultivated for centuries for its edible fruits. Olive trees are very resistant to drought, disease and fire. They are known for their longevity. For example, most of the areas under olive trees in Europe are old. Nearly 2.7 million ha are at least 50 years old, almost 1.5 million ha are 12–49 years old, 313 000 ha are between 5 and 11 years old and about 130 000 ha are less than 5 years old [24]. This plant is suitable for all countries included in a latitude from 30° to 45° in both hemispheres [25].

However the olive trees grow almost exclusively around the Mediterranean Sea. It must keep in mind that olives are one of the most extensively cultivated fruit crops in the world. In 2011 there were about 9.6 million hectares planted with olive trees, which is more than twice the amount of land devoted to apples, bananas or mangoes [26]. Cultivation area tripled from 2,600,000 to 7,950,000 hectares (6,400,000 to 19,600,000 acres) between 1960 and 1998 and reached a 10 million ha peak in 2008. In recent years, the olive production area has increased world-wide, due to the introduction of innovations in the farming systems and cultivars [28]. Nowadays, according to the International Olive Oil Council (IOOC) data, over 10 million hectares are cultivated with olive groves globally, of which 95% are located in the Mediterranean basin. [29]. In fact, according to Eurostat data [30], the European Union accounts for some 70% of the world's olive production, from about 1.9 million olive growing farms. The area under olive trees accounted for about 4.65 million ha in the EU in 2012. Eight EU Member States have area under olive trees exceeding 1 000 ha. Spain (53 %) and Italy (24 %) account for over three quarters of the total EU area under olive trees. They are followed by Greece and Portugal with 15 % and 7 % of the total EU area under olive trees. The other olive producing EU Member States (France, Croatia, Cyprus and Slovenia) each hold a small share of the total olive tree area (together about 1 %), as it can be seen in the pie chart reported in figure n. 4 below [31].

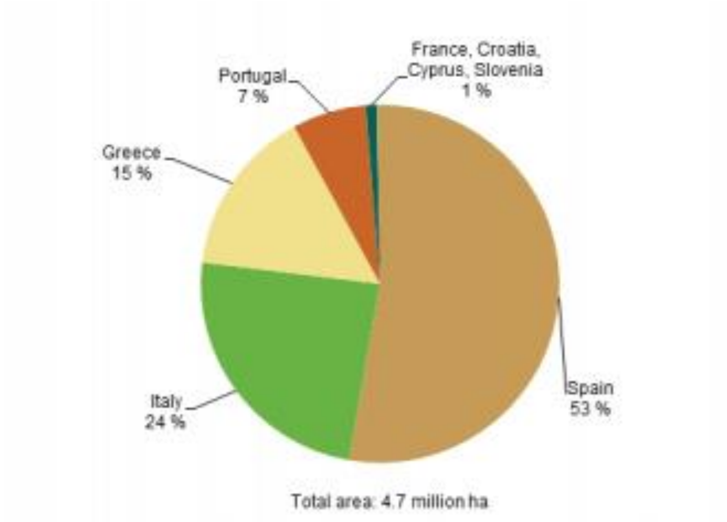

Figure 4 Area under olive trees by EU Member States in EU-28, 2012.

Whilst olive plantations are found over most of the Mediterranean region, the greatest concentration of oil production is found in two Spanish provinces, Jaén and Córdoba in Andalucía, which between them account for over a third of EU output.

Plantations, which produce table olives, cover a far smaller area than those producing olive oil. In Spain, less than 6% of the total area is devoted to table-olive production whereas the figure in Italy is less than 3%.

The EU currently dominates the global market, producing over 70 per cent of the world's olive oil. Tunisia, Turkey and Syria are the only other producers of significance, accounting for over 20 per cent of world production [32].

In general, cultivating olive trees takes time, as the first sizeable crop is expected after 8 to 10 years; however, there are some varieties that are giving excellent olive production in 4–6 years. The tree bears small, creamy white flowers in May and has characteristic small leaves: pale green above and silvery below. The olive fruit starts maturing in October, when it may be harvested for table olive as pickled green olive. It then slowly turns black until December and is consumed as salted or pickled black olives or is sent to oil production. The harvest period can range therefore from September through to February, depending on climatic conditions, variety of olive tree, whether the olives are for table use or oil, etc. There is a tendency in many areas to harvest earlier now than in the past, in the pursuit of improved oil quality. The olive tree yield is greatly affected by a biennial cycle: one year it grows and the other year gives more fruits [33].

Potato

The **potato** (*Solanum tuberosum*) belongs to the solanaceae family of flowering plants. It originated and was first domesticated in the Andes mountains of South America.

The potato is the third most important food crop in the world after rice and wheat in terms of human consumption. More than a billion people worldwide eat potato, and global total crop production exceeds 300 million metric tons.

There are more than 4,000 varieties of native potatoes, mostly found in the Andes. They come in many sizes and shapes. There are also over 180 wild potato species. [34]

Potatoes produce more food per unit of water than any other major crop and are up to seven times more efficient in using water than cereals.

Since the early 1960s, the growth in potato production area has rapidly overtaken all other food crops in developing countries. Presently, more than half of global potato production now comes from developing countries. [34]

The total world potato production is estimated at 385.074.114 tonnes in 2014 (Source: FAOSTAT). The world potato sector is undergoing major changes, in fact until the early 1990s, most potatoes were grown and consumed in Europe, North America and countries of the former Soviet Union. Since then, there has been a dramatic increase in potato production and demand in Asia, Africa and Latin America, where output rose from less than 30 million tonnes in the early 1960s to more than 165 million tonnes in 2007. FAO data show that in 2005, for the first time, the developing world's potato production exceeded that of the developed world. China is now the biggest potato producer, and almost a third of all potatoes are harvested in China and India [35]. The EU potato sector is mainly represented by few Member States, responsible for the largest proportions of production, trading and processing, while several others account individually for almost negligible volumes. In 2014, 59 million tonnes of potatoes were harvested in the EU. Germany was the biggest producer, with a share of 19.7 %, ahead of France (13.6 %), Poland (12.6 %), the Netherlands (12.0 %) and the United Kingdom 10.0 %).

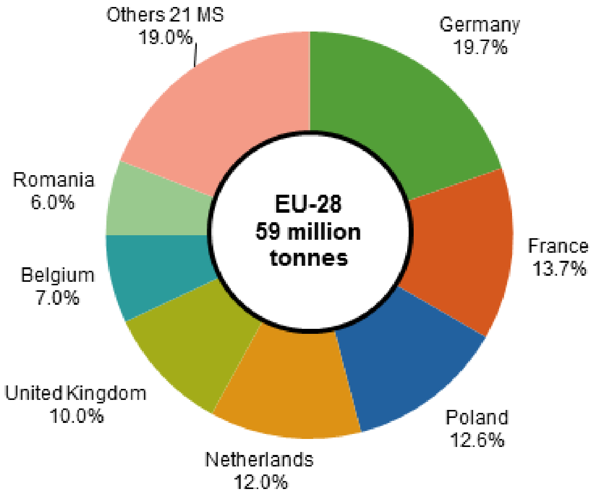

Figure 5 Production of potatoes by main producing EU Member States

In 2000, the EU-28 potato harvest was 83 million tonnes; however overall production has declined steadily since then (down by 28.9 % between 2000 and 2014). Various trends emerge at national level: harvests have fallen in four of the five big producer countries, albeit at different rates. Poland has seen the sharpest drop (-69.4 %). In France, the trend has been slightly positive.
According to the most recent (2013) farm structure survey, potatoes were cultivated on 1.59 million ha in the EU-28. Just three Member States accounted for almost half (46.9 %) of this total: Poland (21.2 %), Germany (15.2 %) and France (10.5 %), followed by the Netherlands (9.8 %) and the United Kingdom (8.8 %) [36]. Potato is cultivated in more than 100 countries, under temperate, subtropical and tropical conditions. It is essentially a "cool weather crop", with temperature being the main limiting factor on production: tuber growth is sharply inhibited in temperatures below 10°C and above 30°C, while optimum yields are obtained where mean daily temperatures are in the 18 to 20°C range.
For that reason, potato is planted in early spring in temperate zones and late winter in warmer regions, and it is grown during the coolest months of the year in hot tropical climates. In some sub-tropical highlands, mild temperatures and high solar radiation allow farmers to grow potatoes throughout the year, and harvest tubers within 90 days of planting (in temperate climates, such in northern Europe, it can take up to 150 days).
Potatoes can grow from sea level up to 4,700 meters above sea level being a very accommodating and adaptable plant, and it will produce well even without ideal soil and growing conditions except for saline and alkaline soils (soil with a pH range of 5.2-6.4 is considered ideal [37]).
The potato can be classified as an annual, although it can persist in the field vegetative (as tubers) from one season to the next.

3. Principal industrial transformation processes of the starting vegetable products from which origin the AFPW.

A very large part of agricultural production undergoes some degree of transformation between harvesting and final use. They range from simple preservation (such as sun drying) and operations closely related to harvesting to the production, by modern, capital-intensive methods, of such final elaborated food. [38]. Food processing may be considered to include any deliberate change in a food occurring before it's available for consumption. The change can be as simple as freezing or drying food to preserve nutrients and freshness, or as complex as formulating a frozen meal with the right balance of nutrients and ingredients. Examples of processed foods include canned and frozen fruits and vegetables; packaged foods labelled "natural" or "organic, such as cereals, fresh meat and poultry, and jarred baby foods. In general food processing is applied for one or more of the following reasons: preservation, extending the harvest in a safe and stable form; safety; quality; availability; convenience; innovation; health and wellness; and sustainability [39]. Most preservation techniques are basically similar over a whole range of perishable food products, whether they are fruit, vegetables, milk, meat or fish. In fact, the processing of the more perishable food products is to a large extent for the purpose of preservation. A typical feature of most fruit and vegetable products that affect the whole sector is their high perishability, in this sense they represent high wasting food items. As a result, they have to be consumed soon after harvesting or have to be processed directly into a less perishable form after harvest [40].

Processing steps include preparation of the raw material, namely cleaning, trimming, and peeling followed by cooking, canning, or freezing [41].

Transformation and packaging of fruits and vegetables by food industry generate every year a huge amount of wastes that represent a worldwide problem for both the environmental and the economic aspects. Processing of fruits and vegetables is wasteful. As an example, industrial processing of vegetables for juices production or canning generates huge amounts of wastes constituted by peels, seeds, pulps that account for 30-50% of input materials; on the other hand selection for packing and preservation discards about 5-30% of the original feedstocks, mainly including fruits or vegetable that are unripe, damage during transportation or that lack the required features for packing and selling [42].

Fruit and vegetables industry by-products can derive from the "primary production", since they derive from primary production fields, such as in the case of leaves, unripe fruit or vegetable or they can derive from "food industry production", since they derive from the processing factories, such as pomace [43].

After harvesting, fruits and vegetables still undergo active biological processes, such as respiration, ripening and senescence. In some fruits and vegetables, these activities cause significant changes in the quality so the postharvest storage conditions and processing steps need to be carefully conducted to prevent these changes. For example, the level of sugar in potatoes increases up to 5–10 times compared to the original sugar concentration at harvest if they are stored below 10°C after harvesting. The high sugar content in these potatoes can cause Maillard browning reactions during further processing steps, especially drying and frying. In ripe sweet corn, the opposite reaction is of concern. During storage, the level of sugars decreases and starch is produced, causing losses in flavour and texture [44].

Many fresh fruits and vegetables have a shelf life of only days before they are unsafe or undesirable for consumption. Storage and processing technologies have been utilised for centuries to transform these perishable fruits and vegetables into safe, delicious and stable products. Refrigeration slows down the respiration of fruits and vegetables and allows for longer shelf lives. Freezing, canning and drying all serve to transform perishable fruits and vegetables into products that can be consumed year round and transported safely to consumers all over the world, not only those located near the growing region. As a result of processing, respiration is arrested, thereby stopping the consumption of nutritious components, the loss of moisture and the growth of micro-organisms. The first objective of fruit and vegetable processing is to ensure a safe product, but processors also strive to produce the highest-quality products. Depending on how processing is carried out, it may result in changes in colour, texture, flavour and nutritional quality.

Tomatoes are the world's most consumed vegetable, present in 2 sectors: fresh and processed. The fresh tomato market is primarily regional due to weak conservation and fragility. Production is mainly in greenhouses with the main production countries being Spain, Italy, Holland, France and Belgium. [45].

On a global scale, the annual production of fresh tomatoes amounts to approximately 170 million tonnes. More than a quarter of those 170 million tonnes are grown for the processing industry, which makes

tomatoes the world's leading vegetable for processing. About 40 million tonnes of tomatoes are processed every year in factories belonging to the greatest labels of the global food industry [9].
A simple classification of the main products obtained from the processing of tomato can be the following:

- **Peeled tomatoes**: canned whole peeled tomatoes, of the elongated variety, to which tomato juice is added, whence skins has be removed
- **Tomato purée** or **passata**: is the product obtained (as is a thick liquid) by pressing and refining, in order to remove seeds and skins. Tomato purée has approx. 14% solids content. Lower solids content is due to filtering, higher content is due to concentration of the product.
- **Crushed tomato**: is the product obtained from crushed peeled tomatoes.
- **Tomato concentrate**: is the product obtained, concentrating the refined product (with evaporators or reverse osmosis). Different types of products are commercially available with solid content from 12% to 55%.
- **Tomato juice**: is the pulposus liquid obtained by crushing and sieving of fruit devoid of the skins and seeds.
- and also **powder tomato** (obtained by drying, by boiling under vacuum, with the spray-drying method and lyophilisation),
- and **ketchup** (obtained from fresh tomato or concentrate with added salt, sugar, vinegar and spices) [46].

From all these industrial processes, the tomato wastes originated are briefly: cull tomatoes, pomace, peels and seeds (these waste will be described in paragraphs further below).

Cereal products derive either from the processing of grain through one or more mechanical or chemical operations, or from the processing of flour, meal or starch [47].
Most cereals are milled or similar processes to get cereal products. Milling generally is described as a process that involves grinding, sifting, separation and regrinding. Cereal products derived from milling process include wheat, rye, and oat flours and semolina, cornmeal, corn grits. Flour from cereals is used for making breads. Other products are breakfast cereals pasta, snack foods, dry mixes, cakes, pastries, and tortillas. In addition, cereal products are used as ingredients in numerous products [48].
In particular in Agrimax the cereal waste, that will be valorised, will be the by-products derived from the wheat bran and from the oat, more precisely the wheat bran, the oat screening, the oat husks, the oat mill feed and the oat bran (this waste will be described in paragraphs further below).

Olive oil and table olives are typical Mediterranean products obtained from olive tree cultivation, whose nutritional and economic importance is well-known [49].
Harvested olives for oil production were traditionally ground to a paste in mills consisting of stone wheels on a granite slab. The paste was pressed between straw disks under high pressure. Finally, the oil was decanted or more recently centrifuged to eliminate residual water and solids, yielding extra virgin olive oil [32].
Olive oil production is carried out in "mills." Batch (press) and continuous processes are the main methods used in olive oil production. Depending on the pressing method used in continuous operation, three technologies are recognized: traditional pressing, two- and three-phase processes [50].
Olive oil extraction generates several by-products that can be used to feed animals, particularly the cakes and pomaces obtained from the extraction process, and leaves and other residues resulting from the cleaning operations. The products of olive oil manufacture are the following: crude olive cake or pomace, two-phase olive mill waste (TPOWM), exhausted olive cakes, partly destoned olive cake, vegetation

waters or olive mill wastewater (OMWW), leaves collected at the oil mill, olive stones, pruning and harvest residues. (in the next paragraph this waste will be described).

Potatoes are used for a variety of purposes, and not only as a vegetable for cooking at home. In fact, it is likely that less than 50 percent of potatoes grown worldwide are consumed fresh. The rest are processed into potato food products and food ingredients; fed to cattle, pigs, and chickens; processed into starch for industry; and re-used as seed tubers for growing the next season's potato crop.
The food industry can require potatoes for different types of products:

- pre-cooked products (mostly French fries),
- de-hydrated products (i.e. potato flours, potato flakes or potato granules),
- snacks,
- other products (gnocchi, salads, ready prepared meals, etc.) [51]

Fresh potatoes are baked, boiled, or fried and used in a various and different range of recipes: mashed potatoes, potato pancakes, potato dumplings, twice-baked potatoes, potato soup, potato salad and potatoes au gratin, to name a few.
But global consumption of potato as food is shifting from fresh potatoes to added-value, processed food products. One of the main items in that category is frozen potatoes, which includes most of the french fries served in restaurants and fast-food chains worldwide. Another processed product, the potato crisp is the long-standing king of snack foods in many developed countries.
Dehydrated potato flakes are used in retail mashed potato products, as ingredients in snacks, and even as food aid. Potato flour, another dehydrated product, is used by the food industry to bind meat mixtures and thicken gravies and soups [52].
The waste originated from the cultivation and processing of potatoes are the following: raw pieces, raw pulp, cooked pulp, potato starch waste (PSW), potato peels, potato fruit juice (PFJ) and dissolved solids. (in the next paragraph this waste will be described).
The basic principal processes, during which the waste originated, for tomato, cereals, olive and potato are washing, cooling, peeling, blanching, size reduction, grinding and cutting, milling for olive, centrifugation, some general production processes (extraction, fermentation, cooking, dehydration) and high-temperature processes.

Washing

Washing is a critical control step in producing fruit and vegetable products with a low microbial count. After harvesting, fruits and vegetables are washed not only to remove field soil, dirt, surface microorganisms, mould, but also to remove insects, fungicide, insecticide, and other pesticide residues [53]. The efficiency of the washing process will determine microbial counts in the final product. Spoiled fruits and vegetables should be removed before washing to minimize the contamination of washing tools, equipment, and produce during washing. Lye or surfactants may be added to the water to improve the efficiency of dirt removal; however, surfactants have been shown to promote infiltration of some bacteria into fruits and vegetables by reducing the surface tension at the pores [54], which jeopardizes food safety. The washing step also serves to cool fruits and vegetables. Since some of them are harvested on hot summer days, washing removes the field heat, slowing respiration and therefore quality loss.
The washing equipment will depend upon the size, shape and fragility of the particular kind of vegetable (see figure n. 6):

- Flotation cleaner, for small vegetables;
- Rotary washer in which vegetables are tumbled while they are sprayed with jets of water, this type of washer should not to be used with clean fragile vegetables [55].

Several methods can be used to increase the efficiency of the washing step. Agitation increases the efficiency of soil removal. The warmer the water spray or dip, up to 90°C, the lower the microbial count [56], although warm water is not typically used because of economic concerns. Immersion or spraying is usually used with the application of detergents, 1.5% HCl solution, warm water (approximately 50°C), or high water pressure (for spray or shower washing). For washing detergents or sanitizers can be used.
Chlorine is frequently added to the wash water at 100–150 ppm. Chlorine will not significantly reduce microbial counts on fruits and vegetables itself because the residence time is too short. However, it is effective at keeping down the number of microorganisms present in the flume water. When there is a large amount of organic material in the water, such as occurs in dirty water, chlorine is used up rapidly, so it must be continuously monitored. Other potential alternative sanitizers, such as peroxyacetic acid and chlorine dioxide, are also suggested for some fruits and vegetables such as lettuce leaves and apples [57]. Washing step is usually required for tomato, olive and potato processing.

Figure 6 Tomato washing in a tank before transporting to the lye peeler.

Cooling

Cooling is used to remove the field heat from fresh fruits and vegetables before further processing. This reduces water loss, slows down respiration and ripening (for fruits), and minimizes microbial growth. The cooling conditions for different fruits and vegetables depend on the type, maturity, and cultivar. The most common cooling methods are water cooling, vacuum cooling and air cooling.
In water cooling or hydro cooling, fruits and vegetables are immersed in cold water, which is usually in the bulk bins or flumes for transporting fruits and vegetables from the truck to the next processing step. This cooling method can be used for stem vegetables, leafy vegetables, and small fruits.
Water cooling produces uniform cooling and there is no weight loss from dehydration; however, it produces a lot of waste water and there can be a high risk of microbial contamination in the cooling water. Sanitation, such as chlorination, of the water is often used to prevent contamination of the fruits and vegetables.
Vacuum cooling is one of the most rapid cooling methods, providing uniform cooling using a vacuum chamber. The pressure around the fruits and vegetables is decreased, decreasing the boiling point of water. The heat in the fruits and vegetables is absorbed by the surface water as it evaporates. This method is used for cooling fruits and vegetables that have a large surface area to volume ratio. Vacuum cooling can cause up to 3% moisture loss in the product but water sprayed on the surface of fruits and vegetables before cooling can help reduce the loss of water during cooling.
Air cooling cools fruits and vegetables by heat transfer from the product to cold air circulating at −1°C to 16°C with a relative humidity (RH) of 85–90%. This step can also be done with room temperature air. Air

cooling is efficient for cooling tomatoes, apples, and cherries. This cooling method requires an intermediate investment cost and the system is easy to control; however, air cooling takes more time when compared to other methods. The rate of cooling can be improved by using forced air, where the cold air is forced with a pressure gradient into the chamber or container.
A cooling step is usually required for tomato processing.

Peeling

Peeling is a critical step in the processing of many fruits and vegetables to remove undesirable parts which are either inedible or difficult to digest, and to enhance the physical appearance of the product. Efficient peeling methods remove minimal skin to produce a clean and undamaged surface. They should also use minimal energy and labour, and have low operating costs. The main methods for peeling fruits and vegetables can be classified as follow:

- Chemical peeling

  Lye or caustic peeling applies a solution of lye (sodium hydroxide) at 0.5-3% at about 100°C for 2–6 min. During this process, the lye hydrolyses the pectin, loosening the skin, and a high-pressure water spray with rubber disks or a perforated mesh cage is then used to remove the skin. The average product loss during this peeling method is 17% [58]. Lye peeling produces waste water that contains a high organic load and high pH. Time in the lye, temperature of the bath, and concentration are the three major controllable factors that determine peeling efficiency. Increasing any of these factors increases the extent of peel removal. Time and temperature are linearly correlated, while time and concentration are correlated exponentially; therefore, longer time in the lye at higher lye concentration and higher temperature increases peel removal [59].

- Thermal peeling

  Steam peeling is the application of high-pressure steam at 1500 kPa in a pressure vessel to peel fruits and vegetables [58]. This kind of thermal peeling is possible with vegetables with thick skins as beets, potatoes, carrots and sweet potatoes. In steam peeling, peel removal is possible because of rupture of the cells just underneath the peel. Due to the high temperature and pressure, the temperature of the water inside these cells exceeds the boiling point, but remains in a liquid state. When the pressure in the chamber is released, the water changes to steam, bursting the cells. Time, temperature, and pressure are the most critical factors to control to optimize the peeling process. The higher the temperature and pressure, the shorter the time required and the more complete the peel removal. The process uses relatively little water and produces little waste effluent; however, the peeling is less complete than in lye peeling.

- Mechanical peeling is mainly used for peeling fruits. This type of operation is performed with various types of equipment which depend upon the result expected and the characteristics of fruit and vegetables, for example:
  1) A machine with abrasion device (potatoes, root vegetables), reported in figure n. 7
  2) Equipment with knives (apples, pears, potatoes, etc.). In knife peeling, the skin of fruits and vegetables is removed by either pressing stationary blades against the surface of fruits and vegetables, which are rotated, or rotating blades against the surface of stationary fruits and vegetables (see figure n. 7). This method operates with low energy and capital costs and no heat damage occurs; however, the average product loss can be up to 25%.
  3) Equipment with rotating sieve drums (root vegetables). Sometimes this operation is simultaneously with washing (potatoes, carrots) or is preceded by blanching (carrots).

The most common mechanical peeling method uses either cutting tools (knife peeling) or an abrasive peeler.

Peeling step is usually found in tomato and potato processing.

Figure 7 (left) Abrasion peeler for potatoes and sweet potatoes. **(right)** Rotating cylinder with an abrasive surface along the inner wall to remove the skins as the cylinder rotates.

Blanching

Blanching is the application of heat at 85–95°C for a few minutes, depending on the product, to inactivate enzymes in some fruits and vegetables before processing. In particular two of the more heat resistant enzymes important in vegetables are catalase and peroxidase. If they are destroyed, then the other significant enzymes in vegetables also will have been inactivated. The other reasons for blanching are reducing surface microbial load, removing intercellular gases, preheating the materials, softening the product, and stopping respiration and maturation. This heat treatment is applied according to and depends upon the specificity of vegetables. Because various type of vegetables differ in size, shape, heat conductivity, and the natural levels of their enzymes, blanching treatments have to be established on an experimental basis. Small vegetables may be adequately blanched in boiling water in a minute or two, large vegetables may require several minutes. Blanching as a unit operation is a short time heating in water at temperatures of 100°C or less. Water blanching may be performed in double bottom kettles, in special baths with conveyor belts or in modern continuous blanching equipment. There are two common blanching methods used commercially: steam and hot water. The fruits and vegetables are rapidly heated by steam or hot water immersion to a pre-set temperature and then, depending on the next step, may be cooled to ambient temperature. Blanching is generally used in the tomato processing.

Size reduction

Size reduction decreases the average size of the pieces of the fruit or vegetable by cutting. Beside consumer demand and standard of identity, size reduction of fruits and vegetables before thermal processing decreases the thickness of the products, increasing the efficiency and rate of heat transfer during freezing, drying, and heating. In fruit and vegetable processing, methods of size reduction include chopping, cutting, slicing, and dicing, depending on the specific requirement of the processing technology. The equipment for size reduction includes slicers, dicers, shredders, and bowl choppers, depending on the preferred size of the final products. Size reduction is a step usually required for tomato and potato processing.

Grinding / crushing and cutting

Grinding and cutting reduce the size of solid materials by mechanical action, dividing them into smaller particles. Perhaps the most extensive application of grinding in the food industry is in the milling of grains to make flour. In the grinding process, materials are reduced in size by fracturing them. The mechanism of fracture is not fully understood, but in the process, the material is stressed by the action of mechanical moving parts in the grinding machine and initially the stress is absorbed internally by the material as strain energy. When the local strain energy exceeds a critical level, fracture occurs along lines of weakness and the stored energy is released. Some of the energy is taken up in the creation of new surface, but the greater part of it is dissipated as heat. Time also plays a part in the fracturing process and it appears that material will fracture at lower stress concentrations if these can be maintained for longer periods. Grinding is, therefore, achieved by mechanical stress followed by rupture and the energy required depends upon the hardness of the material and also upon the tendency of the material to crack - its friability.

When a uniform particle is crushed, after the first crushing the size of the particles produced will vary a great deal from relatively coarse to fine and even to dust. As the grinding continues, the coarser particles will be further reduced but there will be less change in the size of the fine particles. Careful analysis has shown that there tends to be a certain size that increases in its relative proportions in the mixture and which soon becomes the predominant size fraction. For example, wheat after first crushing gives a wide range of particle sizes in the coarse flour, but after further grinding the predominant fraction soon becomes that passing a 250 um sieve and being retained on a 125 um sieve.

The surface area of a fine particulate material is large and can be important. Most reactions are related to the surface area available, so the surface area can have a considerable bearing on the properties of the material. For example, wheat in the form of grains is relatively stable so long as it is kept dry, but if ground to a fine flour it has such a large surface per unit mass that it becomes liable to explosive oxidation.

The equipment for size reduction includes slicers, dicers, shredders, and bowl choppers, depending on the preferred size of the final products.

Grinding equipment can be divided into two classes - crushers and grinders. In the first class the major action is compressive, whereas grinders combine shear and impact with compressive forces.

Cutting machinery is generally simple, consisting of rotating knives in various arrangements. A major problem often is to keep the knives sharp so that they cut rather than tear. An example is the bowl chopper in which a flat bowl containing the material revolves beneath a vertical rotating cutting knife. [60]. Generally the processes of grinding and cutting are referred to cereal processing.

Olive milling

Olive oil production is carried out in “mills.” Mill wastes are composed of solid wastes consisting of olive pulp and pits left over after pressing the fruits, as well as liquid wastes consisting of vegetable and additional water generated during decantation. Batch (press) and continuous processes are the main methods used in olive oil production. Depending on the separation method used in continuous operation, two technologies are recognized: two- and three-phase processes. These processes mainly differ in the process water requirements.

In three-phase systems process water is added and three phases (oil, wastewater, solid wastes in the form of an olive cake) are produced. A two-phase plant, however, involves two phases (oil and water-solid mixture) and much less additional water is used than in the three-phase process.

In the traditional press process, the olives are washed, crushed, and kneaded with the addition of hot water. The resulting paste is then pressed to drain the oil. The liquid waste originating from presses consists of a mixture of olive juice and added water and contains residual oil. Finally, olive oil is separated

from the water by vertical centrifugation or decanting. Pressed solids is a cake that can be further de-oiled elsewhere. This requires special facilities. De-oiled solids are usually burned for energy, and oil is sold for soap manufacture or for edible oil if the quality is assured after refining. Press technology is the traditional olive oil extraction process, which needs little water but produces highly polluted wastewaters. Even today, a significant part of the world olive oil production is still achieved by press technology.
In the continuous process, a horizontal centrifuge allows continuous operation. The main advantages of the continuous centrifugation process with respect to the traditional press technology are increased production, minimized labour cost, smaller space requirement, better quality due to elimination of mat flavor, improved process control, and ease in automation. But it has high capital cost compared to press technology [32]

Centrifugation

Centrifugation is a process utilized in the olive oil extraction. This separation technique is usually used on a liquid. It can be used to separate out solids or to separate out one or more liquids with different densities than the main liquid. For instance; it is used to separate vegetable oils from other liquid products of the crushing process, or to clarify beverages that have developed a cloudy appearance because of dissolved solids. The process of centrifugation involves spinning a container, with the food inside it, in circles at a very high rate of speed. One of the ingredients moves to the outside of the spinning radius, and the centrifugation machine has nozzles or separated pans to collect the material that spins out. [61]

Production Processes

Operations in processing food products are extremely varied and can be described only after individual study of each industry, but the following general procedures are used: extraction, fermentation, cooking and dehydration.
Extraction removes some food compounds that are closely co-mingled with other materials. Extraction involves soaking the food in a solvent that dissolves the food product or food waste, then filtering that solvent out or using centrifugation to separate it.
To extract a specific food product from fruit, cereals or liquids, some used methods are extraction by heat (direct or indirect), extraction by solvents, drying and filtration.
Heat can be used directly as a means of preparation by extraction, as in roasting (e.g., cocoa, coffee and chicory); in manufacturing it is usually used directly or indirectly in the form of steam (e.g., extraction of edible oils or extraction of sweet juice from thin slices of beet in the sugar industry).
Oils can be extracted equally well by combining and mixing the crushed fruit with solvents that are later eliminated by filtering and reheating. The separation of liquid products is carried out by centrifuging (turbines in a sugar refinery) or by filtering through filter presses in breweries and in oil and fat production.
Fermentation, obtained usually by addition of a micro-organism to the previously prepared product, is practiced in bakeries, breweries, the wine and spirits industry and the cheese products industry.
Cooking occurs in many manufacturing operations: canning and preserving of meat, fish, vegetables and fruits; ready-to-serve meat-processing plants (e.g., chicken nuggets); in bakeries, biscuit making, breweries; and so on. In other cases, cooking is done in a vacuum-sealed container and produces a concentration of the product (e.g., sugar refining and tomato-paste production).
Besides the drying of products by the sun, as with many tropical fruits, dehydration can be carried out in hot air (fixed dryers or drying tunnels), by contact (on a drying drum heated by steam, such as in the instant-coffee industry and the tea industry), vacuum drying (often combined with filtering) and

lyophilization (freeze drying), where the product is first frozen solid and then dried by vacuum in a heated chamber [62].

High-temperature processes

High-temperature processes can destroy bacteria, depending on the cooking temperature and duration, to ensure microbial safety and shelf life extension of food products. Sterilization (mainly used in canneries) involves submitting the already canned product to the action of steam, generally in a closed container such as an autoclave or continuous cooker. Retorting is a process that relies on the transfer of heat to guarantee the safety of canned food. In this process, cans are filled with the food product and then sealed hermetically before retorting. Wet heat and pressure are applied within the retort to sterilize both the container and food product. This heat sterilization is essential in canning, especially for low-acid foods, which have a pH greater than 4.6 and a water activity greater than 0.85, such as papaya, bananas, melons, corn, green beans, and peas. These foods provide appropriate conditions for some spore-forming microorganisms and anaerobic microorganisms, such as Bacillus coagulants and Clostridium botulinum, to grow. Therefore low acid food requires more severe heat treatment, such as 121.1°C for 25 min for canning small carrots (FAO, 1995), than acid or acidified food (pH below 4.6 and water activity below 0.85), which can be canned at 100°C.

Many fruits are acid and have a pH below 4.6, such as apricots, grapefruit, pineapples, tomatoes, and peaches. Pasteurization—the term is particularly reserved for liquids such as fruit juice, beer, milk or cream—is carried out at a lower temperature and for a short time. In particular a thermal process at temperatures at or below 100°C is used to destroy vegetative cells of spoilage microorganisms and inactivate enzymes. Hot-filling, a process of heating the juice with a heat exchanger to a fill temperature of 88–95°C, then filling the juice into a container, is also sufficient for acidic beverages, such as cherry, cranberry and apple juice. The maximum pH of the fruit juice to be hot-filled is 4 and the shelf life of the product is between 9 and 12 months [63].

4. Feedstocks residues availability at European level

Harvesting fruit and vegetables is an imperfect process. Even when using the most efficient method, farms end up with damaged fruit and fruit that have over ripened. In Europe about 1/3 of the vegetable crop remain in the field due to either not meeting marketing standards or insufficient market demand [64].

In addition to the waste left on the field, there are even the wastes generated during the transformation and processing of the vegetables. Consequently it's possible identify two types of agricultural crop residues. Field residues are materials left in the field after the crop has been harvested. Process residues are material left after the crop is processed into a usable resource.

Therefore significant amounts of agricultural residues and by-products are derived both from agricultural crop production and from food processing.

According to FAO (2011), around 45% of fruit and vegetable biomass is wasted during agriculture, postharvest, processing, distribution and consumption. As an example, the sector of fruit and vegetable processing, packaging, distribution and consumption in India, the Philippines, China and the United States of America generate a total of approximately 55 million tons of fruit and vegetable waste[65].Data on crop yields are easily available, while data on the feedstocks residues are very limited and difficult to find, since the aim of agricultural production was always to maximize yields, while the total biomass yield was not considered important[66].

Sometimes it is very difficult to have a precise estimation of the waste's amount, since this value can depend on many different parameters: climate and soil conditions, farming practices, industrial processes to which the species is subjected, etc. Therefore precise figure of the waste's amount are not always available in literature, sometimes it's only possible to find an indication of percentage of waste produced respect to the production data.

Tomato waste availability

Tomato is, after potato, the second most consumed vegetable in the world and approximately 30% is processed into foods, such as ketchup, pasta sauce and canned goods, while the remaining 70% is consumed fresh or sold directly to consumer [67]. This means that in term of ratio 1/3 or a little more of the world tomato production is destined to the industrial transformation and the other 2/3 are destined directly to consumer.

Despite the numerous benefits that can be derived from the crop, postharvest losses make its production in most parts of the world unprofitable. According to Schaefer et al. [68], about 10% of tomatoes in Europe are left in the field during the harvest. At global level, this percentage can rise up until 15-25% for example in Turkey [69 Tatlidül F. F., Kiral T., Gundogúmus E., Fidan H., *Turk J Agric For,* (2005), 29, 499-509] , while postharvest losses for tomatoes can be higher as 25–42% globally [70]. Probably this difference in percentage is due to the geographical area involved, considering that in Europe the agriculture is mostly mechanized and automatized, while at global level there are areas such as Africa, some countries of Asia as Bangladesh and other developing countries where the conditions of agriculture are still rural and for example the harvest is not mechanized, therefore the losses are major. These losses bring low returns to growers, processors, and traders as well as the whole country which suffers in terms of foreign exchange earnings.

Postharvest losses in tomatoes can be either quantitative or qualitative. Even though emphasis in crop research nowadays is increasing shifting from quantity to quality of produce there is still little improvement in the quality of commercially produced tomato varieties, hence resulting in high amount of qualitative losses. However, qualitative loss in tomato production can have a negative impact on many parameters like consumer acceptability, nutrient status of fruits, and financial income to producers. The postharvest qualities of tomatoes are dependent not only on postharvest handling and treatment methods but also on many preharvest factors such as genetic and environmental conditions. Many cultural practices such as types of nutrient, water supply, and harvesting methods are also believed to be factors influencing both pre-and postharvest quality of tomato [71]. Many postharvest quality losses are as a result of many preharvest factors. Tomato fruits that are diseased and infected by pest, inappropriately irrigated, and fertilised or generally of poor quality before harvesting can never be improved in quality by any postharvest treatment methods. [72]. Successively, when tomatoes are processed into products, about 10-30% of their weight becomes waste or pomace [73]. In fact during tomato industrial processing, waste solids obtained, comes both from defects in fresh tomato supplied (immature tomatoes, lesioned tomatoes for mechanical or microbial action) and from processing stages (processing residues, wastes of refining, cleaning, skins and seeds). The refuse is an additional cost for companies because of the disposal processes. Among the tomato waste, there are skins and seeds. The skin of fruits and vegetables is commonly removed because they are thought to be indigestible and contain low levels of nutrients, furthermore, approximately 2-3% of total weight of tomatoes in the form of skin and seeds are discarded during processing of tomatoes into paste. In Europe the tomato production in 2014 has been 16.6 million tons, as reported in the previous paragraph. Of these, 6.8 million tons went to the fresh market and 9.8 million were earmarked for processing, as it can be noted the percentage of fresh and processed product is quite different respect to those indicate above, probably because in Europe the tomato industry is much spread. Of these 16.6 million tons, 10% are lost as they remains in the field, 1.6 million. On the processed tomato, 9.8 million tons, we can calculate a percentage of waste included between 10 and 30 %, which means 980 thousand and 2.9 million tons. Adding the waste left in the field it's possible to obtain a final calculated value of about 2.6-4.5 mln ton of tomato waste. Instead In 2015, The EU-28 produced an estimated 17.6 million tonnes of tomatoes. Respecting the same percentage between fresh and processed as for the previous year 2014, we can consider that 7.04 million tons went to the fresh market and 10.56 million were earmarked for processing. Of these 17.6 million tons, 10% are lost as they remains in the field, 1.7 million. On the processed tomato, 10.5 million tons, we can calculate a percentage of waste included between 10 and 30 %, which means 1 million and 3.1 million tons. Adding the waste left in the field it's possible to obtain a final calculated value of about 2.7-4.8 mln ton of tomato waste. Therefore we can consider an European average tomato production of 15 mln tonnes annually. Of these 15 mln, 10% are lost as they remain in the field, that means 1.5 mln. About 4.5 mln of tomatoes are processed and from these the waste generated are included between 10 and 30%, that means 450 thousand and 1.35 mln tons. Adding the waste left in the field it's possible to obtain a final calculated value of about 2.8-3 mln ton of tomato waste. From the calculations above reported it's possible and correct to estimate an amount of tomato waste equal to 4 million tons produced each year in Europe, according to the data reported in the Issue Brief "Food and Crop Waste: A Valuable Biomass Feedstock" [74].

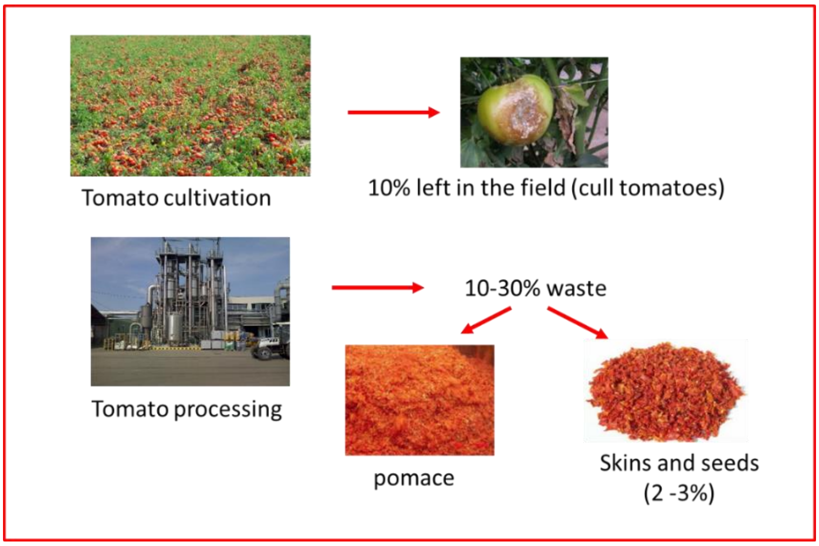

Figure 8 Tomato waste

Cereals waste availability

Wheat bran, a by-product of the dry milling of common wheat (*Triticum aestivum L.*) into flour, is one of the major agro-industrial by-products used in animal feeding. Other wheat processing industries that include a bran removal step may also produce wheat bran as a separate by-product: pasta and semolina production from durum wheat (*Triticum durum Desf*.), starch production and ethanol production.

It is important to note that wheat bran is not a product with a universally accepted definition and clear boundaries. Though national regulations may contain mandatory requirements on bran composition, ingredients sold under that name encompass a wide range of wheat by-products. Milling yields variable proportions of flour, depending on the quality of the final product. The extraction rate (flour:grain ratio) goes from 100% for a wholemeal flour to less than 70% for pastry flour[75]. Wheat bran represents roughly 50% of wheat offals and about 10 to 19% of the kernel, depending on the variety and milling process [76; 77; 78]. In the industrial milling process, after a cleaning step that removes grain impurities, the grains are tempered (soaked to toughen the outer layers and mellow the starchy endosperm in order to facilitate their separation) and then subjected to a series of grinding operations that produce finer and finer flour particles. The first grinding steps yield coarse particles of broken wheat and bran, and the later steps produce other by-products. Milling by-products are traditionally named after their quality (fineness, colour, etc.) and/or the stage of the process at which they arose, with considerable variations between languages, countries, regions, milling processes and even mills. In industrial countries, these products used to be sold separately (coarse bran, fine bran, middlings, second clear, thirds, etc.) but are now mixed together in variable proportions [79].

During the wheat milling process, about 70 to 75% of the grain becomes flour, and the remaining 25 to 30% is available as wheat by-products largely destined for livestock consumption. These by-products commonly are referred to as millfeed (MF), wheat mill run (WMR), or wheat middlings (WM) with little regard for the various mill streams and proportions that are combined and ultimately constitute the by-product's final composition[80]. Another estimation about the cereals by-products quantity is indicated by Awarenet [81], where it generally evaluate a percentage of waste produced included between 20 and 60% for cereal processed. Considering an European production of wheat equal to 150 mln tons, as reported in paragraph 1, we can estimate a wheat bran production equal to 37.5 – 45 mln tons, that is about 25-30% of the production. As regarding the oat production, the by-products generated by its transformation are different and several (oat creening, oat hulls, oat mill feed, oat bran), as it will be explained in the next paragraphs. About 2% of global oats production is lost as waste. The highest loss rate is in Asia (6%) and South America (5%), while in Europe is 2.75%, according to Seungdo K. et al. [82]. This percentage resulted very low, compared to the other products, a possible reason could be due to the fact that oat is mainly destined to animal feed, therefore it doesn't require a fine processing. In fact the main use of oat grain is as animal feed, alone or in mixtures. About 73% of global oat production is consumed as animal feed. The fraction of oats used for seed is 14%, which is higher than the fraction for human food use (11%) [82]. Oats are not suitable for bread making but are consumed in breakfast cereals and as porridge, hard, or added to other dishes as a thickening agent. The preparation of oats for human consumption is more laborious than for wheat because oats must be milled to remove the glumes before any further processing can be carried out [83]. The European production of oat equal is to 15 mln tons and we can estimate a oat by-products production equal to about 400 thousand tons, that is about 2.7% of the production.

Olive waste availability

Olives are one of the characteristic agricultural products of Mediterranean regions, with 20.8 million tonnes produced globally each year (FAO, 2013). Wastes generated by the olive sector can be divided into solid wastes (such as olive husks or crude olive cake, a residue remaining after the first pressing of the olives) and liquid wastes (olive mill wastewater).

The olive oil waste management was always one of the biggest problems in agricultural and environmental sector. Besides, it has been observed that the olive oil industries produce globally every year more that 10 million tons of waste including wastewaters and solid waste (leaves, dry pomace) [50]. Water consumed during the oil production and wastewaters generated are an important issues and factor in the olive waste management. Every year almost 20 million tons of fresh water are consumed during the oil production period while 12 million tons of wastewater is produced. Mostly, this wastewater goes to the closest aquatic systems such as sea, rivers, lakes, etc. More specifically, 58% of the olive oil mills dispose of their wastewater into streams, which consequently in most of the cases ends up in larger water reservoirs, in the sea or in the soil [84]. Therefore the olive oil industry generates large quantities of by-products. A scientific paper of Greco report that every 100 kg of olives, about 35 - 45 kg of olive solid waste (OSW) are generated depending upon the methodology employed in oil extraction [85]. This OSW contains a number of environmental toxins such as phenols that can pollute water bodies and are harmful to soil microbial communities and plant growth [86]. Another paper calculated that olive mills produce significant quantities of solid wastes with outputs of 0.35 tonnes of olive pomace and 0.05 tonnes of leaves per tonne of olives. The huge quantities of olive pomace and olive leaves produced within the short oil extraction season cause serious management problems in terms of volume and space. The solid wastes (olive pomace and olive leaves) that are produced contain almost 95% organic matter and although they could be highly beneficial to agricultural soils, it has been shown that they also contain toxic compounds and lipid which increase soil hydrophobicity and decrease water retention and infiltration rate [87]. The resulting wastes depend on the production process. Until the introduction of the two-phase decanters, both the press-systems and the decanter systems resulted in solid residue called olive cake (sludge) and the vegetable water (liquid effluent). In the early 90's, the 2-phase decanters appeared which practically eliminate liquid effluent, since there is no water addition and there is only one residue resulting from the process as liquid and solid residue comes together, in the form of a sludge. Traditional olive oil processing methods are estimated to produce between 400 and 600 litres/ton of processed olives, three-phase processes produce 800-1000 litres/ tonne of processed olives while almost no wastewater is produced by the two-phase process. The characteristics of olive mill waste are variable, depending on many factors such as method of extraction, variety and maturity of olives, region of origin, climatic conditions and associated cultivation/processing methods [88]. For example almost all of the olive mills in Spain use the two–phase centrifugation system for oil extraction to reduce wastewater generation and lower the contaminant load, compared with the three–phase centrifugation system which is currently used by other Mediterranean countries. The main by–product of the two–phase extraction system is olive mill pomace (OMP), which in Mediterranean areas is produced during a short period over the winter, from November to February [89], the amount generated varying between 7 and 30 million m^3 per year [90; 91].

With more than 4.5 million hectares under cultivation, olive is the second-most important agro-food sector in Europe. Mediterranean countries of the European Community, led by Spain, produce 10 million tons per year, which is 75% of the world olive harvest. In terms of olive oil this share is about 18.8%, amounting to 1.8 million tons per year, and the total waste generation is nearly 75% of the olive harvest [92; 93].

If we considered a percentage of 35-45% of solid waste produced, we can estimate for Europe an amount of 3.5-4.5 mln tons of waste generated every year from the olive cultivation and production, including stones/pits and exhausted olive pomace. In Spain alone some 300 000 tons of leaves must be transported and disposed each year. Nowadays, leaves are treated with natural composting and the residues are used for energy production [94]. In conclusion as a final result we can cite the study of Spyridon Achinas, that stated that an "average" scale mill produces daily 13 tons of waste per day. This value is estimated with an error margin of about 10% and does not include the recycling for its own consumption [50]. Finally, olive oil mill wastes should be considered as economic resources that can be turned into valuable products in progressing toward a permanent solution to waste disposal problems.

Potato waste availability

Potato production can be conducted in a variety of different conditions, which makes it a commonly cultivated crop across the world, also grown in all EU countries. Global annual production of potato is over 350 million tons from which EU countries produce nearly 55 million tons (FAO, statistics from 2012).

Potato cultivation and processing creates significant amounts of side streams that are not included in the main products. These are especially produced during processing of potato, *i.e.* peeling, packaging and washing, while harvesting residues comprise smaller but still remarkable share of non-used biomass. The amount of produced side streams varies from process to process; in some peeling processes up to half of the biomass ends up to side stream [95]. Further processing of side streams is costly and thus affects economy of industry. It is also notable that the biological burden of these side streams is relatively high.

Thus, it is obvious that the valorisation of potato industry side streams would be beneficial for both environment and industry. The majority of potato industry side streams are formed during peeling, cutting and packaging. In fact while consumption of potatoes has decreased, processed products such as French fries, chips, and puree have experienced growing popularity. Peeling of potatoes produces washing waters that include peel residues and PFJ. In wet peeling 25–50% of the raw material ends up into residues. Its solid content is 10–15%, which includes also some earth. Therefore, it is not usable as animal feed. Dry peeling produces 50–100% less side streams than wet peeling. Therefore it can be said that the losses caused by potato peeling range from 15% to 40% their amount depending on the procedure applied, i.e. steam, abrasion or lye peeling [96]. Plants peel the potatoes as part of the production of crisps, instant potatoes and similar products. The produced waste is 90 kg per Mg of influent potatoes and is apportioned to 50 kg of potato skins, 30 kg starch and 10 kg inert material. [97] The produced side streams include earthy water (produced during washing), peel mass (pure potato), starch and PFJ. Peel mass (potato pulp) resulting from the industrial starch processing is highly viscous and contains 16–17% by weight of dry matter of which 30–35% starch and 60–65% non-starch polysaccharide material (NSP) [98].

Cutting processes produce classification and cutting residues. In addition, spoiled, under – or over dimensioned and incorrectly shaped potatoes are discarded to waste during packaging [94]. The amount and solid content of side streams vary between processes. For example in a guidelines published in Canada the data reported indicated that about 15% of field-run potatoes go into culls when potatoes are packed for the fresh market, and about 20% by weight of processed potatoes end up as waste. The amount of processing waste varies with the type of processing and with the cost of the raw material, which directly influences the extent of the salvage operation. When potatoes are expensive, processors can afford to hire more workers to salvage undamaged parts rather than discard the whole tuber [99].

Starch production creates potato fruit juice (PFJ) and potato pulp as side streams, both of which contain proteins and fibres. These side streams could be utilized better which would eventually also improve the economy of industry [100]. The problem of the management of potato peel waste (PPW) causes considerable concern to the potato industries in Europe, thus implying the need to identify an integrated, environmentally-friendly solution. Potato peel is a zero value waste from potato processing plants. The waste products from processed potatoes are a disposal problem to the processors but a valuable source of feed for the livestock industry. Cull potatoes and, in some years, surplus production of potatoes are other sources of high-energy feed that often are not used to best advantage. In Europe, if we consider a total potato production equal to 59 mln ton (2014), as reported in paragraph 1, it is possible to calculate an amount of waste equal to 5.31 mln ton, considering a percentage of waste equal to 0.09 ton every ton of potato.

Questionnaires development and distribution - Analysis and evaluation of the results of the survey

In order to collect much data as possible and to verify the data found in literature, two types of questionnaires have been prepared for processing vegetable companies and for agricultural farms. The questionnaires prepared included 10 questions related to types and volumes of vegetables processed per year, the deriving percentage and type of by-products/residue produced, the composition, the storage conditions, the actual destination of use and the disposal costs. (The questionnaires are annexed to the present document in Annex I). The questionnaires were distributed in Spain, Italy and Austria among associations, SME and RTDs involved in the Agrimax project, reaching 170 sendings. The answers received were respectively 44 from Spain, 4 from Austria and 3 from Italy, for a total of 51 answers collected.

Therefore the response rate has been equal to a 29%, as it is showed in the figure n.9 below reported. Among all the questionnaires received, 31 were relative to companies and farm which process and/or cultivated olive, corresponding to a percentage of 53% on the total answers received, 9 tomato corresponding to a percentage of 15%, 7 potato corresponding to a percentage of 12%, 12 cereals corresponding to a percentage of 20%, as it is showed in the graph reported in figure n. 10. Sometimes there were some companies which processed even more than only one product, therefore the sum of the data listed in the sentence just over (59) is more than 50 (the total answers received).

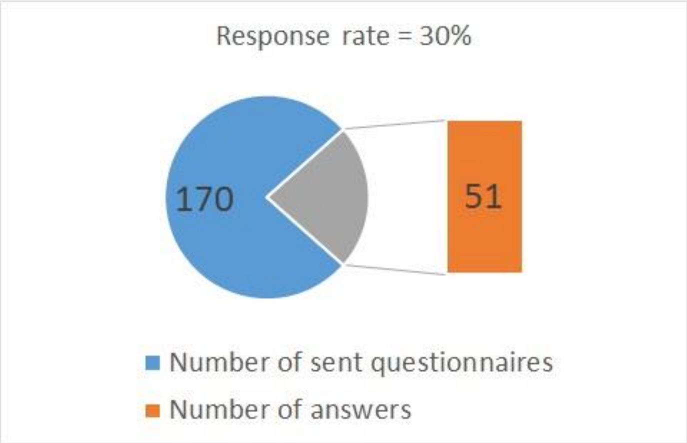

Figure 9 Response rate of questionnaires

As regarding the answers collected about the type, nature and percentage of residue/by-products produced by each company or farm, the data confirm the information find in literature.

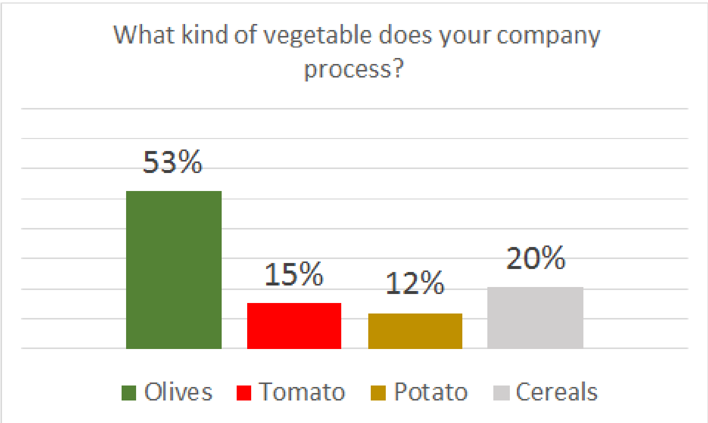

Figure 10 Type of agricultural product processed

For tomato processing, the majority of the answers identifies only one type of by-product from the processing of tomato, referred to as non-compliant product or cull tomatoes, only two answers identifies two and three type of by-products, considering also the peels and seeds. The nature of tomato residue is solid, as it is referred by the majority of answers. The percentages of residue indicated by the companies were ranging from about 4 to 10%, the mean percentage calculated of residue produced is 13.25%, considering cull tomato, peels and seeds. In literature higher percentage of residue, related to pomace, have been founded, but in general, the percentage of by-products obtained from processing depends on the feedstocks type, the starting form of raw materials and the transformation process, this could be a reason of this discrepancy.

For cereals processing, the answers identified two type of by-products (husk, and bran from rice grain), both of solid nature. The percentages of residue indicated by the companies were around 20%, the mean percentage calculated of residue produced is 22.3%. This data agrees with the data found in literature for wheat by-products.

For olive processing, the most part of the answers (50%) identified 2 by-products (pomace and pulp resulting from two-phase process), while 38% of the answers identified only one by-product (pomace) and finally the remaining 14% identified three by-products (pomace, pulp and stones or also waste waters). The nature of these residues can be solid or liquid, in the main cases the nature is solid, but some answers indicated also semiliquid. The percentage of residues indicated by the companies were higher and variables among them, the major part around 70-80% and someone else around 50%. This difference is probably due to the presence of waste waters, if they are included or not in the percentage estimated. The mean percentage calculated was 68%, almost in agreement with the data found in literature. All data collected for olive came from Spanish processing companies.

For potato processing, all the answers identified one by-product (peels), only one answer identified three by-products (peels, pulp, raw pieces). The nature of the residue is solid only in one case is liquid. The percentages of residue indicated were included between 5 and 20%, depending on the waste considered (if only peels or even other pulp residues, starch, powder…). The mean percentage calculated on all answers is resulted 10%. The value of residues is quite different from the data reported in literature, as already said above. The variability of the data depends on the variety of starting potato and on the transformation to which the vegetable is subjected.

As regarding the storage conditions of the waste, the most often indicated conditions have been storage in tank and storage in hopper. Other storage conditions indicated were storage in silos, in bags, bins, refrigerator cells. However about a quarter of the companies surveyed didn't indicated storage conditions of waste, since they don't retain the residues.

As regarding the destination of by-products, the options are variable and depending on the waste, as it is presented in the graph reported in figure n.11.

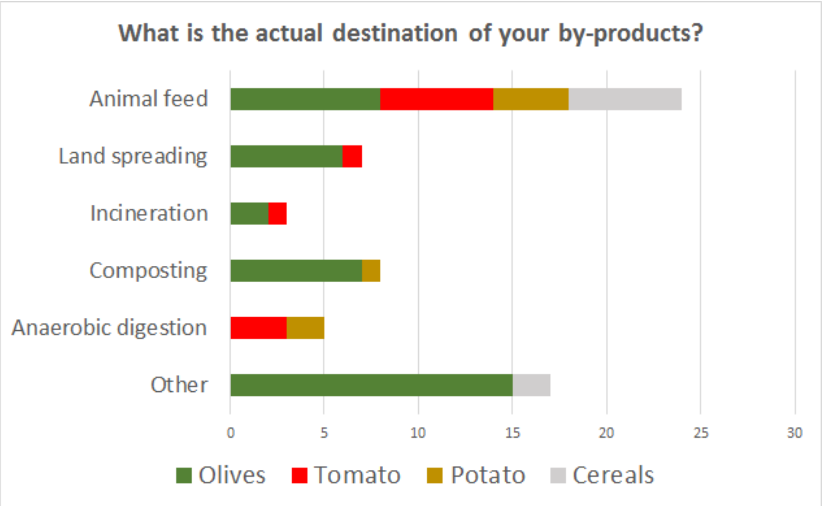

Figure 11 Destination of by-products

For all type of waste the most indicated destination is animal feed (in the case of olive waste only leaves are used for this purpose, while pomace is used for pomace olive oil).

Other further destinations indicated by the answers are: land spreading, incineration and composting. All these three options are utilised with olive waste, while land spreading is used also for tomato waste and composting also for potato waste. For tomato and potato waste, even anaerobic digestion has been indicated as destination. As regarding the cost of by-products disposal, 52% of the companies surveyed didn't pay a cost for waste disposal, the remaining 48% paid a cost, which is in the majority of cases ranging from 1 to 5 euros per ton, as it can be seen in the graphs reported in figure n. 12.

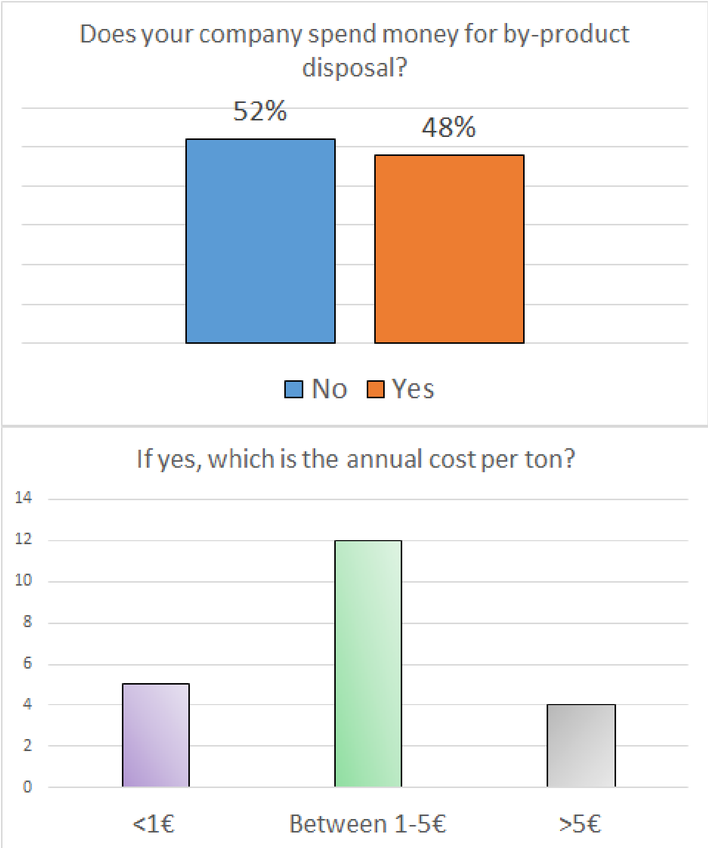

Figure 12 Disposal cost of by-products

The results obtained from the survey carried out confirm and agree with the data found in literature, although there is a wide variability about these data, in particular the type of waste generated can be very varied and the percentage of residues obtained can be very variable. In fact the amount of this residue percentage can depend on type of transformations, on the nature state of the starting products, on type of waste considered for the amount of residues (for example if effluent or waste waters are comprised or not). Therefore this kind of data always needs a deep investigation and interpretation.

5. Feedstocks residues composition

The composition of selected AFPW is described in this section. In particular the AFPW fractions examined are:

- tomato waste (tomato plant and the industrial processing by-products);
- cereal waste (wheat bran, oat hulls, oat mill fed, oat bran);
- olive waste (olive cake, two-phase olive mill waste, olive mill wastewater, olive stone and olive leaves);
- potato processing by-products (raw pieces and pulp, potato starch waste and peels).

Tomato waste composition

The main components of **tomato plants** are the roots, the stems, the leaves, the flowers and fruits (figure 13).

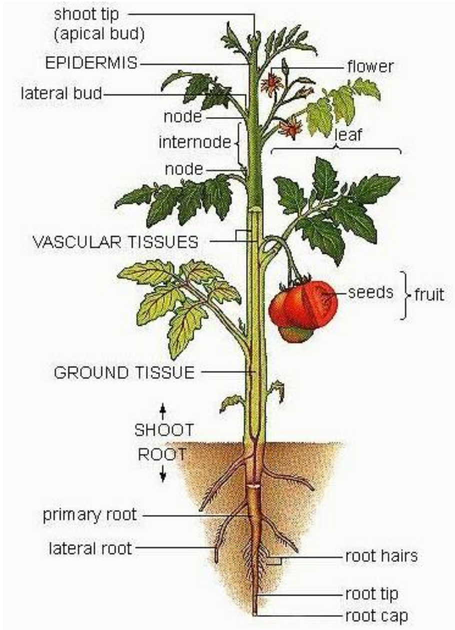

Figure 13 The components of tomato plant [101].

In the anatomy of the tomato steam is possible characterize the following sections:

- shoot apical meristem (SAM)
- primary tissues (young stems)
- secondary tissues (old stems)
- branch and leaf patterns

The stem of tomato plant comprises three main tissue types each with different functions. The *dermal tissue* is a protection and interface with the environment. The *ground tissue* is frequently the site of storage, sometimes support. The vascular tissue is the conductor of water and materials used in synthesis. The *vascular tissue* system conducts water and nutrients from roots to leaves through specialized cells and conducts the products of photosynthesis, sugars, from leaves in different but equally specialized cells. There is continuity of these individual tissue systems through the plant [102]. The tomato plant has compound leaves. A compound leaf is made up of leaflets which are distributed along the leaf rachis. While the entire leaf is connected to the stem by the petiole, the leaflets are connected to the rachis of the leaf by the petiolule. Some of the leaflets on this leaf are compound as well. The tomato flowers can occur in a simple or a complex inflorescence. Simple flowers can appear as well as simple cymes and branched cymes. The number of flowers that occur in an inflorescence is dependent upon environmental factors such as temperature. The tables 3, 4 and 5 show the composition of the whole tomato plant, tomato leaves and tomato stems. [103]. The main component of tomato whole plant tomato leaves and tomato stems is the no-dietary fibre (NDF). The tomato plant powder (TP) composition was reported by Monterumici et al. (2015). The chemical nature of the organic matter in TP was first analysed according to a procedure expected to separate the major biomass proximates on the basis of the components solubility in benzene/ethanol and in mineral acid at different temperatures [104]. TP contains 11.9% *w*/*w* lipids and non-polar compounds, 44% *w*/*w* hemicelluloses and proteins, 15.5% *w*/*w* cellulose and 28.5% *w/w* lignin. Concentrations of nutrients in leaves and plant are shown in tables 3 and 4. Nitrogen concentration was within the range 3-5%, phosphorus concentration was within the range 0.2-0.6%, potassium concentration was within the range 3.0-5.0 %, calcium concentration was within the range l.0-5.0%, Mg concentration was within the range 0.3-0.5 % in tomato leaves in according to Demir et al. (2010) [105].

Main analysis	Unit	Avg
Dry matter	% as fed	17.7
Crude protein	% DM	7.4
NDF	% DM	37.4
ADF	% DM	29.2
Lignin	% DM	12.8
Ether extract	% DM	1.2
Ash	% DM	18.1
pH		7.6
Organic C	g/Kg	364
Total N	g/Kg	35
Nitric N	g/Kg	4
C/N		10
Total P	g/Kg	3
Available P	**g/Kg**	**0.8**

Table 3 Composition of tomato whole fresh plant [106; 107].

Main analysis	Unit	Avg
Dry matter	% as fed	12.6
Crude protein	% DM	8.8
NDF	% DM	29.9
ADF	% DM	20.2
Lignin	% DM	17.0
Ash	% DM	17.6
Gross energy	MJ/kg DM	10.3
Minerals	Unit	Avg
Calcium	g/kg DM	42.5

Phosphorus	g/kg DM	2.1

Table 4 Composition of tomato fresh leaves [106].

Main analysis	Unit	Avg
Dry matter	% as fed	24.2
Crude protein	% DM	5.4
NDF	% DM	42.1
ADF	% DM	34.7
Lignin	% DM	10.1
Ash	% DM	18.4

Table 5 Composition of tomato fresh stems [106].

A variety of secondary metabolites are found in tomato plant. That includes phenolic compounds, phytoalexins, protease inhibitors, and glycoalkaloids. These metabolites protect against adverse effects of hosts of predators including fungi, bacteria, viruses, and insects.

The tomato glycoalkaloids (a glycoalkaloid is an alkaloid bonded with a sugar) comprising R-tomatine and dehydrotomatine. Tomatine exists in all green parts of the plant, including the stems, green tomatoes and in particular in leaves [108]. The tomato industries produce several tomato by-products: cull tomatoes, pomace, skins, seeds, tomato paste fibrous matter and tomato seed cake [106].

Cull tomatoes.

Tomato fruits that do not meet grade standards for fresh market or processing are discarded. Such fruits may be damaged, diseased, too small, misshapen, etc. This large amount of tomato wastage has always been a problem for tomato growers, and cull tomatoes are often scattered on vacant land and pastures or buried in the ground. Feeding them to livestock is a common way to get rid of them [109]. Tomato fruits are berries with different forms and dimensions. The Tomato is a fruit because fruits are the edible part of the plant that contains the seeds [110].

Under the morphological appearance (figure), starting from the outside to the inside the tomato consists of:

- exocarp - the external layer of polygonal flattened cells of yellow colour (skin)
- mesocarp - the compact part of the fruit, formed by round-ovoid cells with thin round walls. These contains, when ripe granules of a red pigment insoluble (licopene) and a liquid which is chemically an acqueous solution of flavor and savory compounds

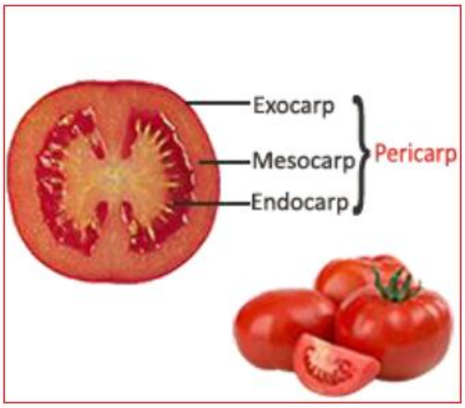

Fig. 14 : Tomato sections

In the mesocarp there are also small vessels or tracheae spiral that give consistency to the whole berry and chemically consist of cellulose, hemicellulose, lignin and pectin substances [111; 112].

Main analysis	Avg
pH	4.39
Refractometric residue (°Bx)	4.20
Colour (a/b)	2.54
% sugars (glucose and fructose)	2.44
Total acidity (%)	0.30
Sugars ratio (%)	58.09
Acidity ratio (%)	7.14

Table 6 General parameters of fresh tomato [111]

Tomato fruit consists of 94 – 95% water and 5-6% organic compounds (solids) [A113]. The percentage of solid in tomato varies over wide limits for a number of reasons, such as variety, character of soil and especially the amount of irrigation and rainfall during the growing and harvesting season. Tomatoes and tomato products are rich sources of folate, vitamin C, and potassium. Relative to phytonutrients, the most abundant in tomatoes are the carotenoids. Lycopene is the most prominent carotenoid followed by beta-carotene, gamma-carotene and phytoene as well as several minor carotenoids. In addition to lycopene, violaxanthin, neoxanthin, lutein, zeaxanthin, a-cryptoxanthin, b-cryptoxanthin, a-carotene, b-carotene, g-carotene, z-carotene, neurosporene, phytoene, phytofluene, cyclolycopene and b-carotene 5,6-epoxide are other carotenoids commonly described in tomato and tomato-derived products [114]. Tomatoes are a rich supply of vitamin A activity. Tomatoes also contain several other components that are beneficial to health, including vitamin E, trace elements, flavonoids, phytosterols, and several water-soluble vitamins. However vitamins account only for a small portion of the total dry matter [115]. Chemical analysis reveals that sugar and organic acids make major contribution to the total dry solid. The sugars are mostly glucose and fructose and constitute about 65% of total soluble solid [116]. Whereas the acids are mostly malic and citric acids, organic acid comprise about 15% of the dry content of fresh tomatoes. Citric acid is the most abundant organic acid with some malic acid also present. [117] Minerals commonly found in tomato fruit are potassium, calcium, magnesium and phosphorus and may reach to 8% of dry matter. Free amino acids form about 2-2.5% of the total dry matter of tomatoes [118].

Principle	Nutrient Value	Percentage of RDA
Energy	18 Kcal	1%
Carbohydrates	3.9 g	3%
Protein	0.9 g	1.6%
Total Fat	0.2 g	0.7%
Cholesterol	0 mg	0%
Dietary Fiber	1.2 g	3%
Vitamins		
Folates	15 µg	4%
Niacin	0.594 mg	4%
Pyridoxine	0.080 mg	6%
Thiamin	0.037 mg	3%
Vitamin A	833 IU	28%
Vitamin C	13 mg	21.5%
Vitamin E	0.54 mg	4%
Vitamin K	7.9 µg	6.5%
Electrolytes		
Sodium	5 mg	>1%
Potassium	237 mg	5%
Minerals		
Calcium	10 mg	1%
Iron	0.3 mg	4%
Magnesium	11 mg	3%
Manganese	0.15 mg	6.5%
Phosphorus	24 mg	3%
Zinc	0.17 mg	1.5%

Table 7 Nutritional value of tomato.

Carotenoid	Concentration	Polyphenol	Concentration
Lycopene	7.8–18.1	Naringenin chalcone	0.9–18.2
Phytoene	1.0–2.9	Rutin	0.5–4.5
Phytofluene	0.2–1.6	Quercetin	0.7–4.4
β-Carotene	0.1–1.2	Chlorogenic acid	1.4–3.3
γ-Carotene	0.05–0.3	Caffeic Acid	0.1–1.3
δ-Carotene	0–0.2	Naringenin	0–1.3
Lutein	0.09	Kaempferol-3-rutinoside	0–0.8
Neurosporene	0–0.03	*p*-Coumaric acid	0–0.6
α-Carotene	0–0.002	Ferulic acid	0.2–0.5
Neoxanthin	-	Kaempferol	0–0.2
Violaxanthin	-	Myricetin	-
Anteraxanthin	-	Cyanidin	-
Zeaxanthin	-	Pelargonidin	-
		Delphinidin	-

Table 8 Typical composition (mg/100 g^{-1} fresh weight) in tomato ripe fruits of carotenoids and polyphenols [119].

Tomato pomace consists of crushed skin and seeds being rich in protein (20-23%, dry basis), fat (12- 18% contained mostly in seeds) and crude fibre (12-30%). Tomato pomace is extremely rich in anti-oxidant compounds: in particular the lycopene.

Tomato peel composition.

The exocarp of tomato includes the cuticle, the epidermis, and a variable number of hypodermal cell layers. The cuticle covers the external part of epidermis cells (from the Greek "επίδερμίδα", meaning "over-skin"). Cuticles have a thickness of up to a few micrometers and are attached to the underlying epidermis cells by a network of polysaccharide fibrils. The cuticle acts as a skin, protecting against biological attack and weather variability, and allowing controlled exchanges, namely of water vapour, with the environment. In agricultural crops, the cuticle avoids premature desiccation and rotting and is the frontier biocide or surface treatments must deal with [120].

As regarding the composition, the cuticle contains a number of components such as lipids, polysaccharides (mainly cellulose and pectin), polypeptides and phenolic compounds.

Cutin is the main component (between 40% and 85%, w/w) of the plant cuticle. Considering the average weight of an isolated cuticle (around 600 Ag cm2), cutin can be considered the major lipid plant polymer. From a chemical point of view, cutin is defined as a polymeric network of polyhydroxylated C16 and C18 fatty acids cross-linked by ester bonds [121]. Cutin plays an important role in cuticle as a structural component, as a defence barrier against pathogens [122], as protection against the uncontrolled loss of water together with waxes [123], as well as in transporting substances across plant tissues [124].

In addition to cutin in the cuticle there are cuticular waxes or lipids soluble, which are embedded within the matrix cuticular waxes intracuticulares, or deposited on the outer surface of the cuticle waxes epicuticular. In Figure 24 a diagram of the plant cuticle can be seen where its various components are indicated.

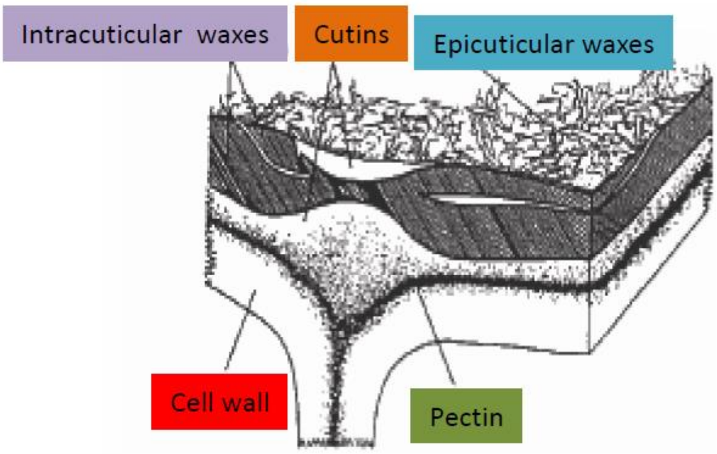

Figure 15 Scheme of a cross section showing a major plant cuticle constituent components.

Data in Table 9 summarize the proximate composition of the tomato skins.
The peel by-product contained 100.8 g protein, 256.4 g ash and 299.4 g acid detergent fibre kg^{-1}. The main unsaturated fatty acid found in tomato peel are linoleic acid and oleic acid, that constitute about 77.6% of the total fatty acids; while the saturated fatty acids were myristic, palmitic and stearic acid with a total percentage of 22.37% of total fatty acids.
The lycopene content of peel by-product was 734 μgg−1 of dry material. Significant amounts of lutein, β-carotene, and cis-β-carotene were also present (table 10) [125]. The skins of tomatoes have been found to be richer sources of polyphenolic compounds (flavonoids - quercetin, kaempferol and narangenin, and phenolic acid - caffeic, chlorogenic, ferulic and p-coumaric acids) than the pulp. The free polyphenolic content (expressed as mg catechin/100 g, fresh weight) in skin ranged from 10.4 to 40.0 mg/100 g. [126].
The peel by-product contained a high proportion of fibre (Table 9). It was found that dried peels content of total dietary fibre (TDF) was 83.54% (w/w) with the following distribution: insoluble dietary fibre (IDF) 74.68% (w/w) and soluble dietary fibre (SDF) 8.86% (w/w). The TDF content was higher than those reported in other vegetables, since vegetables peels are usually rich in cellulose and hemicellulose [127]
The xyloglucomannanis the main hemicellulosic polysaccharide in tomato peel, which also contains a small amount of xylan-pectin complex. Side chains of pectic polysaccharides from tomato are composed mainly of ß-(1-4)-linked galactopyranosyl and α-(1-5)-linked arabinifuranosyl residues. [128]. The sodium content of the peel by-product was high (Table 11) as a result of using a sodium hydroxide solution to peel the tomatoes. The potassium content of this by-product was also relatively high. The concentrations of other minerals were moderate.

Tomato seed composition.

The seeds are present in locules located in the internal morphological part of tomato named endocarp. The seed by-products are composed of about 202.3 g protein, 51.8 g ash, and 537.9 g acid detergent fibre kg^{-1}. An amino acid analysis of seeds indicated that approximately 60% of the protein results from amino acids. Seed by-product contained 130 μg lycopene kg^{-1} of dry matter. The content of other carotenoids was approximately half of that present in the peels [*129*]. The seed by-product contained a high proportion of fibre (Table 9). More than half of the seed by-product was acid detergent fibre, which caused it to have a low bulk density. Crude protein of the seed by-product was approximately twice that of the peel by-product; however, the total of the analyzed amino acids accounted for only about 60% of the crude protein. Tomato seeds were a rich source of iron. The concentrations of other minerals were moderate for this by-product.

Component	Peel byproduct	Seed byproduct
Proximate analysis ($g\,kg^{-1}$)		
Crude protein	100.8	202.3
Crude fat	32.2	63.7
Ash	256.4	51.8
Acid detergent fiber	299.4	537.9
Amino acids ($g\,kg^{-1}$)	83.4	116.9

Table 9 Composition of tomato peel and seed by-products on a dry matter basis *[129*].

Carotenoid	Peel byproduct	Seed byproduct
Lycopene	734.0	130.0
Lutein	14.5	6.5
Zeaxanthin	3.7	1.0
α-Carotene	0	0.4
β-Carotene	29.3	14.4
cis-β-Carotene	11.7	5.6

Table 10 Carotenoid content *(*µgg−1*)* of dry tomato by-products

Mineral	Peel byproduct	Seed byproduct
Macrominerals ($g\,kg^{-1}$)		
Calcium	01.8	01.4
Magnesium	01.4	02.1
Phosphorus	02.7	04.0
Potassium	28.3	15.3
Sodium	83.8	02.8
Sulfur	01.4	01.9
Microminerals ($mg\,kg^{-1}$)		
Copper	7.6	16.1
Iron	75.5	242.6
Manganese	12.5	25.4
Zinc	27.5	37.1

Table 11 Mineral composition of dry tomato by-products.

Cereals waste composition

Bran, also known as miller's bran, is the hard outer layers of cereal grain. Bran is present in and may be in any cereal grain, including rice, corn (maize), wheat, oats, barley, rye and millet. Bran makes up about 13–19% of total wheat grain weight depending on the milling process (wet or dry) used for its extraction (Hossain et al., 2013).

Wheat bran (WB) is subdivided into three distinct layers, testa, aleurone and pericarp. (figure 16).

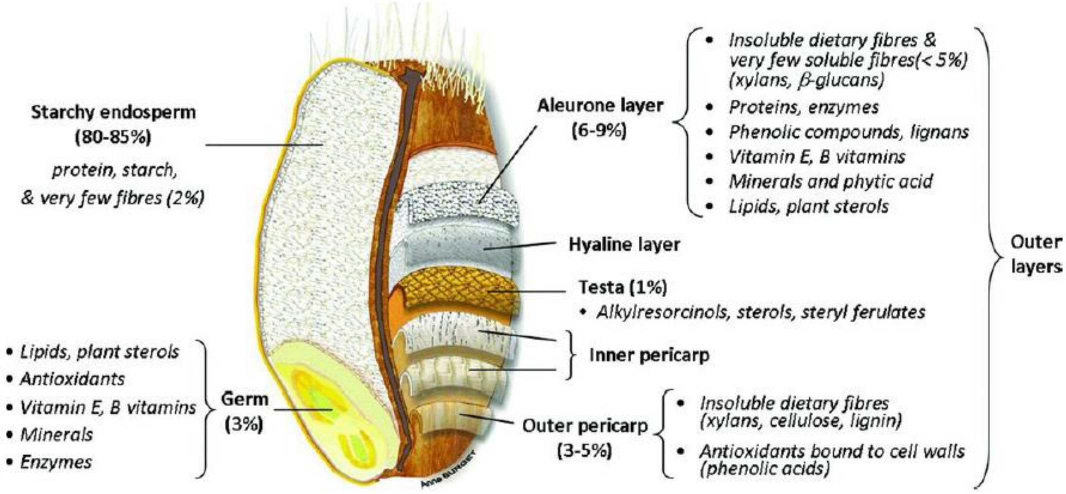

Figure 16 Wheat grain structure.

WB is composed of about 53% dietary fibre (xylans, lignin, cellulose, and galactan, fructans). Other components include vitamins and minerals (Table 12) and bioactive compounds such as alkylresorcinols, ferulic acid, flavonoids, carotenoids, lignans and sterols. The pericarp is divided into outer and inner layers, which contains insoluble dietary fibre as well as phenolic acids in bound state. [129].WB is high in dietary fibre DF and it ranges from 33.4% to 63.0%; it can be classified as 'soluble' or 'insoluble dietary fibre' based on their solubility in water. Soluble dietary fibre (SDF) in WB is <5% of total dietary fibre and it consists of glucan and xylans [131].

In particular, arabinoxylan were found abundantly in WB. Arabinoxylan (AX) is a fibre that has a b-D-xylan backbone with arabinose side chains linked by a-1, 2 and a-1, 3 glycosidic linkages. The content of AX in WB ranges between 5.0 and 26.9 g per 100 g of WB.

The chemical and antioxidant found in WB include flavonoids, phenolic acids, tocopherols, lignans, phytosterols and carotenoids[132].

Phenolic acids are the most complex class of phytochemicals found abundantly in the bran of cereal grains, and they are derivatives of cinnamic and benzoic acid. The cinnamic acid class of phenolic compounds includes ferulic acid, sinapic and pcoumaric acid. Phenolic acids in WB exist in bound and free state, with around 99% of ferulic acid in WB in insoluble bound state [133; 134].

Bran component	Range % dm
Dietary fibre	33.4–63.0
Moisture	8.1–12.7
Ash	3.9–8.10
Protein	9.60–18.6
Total carbohydrates	60.0–75.0
Starch	9.10–38.9
Phytochemicals	**µg g^{-1}**
Alkylresorcinol	489–1429
Phytosterols	344–2050
Ferulic acid	1376–1918
Bound phenolic compound	4.73–2020
Flavonoids	3000–4300
Micronutrients	**mg per 100 g**
Phosphorus	900–1500
Magnesium	530–1030
Zinc	8.3–14.0
Iron	1.9–34.0
Manganese	0.9–10.1
Vitamin E (Tocopherols/tocotrienol)	0.13–9.5
B Vitamins	
Thiamin (B1)	0.51–1.6
Riboflavin (B2)	0.20–0.80
Pyridoxine (B6)	0.30–1.30
Folate (B9)	0.088–0.80

Dm, dry matter.

Table 12 General composition of wheat bran.

Oat milling yields several by-products:

- **Oat screenings** result from the cleaning of raw oats before processing.
- **Oat** husk or **oat hulls** (lemma) are obtained by the mechanical separation (rotating drum) of the hulls from the kernels prior to milling. The hulls are removed by air aspiration and the groats, which are the edible huskless grains, are ready for further processing [134]. Oat hulls include small fragments of endosperm and represent up to 25% of the weight of the grain [135]. It has a high fibre Oat hulls are a high fibre content, it contains about 75% NDF, 26% ADF, 30% crude fibre and 7% lignin. Its protein content is low (6%) and its protein is not a particularly valuable source of amino acids (table 13).
- **Oat mill feed**, also called oat dust, is obtained after the transformation of groats into oatmeal. Groats are kiln-dried, sized and cut, producing fines that are mixed with the screenings and the hulls obtained previously [135].
- **Oat bran** is a by-product of oat flour production. It has a high content of proteins (15-20%), B vitamins [133] and a low fibre content (ADF less than 5%).

Main analysis	Avg % dm
Dry matter	90.3
Crude protein	5.2
Crude fibre	30.6
NDF	75.8
ADF	36.0
Lignin	7.1
Ether extract	2.2
Ash	4.6
Starch (polarimetry)	9.9
Total sugars	1.2
Minerals	Avg g/Kg
Calcium	1.9
Phosphorus	1.8
Potassium	5.9
Sodium	0.1
Magnesium	0.6

Tables 13 Chemical composition and nutritional value of oat hulls.

Main analysis	Avg % dm
Dry matter	89.9
Crude protein	8.2
Crude fibre	22.4
NDF	55.4
ADF	27.5
Lignin	7.1
Ether extract	3.8
Ash	4.0
Starch (polarimetry)	25.0
Total sugars	3.9
Gross energy	18.8

Minerals	Avg g/Kg
Calcium	1.7
Phosphorus	2.9
Sodium	0.4

Table 14 Chemical composition and nutritional value of oat mill feed [137].

Main analysis	Avg % dm
Dry matter	90.6
Crude protein	19.3
Crude fibre	4.0
NDF	15.8
ADF	4.7
Lignin	2.9
Ether extract	7.8
Ash	3.3
Starch (polarimetry)	48.3
Total sugars	1.6
Minerals	Avg g/Kg dm
Calcium	1.1
Phosphorus	6.2
Potassium	5.8
Sodium	0.1
Magnesium	2.6

Table 15 Chemical composition and nutritional value of oat **bran** [137].

Olive waste composition

The olive oil extraction industry generates large amounts of two by-products. Olive oil production processes include several steps (Fig. 17). The extraction of olive oil is achieved through discontinuous (pressing) or continuous (centrifuging) processes in traditional mills or in modern units [138].

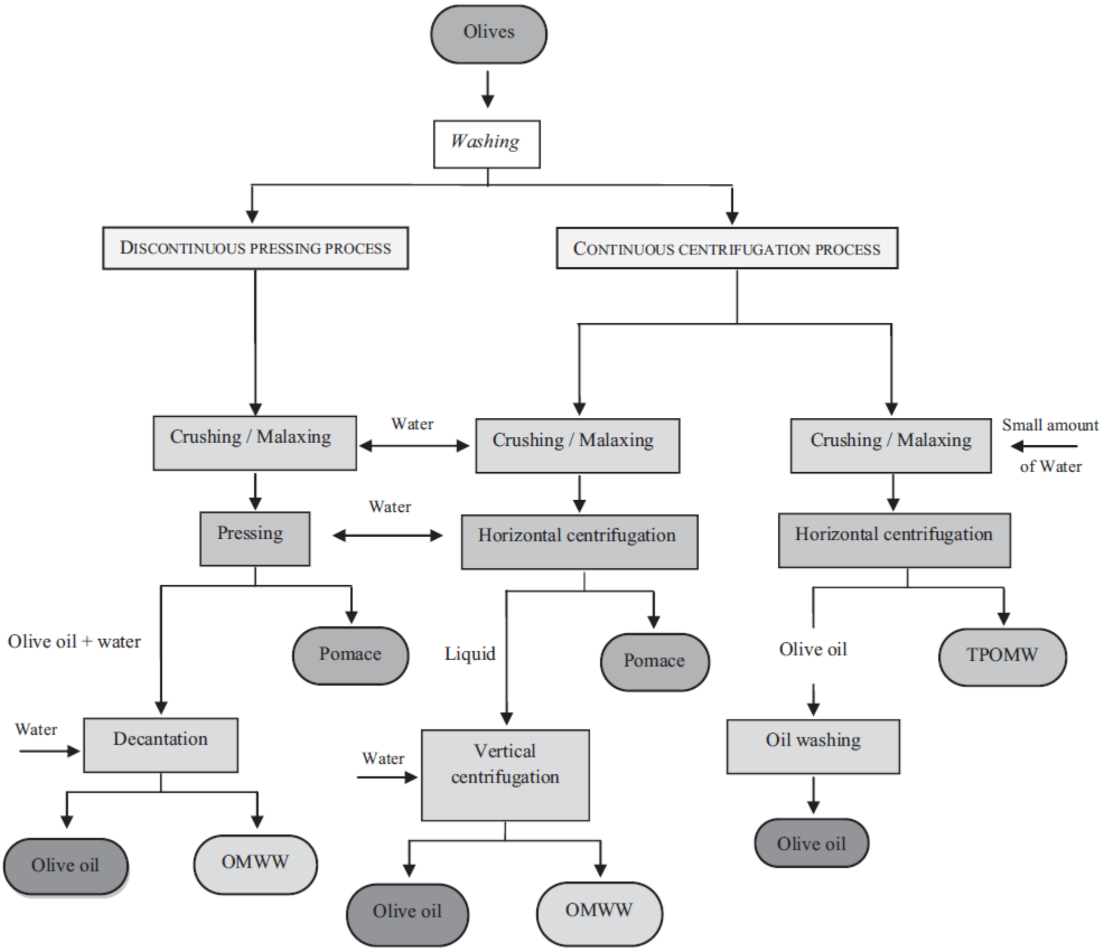

Figure 17 Main processes for olive oil extraction [138].

The following definitions are therefore given for oil extraction by-products [139].

Crude olive cake or pomace. The residue of the first extraction of oil from the whole olive by pressure or from three-phase systems (figure 17). The chemical composition of olive pomace varies according to the olive species, culture conditions, origin of the olives, and extraction process. Olive pulp in Europe is low in protein (approximately 7%) and lipid (approximately 5.5%) and high in neutral detergent fibre (approximately 68%) content. It is largely composed of the solid residues from the pulp, the skin and the stone or pit of the olives, by oil retained in said solid waste (and which has not been possible to extract by conventional mechanical processes). Its moisture content is in the range 22–25% in traditionally pressed olive pomace and 40–45% in three-phase systems. It has a significant content of the dry matter content and the ash (87.1–94.4% and 1.70–4% and respectively) [140]. Cellulose, hemicellulose and lignin are the main components; however, fat and protein are also present in significant quantities. [138]. According to some studies, hydroxytyrosol, oleuropein, tyrosol, caffeic acid, *p*-coumaric acid, vanillic acid, verbascoside, elenolic acid, catechol and rutin are the main phenolic compounds in olive cake [141]. Mineral analysis shows that the major elements in olive cake potassium, followed by calcium and sodium [138].

Two-phase olive mill waste (TPOWM). The residue extracted from two-phase systems (figure). TPOMW is a thick sludge that contains pieces of stone and pulp from the olive fruit and vegetation water. Its moisture content is in the range 65–75% and the ash content is 1.42–4%. The most abundant phenolic compounds in TPOMW are tyrosol and hydroxytyrosol, together with p-coumaric and, to a lesser extent, vanillic acid. Other minor compounds identified include verbascoside, rutin, caffeoylquinic acid, luteolin-

4-glucoside, 11-methyloleoside, hydroxytyrosol-10-b-glucoside, luteolin-7-rutinoside, and oleoside. Mineral analysis shows that the major element in TPOMW is potassium, followed by calcium and sodium [138].

Exhausted olive cake. The residue obtained after extraction of the oil from the crude olive cake by a solvent, usually hexane.

Partly destoned olive cake. The result of partly separating the stone from the pulp by screening or ventilation:

- it is called "fatty" if the oil has not been solvent-extracted.
- it is called "exhausted" or "defatted" if the oil has been solvent-extracted.

The major free phenolic compounds in full-fat and defatted olive cake are protocatechuic acid, sinapic acid, syringic acid, caffeic acid, and rutin. Table 16 shows the bound phenolic compounds profiles of extracts from full-fat and de-fatted olive cake derived in sequential extractions [141].

Bound phenolic compounds	Full-fat olive cake	Defatted olive cake
Gallic acid	ND	ND
Protocatechuic acid	21.2 ± 0.24	13.8 ± 0.41
Hydroxybenzoic acid	5.8 ± 0.17	7.1 ± 0.17
Vanillic acid	4.9 ± 0.12	4.9 ± 0.43
Caffeic acid	13.7 ± 0.28	11.1 ± 0.25
Syringic acid	22.4 ± 0.38	22.7 ± 0.36
Sinapic acid	13.1 ± 0.29	16.6 ± 0.59
Ferulic acid	7.2 ± 0.08	7.9 ± 0.35
p-Coumaric acid	ND	ND
Rutin	11.7 ± 0.39	8.2 ± 0.24
Hesperidin	ND	4.3 ± 0.13
Quercetin	ND	3.4 ± 0.19
Cinnamic acid	ND	ND

Table 16 Amount (%[a]) of bound phenolic compounds analysed in full-fat and defatted olive cake extracts by using RP-HPLC [141].

Vegetation waters or olive mill wastewater (OMWW). OMWW is a mildly acidic, brown watery liquid residue of high conductivity which is separated from the oil by centrifugation or sedimentation after pressing. Its composition varies both qualitatively and quantitatively according to the olive variety, climate conditions, cultivation practices, the olive storage time and the olive oil extraction process. Apart from water (83–92%), the main components of OMWW are phenolic compounds, sugars, and organic acid (Table 17). The prevalent classes of hydrophilic phenols identified include phenyl alcohols, phenolic acids, secoiridoid derivatives, flavonoids (luteolin, luteolin-7-glucoside). Moreover, the typical brownish-black colour of this effluent is explained by the presence of polymeric phenols that display a lignin-like structure and constitute its most resistant fraction. Soluble polysaccharides were identified in OMWW. OMWW also contains valuable resources such as mineral nutrients, especially potassium.

Parameters	Olive oil by products		
	OMWW	Solid residue	
		Olive cake	TPOMW
Pulp (%)		12–35	10–15
Olive-stone (%)		15–45	12–18
Dry matter (%)	6.33–7.19	87.1–94.4	
Ash (%)	1	1.7–4	1.42–4
pH	2.24–5.9		4.9–6.8
Electrical conductivity (dS/m)	5.5–10		1.78–5.24
Total carbon (%)	2–3.3	29.03–42.9	25.37
Organic matter (%)	57.2–62.1	85	60.3–98.5
Total organic carbon (g/L)	20.19–39.8		
Total suspended solids (g/L)	25–30		
Mineral suspended solids (g/L)	1.5–1.9		
Volatile suspended solids (g/L)	13.5–22.9		
Volatile solids (g/L)	41.9		
Mineral solids (g/L)	6.7		
Volatile acidity (g/L)	0.64		
Inorganic carbon (g/L)	0.2		
Total nitrogen (%)	0.63	0.2–0.3	0.25–1.85
P (%)	0.19	0.03–0.06	0.03–0.14
K (%)	0.44–5.24	0.1–0.2	0.63–2.9
Na (%)	0.15		0.02–0.1
Ca (%)	0.42–1.15		0.23–1.2
Mg (%)	0.11–0.18		0.05–0.17
Fe (%)	0.26 ± 0.03		0.0526–0.26
Cu (%)	0.0021		0.0013–0.0138
Mn (%)	0.0015		0.0013–0.0067
Zn (%)	0.0057		0.0010–0.0027
Lipids (%)	0.03–4.25	3.5–8.72	3.76–18.0
Total phenols (%)	0.63–5.45	0.2–1.146	0.4–2.43
Total sugars (%)	1.5–12.22	0.99–1.38	0.83–19.3
Total proteins (%)		3.43–7.26	2.87–7.2
Chemical oxygen demand (g/L)	30–320		
Biological oxygen demand (g/L)	35–132		
Cellulose (%)		17.37–24.14	14.54
Hemicellulose (%)		7.92–11.00	6.63
Lignin (%)		0.21–14.18	8.54

Table 17 Chemical characteristics of OMWW and solid residue [138].

Leaves collected at the oil mill. These are not pruning residues, but the leaves obtained after the olives have been washed and cleaned on entering the oil mill. In Greece their estimated quantity is about 5 percent of the weight of the olives.

Dry matter, g/kg fresh matter	586
g/kg dry matter	
Organic matter	838
Crude fat	32.1
Neutral detergent fibre	413
Acid detergent fibre	333
Acid detergent lignin	190
Crude protein (total N × 6.25)	70.0
Nitrogen attached to ADF, g/kg total N	533
Gross energy, MJ/kg dry matter	16.8
g AA-N/kg total N	
Histidine	38.0
Arginine	111
Threonine	41.7
Valine	90.2
Methionine	18.2
Isoleucine	38.2
Leucine	100
Phenylalanine	53.3
Lysine	52.5
Aspartic acid	43.1
Glutamic acid	47.4
Serine	44.9
Glycine	63.0
Alanine	83.3
Proline	45.9
Tyrosine	14.7
Cysteine	13.6
g/kg dry matter	
Total extractable polyphenols	25.3
Total extractable tannins	1.00
Total extractable condensed tannins	0.75
Total condensed tannins	8.30

Table 18 Chemical composition and nutrients availability for olive leaves [142].

Low molecular weight polyphenols such as oleuropein (up to 60–90 mg/g dry leaves weight), hydroxytyrosol, tyrosol, tocopherol, elenolic acid derivatives, caffeic acid, p-coumaric acid and vanillic acid as well as flavonoids: luteolin, diosmetin, rutin, luteolin-7-glucoside, apigenin-7-glucoside, and diosmetin-7-glucoside are abundant in olive leaves [141]. Glucose, hemi-sugars, mannitol, xylitol, lignin are in olive leaves [143].

Phenolic compound	TEAC (mmol/L)
Olive-leaf extract	1.58 ± 0.06
Rutin	2.75 ± 0.05
Catechin	2.28 ± 0.04
Luteolin	2.25 ± 0.11
Hydroxytyrosol	1.57 ± 0.12
Diosmetin	1.42 ± 0.07
Caffeic acid	1.37 ± 0.08
Verbascoside	1.02 ± 0.07
Oleuropein	0.88 ± 0.09
Luteolin-7-glucoside	0.71 ± 0.04
Vanillic acid	0.67 ± 0.09
Diosmetin-7-glucoside	0.64 ± 0.09
Apigenin-7-glucoside	0.42 ± 0.03
Tyrosol	0.35 ± 0.05
Vanillin	0.13 ± 0.01

Abbreviation: TEAC, Trolox equivalent antioxidant capacity.

Table 19 Antioxidant activity of phenolic compounds from olive leaves [144].

Olive leaves also contains several minerals, especially potassium, calcium, sulfur and phosphorus [145].

Olive Stone. The olive stone and seed are important by-products generated in the olive oil extraction and pitted table olive industries. The whole olive stone consists of the wood shell (stone) and the seed. In the olive oil industry, only the olive stone without seed can be recovered by filtration of solid waste. The main lignocellulosic components in olive stone are hemicellulose, cellulose and lignin with 21.45–27.64%, 29.79–34.35%, 20.63–25.11%, respectively. Protein, fat, phenols, free sugars and phenolics are also present in considerable quantities (Table 20).

Components	Whole stone (%, w/w)	Seed (%, w/w)
Ash content	0.01–0.68	0.03–0.13
Moisture content	9.79	9.98
Fat	5.53	1.01
Protein	3.20	1.29
Free suger	0.48	0.36
Phenolics	0.1	0.5–1

Table 20 Chemical composition of olive whole stones and olive seeds (as % dry weight) [141].

Pruning and harvest residues. Olive trees are usually subjected to severe pruning every second year and light pruning in the alternate year. Olive wood is source of antioxidants. The main components from olive wood are the tyrosol, hydroxytyrosol, (+)-cycloolivil, ligustroside, oleuropein and 7-deoxyloganic acid. [141].

Potato waste composition

The composition of a waste stream from a potato-processing plant is largely determined by the processes used. Most potato processing can be separated into the following general steps: washing the raw potatoes; peeling, which includes washing to remove softened tissue; trimming to remove defective portions; shaping, washing, and separation; heat treatment; final processing or preservation; and packaging. In wet peeling 25–50% of the raw material ends up into residues. Its solid content is 10–15%, which includes also some earth. The analysis of waste stream from potato-processing operations relates closely to the composition of the potato. Components foreign to the potato that also may be present include dirt, caustic, fat, cleaning and preserving chemicals, and other food ingredients in small quantities. A typical proximate analysis of potato waste solids from a plant employing steam or abrasive peeling is shown in Table 21[146].

Component	Amount (%)
Total organic nitrogen as N	1.002
Carbon as C	42.200
Total phosphorus as P	0.083
Total sulfur as S	0.082
Volatile Solids	95.2

Table 21 Percentage composition of potato waste solids.

The main components of potato-processing waste are listed below:

Raw Pieces. Cutting processes produce classification and cutting residues. Raw pieces that are not suitable for processing range in size from whole potatoes to small fragments. In addition, spoiled under – or over dimensioned and incorrectly shaped potatoes are discarded to waste during packaging [95]. Since these materials are normally firm, they present little problem in removal by screening or settling.

Raw Pulp. Raw potato that has been finely subdivided is usually designated as raw pulp. Sources of this include abrasion peeler discharge, cutting waste, and pulp from starch separation. Because of the large amount of water normally in contact with the pulp, much of the soluble solids are leached out.

Cooked Pulp. The softening action of heat during peeling or processing steps weakens the intercellular bonds of the potato tuber and results in separation of large quantities of potato cells and agglomerates of cells during washing and handling steps. These rapidly disperse in the wastewater.

Components	% (w/w) of Wet Pulp	% (w/w) of Dry Matter
Dry matter	13.0	–
Ashes	0.5	4.0
Starch	4.9	37.0
Cellulose	2.2	17.0
Hemicellulose	1.8	14.0
Pectin	2.2	17.0
Fiber (unidentified)	0.9	7.0
Protein/amino acids	0.5	4.0

Table 22 Components of conventional wet potato pulp [147].

The potato pulp contains starch, cellulose, hemicellulose, pectin, proteins, and some amount of fruit liquid and water in intact cells. On a dry matter basis, the pulp contains 1.5-2.5% protein, which is around 74% of that found in potato tubers [147]. The composition of conventional wet potato pulp is in table 1 [148].

Potato starch waste (PSW). Potato starch contains amylose and amylopectin, with 0.093% phosphorus. Much of the starch is present in starch granules. The amylose content increases with maturity and varies according to storage temperature [149].

Potato Peels. Peeling of potatoes produces washing waters that include peel residues. Dry potato peel waste (PPW) composition is given in Table 23. Soluble sugar, reducing sugar and starch are part of total carbohydrates. Lignin was not estimated. As shown, potato peel waste (PPW) had a high starch content (52% d.w.) but the fermentable reducing sugar was very low (0.6% d.w.) [150]. Potato peels are a good source of vitamin C, vitamin B_6, copper potassium, manganese, and dietary fibre. They also contain a variety of phytonutrients, which are a natural source of antioxidants that help to prevent cellular deterioration of the body. The phytonutrients found in potato skins include polyphenols, carotenoids, flavonoids and caffeic acid [151].

Parameters	Dry weight (%)
Moisture %	85.06
Total carbohydrate	68.7
Total soluble sugar	1
Reducing sugar	0.61
Starch	52.14
Nitrogen	1.3
Protein (N_{tot} 6.25^a)	8
Fat	2.6
Ash	6.34

Table 23 Chemical composition of potato peel waste (PPW). Lignin was not estimated.

Potato fruit juice (PFJ). Peeling process and starch production creates PFJ as side streams, which contain proteins and fibres. The amount of produced PFJ is approximately 70% the whole peel mass. It is easily spoiling and difficult to handle and its biological oxygen consumption is rather high. PFJ contains 23.5% solids consisting of starch (17.4%), proteins (2.5%), fibres (1.8%), soluble carbohydrates (0.5%) and minerals (1%). Nutrients are present as follows: N : 0.33% (from which half is soluble), P : 0.045%, K : 0.47%, Mg : 0.03% and Ca : 0.002% [152; 153].

Dissolved Solids. Constituents of the potato that are readily water soluble appear as dissolved solids in the final waste stream. These include solubilized starch, proteins, amino acids, and sugars.

6. Overview of the process parameters that could influence the composition of waste

Agricultural products are harvested, transported, and stored in ways that can impose physiological stresses that lead to adverse changes in their visual quality and chemical profile. Domestic and commercial food processing typically has drastic effects on the structural integrity of agricultural products.

Changes occasioned by food preparation can affect the favour, texture, appearance and the nutritional quality of foods. For example domestic preparations of vegetables normally involve washing, peeling and cutting. Modifications on texture of vegetables are strongly related to the transformations in cell wall polymers due to non-enzymatic and enzymatic reactions [154, 155].

The processes that vegetables and cereals subjected and from which the waste originated have been already generally presented and discussed in previous paragraph. It is difficult find in literature how these processes could influence the composition of waste, what is generally discussed is how these industrial processes influence the composition and quality of the final food products, not the waste.

Some of the vegetables are used in raw form as salad, but most of them require cooking for the improvement of digestibility and palatability. Some other vegetables require peeling to decrease their fibrous content [156]. Minerals and other nutrients are affected by both peeling (i.e. the removal of outer coarse covering) and cooking. Peeling is considered an inevitable treatment for rendering them more digestible and may result in fairly heavy loss of some nutrient, especially of vitamins. Peeling before boiling increases the loss of ascorbic acid, folic acid or other vitamins of group B [157].

Vitamins, carotenoids, flavonoids and fibres are more concentrated in the peel than in the pulp. Thus, the simple trimming or peeling of fruits and vegetables can discard appreciable amounts and significantly reduce the levels of these substances in the portion utilized. Alkaline treatments to facilitate peeling can also cause losses, although relatively small, of labile vitamins such as folate, ascorbic acid, and thiamine at the surface of the product [158].

Washing and peeling treatment prior to thermal treatment processing or dipping may influence final quality. The method used for peeling can also influence quality. Steam peeling may induce some enzyme inactivation particularly in the outer layers of the vegetables.

Vitamins and bioactive compounds are naturally protected in plant tissues. Cutting, chopping, shredding, and pulping of fruits and vegetables destroy this protection, increase exposure to oxygen, and release enzymes that catalyse their degradation. Enzymatic degradation may be a more serious problem than thermal decomposition in many foods. Thus, thermal processing should be carried out immediately after peeling and cutting operations.

Methods, temperature and duration of cooking may also effect significantly on the nutritive values of vegetables. Some of the important nutrients such as ascorbic acid and folic acid which are susceptible to oxidation are readily oxidized by brisk cooking. Minerals are also affected by high temperature, in some other cases flavour may be lost by brisk cooking. Excessive cooking may also cause an adverse effect on the digestibility of the vegetables [157].

Thermal pasteurization may also influence the bioaccessibility of carotenoids of vegetables. The bioaccessibility refers to the fraction of a nutrient that is released from its food matrix during digestion and made accessible for absorption into the intestinal mucosa. The food matrix is one of the important factors that relates to the bioaccessibility of carotenoids, and may be changed by heat through cell wall softening. Several studies have shown an increased bioaccessibility of β-carotene in carrots and carrot products by thermal pasteurization [159, 160]. Higher β-carotene bioaccessibility is normally associated with intense thermal processes [161].

The heat treatment given in blanching is less severe than, in heat sterilization, and the resulting changes in food quality are less pronounced. Some minerals, water-soluble vitamins, and other water-soluble components are lost during blanching. Losses of vitamins are mostly due to leaching, thermal destruction, and to a lesser extent, oxidation. Losses of ascorbic acid are used as an indicator of food quality, and therefore the severity of blanching. Considerable losses of carotenoids and flavonoids, have been observed when fruits and vegetables are processed into juice because substantial amounts of the bioactive compounds are left in the discarded skin and pulp.

Mechanisms that contribute to texture loss during heating of vegetables generally include turgor loss due to the breakdown of cellular membranes, and cell wall degradation and disassembly resulting from enzymatic and non-enzymatic transformations in pectin structure and composition [162, 163].

However, not all enzyme-catalysed reactions to pectin reduce the texture of processed vegetables.

Most authors observed a decreased texture in processed vegetables in comparison to the raw materials. Processed vegetables may also lose their texture during the storage period, and sometimes this loss in storage may exceed the texture loss during the production process.

Vegetables are great sources of various essential vitamins. Vitamin C (ascorbic acid) is one of the numerous vitamins in vegetables. However, vitamin C is readily changed or broken down in the presence of oxygen and light, and high temperature will accelerate this degradation process. Due to its thermolability, vitamin C in vegetables is often used as an indicator for the loss of other vitamins and thermolabile nutrients in studies that evaluate the influence of thermal processing on food qualities [161].

More in details considering the agricultural and food processing waste, we can cite some example and case found in literature. For example the seeds separated from tomato pomace may contain valuable protein with unique functional properties. In fact in a study reported in literature it has been found that the hot and cold break tomato processes could influence the protein content in tomato seeds. In fact the results of the research showed that the high temperature of hot break process denatured the protein, resulting in the lower protein extraction yield from 9.07 % to 26.29 % for defatted hot break tomato seed (DHTS) compared to from 25.60 % to 32.56 % for defatted cold break tomato seed (DCTS) under various extraction conditions [164].

As regarding cereals waste, as already said cereal by-products arise from dry milling (to produce flour), wet milling (for starch and glucose production) and brewing. The nature of the by-products is influenced by the particular cereal concerned and the exact conditions of processing.

Wheat is frequently imported into tropical countries and wheat by-products often occur in large quantities in countries where wheat is not grown. By-products are wheat germ meal, bran and middlings. Depending upon the level of true bran or starchy endosperm included in the dry milling by-products, coarse bran, fine bran, coarse middlings and fine middlings are obtained. Wheat mill feed is a mixture of fine and coarse middlings. Since the main processes that cereals generally subjected are mechanical processes such as grinding and milling, practically only in these mechanical processes of trituration and grinding it is possible to admit that the chemical composition of the material doesn't change [165].

As regarding the olive waste, an example refers to the olive pomace, which may present different moisture degree depending on the oil-production system used. If a centrifugation system is used, the moisture content can be included between 40-60%, as a consequence of the water's use in the kneading operations. Instead in the pomace obtained with the traditional methods of pressing, the moisture content is surely lower, about 25-30% [166].
Besides using the two-phase system, both malaxation time and temperature affected the phenol content and antioxidant capacity of olive waste. Air drying and drying at 60°C resulted in a substantial decrease in the phenol content and antioxidant capacity. Drying at 105°C and freeze drying produced less degradation [167].
Finally chemical composition of potato coproducts varies depending on the combinations of coproducts. Dry matter contents typically vary from 10 to 30% depending on the coproduct [168].
The potato composition used in potato processing operations determines the components of the resultant waste stream. Foreign components that may accompany the potato include dirt, caustic, fat, cleaning and preserving chemicals. Generally, the various waste streams are discharged from the potato plant after being combined as effluent. It is difficult to generalize the quantities of wastewater produced by specific operations, due to the variation in process methods. Many references and studies in this respect show wide variations in water usage, peeling losses, and methods of reporting the waste flow.
Processing involving several heat treatment steps such as blanching, cooking, caustic, and steam peeling, produces an effluent containing gelatinized starch and coagulated proteins. In contrast, potato chip processing and starch processing produce effluents that have unheated components.
The characteristics of the potato processing wastewater were influenced by potato processing operations. Potato peeling was the first stage of potato processing. Caustic soda was used to soften the potato skin so that it can be removed by the scrubbing and spraying action of the polisher. The liquid effluent from the polisher, which contained a majority of the contaminants of wastewater, accounted for about 75% of the alkalinity of the wastewater from the plant. It was also high in COD and BOD, with values of about 2000 and 1000 mg/L, respectively.
Polished potatoes are then conveyed to the cutter. The degree of size reduction depended upon the requirements of the final product. Here the surface of the potato and the amount of water used for washing determine the quantity of soluble constituent in the waste stream. The pH of the stream was about 7. The COD and BOD values were about 50% of those of the effluent from the polisher. The blanching process removed reducing sugar, inorganic salts, gelatinized starch, and smaller amounts of protein and amino acids. The effluent stream from this operation had pH 6.2, total dissolved solids 1500 mg/L, phenols 8.2 mg/L, COD 1000 mg/L, and BOD 800 mg/L, respectively [169].

7. Actual use of feedstocks residues

The AFPW actually are employed in several fields: animal feed, anaerobic digestion, composting and as feedstock for the extraction of chemicals.
The derived compounds from different fractions of AFPW provide a wide range of applications. The paragraph 6 includes literature on the processing and applications of bio-waste derived compounds, up to date review papers, patents and commercial information.

Tomato waste use

Usually, food industry by-products, in particular tomato cull and pomace are used for **animal feeding.**
Tomato by-products are usually fed to ruminants due to their high fibre content.

They are not excellent feed ingredients, being less digestible than most major oil meal. They can be bitter and should then be used together with more palatable feeds [170]. Caluya et al. recommend to include tomato pomace at up to 50 % of the daily roughage requirement irrespective of whether it is fresh, dry or ensiled [171]. The pomace should be given before the roughage or mixed (particularly when dry) thoroughly with the chopped roughage. In vivo organic matter (OM) digestibility of dried tomato pomace was estimated at 56 % in sheep, using a balanced diet containing 34 % of pomace. In vitro dry matter (DM) degradability was 48% [172]. A close value of 62 % for OM digestibility was obtained using the gas test method. Extremely wide estimates of metabolizable energy (ME) have been obtained: depending on the method (in vitro) and equation used, ME values of 4.9 [173], 7 to 9 [174] and 11.8 MJ/kg DM [175] were proposed.

Also the use of tomato pomace, skins and seeds in non-ruminants feeding is common. For example, dried tomato pomace is a valuable ingredient for rabbits feeding because it is one of few products that are simultaneously rich in digestible energy (13.7 MJ/kg), mainly as a consequence of the high lipid content, rich in digestible protein (71-74 % digestibility) [176]; and also rich in fibre and particularly in lignin, which is important fibre component necessary to control digestive diseases in the rabbit [177].

Energetic use of the tomato plant waste was proposed by several studies [178].

The gas phase produced by pyrolysis process of the tomato plant waste is mainly composed of H_2, CO, CH_4, CO_2 and traces of ethane and ethylene. The solid phase is constituted for a charcoal with an average higher heating value (HHV) of 26 MJ kg^{-1}, the liquid phase presents a HHV of 7.8 MJ kg^{-1} at 400 °C. The key operation variables of the process are the temperature (400–800 °C), the initial sample mass and the particle size.

Among all different biomass conversion technologies tomato plant wastes (TPW) the hydrothermal liquefaction has attracted much attention, since this process can efficiently convert inedible biomass into bio-oils (or bio-crude oils) that can be utilized directly as a source for chemicals (such as bio-phenols and bio-polyols) or can be upgraded into drop-in bio-fuels (such as green gasoline and biodiesel) [179].

Humic-like substances obtained by alkaline hydrolysis of composted organic wastes are known to improve plant productivity. Baglieri et al. studied the effect on plant growth of hydrolysates obtained by alkaline treatment of non-composted vegetal residues of tomato plants [180].

Several patents describe methods for the delivery of organic nitrogen and phosphorus from TPW. The organic nitrogen comprises an effective amount of hydrolysed plant protein and the phosphorus comprises phytic acid [181]. Concentrated phosphorus **fertilizers** are described which are absorbed quickly into plant systems and improve plant growth [166].

Mixtures of fibres derived from plant residues where incorporated into soils, they were found to be more lasting in effect and less injurious to young plants than inorganic fertilizers of comparable nitrogen content [183].

Other uses of TPW were proposed in literature. For example, A microwave-assisted protocol for the conversion of non-edible polysaccharides and tomato plant waste to levulinic acid was developed. Full conversion was achieved in all cases at 2 min irradiation and clean levulinic acid was obtained without any purification in high yields (63–95%). [184]. Tomato leaves were used to extract volatile **aroma** components. The volatiles of tomato leaves were isolated by adsorbant trapping and by direct solvent extraction [185]. Application of tomato leaf volatiles as antifungal agents against plant pathogenic fungi was proposed by Baldwin et al. [186].

The extraction and purification of phytochemicals from tomato wastes is desirable, since these bioactive substances are often used in the preparation of dietary supplements, nutraceuticals, functional food ingredients, food additives, pharmaceuticals and cosmetic products [184]. The purpose of the extraction of natural **antioxidants** from tomato skins is to liberate these compounds from the vacuolar structures where they are found, either through rupturing plant tissue or through a process of diffusion [188]. Extraction yield is dependent on the solvent and method of extraction [188]. Water, aqueous mixtures of ethanol, methanol and acetone are commonly used as solvents [190]. The chosen extraction method should enable complete extraction of the compounds of interest and avoid their chemical transformation [191]. The application of ultrasound as a laboratory-based technique for assisting extraction from plant material is widely published [192]. Among the several types of sonicator systems currently available, bath and probe-type sonicators are used. The homogenization is also a process which is commonly used for assisting extraction [193, 194].

Tomato waste is as a source of carotenoids in particular **lycopene** a compound known for its role in disease prevention, it is in high demand from food, pharmaceutical and cosmetic industries [195]. Commercially available lycopene mostly comes from standardized tomato fruit extraction or from chemical synthesis, but the product is generally expensive due to the complicated extraction procedures necessary to obtain a product with a high purity under conditions that preserve the activity of the carotenoids *in vivo*; so, the lycopene recovery from tomato is a current research topic [196]. Lycopene extractability by various organic solvents was investigated optimizing the extraction parameters (type of solvent, extraction time, temperature and extraction steps) for maximum yield. The conventional food-grade organic solvents used for lycopene extraction are hexane, ethanol and ethyl acetate [197]. Among other solvents, the authors tested new environmentally friendly solvents such as ethyl lactate [198], and d-limonene [199].

It was established that an enzymatic pre-treatment of tomato peels with a pectanolitic enzyme preparations, together with the use of surfactant-assisted extraction, significantly increased the level of lycopene recovery [200].

The extraction method for lycopene provided by patent 104610009 uses the aqueous two-phase system (ethyl alcohol and an ammonium sulphate solution) and the ultrasonic extraction in combination [201].

Machmudah et al. discussed the extraction of lycopene from tomato peel by-product containing tomato seed using supercritical carbon dioxide [202]. There are the affecting factors like matrix type, particle size (drying, grinding and sieving operations are needed), flow rate of SC-CO_2, temperature, pressure and co-solvent addition on lycopene yield. Several patents were published on lycopene extraction by supercritical CO_2 [203]. Tomato peels were used to enrich edible oils with carotenoids and lycopene. These industrial tomato wastes were incorporated in refined olive oil, extra virgin olive oil and refined sunflower oil [204]. In addition, tomato peels by-products were used for isolation of **cellulose** nanofibers [205]

Cutin is generally extracted from tomato peels using enzymatic treatments, organic solvents or acid hydrolysis and alkaline hydrolysis. It was established that an enzymatic pre-treatment of tomato peels with a pectinolytic enzyme preparations, significantly increased the level of cutin recovery by organic solvents [206]. Generally the solvent used are chloroform, methanol and aceton [207]. In addition, Luque et al. proposed the extraction with diethyl ether of the de-waxed product obtained by saponification with potassium hydroxide in methanol to isolate cutin from tomato mature green cuticles [208]. In literature there are some examples of cutin extraction methods combining organic solvent extraction and acid hydrolysis [209].

Today the eco-friendly and innovative re-use of waste tomato seeds and skins, is becoming increasingly important. In particular some studies focus on the bio-mimicry of the plant cuticle, in order to obtain **bioplastics** with commercial purposes [210].

Several patents relate to a method for preparing **tomato seed oil**. For example, the patent 201010271830.X shows the extraction of tomato seed oil by using supercritical CO_2. A microwave pre-treatment on tomato seeds crushed was performed.

Tomato-seed oil has been utilized in the manufacture of soap, and the conversion of the crude oil into an edible oil is also receiving attention. The composition of tomato seed oil is quite similar to essential oil [211].

Furthermore, the use of the carbohydrates present in tomato pomace and in by-products as biomass for bioethanol production was proposed. The presence of large sucrose content makes tomatoes to be used for the production of ethanol, using for example Saccharomyces Cerevisiae as the organism [212].

Cereals waste use

7.1.1 Fiber Extraction

In literature are proposed different methods to extract cellulose **fibres** from brain waste. Cellulose nanofibrils of diameter 10-50 nm were obtained from wheat straw using alkali steam explosion coupled with high shear homogenization. High shear results in shearing of the fibre agglomerates resulting in uniformly dispersed nanofibrils [213]. In particular, cellulose microfibrils (MFC) were isolated from oat husk by fibre pretreatment [214].

A microfibrillated **cellulose** containing at least around 80% of primary walls and loaded with carboxylic acids, were extracted by the pulp hydrolysis at a moderate temperature of 60-100° C using a base having a concentration of less than 9 wt%; and the cellulose residue is homogenised by mixing, grinding or any high mechanical shear processing, where after the cell suspension is fed through a small-diameter aperture, and the suspension is subjected to a pressure drop of at least 20 MPa and high-speed sheer action followed by a high-speed deceleration impact. The cellulose is remarkable in that a suspension thereof can easily be recreated after it has been dehydrated [215].The patent US20090221812 proposed a method for treatment of chemical pulp for the manufacturing of microfibrillated cellulose [216] which includes the following steps: a) providing a hemicellulose containing pulp, b) refining the pulp in at least one step and treating the pulp with one or more wood degrading enzymes at a relatively low enzyme dosage, and c) homogenizing the pulp thus providing the microfibrillated cellulose [217].

The super microfibrillated cellulose has an arithmetic average fibre length of 0.05 to 0.1 mm and a water retention value of at least 350%. The super microfibrillated cellulose is produced by passing a slurry of a previously beaten pulp through a rubbing apparatus having two or more grinders which are arranged so that they can be rub together to microfibrillate the pulp to obtain microfibrillated cellulose and further super microfibrillate with a high-pressure homogenizer [218].

Cellulose nanofibres extracted by a chemi-mechanical technique to examine their potential for use as reinforcement fibres in **biocomposite** applications [219].

The reinforcing potential of cellulose nanofibres obtained from agro-residues was investigated in a starch-based thermoplastic polymer. Cellulose nanofibres were isolated from wheat straw by a chemi-mechanical technique and determined to have diameters in the range of 10–80 nm and lengths of several thousand nanometers. The nanocomposites from the wheat straw nanofibres and the thermoplastic starch were prepared by the solution casting method. The tensile strength and modulus of the nanocomposite films revealed significantly enhanced properties compared to the pure thermoplastic starch [220].

A series of glycerol-plasticized starch composites reinforced by rice-husk cellulose nanocrystals was successfully fabricated through the solution casting technique. The rice husks must undergo alkali treatment, bleaching, and sulphuric acid hydrolysis before cellulose nanocrystals can be produced. The cellulose nanocrystal content was used as filler. The starch biocomposite films reinforced with rice-husk cellulose nanocrystals showed improved tensile strengths and tensile moduli. At the optimum 6% filler loading, the cellulose nanocrystals exhibited a higher reinforcing efficiency in the plasticized starch biocomposites than at any other filler loading [221].

In addition, wheat bran was used as cellulosic filler in biocomposites based on natural rubber. The impact of wheat bran content [ranging from 10 to 50 parts per hundred rubber (phr)] on processing, structure, dynamic mechanical properties, thermal properties, physico-mechanical properties and morphology of resulting biocomposites was investigated. For better characterization of interfacial interactions between natural rubber and wheat bran, achieved results were compared with properties of biocomposites filled with commercially available cellulosic fillers—wood flour and microcellulose. It was observed that wheat bran, unlike commercial cellulosic fillers, contains high amount of proteins, which act like plasticizers having profitable impact on processing, physical, thermo-mechanical and morphological properties of biocomposites. This is due to better dispersion and distribution of wheat bran particles in natural rubber, which results in reduction of stiffness and porosity of the biocomposites. The wheat bran presents interesting alternative for commercially available cellulosic fillers and could be successfully applied as a low-cost filler in polymer composites [222].

The patent US 8287691 B2 describes the production of an enhanced fibre additive (EFA). The process includes an acid treatment step and optionally at least one fibre modification step. Preferred EFA products and uses are described [223].

A woody or non-woody biomass is delignified through continuous extrusion technology, utilizing high-pressure steam to break down complex biomass materials. The process is useful to form a hydrophobic fibre material for use as an extrusion filler, a plastics modifier, and in the papermaking arts. Alternatively, the process is useful for preparing dietary **feeds for ruminant** [224] animals, as well as to produce a broad range of alcohols or polymers from lignocellulosic substrates.

Microfibrillated cellulose according literature found application in food products, paper products and coatings is provided [225].

Multifunctional surface-modified cellulose-containing fibres, especially for producing paper and cardboard **packaging** are provided with numerous specific advantages regarding production and the product. The invention particularly relates to cellulose compounds and microcomposites in which solid materials, liquids, and dispersed or amorphous additives, for example, are coated onto the surface of the cellulose, and methods for the production of said compounds.

Antibacterial activities of neat and cationized MFC from oat husk samples were investigated against Gram positive bacteria (*Bacillus subtilis, Staphylococcus aureus*) and Gram negative bacteria (*Escherichia coli*). The CATMFC sample at DS greater than 0.18 displayed promising results with antibacterial properties without any leaching of quaternary ammonium into the environment. This work proved the potential of cationic MFCs with specific DS for contact active antimicrobial surface applications in active food **packaging**, medical packaging or in health and cosmetic field [226].

Bran wastes is processed to produce useful products, such as food products and amino acids bran wastes were employed for production of **food additives** because they have a balanced fibre composition, approximately 30 to 48.5% fibre derived from the cereal group, wherein at least 10% of the total dietary fibre in the entire composition is soluble dietary fibre [06898056Balanced fibre composition].

Different patents describe methods for making pentoses and pentose-based soluble **oligo/polysaccharides** [227]. Soluble arabinoxylan, arabinoxylan-oligosaccharides, xylose, arabinose, ferulic acid and mixtures thereof were obtained mashing of at least part of said cereal bran in water optionally treatment involves the mash with any one of an enzyme preparation, an acid, a base, a peroxide or combinations thereof, either simultaneously or sequentially, to solubilize and optionally depolymerize a fraction of the arabinoxylan comprised in said cereal bran. Preferably, said treatment is done with an enzyme preparation containing an endoxylanase. The method further comprises the separation from said mash of a solubilized fraction, which comprises at least part of the solubilized soluble arabinoxylan

products. Method for making pentoses and pentose-based soluble oligo/polysaccharides from cereal grain involving debranning technology [228].
Method for Preparing Oat Husks was employed for xylan production. The xylan production from oat husk consists of a step of roughening oat husks on their surface by a roller mill, wherein the hull layer of the oat husks is partially destroyed, whereas the oat husk is essentially retained as a whole [229].
The oligo/polysaccharides from brain waste were employed as food additives for the sodium phosphate natural replacement that may be one or more natural sources of polysaccharides and/or starches (e.g., trehalose or plant-derived fibres) from cereal waste [230].

7.1.2 Ferulic acid (FA) extraction

Industrial enzymatic processes are able to hydrolyse the different molecular fractions that are present in wheat bran cell walls structures, focusing on the hydrolysis of polysaccharidic chains and phenolics cross links. The enzymatic treatment was able to solubilise up to the 30 % of the alkali extractable ferulic acid. An extraction process of the phenolic fraction of the hydrolysed wheat bran based on an adsorbtion/desorption process on styrene-polyvinyl benzene weak cation-exchange resin was developed. The extraction process developed had an overall yield of the 82% and allowed to obtain concentrated extracts containing up to 3000 ppm of ferulic acid [231, 232].
A process for extraction of ferulic acid present in an aqueous phase, obtained by treatment of brain waste, was described in patent 14892790 [233]. The process comprises different steps, a) the treatment of said plant material followed by a solid/liquid separation to recover a solid phase and an aqueous liquid phase comprising the ferulic acid and polysaccharides; b) the treatment of liquid phase to selectively separate, on the one hand, the polysaccharides and, on the other hand, the ferulic acid present in an aqueous fraction, c) the concentration of aqueous fraction containing the ferulic acid so as to recover a ferulic acid-concentrated stream, d) the recovery of the ferulic acid in solid form [234]. Ferulic acid and arabinoxylan present in cereal brans were separated by the extrusion process and the subsequent treatment with plant cell wall hydrolysing enzymes. This combined process of extrusion and enzyme treatments for cereal brans, compared to the individual treatment, significantly increased the separation efficiency of physiologically active materials in cereal brans, ferulic acid and arabinoxylan, which inherently exist as insoluble materials in the cell wall of cereal bran [235].
Also ultrasound-assisted enzymolysis wheat bran method significantly increased the separation efficiency of ferulic acid.
The patent 201310666358.3 [236] discloses an ultrasound-assisted enzymolysis wheat bran method for preparing ferulic acid, comprising the following steps: a) crushing wheat bran; b) heating wheat bran obtained in step (a) in water bath; c) removing starch in wheat bran by enzymolyzing alpha-amylase; d) removing protein in wheat bran by using alkaline protease; e) centrifugally precipitating suspending liquid, abandoning supernatant, and washing the suspending liquid with distilled water to obtain bran residue; f) drying bran residue; g. carrying out ultrasound treatment on dried wheat bran; h) carrying out enzymatic reaction on bran obtained in step (g) by xylanase; and i) centrifuging suspending liquid obtained in step (h) by enzymatic reaction, taking supernatant, after washing residue at the lower level, combining supernatant to carry out concentration and vacuum drying to obtain crude ferulic acid; dissolving the crude product in anhydrous ethanol, centrifuging to remove precipitation and obtaining transparent faint yellow supernatant, and then concentrating and drying to obtain ferulic acid crystallization with higher purity [237].
Other patent provides a method for preparing ferulic acid from wheat bran by using a two-enzyme method. Wheat bran is subjected to enzymolysis by utilizing the synergistic effect of two enzymes, so as to release ferulic acid and obtain a crude ferulic acid extract. The crude ferulic acid extract is purified by using an weal-polarity macroporous resin, and the fraction with the ferulic acid obtained from purification

is dried in vacuum so as to obtain a ferulic acid product. By adopting the method, raw materials for extracting and preparing the ferulic acid are cheap and easily available, in the product purity is high, the preparation process is simple, and the method is simple, convenient and feasible in operation, environment-friendly and applicable to industrial expansion production [238].

Biomass (which contains 3-8% of phenols) represents a substantial source of secondary chemical building blocks presently underexploited. These phenolic derivatives are currently used in ten thousands of tons to produce high cost products such as food additives and flavours (i.e. vanillin), fine chemicals (i.e. non-steroidal anti-inflammatory drugs such as ibuprofen or flurbiprofen) and polymers (i.e. poly p-vinylphenol, a photosensitive polymer for electronic and optoelectronic applications) [231].

Ferulic acid-based polymers with glycol functionality as a versatile platform for topical applications were proposed. s with aliphatic linkages The chemical structures and physical properties of ferulic acid-based polymer were shown to influence ferulic acid release rates and antioxidant activity. These polymers demonstrate the ability to strategically release ferulic acid at rates and concentrations relevant for topical applications such as skin care products. In all polymers ferulic acid release was achieved with no bioactive decomposition [239].

FA exhibits wide variety of biological activities such as antioxidant, antiinflammatory, antimicrobial, antiallergic, hepatoprotective, anticarcinogenic, antithrombotic, increase sperm viability, antiviral and vasodilatory actions, metal chelation, modulation of enzyme activity, activation of transcriptional factors, gene expression and signal transduction [240].

Ferulic acid may be converted into flavour components, particularly for a vanilla composition, directly or indirectly [241]. The crude enzymatic hydrolysed wheat bran and the concentrated extract were fused as substrate in a bioconversion process of ferulic acid into vanillin through resting cells fermentation. The bioconversion process had yields in vanillin of 60-70% within 5-6 hours of fermentation [231].

Other uses of cereal waste include the formulation of ingredients for a medium for growing fungi and the like. The patent US 20070294939 A1 provides for a formulation of a growing medium including oat hulls for the cultivating of mushroom mycelium [242].

Olive waste use

7.1.3 Animal feed, Anaerobic Digestion and Composting.

There are several limitations in use of olive processing by-products in animal feed, anaerobic digestion and as fertilizers. Only the leaves and twigs (less than 3 cm in diameter) can be distributed to ruminants, after separation of the large branches, Olive pomace contains condensed tannins. The consumption of condensed tannins by animals, has been associated with damage to the liver, kidneys and gastro-intestinal tract [243]. Even if the olive wastes contain many nutrients such as K, the direct application on soil of olive wastes produce negative effects due to low pH, and the presence of phytotoxic compounds, especially polyphenols [244]. Expensive pretreaments of wastes are necessary to employ them as fertilizers. The main limitation in use of olive waste to produce biogas is the inhibition of methanogenic bacteria by phenolic compound and the organic acids present in olive mill wastes **[**245].

7.1.4 Phenolic Compounds extraction.

Olive leaves contain many potentially bioactive compounds that may have antioxidant, anti-hypertensive, anti-inflammatory, hypoglycaemic and hypocholesterolemic properties and antimicrobial properties against some microorganisms such as bacteria, fungi, and mycoplasma. Due to these activities and valuable biophenol compounds, usage of whole olive leaf and olive leaf extract has increased rapidly in both the pharmaceutical and food industries as food additives and functional food materials. The whole leaf extract is recommended to achieve health benefits due to the presence of additive and/or synergistic effects of their phytochemicals [246].

Several techniques have been used to recover phenolic compounds from olive by-products, including enzymatic preparation, solvent extraction, supercritical fluids (supercritical CO_2) membrane separation, centrifugation, and chromatographic procedures. Khoufi et al. demonstrated that the OMWW hydrolysed with an enzymatic preparation from Aspergilus niger grown on wheat bran is a potential source of bioactive-free phenolic compounds [247]. Romero-García et. al. evaluated steam-explosion treatment was as a procedure to recover phenolic compounds from olive tree leaves [248]. While Felizón *et al.* recovered hydroxytyrosol from olive cake by steam-explosion [249]. Recently, Aludatt *et al.* optimized some parameters for extraction of phenolic compounds from olive cake and reported that the highest total phenolic compounds and antioxidant activity were achieved using methanol at 70 °C for 12 h, and proved that ethyl acetate extract of olive cake and olive wood contains low molecular weight phenols [246]. European Patent Application No. EP 0 811 678 A1 disclosed a process for extracting antioxidants from olives, in which olives are crushed, vacuum dried, and pressed to form a cake [249]. The cake is then extracted with a hot medium chain triglyceride or a C_2 to C_6 alkylene glycol at a pressure of at least 40 bar, to obtain an antioxidant-enriched extract. U.S. Pat. No. 6,361,803 to Cuomo et al. disclosed obtaining antioxidant compounds by extraction of olive oil or whole olives which have been mashed. U.S. Pat. No. 6906100 identified a method to recovery antioxidants from olive pomace [250]. PCT Publication WO 02/18310 describes methods for obtaining a hydroxytyrosol-rich composition from vegetation water comprising acidifying olive wastewater and incubating it, then fractionating to separate hydroxytyrosol [251].

7.1.5 Oligomers/monosaccharides extraction.

Olive waste derived soluble carbohydrates are interesting source of food additives**.** Soluble sugars, such as mannitol, is used as sweetener in the food industry, e.g. in diabetic people. Other potential uses like stabilizer and excipient in pharmacy are reported [252]. In addition, olive processing by-products represent a low cost nitrogen and carbon source and represent a cheap substrate to microbial growth [253]. Olive cake and olive leaves were processed by steam-explosion, followed by fractionation to separate the main components. In the water-soluble fraction, the main compounds were carbohydrates. Glucose represented a significant part of the total monosaccharide content, followed by arabinose and mannitol, but the solubilization of sugars occurred predominantly in the oligomeric fraction [248, 249]. Fernandez-Bolaños et al. developed a process that includes a hydrothermal treatment and an autohydrolysis of OMWW, for the recovery of carbohydrates of low molecular weight from the water-soluble fraction. The total mixture of oligosaccharides was mainly constituted of xylose residues and relatively small amounts of rhamnose, arabinose and glucose, representing about 23 % of the total sugars [252].

7.1.6 Other application.

Triterpenic acids are subject to demand by the food, cosmetics and pharmacology industry. Because of their antimicrobial and anti-hyperglycaemic activities, their anti-inflammatory and anti-tumour activities, they are growth stimulating factors if used in trout diets, and have a liver protection effect. Triterpenic acids, constituents of olive skin, pass to the oil due to the hydrolytic processes that take place in the olive and in the pomace. Thus, appreciable quantities of these acids are found in the pomace oils and in the virgin olive oils with an acidity above 1% [246]. Several patents proposed the recovery of triterpenic acids with low volatility from olive pomace oil by solvent [254] and by mechanical process using a second centrifugation [255].

The cell wall of olive fruit contains considerable quantities of pectic polysaccharides and hemicellulosic polymers that are rich in xylans and xyloglucans. Cell wall-derived components can also have nutritional and physiological benefits. Nondigestible oligosaccharides are usually considered to enhance the growth of bifidobacteria and lactic acid bacteria in the human large intestine, with certain evidence of a preventive effect against colon cancer and other intestinal dysfunctions. Quality evaluation revealed that this olive pectin has favourable gelling properties [251]. Olive cell wall polysaccharides recovered from olive mill by-products have been proposed as sources for several *natural polymers*, such as cellulose, gelling agents (pectins) and fat replacements. The polysaccharides are considered by their advantages in food nutritional) and even physiological terms [256, 257]. Olive cake was processed by steam-explosion, followed by fractionation to separate the main components. The constitutive polymers were quantified in the insoluble fraction, the cellulose was associated with a high proportion of xylans and other polysaccharides rich in arabinose and galactose. This cellulose was nearly amorphous, as it was highly susceptible to hydrolytic enzymes [249].

Biological conversion processes of olive oil waste into various value added products through liquid submerged and or/and solid-state fermentation (SSF) is of great interest (table 24). Nevertheless the polyphenolic fraction in all these olive waste is detrimental to microbial growth. In some cases, intensive pre-treatments (chemical, physical or biological) are needed and sometimes, it is also required a fermentation with selected microorganisms, single or mixed culture, as well as an adaptation processing. Biotechnological production of *natural aroma* as lactones from fatty acids is of great interest because there is an increasing economic interest in natural flavours. Exopolysaccharides and *β–glucan* have recently been found to have important pharmacological properties [252].

Olive oil wastes are also employed as filler in high density polyethylene *bio-composites* [258] and in (ethylene–propylene) copolymer [259]. Organic biomaterial based olive solid waste in combination with nano layered silicates are produced to realize hybrid filler for reinforceted carboxylated nitrile-butadiene rubber. The role of the olive solid waste is to promote the crosslinking reaction [260].

The main use of olive stone is in combustion to produce electric energy or heat. Other uses such as production of activated carbon, applied for removal of unwanted colours and dyes, odours, tastes or contaminants such as arsenic or aluminium, furfural production, have also been cited. Besides, this bio-mass has been reported to be used as metal bio-sorbent, and in resin formation [246].

Residues	Description process/ Biocatalyst	Products
OMWW	*Clostridium* spp. (Medium with 50 % v/v OMWW)	Butanol (2.8-8 g/L)
OMWW	*Arthobacter* spp.	Indolacetic acid.
OMWW	*Pseudomonas aeruginosa* (OMWW as the sole carbon source)	Biosurfactant: rhamnolipid
OMWW	*Propionibacterium shermanii*, on predigested OMWW with *Aspergillus niger*	Vitamin B_{12}
OMWW	Recombinant strain *Eschericha coli* P-260, by expression of the enzyme 4-HPA hydrolase of *Klebsiella pneumoniae*	Synthesis of pigments, colorants, alkaloids and polymers, which structure base is a quinone
Olive oil cake (OOC)	SSF: *Rhizomucor pusillus, R. rhizopodiformis*	Lipase (applied in bakery, pharmaceuticals)
OOC	SSF: Delignification (with four fungi), saccharification with *Trichoderma* spp. and biomass formation with *Candida utilis* and *Saccharomyces cerevisiae*.	Crude protein enriched from 5.9 to 40.3%. Source for animal fodder
OMWW	*Funalia trogii* ATCC200800 *Trametes versicolor* ATCC200801	Plant growth hormones: Gibberellic acid, abscisic acid and indolacetic acid and cytokinin
OMWW	*Xanthomonas campestry*, in a medium with OMWW (50-60% v/v)	Xanthan gum, for food and non-food applications as thickener or viscosifier
OMWW	*Paenibacillus jamilae* CP-7, in aerobic condition in a medium with OMWW (80% v/v)	Exopolysaccharide, antitumor agent with inmunomodulatory properties
OMWW	*Azotobacter chroococcum* (OMWW as the sole carbon source)	Bioplastic: Homopolymers of β-hydroxybutyrate and β-hydroxyvalerate
OMWW (undiluted)	*Botryosphaeria rhodina* mycelium growth	β-glucan β(1→3), β(1→6)
OMWW	SSF: *Panus tigrinus*, on OMWW-based media	Laccase and Mn-peroxidase with interest by ligninolytic activity
OOC	SSF: *Ceratocystis moniliforms, Moniliella suaveolens, Thichoderma harzianum*	Flavor active δ- and γ-decalactones
Alperujo	Growth of six phenotypically distinct group of yeast, by a dynamic fed-batch microcosm system	Promising fermented product
OMWW	Anaerobic fermentation to obtain volatile fatty acids, as substrate for polyhydroxyalkanoates production	Biodegradable polymers
OOC	SSF: Aspergillus oryzae	Neutral protease

Table 24 value added products obtained by bioconversion of olive oil residues.

Potato waste use

Actually, the potato processing by-products are currently used as fertilizer or animal feed. For example, PFJ may be utilized as fertilize in farming according to respective legislation [95].

7.1.7 Animal Feed.

The nutritive value of potato processing wastes (PPW) for animal feed has been studied in mixed ration for dairy cattle [261]. According to the study potato waste did not significantly affect the digestibility of crude protein or dry matter, but at 20% substitution for high moisture corn, the digestibility of acid detergent fibre as well as milk fat concentration was decreased. The direction of PPW for animal feed may be a risky option. Firstly the material as it comes out of factory has high moisture content (70-80%) which limits its value as an animal feed. Drying might prove very costly and increase significantly haulage costs. Second, the amount of protein (8%) of dry matter is considered low for animal feed even for ruminants. However this level maybe enhanced by appropriate semisolid fermentation especially with the used of edible basidiomycete strains which contain powerful lignocellulolytic enzymes. [262]. A method of producing livestock feed from potato processing waste is disclosed that uses a starch-hydrolysing enzyme, two fermenting yeasts, such as Saccharomyces cerevisiae and *Candida utilis*, and the yeast *Saccharomycopsis fibuliger*. The enzyme and yeasts are added in a particular sequence to comminuted potato waste after the potato particles have been heated and cooled to certain temperatures. [263]. Actually, raw pieces and potato pulp are commonly used for cattle feed [264].

7.1.8 Composting

Composting PPW, is a simple and easy process which could be done on site. The produced compost has a sale value of 300 €/tn. Given an estimated cost of production of 200 €/tn, for a factory producing 450 tn PPW/year the net gain from the selling of compost would be 450 tn x 100 €/tn = 45.000 €/year.

7.1.9 Anaerobic fermentation

Biogas (CH_4) production based on anaerobic digestion process may be an ideal energy replacement. Biogas fermentation is a relatively complicated process cooperated by multiple flora, which is composed of hydrolysis, acidification, enzyme digestion and methanogenesis stages in dynamic equilibrium [265]. Anaerobic fermentation for the production of biogas could be done together with the liquid (starch waste) stream and utilizing all the other wastes from the potato processing. It has the advantage that it is a simple and low cost operation and could be done in the same area *in situ*. It has been proven that for each ton of starch waste about 250 m^3 of methane is produced and 5 ton of starch waste per day minimum is necessary for a feasible application [266]. Biogas production based on waste residue in potato starch processing has been researched more: FU et al. [267] start potato residue biogas fermentation system based on reloading acclimatization method, a typical technology of mixture fermentation, the average biogas production ratio may reach 0.55L/g, much higher than multiple inoculum fermentation of 0.32L/g. Many researchers are focus on biogas production by co-digestion of potato pulp with cow manure in a continuously stirred tank reactor system, they pointed that an average energy production of 2.8 kWh $(kg)^{-1}$ was achieved and the COD removal treatments was about 61%. The energy efficiency of 92% of the process also showed the optimum control of the process [268].

Actually, many studies are focus on the possibility to recover main fractions from potato side streams, in order to produce more value added products, like fibres and proteins. The figure 18 shows the flow chart of value added products from potato residue feedstock.

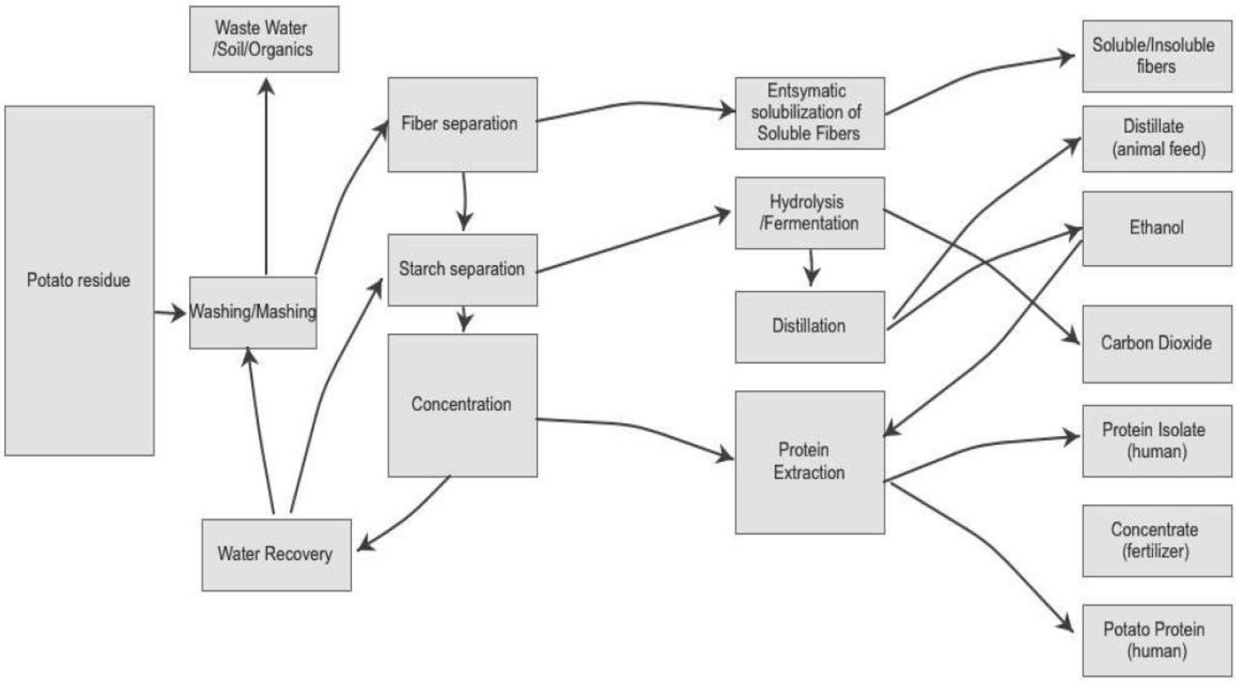

Figure 18 Flow chart of value added products from potato residue feedstock [267].

The table 25 shows the yield estimate of value added products from potato residue feedstock.

Product	Yield kg t^{-1}	Available products in market
Recovered wastewater	2,000	Process Water,
Ethanol	33[1]	Several potable vodka brands
Potato protein	10[2]	Tubermine®, PRO GO™,
Potato protein isolate	0.6[3]	Slendestra™, SUPRX™, Gly-Sea-Max™, Solathin™
Potato fiber	38[4]	Vitacel™, PENFibe®RO, Pofiber (Semper), Potex

Table 25. The yield estimate of value added products from potato residue feedstock.

1] Izmirlioglu & Demirci (2012) (33g L-1 ethanol from waste potato mash); 2] Approximate value based on Karup Kartoffelmelfabrik (2007); 3] US Patent 6414124 2002 (900 mg kg-1 potato); 4] Mayer et al. (2012) (24% by weight of the pulp dry matter).

7.1.10 Production of hight added value products through fermentation.

PPW has been shown to be a suitable feedstock for industrial fermentations, comparable to traditional substrates [269]. In particular, a sugar preparation method by using biomass sweet potato dregs for microbial fermentation as a sugar source is proposed. The liquid sugar product prepared by enzymatically hydrolyzing sweet potato waste essentially comprises glucose [270]. PPW contain sufficient quantities of starch, cellulose, hemicellulose and fermentable sugars to warrant use as an ethanol feedstock. Several patents show ethanol production by fermentation of potato peels. Ethanol production [271]. Ethanol production from corn, potato peel waste and its process development [272].

Starch is a high yield feedstock for ethanol production, but its hydrolysis is required to produce ethanol by fermentation. Starch processing is a technology utilizing and saccharification. Starch was traditionally hydrolyzed by acids e/o enzymes, amylases are commonly used as catalysts in this process (enzymatic liquefaction process), which produces a relatively clean glucose stream that is fermented to ethanol by Saccharomyces yeasts. [Ethanol production from potato peel waste (PPW)[273].

7.1.11 Extraction of fibres and proteins

Potato wastes showed to be a good source of fibre and protein. Potato peel and potato pulp wastes can be used as dietary fibre source [274]. Potato peel waste can be used in bakery production and replace up to 10% of flour amount without changes in sensory quality [275]. The quality of potato protein depends on amino acid composition and is measured using biological value, which describes the proportion of nitrogen in protein available for human consumption [276]. Potato fruit juice, contains up to 2.5% [w/w] of high-valued protein fractions that could be utilized commercially [277]. However, today the recovery of protein from the PFJ with reverse osmosis membranes results in a protein concentrate that is not suitable for human consumption. The use of ultrafiltration with additional diafiltration is able to produce a higher quality protein [278]. An extraction technology for extracting protein from potato starch processing liquid waste is proposed. The potato starch processing liquid waste is centrifugated for reducing starch content and to obtain potato protein rich liquid; heated under the steam function to enable the potato protein to agglutinate to be flocculed under heating effect, and cooled to obtain potato protein suspension. The obtained potato protein is high in purity, and any chemical substance is not added in the process, so that the protein is safe and reliable to eat [279].

7.1.12 Phenolic acids extraction.

PPW showed strong antioxidant, free radical scavenging activity, suggesting the possibility that PPW could be employed as an ingredient in health or functional foods. [280] This is due to the fact that PPW are a source of phenolic acids, especially of chlorogenic, gallic and caffeic acids. This natural antioxidant activity of PPW was also reported for retarding lipid peroxidation in radiation processed lamb meat [281]. Phenolic acids are used widely not only in food preservation and feeds but also in and packing materials for their antibacterial properties. Chlorogenic acid isomers, the main phenolic compounds in potato peels, have no strong antibacterial property but can be hydrolyzed to quinic and caffeic acids. The former is a starting material synthesizing drugs such as Oseltamivir for flue [282], and the latter shows antimicrobial activity against gram positive and game negative bacteria [283].

7.1.13 Lactic acid extraction

Lactic acid (LA) is a useful organic acid that is widely used in food, pharmaceutical, cosmetic and industrial applications [284]. The global market for LA is experiencing steady growth, and rapid development and commercialization of polylactic acid is driven by rising oil prices, strict government regulations and consumer demand for green products. Generally LA is produced through carbohydrates fermentation with bacteria and fungi. Recently with the popularizing of mixed fermentation technology, great achievement has been made in lactic acid extraction from potato peel waste. Liang et al. made research on lactic acid production from potato peel waste by anaerobic sequencing batch fermentation using undefined mixed cultures [285]. They illustrated that lactic acid could be produced successfully by anaerobic fermentation with undefined mixed cultures in a sequencing batch bioreactor. Fermentation with gelatinized potato peel waste generated a significantly higher yield of lactic acid than that of feeding with un-gelatinized one [286].

7.1.14 Extraction of steroidal alkaloids.

Utilization of potato solid waste in particular potato peel for the extraction of steroidal alkaloids open the way for a new phyto-pharmaceutical industry. Extraction choice for gylcoalkaloids from potato peels waste, which can be scaled up to industrial level, request obvious improvement in extraction efficiency.

Ultrasonic technology improves the extraction efficiency, but cost increase brought by strict operation and complicated process still needs a solution [287].
The conventional application of potato peel and pulp are listed in table 26 and 27.

ethanol, lactic acid and enzyme (α-amylase and β-mannanase) production through fermentation
phenol extraction, used as antioxidant in food systems. It can prevent lipid oxidation in oils and meat
base for fermentation reactions because of high starch content, but due to its low fermentable reducing sugar content, requires initial hydrolysis of carbohydrates
in healthy and functional food production as dietary fibre source

Table 26 The conventional application of potato peel waste [288].

Treatment/Product	Application
Pulp supplemented by potato proteins or other nitrogen-containing components (wet or partially dried and pelleted)	Cattle feed
Preparation of pectin or pectin-starch mixtures	Nutritional and technical applications
Conversion into sugars and extraction of a syrup	Treatment of potato chips and pommes fries
Hydrolysis for substrates used in fermentation	Alcohol production
Extraction of nitrogen-containing components from the liquid phase	Fertilizer
Dilution with water	Stabilizing factor in deep drilling (lubricant)
Untreated, substrate for growth of yeast	Vitamin B_{12} production
Untreated, component of growth substrate	Biogas production

Table 27 The conventional application of potato pulp waste [289].

7.1.15 Other applications.

Carbohydrate materials, and in particular starches, are well known for use as components in adhesive compositions such as corrugating adhesives for paper and paperboard. A particularly useful corrugating adhesive comprises starch which is cooked in the presence of borax and caustic carbonate or other minerals. [U.S. Patent No. 5,385,764 and Anderson et al., U.S. Patent No. 5,545,450]. In addition packaging and structural materials comprising potato peel waste are proposed. The invention provides adhesive and binder compositions comprising a potato peel product characterized on a dry solids basis by at least 30% starch, at least 5% protein and at least 2% fibres [290]. Other achievements such as value added utilization of potato peel are biocomposites reinforced with cellulose nanocrystals [288].
Potato peel waste can be employed as a basis for edible film production. Tammineni et al. develop of antimicrobial potato peel waste-based edible films with oregano essential oil to inhibit Listeria monocytogenes on cold-smoked salmon [291]. Potato waste particle, flake and/or fibre material from potato processing Green reinforced composite materials were treated with a coupling agent and blended with a matrix material to form reinforced composite material [292].

Potato peels are used for the aroma recovery process [293]: the result indicated that a total of seventy-five compounds from Ipomoea batatas, eighteen odour-active compounds were identified. The process for producing a potato flavor concentrate comprises the steps of heating a potato material; extracting the browned potato material with a solvent; purification with a cation-exchange resin, and eluting the adsorbed flavouring compounds from the resin by means of a suitable solvent [294]. Potato wastes are used also in biotechnological field. A semi-solid filter cake waste product from potato processing is used as a growth medium for producing single-cell protein [295]. A method for the aerobic production of xanthan by bacteria of the genus *Xanthomonas* on a solid or semi-solid substrate made of potato waste is proposed [296].

8. Available storage conditions

The problem usually encountered with agro by-products is seasonality of supply. The availability of seasonal raw materials should be ensured by optimal storage conditions and technologies.

Restrictions and practices on the storage of AFPW

There are some restrictions on the storage of some by-products of food industries or crops residues.

For example, olive mill wastewater (OMWW) properties may vary during storage because of the sedimentation process of the in-soluble fraction, the transformation of the organic matter carried out by microorganisms and the evaporation of the water fraction. Specifically, the concentration of easily fermentable organic compounds is decreased thanks to the action of decomposing microorganisms, pH normally increases, BOD5 and the quantity of suspended solids decrease.

Spreading the olive waste, in particular olive husk and wastewater from olive oil extraction process on farm lands and storing the wastewater in anaerobic ponds causes enormous pollution to the land and air, such as odour and ammonia released into the atmosphere and leaching of nitrates and other pollutants into the ground water. From a microbiological point of view OMWW contain mainly bacteria (mostly cellulolitic and not nitrificant) but also yeasts and fungi. Despite the absence of toxic compounds or pathogens, OMWW can cause serious problems, especially to waters, because of their low pH values and their high content in salts and organic matter [297]. The introduction of olive solid and liquid waste into soil tends to increase the average diameter of the soil aggregates, bulk density and slows down hydraulic conductivity. Polyphenols in olive husk are well known to affect nitrification in the soil and have deleterious effect on soil microbial activity. The high C:N ratio and low pH in the olive husk are also known to immobilise nitrogen in the soil [298].

For these reasons, some countries have a special legislative acts for olive waste disposal and also indications for temporary storage. Of particular interest is the case of Cyprus. Cyprus Ordinance No. 254/2003 of 1st November 2004 on Water Pollution Control indicates that liquid wastes should be temporarily stored in waterproof sealed tanks. Sludge should be temporarily stored in a covered area with concrete base (platform). Liquids originating from leakages or run-offs from the temporary storage areas for the solid wastes or sludge should be collected and transferred to the liquid wastes tanks, via open-air waterproof pipes. Italy is the first European country that has in 1996 established a specific law for the disposal of mill wastes on soil. This law shall ensure that the spread of moderate quantities of olive mill wastes on soils does not cause damages to crops nor does it modify key soil properties or the micro flora composition for more than few months. For these reasons, olive mill wastewaters could be used for olive oil trees irrigation in Italy. The Italian olive oil producers (using a 3-phase extraction system) separate the produced wastes into waste water and husks. They use two different tanks at the end of the production system, one for wastewater and one for husks to recovery these by-products, for example (figure 19) [297].

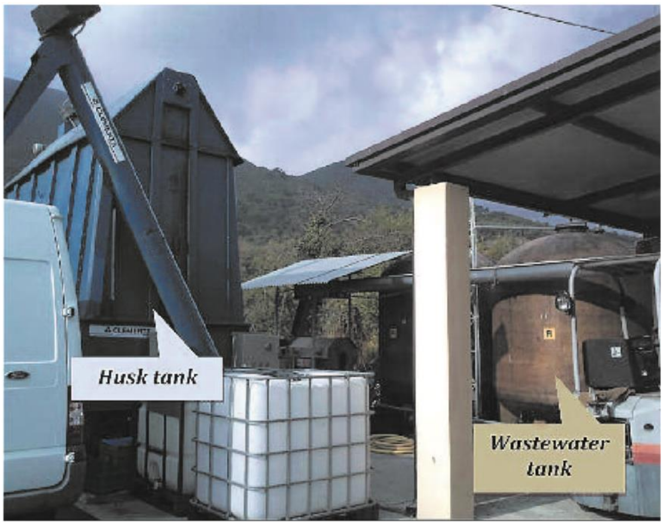

Figure 19 Tanks for the collection of olive processing by-products at the end of production system.

The effects of different prestorage drying treatments of Olive Mill Waste on phenol content and antioxidant capacity were assessed by several studies [300]. Using the two-phase system, both malaxation time and temperature affected the phenol content and antioxidant capacity of olive waste. Air drying and drying at 60°C resulted in a substantial decrease in the phenol content and antioxidant capacity. Drying at 105°C and freeze drying produced less degradation. The phenol content and antioxidant capacity of OMW stored at 4°C were monitored for 30 days and compared with those of OMW stored at room temperature. None of these storage conditions could prevent the rapid decrease in phenolic concentrations and antioxidant capacity, which happened within the first 24 h.

The potato processing by-product should be dumped onto a cement pad and protected or from the weather as much as possible.

The spreading of some vegetables (such as cull potatoes) on frozen land during the winter is permitted under the following conditions:

• all potatoes must be spread evenly on a field to ensure freezing. Potatoes must not be dumped in piles.

• areas subject to application of potatoes must be at least 150 metres away from any dwelling occupied by persons other than the person owning and/or disposing of the potatoes. Spreading is not permitted within 15 metres of the edge of a public highway right of way.

• sections of farm fields subject to application must be at least 37 metres from any watercourse where slopes average 2-5%, and 107 metres where slopes average 5-10%. Potatoes should not be spread on slopes greater than 10%.

• maximum application rates should not be more than 10 tonnes/acre.

• wash line sediment is removed from settling ponds and spread on land.

The storage of potato waste with a high strach content is more difficult. The starch is broken down a simple sugars by enzymatic and microbial action. This produce acids and CO_2. For example, the total bacteria counts of fresh filter cake (60-75% starch) range from 1 to 10 million/g in fresh samples and multiply rapidly during the storage. Certain species of bacteria and molds produce toxins during growth.

Potato peels waste is the residue from potato peeling operations which use a sodium hydroxide dip followed by mechanical action to remove the peel from potatoes. Lye peel is very alkaline (pH 12-14), when stored it is quite stable microbiologically as long as the pH remains high [301].

Storage of agro by-products with high moisture content.

The Environment Agency of England gives several outlines regarding the requirements for storing food waste, including liquid waste, away from where it is produced without an environmental permit [302].
According to this general rules collection, the temporary storage of food waste for the purpose of bulking up prior to recovery at another location is permitted at any place, using a secure **weatherproof container(s)** on an **impermeable pavement** which is provided with a sealed drainage system or spillage plan (figure 20).

Figure 20 Impermeable soil cover.

The problem usually encountered with storage of agro by-products is their high moisture content. The strategy for using this waste would be to convert it into a modified dry form that could be stored as flour and be suitable for various applications. The **drying** operation is a method by which free water is extracted from the food, which directly contributes to stability, both microbiologically and in terms of deteriorative enzymatic reactions such as browning and rancidity. By decreasing the water content, these reactions are decelerated, if not avoided, ensuring longer shelf life to the product. In industrial countries, there are well-developed technologies for recovering by-products and converting them in dehydrated products. But, the dehydration increases cost: between 250 and 300 litres of fuel and 200 kWh of electricity are required to produce 1 t of dry product (88 - 90% DM).
For example, potato pulp waste (PPW) is one type of waste with a high water content. There are studies aimed to understand the kinetics of the drying process of PPW under various experimental conditions (temperatures from 50 to 70 °C and air flow from 0.06 to 0.092 $m^3\ m^{-2}\ s^{-1}$). The results revealed that temperature and air velocity are important parameters to reduce PPW drying time [303].

The silage: conservation of by-products

Research has shown that the **ensiling** of by-products is the most suitable method of conservation for long periods [303] and it is an appropriate method of conservation in particular in small-scale farmers.
The basic principles of silage making from by-products are the same as for silage-making from green forage, so attention must be paid first to ensuring anaerobic conditions, i.e. the by-products must be stored under airtight conditions at all times, and, second, there must be sufficient natural acid in the silage to restrict the activities of undesirable bacteria (for this the ensiled material must be sufficiently rich in carbohydrates).

In order to achieve a successful ensiling of by-products, the following parameters require very careful attention:

- *Moisture content* Ensiled material should contain more than 50% moisture so that it is easy to compress it tightly in order to obtain good compaction and to eliminate air. However, excessive moisture, more than 75%, can also be harmful, leading to an undesirable fermentation in later phases.
- *Length of chopping* The finer the chopping, the better the compaction and therefore the more successful the storage, due to the effective exclusion of air.
- *The time it takes to fill a silo* The rapid filling and sealing of the silo is very important because slow filling or delayed covering can easily increase feed losses due to extended aerobic fermentation.
- *Presence of enough easily fermentable energy (naturally present or added)* The major objective in silage fermentation is to achieve a stable low pH at which biological activity virtually ceases. In this way preservation is obtained whilst minimizing nutrient losses and avoiding adverse changes in the chemical composition of the material. The final pH of the ensiled by-product depends largely on the carbohydrate content in the original materials.

The technique of silage making from by-products was extensively described by Kayouli and Lee [305]. The silage can be stored in stacked layers, packed in succession on a soil surface that has been covered beforehand with a plastic sheet. This heap, once finished, is then tightly covered with plastic sheets, pressed down by some heavy objects, which are placed on top.

The main advantages of silage are:

- it can be efficiently used for strategic off-season feeding;
- reduces significantly toxic substances present in some fresh vegetables to safe level concentrations and destroys harmful micro-organisms possibly present

Silage can be suitably preserved for as long as air is kept away from the ensiled material [306] and it is suitable for many crops residue and industrial by-products.

Leaves, root crops, and pseudostems (trunks) can be chopped and ensiled. The use of chopped and ensiled pseudostems is particularly recommended when the bunch has been harvested and plants are cut down; the large quantity of trunks available at harvest time can be safely preserved through a well-planned silage operation.

Wet pulps waste and leaves are potential feed resources. The most suitable method for conserving these materials is to ensile them with the aforementioned ingredients, to ensure good fermentation and enhance the silage quality with their high sugar concentration.

The ensiling of wheat bran, is a simple and appropriate method of conservation. Tomato processing residues becomes sour and mouldy rapidly because it is traditionally processed during summer and has a high moisture content of approximately 80-84%. Consequently, it is advisable to ensile tomato pulp in alternate layers with dry by-products (such as chopped straw) or other impermeable covers, so that the liquid effluent is absorbed and used. Good-quality silages made from such combinations are successfully used by small farmers in Tunisia.

Usually, crude olive cake stored in heaps or tanks next to the processing plant deteriorates quickly because of its high lipid concentration - between 10 and 14%. The ensiling technique of fresh olive cake was tried ten years ago, in Tunisia, and then successfully adopted by many smallholders in the vicinity of olive oil processing plants.

Plastics silage bags (large sacks made from polythene) (figure 21) are an economical alternative to traditional silage storage systems, such as pits and silos. They provide a very effective low cost storage for many products, such as crimped cereals, wholecrop silage, chopped maize, chopped grass, brewers grain, sugar beet pulp, tomato waste, that need to be preserved in a clean anaerobic environment. The anaerobic environment that is created eliminates spoilage from the growth of yeasts, molds and adverse bacteria while maintaining essential physicochemical properties. Allows farmers to store silage anywhere they need it. The silage is completely sealed in the bag. This means that all the acid is retained in the silage, unlke that in pit silage when it seeps out through the bottom of the pit as effluent. Ensiling in a bag avoids the hard work of having to remove silage, as it has to be from a pit, when it has to be dug out every day.

There are a few disadvantages to using silage bags. Among them are: the importance of pest control to prevent damage on the bags, containment and disposal of the plastic, once silage is removed from the bag, the need to chop the green mass, as chopped material tends to make much better silage, because more air can be squeezed out of it during the packing process, and the small pieces cannot puncture the bag . Most loses of silage during the process occur due to: seepage losses when dry matter is less than 32 %; unnoticed bird/rodent damage to the bags resulting in spoilage loss; too wet (gaseous/seepage losses) or too dry silage (spoilage).

There are several bagging machines currently available. The Roto-Press (figure 21) is the fastest bagging machine on the market. The bagging capacity per hour is dependent on the power applied and the type, density and moisture content of the product being bagged It is capable of bagging up to 80 -130 tonnes per hour with a maximum power requirement of 140-260hp at 1,000 rpm

Figure 21 Plastics silage bags made by Roto-Press [307].

9. Conclusions

This deliverable has presented a complete examination of agricultural and food waste deriving from tomato, cereals, olive and potato cultivation and processing.

The data presented in the general mapping of the volumes, of the European geographical areas of cultivation and production and seasonal availability of the starting product from which the AFPW derive, proved that all the products that will be treated in Agrimax project are cultivated and processed in Europe in huge quantities, for example for cereals and olive Europe are the biggest global producers. With its 58 million hectares, cereals were the main crops grown in the EU-28 in 2014, and wheat production in Europe represents 29% of global wheat production. Instead for olive, the European Union accounts for some 70% of the world's olive production, from about 1.9 million olive growing farms.

The periodicity of the product is different, for some product in summer, for other in winter, but in this way the availability of the waste can cover the all duration of year.

The principal industrial transformation processes of the starting products from which the AFPW derive have been presented and briefly analysed; the main phases identified, in the different industrial processes, have been washing, cooling, peeling, blanching, grinding and cutting, milling, centrifugation, in some cases also fermentation and high temperature pretreatments, such as pasteurization and sterilization were identified.

The industrial processes could influence the composition of waste, however the information about this subject are very few in literature, more news are referred to how some industrial process can influence the composition of food, such as the vitamin content, which can decrease after thermal treatment for example.

As regarding the feedstocks waste availability, the data found in literature present a great variability and the amount of the waste produced was not always easy to find, the data depended on which type of waste they referred to and they may need an interpretation to understand the real amount of waste produced from each product. Moreover the amount of the residue can depend on type of transformations, on the nature state of the starting products, on type of waste considered for the amount of residues. The questionnaires that were prepared for the survey and distributed among partners, have represented a valid help in completing the data and confirmed the global vision found in the literature. From the data found both in literature and in the survey carried out, it is highlighted that the waste produced each year are quantitatively significant and they can represent a source of different compounds, bio-active molecule and active ingredients.

The chemical composition of selected AFPW is described in detail in the deliverable. The AFPW fractions examined are tomato waste (tomato plant and the industrial processing by-products), cereal waste (wheat bran, oat hulls, oat mill fed, oat bran), olive waste (olive cake, two-phase olive mill waste, olive mill wastewater, olive stone and olive leaves), potato processing by-products (raw pieces and pulp, potato starch waste and peels).

The AFPW actually are employed in several fields: animal feed, anaerobic digestion, composting and as feedstock for the extraction of chemicals. The analysis has highlighted that from the different fractions of AFPW is possible to obtain compounds, which can find applications in different fields (food additives, bioplastics, composites, aroma, etc.).

The examination showed that different storage methods existed, which allow to overcome the problem of seasonality. The storage method should be suitable to the physical-chemical features (humidity degree, gaseous/seepage losses, etc.) of each raw material. For example, agro by-products with high moisture content (potato fruit juice and potato pulp) could be kept in weatherproof containers or impermeable pavement provided with a sealed drainage system or spillage plan. Olive leaves and tomato stems can be chopped and ensiled. Plastics silage bags are suitable for the tomato and potato peels conservation.

In conclusion the investigation performed in this deliverable on the AFPW, confirmed the technologic and economic interest in the valorization of tomato, olive, potato, brain and oat coproducts and by-products at European and global level.

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Annex I

Questionnaire for crop producers:

H2020-BBI-PPP-2015-2-1
BBI.VC3.D5-2015 - Valorisation of agricultural residues and side streams from the agro-food industry.

Questionnaire

Project Title:
Agri and food waste valorisation co-ops based on flexible multi-feedstocks biorefinery processing technologies for new high added value applications

Acronym:
AgriMax

Grant Agreement No:
720719

Company Data:

Administration questions (free text)
a) Name of company: ____
b) Company's sector of activity*: ____________________________________
c) Address: ____
d) Country*:____
e) Telephone: ____
f) Contact person: ____
g) Position: ____
h) Email: ____

*Required fields

Number of employees: < 5 ☐ 5-10 ☐ 10-20 ☐ > 20 ☐

Questions:

1 What kind of vegetable does your farm cultivate?

	YES	NO
Tomato	☐	☐
Cereals	☐	☐
Olive	☐	☐
Potato	☐	☐

____

2 How many hectares are cultivated in your farm? What is the productivity per hectare of land?

	Area cultivated (ha)	Productivity for hectare (%)
Tomato	____________	____________
Cereals	____________	____________
Olive	____________	____________
Potato	____________	____________

____

3 Which are the areas of production?

	Mediterranean area	Central Europe	Extra-European area
Tomato	☐	☐	☐
Cereals	☐	☐	☐
Olive	☐	☐	☐
Potato	☐	☐	☐

____

4 What percentage of residue / by-products is produced by your farm? Please indicate the number of by-products per input, its physical state (solid/liquid) and the percentage. In case your residue / by-products are affected by seasonality, please indicate their availability.

Tomato
- Number of by-products per input ________________________________
- Physical state (solid/liquid) ________________________________
- Percentage ________________________________
- Months of production ________________________________

Cereals
- Number of by-products per input ________________________________
- Physical state (solid/liquid) ________________________________
- Percentage ________________________________
- Months of production ________________________________

Olive
- Number of by-products per input ________________________________
- Physical state (solid/liquid) ________________________________
- Percentage ________________________________
- Months of production ________________________________

Potato
- Number of by-products per input ________________________________
- Physical state (solid/liquid) ________________________________
- Percentage ________________________________
- Months of production ________________________________

5 Please specify the type of by-products from vegetable obtained by your farm.

Type of waste:	vegetable	amount per ton of vegetable
☐ Waste Water	________	____________________

☐ Cull vegetables ______ ____________
☐ Muddy/earth and leaves residues ______ ____________
☐ Non compliant product ______ ____________

☐ Other ______ ____________

____

6 Please, indicate the composition or by-products, if it is known, or describe the main characteristics.

____
____
____

7 Please, specify the storage conditions of the residue / by-products, if they are stored by your farm.

____
____
____

8 What is the actual destination of your by-products?

	Animal Feed	Land spreading	Incineration	Composting	Anaerobic digestion
Tomato	☐	☐	☐	☐	☐
Cereals	☐	☐	☐	☐	☐
Olive	☐	☐	☐	☐	☐
Potato	☐	☐	☐	☐	☐

____

9 Does your farm spend money for by-product disposal?

NO ☐

YES ☐ If yes, which is the annual cost per ton?

<1€	between 1-5€	>5€
☐	☐	☐

Annex II

Questionnaire for crop processing companies:

H2020-BBI-PPP-2015-2-1
BBI.VC3.D5-2015 - Valorisation of agricultural residues and side streams from the agro-food industry.

Questionnaire

Project Title:
Agri and food waste valorisation co-ops based on flexible multi-feedstocks biorefinery processing technologies for new high added value applications

Acronym:
AgriMax

Grant Agreement No:
720719

Agri and food waste valorisation co-ops based on flexible multi-feedstocks biorefinery processing technology for new high added value applications

AGRIMAX is a 4 year R&D Project that is being funded by the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme. The AGRIMAX consortium is composed of 29 partners from 11 European countries (Austria, Belgium, Hungary, Ireland, Israel, Italy, the Netherlands, Norway, Slovenia, Spain, United Kingdom): 12 SMEs, 4 of which are clusters, 11 research centers, 7 of which are associated BBI member and 6 large enterprises. AGRIMAX targets the use and valorization of Agricultural and Food Processing Wastes (AFPW) that are not currently valorized by combining affordable and flexible processing technologies (ultrasounds and solvent extraction, filtration, thermal and enzymatic treatments) for the valorization of side streams from the horticultural culture and food processing industry to be used in a cooperative approach by local stakeholders.

AGRIMAX objectives: AGRIMAX targets the use and valorisation of Agricultural and Food Processing Waste.
The Purpose of this questionnaire is to gather the information and experiences of agricultural and food processing companies. The information gathered by way of this questionnaire shall serve as the research for valorise the use of AFPW.

Confidentiality:
Although this questionnaire requests your company name and other specific information this is only for our purposes and will not be passed on to third parties or attributed directly in any public way.
All individual responses will remain strictly confidential with the data combined to provide an aggregate indication of the status of the food industry.
Please read all questions thoroughly.

Company Data:

Administration questions (free text)
a) Name of company: ____
b) Company's sector of activity*: ____________________________________
c) Address: ____
d) Country*:____
e) Telephone: ____
f) Contact person: ____
g) Position: ____
h) Email: ____

*Required fields

Number of employees:	<100	100-250	250-500	>500
	☐	☐	☐	☐

Questions:

1 What kind of vegetable does your company process?

	YES	NO
Tomato	☐	☐
Cereals	☐	☐
Olive	☐	☐
Potato	☐	☐

____

2 How many vegetables does your company process per year (average of the last three years)?

	< 100 tons	> 1.000 tons	>10.000 tons
TOTAL	☐	☐	☐
Tomato	☐	☐	☐

Cereals	☐	☐	☐
Olive	☐	☐	☐
Potato	☐	☐	☐

____

3 Which are the areas of production of the vegetable you process?

	Mediterranean area	Central Europe	Extra-European area
Tomato	☐	☐	☐
Cereals	☐	☐	☐
Olive	☐	☐	☐
Potato	☐	☐	☐

____

4 What percentage of residue / by-products is produced by your farm? Please indicate the number of by-products per input, its physical state (solid/liquid) and the percentage. In case your residue / by-products are affected by seasonality, please indicate their availability.

Tomato
- Number of by-products per input ____________________
- Physical state (solid/liquid) ____________________
- Percentage ____________________
- Months of production ____________________

Cereals
- Number of by-products per input ____________________
- Physical state (solid/liquid) ____________________
- Percentage ____________________
- Months of production ____________________

Olive
- Number of by-products per input ____________________
- Physical state (solid/liquid) ____________________
- Percentage ____________________
- Months of production ____________________

Potato Number of by-products per input ________________________________
Physical state (solid/liquid) ________________________________
Percentage ________________________________
Months of production ________________________________

5 During the processing of the vegetable, is there any transformation that affect the composition or chrematistics of the by-product? If yes which transformation?

NO ☐ YES ☐ If yes which: Temperature ☐

Grinding ☐

Peeling ☐

Solvent ☐

Separation techniques ☐

Other ☐

6 **Please specify the type of by-products from vegetable obtained by your farm.**

Type of waste:	vegetable	amount per ton of vegetable
☐ Waste Water	_______	_________________
☐ Cull vegetables	_______	_________________
☐ Typical waste (peels, pulpe, seeds…)	_______	_________________
☐ Muddy/earth and leaves residues	_______	_________________
☐ Non compliant product	_______	_________________
☐ Other	_______	_________________

____

7 **Please, indicate the composition of by-products, if it is known, or describe the main characteristics.**

___

___

___

8 **Please, specify the storage conditions of the by-products, if they are stored by your company.**

___

___

___

9 **What is the actual destination of your by-products?**

	Animal Feed	Land spreading	Incineration	Composting	Anaerobic digestion
Tomato	☐	☐	☐	☐	☐
Cereals	☐	☐	☐	☐	☐
Olive	☐	☐	☐	☐	☐
Potato	☐	☐	☐	☐	☐

___

10 **Does your company spend money for by-product disposal?**

NO ☐

YES ☐ If yes, which is the annual cost per ton?

<1€	between 1-5€	>5€
☐	☐	☐