UNIVERSITY OF SOUTHERN DENMARK

The Faculty of Engineering

MSc in Environmental Engineering

Efficiency and techno-economic analysis of the EU tomato supply chain

Supervisor: Prof. Gang Liu

Author: Alberto Zicari

Academic Year 2018/2019

Table of contents

List of tables

List of figures

1. Abstract

Everyone agrees about the fact that globalization changed our life. There are both many positive and negative sides about the new globalized world in which we are living since the early nineties.

One of the most positive one for us consumers, is the possibility to have access to a large variety and quantity of goods which are relatively safe and more or less cheap.

Let's just think about food: For thousands of years the scarcity of food has been one of the biggest concern of the mankind and now we have access to all kind of food, coming from everywhere in the world, anytime we want. But is this all so good as it appears? What are the socio-economic and environmental implications of it? The target of this thesis is to explore the EU tomato supply chain with all its implications.
How does this chain appear? What are the main stages? How do they work and how are they connected together? What is the role of the trade inside and outside the EU? What are the environmental and socio-economic consequences of food waste? Is it possible to optimize the chain reducing the food waste and the inequalities? What are the possible scenarios? What is waiting for us in the nearly future?

Thanks to the precious work of Prof. Gang Liu and his team, an advanced MFA about tomatoes in the EU has been realized. This work shows all the paths that both raw and processed tomatoes follow from the field to our table. This work was then combined with an economic analysis which mainly focused on the biggest producers tomatoes in the EU: Italy, France, Spain, Netherlands. This was made in order to try to quantify the economic cost of all the food waste which is related to tomato and tomato-based processed products. The social situation of the tomato industry was explored as well with a particular attention on the Italian issue of "caporalato" and on this basis, the tomato industry in the EU seems to be quite impactive and far to be sustainable.

This thesis can be the basis for a wider study about all the food industry both in the EU and outside. Further studies are necessary in order to cover data gaps. Future studies have to be done about the "transportation stage" in order to understand the environmental and the social impact of this phase considering that at the moment the availability of data is not even close to be good enough to develop a reliably strong system.

(Fig.1:[o] Tomatoes: one of the most important vegetables in agriculture)[1]

1.1. Goals of the thesis

The first goal of the thesis is to give a general understanding about tomatoes (cultivation, description diseases, history, nutrition, curiosities, recipes, production, market and trade); about tomato-based products (canned tomatoes, ketchup, tomato paste, tomato powder, tomato flakes, tomato juice, tomato sauce) and about the EU tomato supply chain, investigating what are the main stages and the main processes involved in it, how they are structured, how they are connected, and how they work.

The second goal of the thesis is both to show the patterns and the tomato flows in the EU trade-linked tomato supply chain and to assess the efficiency of this chain with a particular focus on the economic value of the food waste which is generated at every stage of the chain (production stage, processing stage, distribution stage, retailing stage, consumption stage). If the economic point of view is the main focus, it is also true that the social and the environmental impacts of the tomato industry are also investigated.

The third and last goal of the thesis is to try to give several interpretations to the results obtained and to make a general discussion about the present situation of the EU tomato industry. This is also done through the development of some scenarios about the waste handling and suggesting some solutions which may be useful in order to improve the socioeconomic and environmental efficiency of the tomato supply chain. Furthermore, the sources of uncertainty are analysed and investigated also through a sensitivity analysis.

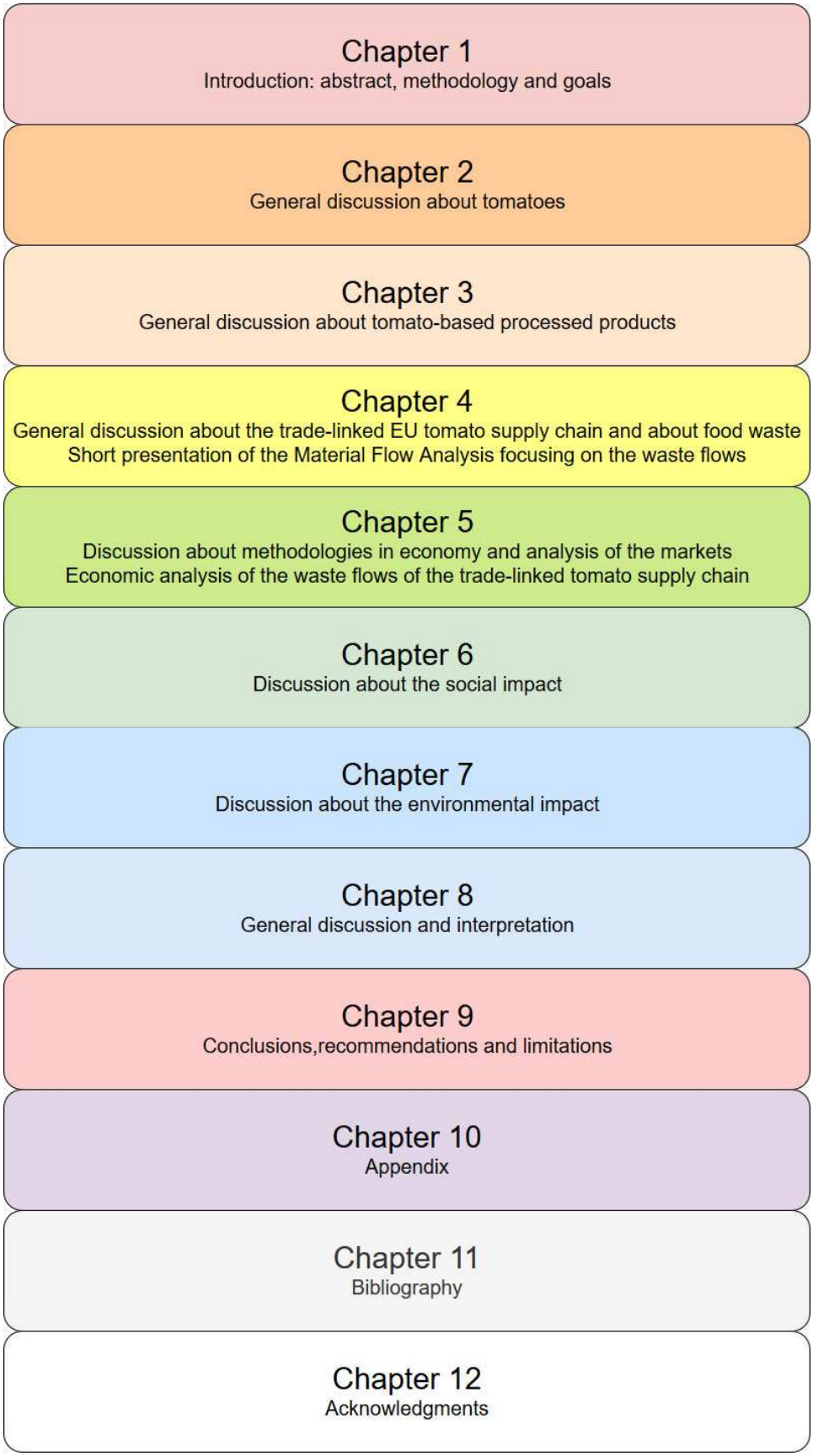
1.2. Methodology and data sources

The first part of the thesis (chapters 2 and 3), tries to give a general understanding about both the fresh and the processed products and it is based mainly on secondary data. When possible, the most recent data were used and apart from very few exemption (such as “Fruit and vegetable juice processing technology Tressler, Joslyn, 1971 Avi Pub. Co.”) all the literature and all the data which were taken in consideration, are not older than five years (with most of them not older than three). Data from international accredited agencies (such as FAO, Eurostat, European Commission and so on) were preferred and when not available, data from national agencies were used. Publications, researches and reliable internet sources were taken in consideration in order to complete the task. No assumption and no relevant data gaps were found out in this part which was basically carried out through a critical study and a further development of a mix of notions coming partly from literature and partly from some previous knowledge of the topic which was acquired during the studies at SDU (especially during the lectures of Material Flow Analysis).

The second part of the thesis (chapters 4, 5 and 6), was developed taking the food waste mass-related data from “Integration of LCC and LCA results to higher system levels: The German meat and EU tomato cases” written by Li Xue, Zhi Cao, Neele Prass, Gang Liu, Sebastian Gollnow, Jennifer Davis, Silvia Scherhaufer, Karin Östergren, Fabio De Menna, Laura García Herrero, Matteo Vittuari; and the economic-related data again from several sources (FAOSTAT, European Commission reports, dedicated researches and studies and reliable internet sources). The comparison of the most used ways to perform an economic analysis has been carried out through an investigation of the available dedicated literature while several market-based researches were made in order to find some data which was not possible to obtain in any other way. Some assumptions were made and some data gaps were found (these will be furtherly investigated later on). The prior knowledge acquired during the lectures of Life Cycle Assessment, Global Sustainability and Business and Economics can be considered the main tools which was used in order to complete the task properly.

The third and last part of the thesis includes the interpretations of the results and the general discussion. It has been carried out without any potential conflicts of interest and in the most possible objective way.

1.3. Scheme of the thesis



(Fig.2: Introductive scheme of the Master Thesis)

2. Introduction: the raw product

The tomato is the edible part of the plant known as Solanum Lycopersicum.[1] It can be eaten both cooked and raw (mainly but not only served in salads). It is also used in the production of paste, sauces and juices or processed in order to be dried, canned etc.

In 1753, the botanist Carl Linnaeus classified tomatoes as "Solanum lycopersicum" while in 1768, the Scottish botanist Philip Miller classified it as "Lycopersicon esculentum". Anyway today, thanks to genetic science, we know that Linnaeus was the correct one and so "Solanum lycopersicum" is considered to be without any doubt the right botanical classification for tomatoes.[2]

The word "tomato" comes from the Spanish word "tomate" which comes from the word "tomatl" which means "the swelling fruit"[3] in Nahuatl language (Nahuatl is a language belonging to the Uto-Aztecan language family which is nowadays spoken by about 2 million people living in the central area of Mexico).

Technically, tomatoes are fruits also if they are commonly considered vegetables due to their low sugar content (it happens for pumpkins, cucumbers, eggplants, zucchini and bell peppers as well).

Tomatoes are one of the most important vegetables in agriculture in fact they represent the 16% of the total consumption of vegetables worldwide (19% in the EU). Furthermore, the production of tomatoes has been grown of 49% between 2000 and 2013 and it's still growing.[4]

2.1. Cultivation

Tomatoes do not self-pollinate themselves enough so the pollination occurs due to the natural action of the insects or due to artificial systems (vibration, artificial wind or cultured insects)[5] and that's because the anthers which are tube-shaped don't release the pollen as long as a vibration doesn't hit the anther itself (due to the fact that most of the pollen lies inside the tube and not on the surface of it).

After the pollination, the formation of the fruit can be observed. The fruit originated itself due to the meiosis process in which ovules and nuclei from pollen merge and develop a zygote first and embryo after. The maturation of the ovary (which occurs after several fertilizations) leads to the formation of the fruit.

Tomatoes are often cultivated in open fields in Mediterranean countries (such as Italy, Spain, Portugal, Greece etc.) but they can also be cultivated in greenhouses where the weather is colder (for example in The Netherlands) with a yield which appear to be much higher. Hydroponic techniques can be used as well.

Tomatoes are usually harvested green in order to make the storage and the transportation easy and then, ethylene is often used due to its property to begin the ripening process.[6] The harvesting season lasts around 14 weeks and the harvesting itself may occur manually or with the auxilium of machines.

The overall yield for tomatoes in 2012 has been 33.7 tonnes per hectare (161.8 million tonnes of production/4.8 million hectares used for tomatoes = 33.7 t/ha). Of course, this yield varies a lot between the tomatoes cultivated in open fields and those which are cultivated in greenhouses. The most productive farms in EU/EEA countries in 2012 have been:[7]

- **Iceland:** 429 t/ha
- **Kingdom of Belgium:** 463 t/ha
- **Netherlands:** 476 t/ha

2.2. Description

Plants of tomatoes are dicotyledons vines which grow between 100 and 180 centimetres. Most of them are annual but some of them can survive for about three years in greenhouses under certain conditions.[8]
The leaves are odd pinnate, between 10 and 25 centimetres long while the flowers, which can hardly ever be self-fertilizing, are yellow and about 2 centimetres long. The fruit is a berry which contains seeds.
Nowadays several varieties of tomatoes are available on the market. They are really different in size (very small, small, medium-sized, big), shape (pear, oval, oblong, round, flat and so on), colour (red, yellow, orange, green, pink, blue, black, brown) consistency, number of seeds, taste and odour. Some of them are:

1) Tomberries tomatoes: very small (1 to 2 g), red or yellow.
2) Strawberries tomatoes: small, round, sweet, red.
3) Cherry tomatoes: small, round and usually red (but also green, yellow and black).[9]
4) Grape tomatoes: sweet, small, oblong and mainly (but not only) red. Coming from Southeast Asia.
5) Beefsteak tomatoes: kidney-bean shaped, big, with a lot of seeds, pink or red.
6) Plum tomatoes: oval or cylindrical-shaped, solid, red.
7) Pear tomatoes: pear-shaped, yellow, orange or red. Coming from England and United States.
8) Campari tomatoes: medium-sized, juicy, sweet and red.
9) Green zebra tomatoes: medium-sized, bitter, green with yellow stripes.
10) Rio Grande tomatoes: medium-sized, egg-shaped, bright, red.
11) Cuor di bue tomatoes: big, with an irregular shape, odorous, almost seedless, red. Cultivated in Italy.
12) Regina tomatoes: medium-sized, sepals have the shape of a crown, sweet-sour. Cultivated in Puglia.
13) Marmande tomatoes: medium-sized, flat-shaped, green.
14) Pink of Bern tomatoes: big, almost seedless, delicate, pink. Coming from Switzerland.
15) Black of Crimea tomatoes: medium-sized, very sweet, black with brown stripes.
16) Blue tomatoes: round, medium-sized, blue, black or purple. Coming from United States.[10]
17) Datterino tomatoes: sweet, small, oval-shaped, red and almost seedless. Coming from Asia.[11]
18) San Marzano tomatoes: hard, medium-sized, pink-green and almost seedless. Cultivated in Campania.
19) Pachino tomatoes: round, smooth, shiny, green (but also red). Cultivated in several areas of Sicily.
20) Belmonte tomatoes: sweet, oblong, big, pink-green. Coming from America, cultivated in Calabria.
21) Grinzoso sanminiatese tomatoes: sweet-sour, wrinkly, bright, red. Cultivated in Toscana, Italy.[12]

(Fig.3: Different varieties of tomatoes. They differ in colour, size and shape)[13]

2.3. Diseases

Tomato plants face several problems. One of the most common disease is called curly top: this disease strongly interferes with the normal cycle of life of the plant and it's spread by the beet leafhopper.
Another problem which is quite popular among tomatoes is the one caused by the tobacco mosaic virus which can be transmitted from any tobacco plant (or from any product made from infected tobacco).
As the majority of agricultural crops, tomatoes are susceptible to temperature stress, not regular supply of nutrients and water and pests. The most common pests which afflict tomatoes are mites, fruit worms, aphids, cabbage loopers, tobacco hornworms, slugs, stink bugs, cutworms whiteflies and flea beetles.

(Fig.4: Examples of tomato diseases: an altered tomato can be still eaten safely sometimes)[o]

2.4. History

Tomato plants are native from Mexico, Ecuador, Peru and Chile (nowadays several wild plants of tomatoes can still be observed there). In those areas the "xitomatl" was first considered poisonous and dangerous for the crops and then integrated in the Aztec cuisine (mainly in the form of sauces).

Several years after the European colonization of the Americas, the conqueror Hernán Cortés Monroy Pizarro Altamirano introduced some tomato plants in Europe but they were considered more as ornamental plants than food. According to the legend, the city of Toulon gave several tomato plants to Cardinal Richelieu as gift while it is said that Sir Walter Raleigh gave one plant to HRH Elizabeth I naming it the "apple of love".

In 1544 Andrea Mattioli wrote for the first time about the possibility to eat tomatoes describing them as similar to eggplants, not so nutritious, and suitable to be eaten like mushrooms: fried with salt and pepper.

We have to wait the 1572 and Costanzo Felici to read the first detailed description of tomatoes:

"Golden apple, so commonly called by its intense colour, or apple from Peru, which is bright yellow, or brightly red, and which is evenly round or distinguished in slices like the melon (variety type heart of ox!). It is desired from those who are always gourmand and greedy of new things. It is desired fried in the pan accompanied with something similar to grape juice. The aspect is better than the taste"

In Spain, in 1590, José de Acosta talked positively about the tomato sauce and about tomatoes in general.
In Italy, in 1692, Antonio Latini included the recipe of tomato sauce in his book "Lo scalco alla moderna".
In France, 1795, one recipe described a really concentred kind of tomato paste.
After this period, the diffusion of tomatoes in Europe is completed.[14] [15]

2.5. Nutrition

As it was shown before, there are several varieties of tomatoes, everyone with its unique characteristics. In average, a tomato is made up of 95% of water and 5% of nutrients (4% if carbohydrates and 1% of proteins and fats). Tomatoes are a good source of vitamin C (more than 1/6 if the recommended daily value) and furthermore 18 calories are supplied by 100 grams of raw product.

Carbohydrates 3.9g per 100g	**Fat** 0.2g per 100g	**Thiamine (B1)** 37µg per 100g *3% of DV*	**Vitamin C** 14mg per 100g *17% of DV*	**Magnesium** 11mg per 100g *3% of DV*	**Potassium** 237mg per 100g *5% of DV*
Sugars 2.6g per 100g	**Protein** 0.9g per 100g	**Niacin (B3)** 59µg per 100g *4% of DV*	**Vitamin E** 540µg per 100g *4% of DV*	**Manganese** 114µg per 100g *5% of DV*	**Water** 94.5g per 100g *5% of DV*
Dietary fibers 1.2g per 100g	**Vitamin A** 42µg per 100g *5% of DV*	**Vitamin B6** 80µg per 100g *6% of DV*	**Vitamin K** 7.9µg per 100g *8% of DV*	**Phosphorus** 24mg per 100g *3% of DV*	**Lycopene** 2.6mg per 100g *5% of DV*

(Tab.1: Principal nutrients of tomatoes: types, grams and % of daily value)[16]

Several studies about the potential health benefits of tomatoes consumption have been carried out:

- Skin reaction if exposed to the ultraviolet radiation positively affected by tomatoes consumption
- Heart function positively affected by tomatoes consumption
- Vision function positively affected by tomatoes consumption
- Cardiovascular diseases risk diminished by tomatoes consumption[17]
- Cancer risk diminished by tomatoes consumption[18]

But unfortunately, none of them was considered conclusive by the European Food Safety Authority.[19]

Of course, tomatoes are not dangerous for human consumption also if they contain small amounts of solanine which is toxic and small amounts of tomatine whose effect on humans are not clear yet. The solanine content of tomatoes has been declared the responsible for one death (due to the use of tomato leaves in tea). Tomatoes were also found to be the co-responsible of some Salmonella outbrakes in USA.

2.6. Curiosities

Reynoldsburg in United States claims to be the first city in the world in which the first type of commercial tomato has been ever sold: that's why it is also known as "the birthplace of tomato"[20] and several States have the tomato in their flag or consider the tomato as the fruit (or vegetable) of the territory such as: Ohio, New Jersey and Arkansas. Furthermore, a tomato appears in the logo of the Dutch Socialist Party.[21]

Every last Wednesday of August, in Buñol, "La Tomatina" takes places: for about two hours, all the participants of the festival get involved in a tomato fight throwing tomatoes to each other.

One of the most famous American website about movies, "Rotten tomatoes", took his name from the practice of the audience of throwing rotten tomatoes in a case of bad performance. Movies are classified as rotten, fresh or certified fresh on the basis of the audience acceptance.

The biggest tomato which has been ever harvested weighed 3.51 kg while the largest plant reached almost 20 metres in length. The most massive plant with more than 32000 tomatoes weighed 522 kg.[22]

2.7. Recipes

Tomatoes are usually eaten raw, sliced, in salads, seasoned with oil, salt, vinegar and pepper. One famous example is the “Insalata Caprese” (Caprese salad) made with tomatoes, basil and mozzarella which is served as side dish or as a starter mainly in the south of Italy.
They can also be eaten in soups: some examples are the “pappa al pomodoro” which is a thick Italian soup made with leftover bread, tomatoes, basil, garlic and olive oil; the “panzanella”, the “cacciucco” or the Spanish “gazpacho” in which tomatoes, cucumbers and garlic are blended and served cold with bread, vinegar and olive oil.

(Fig.5: Insalata Caprese; Google Images)

(Fig.6: Bruschetta al pomodoro; Google Images)

Tomatoes are suitable to be eaten just with bread and every country has its own version: “Bruschetta al pomodoro” (Italy), “Pa amb tomàquet” (Spain) or “tomato sandwich” (USA) and talking about US, fried green tomatoes are a delicatessen in which unripe tomatoes are coated with cornmeal and then fried.

Tomato sauce is one of the main ingredients of some very famous Italian dishes: pasta and pizza and it is, together with wheat, olives and grapes one of the four main ingredients of the Apulian cuisine.

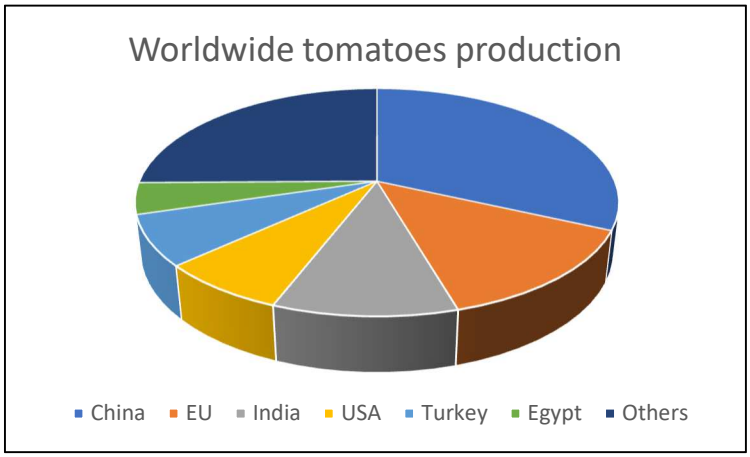
Tomatoes can be boiled, grilled, fried, stuffed and also be used in omelettes, pies (such as the so-called “New Jersey tomato pie”, “Sicilian pizza” and the “southern tomato pie”) or in sauces.

(Fig.7: From the left: pasta, fried tomatoes, pizza, gazpacho, tomato salad, stuffed tomatoes; Google Images)

2.8. Production

In 2016 the worldwide production of tomatoes has reached 177 million tonnes. Main producers were:[23]

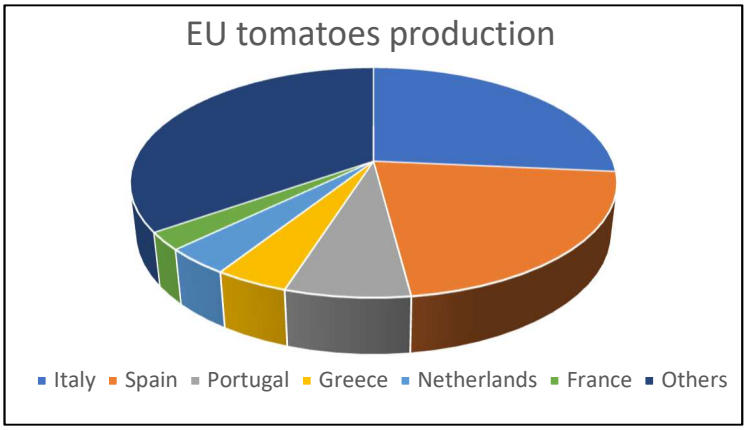
1) **People's Republic of China:**
56.3 million tonnes (31.81% of share)
2) **European Union:**
24.2 million tonnes (13.67% of share)
3) **Republic of India:**
18.4 million tonnes (10.40% of share)
4) **United States of America:**
13 million tonnes (7.34% of share)
5) **Republic of Turkey:**
12.6 million tonnes (7.12% of share)
6) **Arab Republic of Egypt:**
7.9 million tonnes (4.46% of share)



(Fig.8: Worldwide tomatoes production)

These countries alone, accounted for 75% of the total production worldwide.
In 2016, in the EU, the main producers were:[24]

1) **Italian Republic:**
6.4 million tonnes (26.45% of the EU share)
2) **Kingdom of Spain:**
5.2 million tonnes (21.49% of the EU share)
3) **Portuguese Republic:**
1.7 million tonnes (7% of the EU share)
4) **Hellenic Republic:**
1 million tonnes (4.13% of the EU share)
5) **The Netherlands:**
0.9 million tonnes (3.72% of the EU share)
6) **French Republic:**
0.6 million tonnes (2.48% of the EU share)



(Fig.9: EU tomatoes production)

These countries alone, accounted for 65% of the tomatoes production in the European Union with the Mediterranean countries which prefer an open-field cultivation (Italy, Spain, Greece, Portugal) and the remaining countries which, due to their colder weather, have to cultivate using the greenhouses.

In 2016, the vegetables and fruits sector of the European Union employed more than 600000 people and had a value of 150 billion euros. According to that, it's quite clear that tomatoes (that have a big share in the sector of fruits and vegetables) are one of the most important part of the agricultural sector in the EU.

The trade of tomatoes within and outside Europe is quite well developed. In 2014, the equivalent of 357 million euros were exported while in the same year, 415 million euros of tomatoes were imported inside the EU. One of the biggest partner of EU is Morocco from which the volume of imported tomatoes has doubled in the last 10 years. Another important commercial partner for tomatoes trade is Turkey.[25]

A great part of the tomatoes which are product in Europe goes directly in the processing sector and it has to be said that in the past years the price of tomatoes has been more or less steady.

2.9. Market and trade[26]

In June 2018, the European tomato market seemed to be pretty stable with the Northern Europe pressuring the small producers of the South and with producers focusing on the cultivation of specialities.

- In Italy, prices were more or less stable and those producers who were focusing on the cultivation of specialities (which are mainly intended for exportation) achieved good results. Dutch and Belgium markets seemed to pressure the Italian domestic market.

- Apart from the green tomatoes grown in the areas of Valencia, Murcia and Malaga; Spain relied mainly on import from Netherland, Belgium, France, Poland and Portugal. Furthermore, bigger cultivation of sweet peppers made the production of tomatoes lower.

- In France, prices remained low with the consumers who preferred specialities (such as the Pineapple and the Zebra varieties) and with the producers who switched to the production of specialities as well making the normal, round varieties less popular in France.

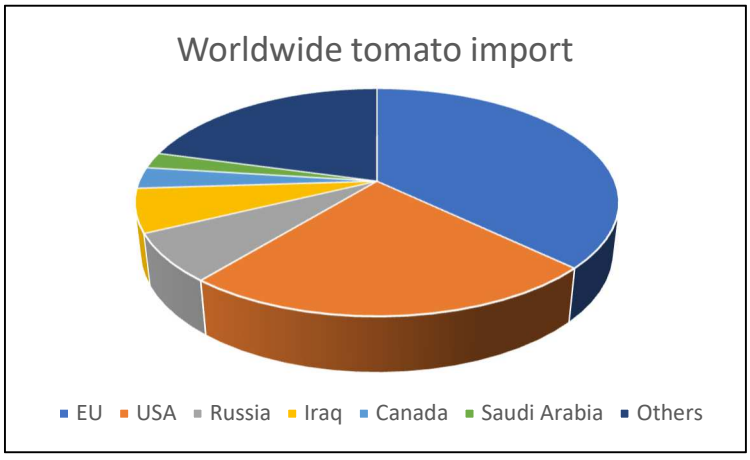
- In Germany, prices greatly fluctuated and the market seemed far to be steady and stable.

- Outside the European Union, in Ukraine, stakeholders invested a quite impressive amount of money in the modern cultivation of tomatoes (black, pink, yellow, cherry, cocktail) in greenhouses while Australia and New Zealand focused their production on an open-field base (and also here the trend of focusing on the cultivation of specialities has been observed) obtaining good results although the market appears to be still pretty closed. Both in Canada and Mexico, the lack of labour has still been the biggest problem in the vegetable industries: in Canada, the labour force was absorbed by the new cannabis industry (which became legal in Canada on the 17th October 2018, under the law known as Cannabis Act) while in Mexico the labour force has been absorbed by car companies.

2.9.1. Import

In 2017, 7.52 million tonnes of tomatoes were imported worldwide. Main importers were:[27]

1) **European Union (TOP 15):**
2.79 million tonnes (37.13% of share)
2) **United States of America:**
1.79 million tonnes (23.80% of share)
3) **Russian Federation:**
0.52 million tonnes (6.86% of share)
4) **Republic of Iraq:**
0.47 million tonnes (6.19% of share)
5) **Canada:**
0.23 million tonnes (3.02% of share)
6) **Kingdom of Saudi Arabia:**
0.17 million tonnes (2.27% of share)

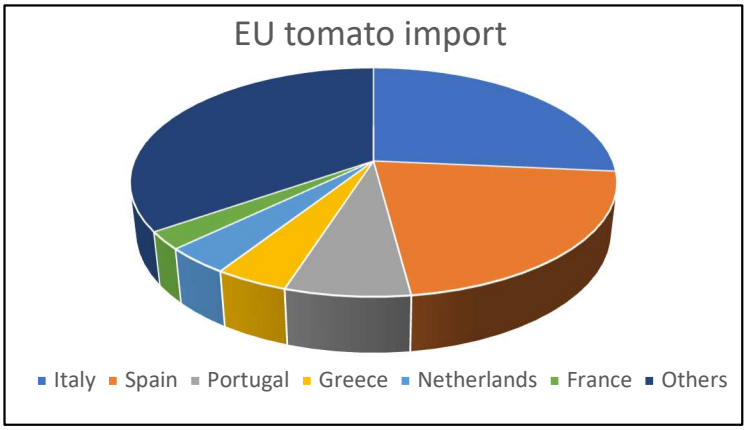


(Fig.10: Worldwide tomato import)

These countries alone, accounted for about 80% of the total tomato import worldwide.

In 2017, in the EU, main importers were:[24]

1) **Federal Republic of Germany:**
0.7 million tonnes (25.87% of the EU share)
2) **French Republic:**
0.5 million tonnes (18.15% of the EU share)
3) **United Kingdom:**
0.4 million tonnes (14.29% of the EU share)
4) **Netherlands:**
0.2 million tonnes (8.13% of the EU share)
5) **Kingdom of Spain:**
0.2 million tonnes (6.77% of the EU share)
6) **Republic of Poland:**
0.1 million tonnes (4.87% of the EU share)

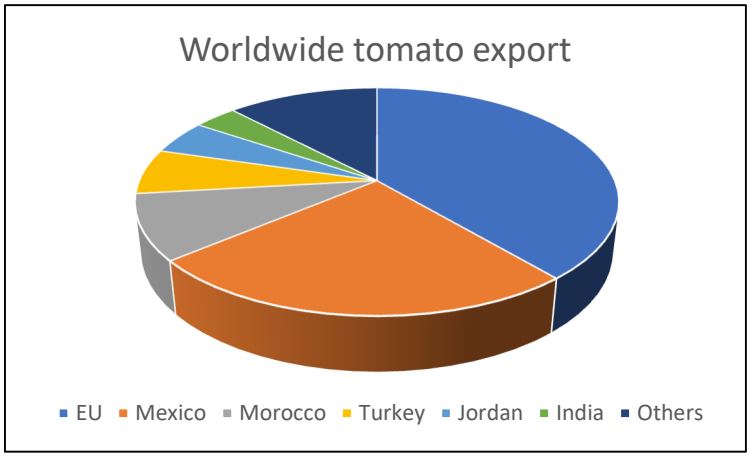


(Fig.11: EU tomato import)

2.9.2. Export

In 2016, 7.53 million tonnes of tomatoes were exported worldwide. Main exporters were:[28]

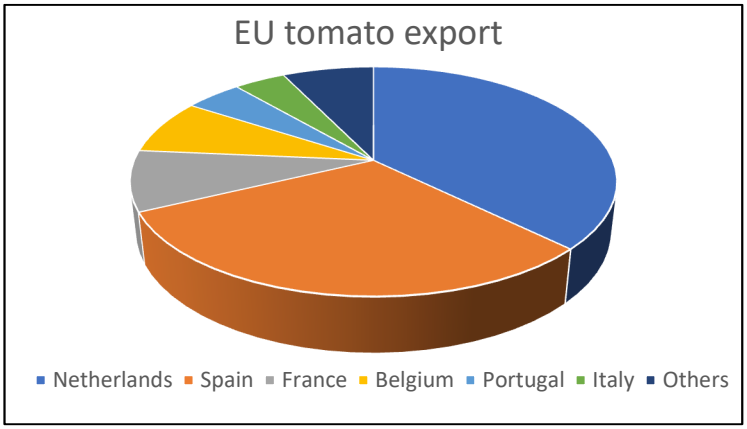
1) **European Union (TOP 8):**
2.92 million tonnes (38.80% of share)
2) **United Mexican States:**
1.89 million tonnes (25.08% of share)
3) **Kingdom of Morocco:**
0.70 million tonnes (9.28% of share)
4) **Republic of Turkey:**
0.48 million tonnes (6.43% of share)
5) **Hashemite Kingdom of Jordan:**
0.37 million tonnes (4.85% of share)
6) **Republic of India:**
0.26 million tonnes (3.47% of share)



(Fig.12: Worldwide tomato export)

These countries alone, accounted for about 88% of the total tomato export worldwide.
In 2016, in the EU, main exporters were:[24]

1) **Netherlands:**
1.1 million tonnes (37.29% of the EU share)
2) **Kingdom of Spain:**
0.9 million tonnes (30.61% of the EU share)
3) **French Republic:**
0.2 million tonnes (8.52% of the EU share)
4) **Kingdom of Belgium:**
0.2 million tonnes (7.74% of the EU share)
5) **Portuguese Republic:**
0.1 million tonnes (4.51% of the EU share)
6) **Italian Republic:**
0.1 million tonnes (4.09% of the EU share)



(Fig.13: EU tomato export)

3. Introduction: The processed product

In this chapter, the most important processed products in which tomatoes are involved will be presented.

It has to be said that the idea of processing tomatoes was born from a fundamental need: to preserve them. When the agriculture was still traditional, tomatoes weren't available all the year and furthermore, refrigerators were still not available and as we all know, tomatoes are really perishable vegetables.

Technological innovations made always available a product which is perishable and seasonally reduced. The strong demand of tomatoes made the tomatoes canning industries (which were the forerunner of all the canning industries) produce always new products which were cheaper, safer and tastier.

3.1. Description

There are a lot of processed products which derive from tomatoes and the main difference among them is the degree of concentration (the content of water contained in the products). The concentration process has two big advantages: it reduces the packaging and transportation costs (due to the lower volume) and it improve the safety of the products due to a better microbiological stabilization.
The most common processed products which are made from tomatoes are:

- Canned tomatoes (whole or in pieces)
- Ketchup
- Tomato paste
- Tomato powder and tomato flakes
- Tomato juice
- Tomato sauce

Ketchup, tomato paste, tomato powder and tomato flakes will be considered in a single category (and not in four different ones) later on in the study. This was made in order to improve the general understanding of the study, to make it simpler and cover some data gaps, making the MFA balanced.

3.1.1. Canned tomatoes

Canned tomatoes are made with bright red whole tomatoes (or in pieces) which are first washed and sorted (manually but also using optical devices) and then peeled and conditioned with tomato paste or/and juice.

(Fig.14: Canned tomatoes)[o]

The peel has to be thick enough to be detached and removed easily from the peelers which can be both pressure drop and mechanical peelers.

It is very important to avoid the presence of rotten tomatoes which could make the overall quality of the product worse (with an important negative alteration of both odour and taste). Furthermore, in order to assure the safety of the product, the pH has to be between 3.9 and 4.6 (because with a pH above 4.6, the development and the spread of sporogenous organisms is more common).

3.1.2. Ketchup

Ketchup is a tomato-based product in which vinegar, spices and sugar are mixed with concentrated tomatoes products. The history of ketchup is old but the first commercial recipe appeared just in 1817.[29] Today, ketchup is popular especially in fast foods where it is offered in tubs or sachets.

3.1.3. Tomato paste

Tomato paste is obtained through the concentration process (elimination of part of the water from the product) and it is typical of Mediterranean countries (in particular Greece, Italy and Malta) where it is sometimes still made in a traditional way: drying the tomato sauce on wooden boards under the sun.[30]

3.1.4. Tomato powder and tomato flakes

Tomato powder and tomato flakes are obtained after drying the chopped tomatoes. They can be used in order to add both flavour and colour in various dishes.

3.1.5. Tomato juice

Tomato juice is a beverage which is consumed in cocktails (Michelada, Bloody Mary, etc.) or plain. It is obtained from the shredding, the refinement and the pasteurization of fresh tomatoes.

3.1.6. Tomato sauce

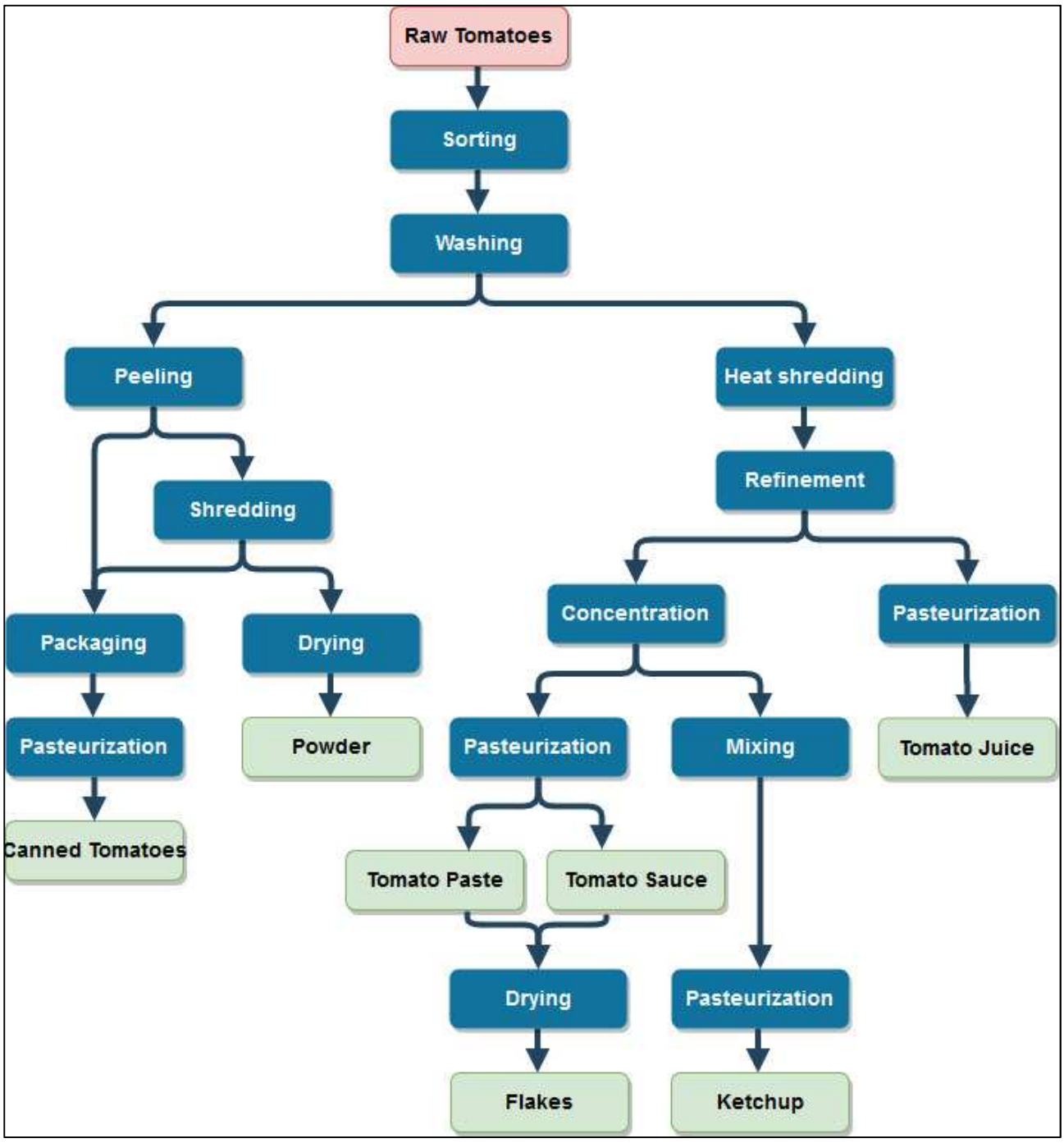
Tomato sauce is a not so refined and concentrated type of tomato juice which is used in order to season a large variety of food (such as pasta or pizza). Sometimes, salt, spices and herbs may be added to it.

(Fig.15: From the left: ketchup, tomato paste, tomato powder/flakes, tomato juice, tomato sauce)[o]

3.2. Industrial processing

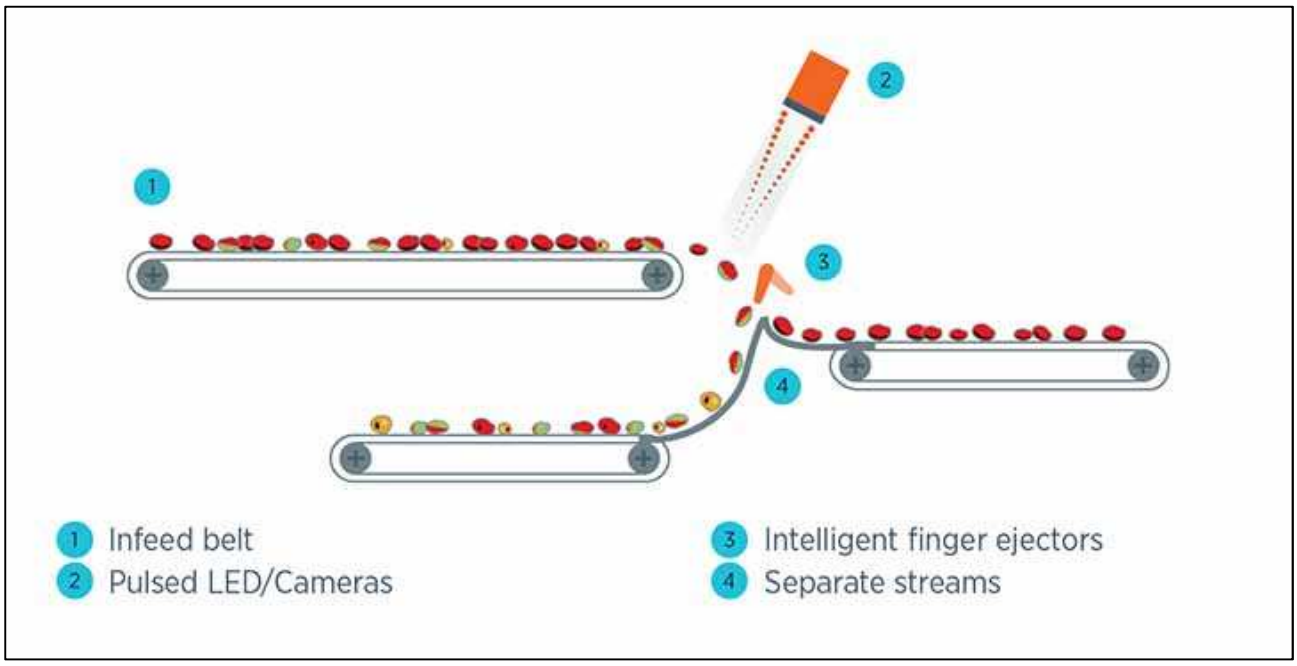
It is possible to draw a simple scheme in which it is possible to see the main industrial processes that are required in order to produce the various tomato-based products.

Basically, all the processes start with washing and sorting the raw products which are first peeled or shredded (or both) and then pasteurized (or dried). It is possible to see that some products require some sort of filtering or refinement and some not. It is also possible to see that some products require the addition of other ingredients such as: salt, herbs, additives, preservatives, sugar, basil, spices and so on.



(Fig.16: Industrial processing of tomatoes: overall scheme)[31]

In detail, every kind of product has to receive some preliminary treatment before being furtherly processed
First, raw tomatoes are delivered to factories with trucks which are filled with boxes and/or bins.
Tomatoes are then weighed and sampled in order to assess the quantity and the quality of the product.
After this, tomatoes are washed in a huge tank with strong jets of water. The washing process continue on conveyors where other jets of high-pressured water eliminate all the impurities (soil, dust, dirt and so on).
The third stage is the sorting: this stage is fundamental in order to have a high-quality product. Sorting is carried out manually (with a quick exchange of the operators involved in the process so that they do not have attention drops and do not make mistakes) but also through mechanical systems.
Finally, the sorted tomatoes are washed one last time in order to assure the best quality possible.



(Fig.17: Simplified scheme of a tomato sorting machine)[32]

(Fig.18: An industrial tomato washing machine)[33]

3.2.1. Industrial processing of canned tomatoes[34]

The industrial phases that are required in order to produce canned tomatoes can be summarized as follow:

- Preliminary treatments: (as it was described above)
- Peeling: raw tomatoes are quickly boiled at 135°C in a pressurised environment, then they are put in a vacuum environment where the quick evaporation causes the breaking of the peel.
  After that, the peel is removed by a separating machine and finally tomatoes are sorted again.
- Packaging: it is carried out with machines which are made up of a rotating plates.
- Pasteurization: first tomatoes are heated up to 50°C (in order to remove the air), then the tins are closed and heated up to 95°C (in order to kill all the microorganism which may affect the product).
- Cooling: tins are cooled in cold water in a controlled atmosphere in order to avoid deformations.
- Labelling and packing: containers are checked, labelled, and packed
- Quality checks and storage: containers are furtherly inspected and stored

(Fig.19: An industrial peeler for tomatoes)[35]

3.2.2. Industrial processing of ketchup

The industrial phases that are required in order to produce ketchup can be summarized as follow:[36]

- Preliminary treatments: (as it was described above)
- Shredding: tomatoes are shredded through the use of machines
- Scalding: tomatoes are scalded in order to kill bacteria and to preserve them
- Pulping: stems, seeds and skin are separated from the juice and the pulp through cyclones
- Filtering: pulp and juice are filtered through several sieves and filters
- Mixing: vinegar, spices, sugar, salt and other ingredients are mixed with the tomato pulp
- Cooking: pulp and added ingredients are cooked for about 40 minutes and furtherly mixed
- Finishing: using finishing machines, there is an adjustment regarding the consistency of ketchup
- Air removal: air is removed for both safety and technical reasons (prevent decolouration)
- Filling: containers are filled, pasteurized and sealed immediately
- Cooling: bottles are cooled down with cold air and cold water in order to avoid taste degradation
- Labelling and packing: containers are checked, labelled, and packed
- Quality checks and storage: containers are furtherly inspected and stored

3.2.3. Industrial processing of tomato paste

The tomato pulp is heated and then put in an extraction unit that is made up of both a refiner and a pulper. Firstly, pulp is sieved up to one millimetre and secondly, through the refiner, up to half millimetre. Refined juice (which will be furtherly concentrated through the use of an evaporator) and waste are coming out from the extraction unit with the yield of the machine that is influenced by several factors such as the variety of tomatoes used, the rotor's shape, the temperature and so on. According to all these factors, it has to be said that generally the yield in production is considered to be usually about 95%.[37]

The industrial phases that are required in order to produce tomato paste can be summarized as follow:

- Preliminary treatments: (as it was described above)
- Shredding: tomatoes are shredded usually in rotating cylinders
- Scalding: tomatoes are scalded in order prepare the separation of the peel from the fruit
    1. Hot-break scalding which is done between 80°C and 100°C (best yield, dense juice)
    2. Cold-break scalding which is done between 65°C and 70°C (better conservation of organoleptic properties but worse yield)
- Refinement: seeds, rotten parts, dirt and peels are separated using sieves and filters
- Concentration: through evaporation, part of the water is removed from the juice
- Packaging: which is carried out by automatic machines in safety conditions
- Pasteurization: tins are sealed and washed for few minutes with hot water
- Cooling: tins are cooled in cold water in a controlled atmosphere in order to avoid deformations
- Labelling and packing: containers are checked, labelled, and packed
- Quality checks and storage: containers are furtherly inspected and stored

(Fig.20: Example of tomato paste production line)[38]

3.2.4. Industrial processing of tomato powder and tomato flakes

The industrial phases that are required in order to produce powder and flakes can be summarized as follow

- Preliminary treatments: (as it was described above)
- Shredding: tomatoes are shredded in various ways
- Drying: tomatoes are dried using mechanicals ways in order to obtain the dried tomato flakes
- Pulverization: dried tomatoes are pulverized in order to obtain the dried tomato powder
- Labelling and packing: containers are checked, labelled, and packed
- Quality checks and storage: containers are furtherly inspected and stored

3.2.5. Industrial processing of tomato juice[39]

The industrial phases that are required in order to produce tomato juice can be summarized as follow:[40]

- Preliminary treatments: (as it was described above)
- Shredding: tomatoes are shredded, sliced or chopped
- Scalding: tomatoes are scalded in order prepare the separation of the peel from the fruit
- Hot break scalding which is done between 80°C and 100°C (best yield, dense juice)
- Cold break scalding which is done between 65°C and 70°C (better conservation of organoleptic properties but worse yield)
- Extraction: juice is extracted through presses and crushers
- Air removal: air is removed for both safety and technical reasons
- Finishing: using finishing machines, there is an adjustment regarding the consistency of the juice
- Pasteurization: bottles are sealed and washed for few minutes with hot water
- Cooling: bottles are cooled in cold water and then dried
- Labelling and packing: bottles are checked, labelled, and packed
- Quality checks and storage: bottles are furtherly inspected and stored

3.2.6. Industrial processing of tomato sauce

The industrial phases that are required in order to produce tomato sauce can be summarized as follow:[41]

- Preliminary treatments: (as it was described above)
- Scalding: tomatoes are scalded in order prepare the separation of the peel from the fruit
- Hot break scalding which is done between 80°C and 100°C (best yield, dense juice)
- Cold break scalding which is done between 65°C and 70°C (better conservation of organoleptic properties but worse yield)
- Draining: through evaporators the liquid part in excess is eliminated
- Refinement: seeds, rotten parts, dirt and peel are separated using sieves and filters
- Filling: sterilized containers are filled with tomato sauce
- Packaging: filled containers are immediately sealed in safety conditions
- Pasteurization: sealed containers are pasteurized in pasteurization tunnels
- Cooling: bottles are cooled in cold water and dried
- Labelling and packing: bottles are checked, labelled, and packed
- Quality checks and storage: containers are furtherly inspected and stored

3.3. Issues

One of the biggest issues of canned vegetables is the possibility to get poisoned by the botulinum toxin which originates from the bacterium botulinum. This may happen both with home-made and industrial-made canned food and every year several cases of intoxication are reported. Luckily, tomato-based products are not really affected by botulinum because of the relatively high level of sugar and because of the intrinsic acidity of tomatoes but anyway also if very rarely, intoxication may occur.[42]

Another possible issue is related with the presence of PBA in some food containers (PBA is currently used in tin cans, plastic containers and resins) The dangerousness of PBA has not been unequivocally settled down:

- Canada has put PBA in the list of toxic substances
- EU has banned the use of PBA in feeding bottles but allowed the use for other reasons
- In the USA, studies about the high level of PBA in some people have been published

In this case the acidity of tomatoes may represent a problem because the acid may corrode partially the containers and transfer part of the PBA (together with the other chemicals) to the food[43]

3.4. History

The idea of processing tomatoes is old: tomato sauce has been made in a traditional way since 1796 (and it's still possible to find some small producers who make the tomato sauce this way) but it was with the industrial revolution that the canning started to spread, becoming popular among people.

At the beginning of the nineteenth century, farmers developed the first way to preserve tomatoes: first the tomatoes were peeled (with the seeds removed) then, they were shredded and boiled for a long time.

In 1804, Charles Nicolas Appert, invented the airtight food preservation method. In his "Livre de tous les ménages, ou l'art de conserver pleusieurs années toutes les substances animales et végétales" (Book of all households, or the art of preserving for several years all animal and vegetable substances) wrote:

"With this process, you will be able to transfer to your cellar everything your garden produces in spring, summer and autumn and after several years. You will find your plant foods still as good and healthy as when you collected them and with a certain prescience you can guard against any periods of poverty and famine"

The method developed by Appert was a revolution for that time but it was still difficult and expensive and the many technical limitations which it had, prevented it to become popular in a very large scale.

In 1810, Pierre Durand improved the invention of Charles Nicolas Appert substituting the fragile glass bottles with robust aluminium cans receiving the first patent (No 3372) for "preserving food using tin cans"

In 1812 Brian Donkin and John Hall opened the first canning factory in Bermondsey while in 1855 the first patent for a can opener has been released to the Englishman Robert Yeates. In Italy, the first factory for tomato processing has been opened in 1875 by Francesco Cirio, Lamberto Gandini and Pietro Rovetta.

At the beginning of the twentieth century, thanks to the use of concentrators and boules, the safer and cheaper vacuum technology could have been applied (boosting the tomato processing industry.)[44]

3.5. Nutrition

The nutrition values related to the analysed processed tomato products are shown below. Tabs show carbohydrates, sugars, fibers, fat, protein, vitamins (A, B1, B3, B6, C, E, K), several minerals and lycopene.

Carbohydrates 7.3g per 100g	**Fat** 0.3g per 100g	**Thiamine (B1)** 24µg per 100g	**Vitamin C** 9.2mg per 100g	**Magnesium** 20mg per 100g	**Potassium** 293mg per 100g
Sugars 4.4g per 100g	**Protein** 1.6g per 100g	**Niacin (B3)** 1.4mg per 100g	**Vitamin E** 1.3mg per 100g	**Manganese** 183µg per 100g	**Water** 89.44g per 100g
Dietary fibers 1.9g per 100g	**Vitamin A** 11µg per 100g	**Vitamin B6** 99µg per 100g	**Vitamin K** 5.3µg per 100g	**Phosphorus** 32mg per 100g	**Lycopene** 5mg per 100g

(Tab.2: Principal nutrients of tomato whole or in pieces: types and grams)[45]

Carbohydrates 27.4g per 100g	**Fat** 0.1g per 100g	**Thiamine (B1)** 11µg per 100g	**Vitamin C** 4.1mg per 100g	**Magnesium** 13mg per 100g	**Potassium** 281mg per 100g
Sugars 21.3g per 100g	**Protein** 1g per 100g	**Niacin (B3)** 1mg per 100g	**Vitamin E** 1.5mg per 100g	**Manganese** 84µg per 100g	**Water** 68.51g per 100g
Dietary fibers 0.3g per 100g	**Vitamin A** 26µg per 100g	**Vitamin B6** 99µg per 100g	**Vitamin K** 3µg per 100g	**Phosphorus** 26mg per 100g	**Lycopene** 12mg per 100g

(Tab.3: Principal nutrients of ketchup: types and grams)[45]

Carbohydrates 18.9g per 100g	**Fat** 0.5g per 100g	**Thiamine (B1)** 60µg per 100g	**Vitamin C** 22mg per 100g	**Magnesium** 42mg per 100g	**Potassium** 1g per 100g
Sugars 12.2g per 100g	**Protein** 4.3g per 100g	**Niacin (B3)** 3.1g per 100g	**Vitamin E** 4.3mg per 100g	**Manganese** 302µg per 100g	**Water** 73.5g per 100g
Dietary fibers 4.1g per 100g	**Vitamin A** 76µg per 100g	**Vitamin B6** 216µg per 100g	**Vitamin K** 11µg per 100g	**Phosphorus** 83mg per 100g	**Lycopene** 28mg per 100g

(Tab.4: Principal nutrients of tomato paste: types and grams)[45]

Carbohydrates 75g per 100g	**Fat** 0.4g per 100g	**Thiamine (B1)** 913µg per 100g	**Vitamin C** 117mg per 100g	**Magnesium** 178mg per 100g	**Potassium** 1.92g per 100g
Sugars 44g per 100g	**Protein** 13g per 100g	**Niacin (B3)** 9.1g per 100g	**Vitamin E** 12mg per 100g	**Manganese** 1.95g per 100g	**Water** 3.06g per 100g
Dietary fibers 16.5g per 100g	**Vitamin A** 862µg per 100g	**Vitamin B6** 457µg per 100g	**Vitamin K** 49µg per 100g	**Phosphorus** 295mg per 100g	**Lycopene** 46mg per 100g

(Tab.5: Principal nutrients of tomato powder/flakes: types and grams)[45]

Carbohydrates 3.5g per 100g	**Fat** 0.3g per 100g	**Thiamine (B1)** 99µg per 100g	**Vitamin C** 70mg per 100g	**Magnesium** 11mg per 100g	**Potassium** 217mg per 100g
Sugars 2.6g per 100g	**Protein** 0.9g per 100g	**Niacin (B3)** 1mg per 100g	**Vitamin E** 0.3mg per 100g	**Manganese** 68µg per 100g	**Water** 94.24g per 100g
Dietary fibers 0.4g per 100g	**Vitamin A** 23µg per 100g	**Vitamin B6** 70µg per 100g	**Vitamin K** 2.3µg per 100g	**Phosphorus** 19mg per 100g	**Lycopene** 9mg per 100g

(Tab.6: Principal nutrients of tomato juice: types and grams)[45]

Carbohydrates 5.3g per 100g	**Fat** 0.3g per 100g	**Thiamine (B1)** 24µg per 100g	**Vitamin C** 7mg per 100g	**Magnesium** 15mg per 100g	**Potassium** 297mg per 100g
Sugars 3.6g per 100g	**Protein** 1.2g per 100g	**Niacin (B3)** 1mg per 100g	**Vitamin E** 1.4mg per 100g	**Manganese** 113µg per 100g	**Water** 91.28g per 100g
Dietary fibers 1.5g per 100g	**Vitamin A** 22µg per 100g	**Vitamin B6** 98µg per 100g	**Vitamin K** 2.8µg per 100g	**Phosphorus** 27mg per 100g	**Lycopene** 14mg per 100g

(Tab.7: Principal nutrients of tomato sauce: types and grams)[45]

3.6. Curiosities

Nowadays ketchup is a worldwide-spread sauce which is often associated with hamburgers, French fries, hot dogs and in general with all those products which are sold in fast food restaurants.

In the collective imaginary, ketchup comes from United States but we know that Henry J. Heinz developed the recipe of ketchup (which is still in use today) just in 1872[46] and in fact, ketchup was actually born in Asia, in particular in China or Malaysia long time before.

The word ketchup itself has two possible etymologic origins:[47]

- From the Chinese word 茄汁 "ketsiap" which means tomato sauce
- From the Malaysian word "kichap" or maybe "kecap" which means chopped fermented fish

During the fascism and after the approval of the law "23 dicembre 1940, n. 2042", the Kingdom of Italy banned the use of foreign words in every circumstance and so "ketchup" became "salsa rubra" that in Latin means "Red sauce". Nowadays, in Italy, ketchup is sometimes still known with the name of "Salsa rubra".

3.7. Recipes

Tomato-based processed products are used in a large variety of recipes:

1. Canned tomatoes:

    - Canned tomatoes can be stuffed, roasted, fried or being eaten just naturally
    - They can also be mixed with the tomato sauce in order to give it a denser consistency
    - They are used in several recipes such as soups, chilli or the Middle Eastern shakshuka

2. Tomato sauce:

    - Tomato sauce is used in very famous plates such as the Italian pizza, pasta, lasagne, cannelloni, parmigiana; the Spanish paella or the French ratatouille.
    - It is also used as a base for other sauces which are obtained adding vegetables (eggplants, peppers, zucchini etc.), mushrooms, fish, meat, cheese or eggs to the tomato sauce.

3. Tomato paste:

    - Tomato paste can be used wherever a stronger flavour is needed. It can be used with several preparation of meat (stew, ribs, steak) in several soups or in savoury pies.

4. Ketchup:

    - Ketchup can be used mainly to season meat and French fries or as side sauce

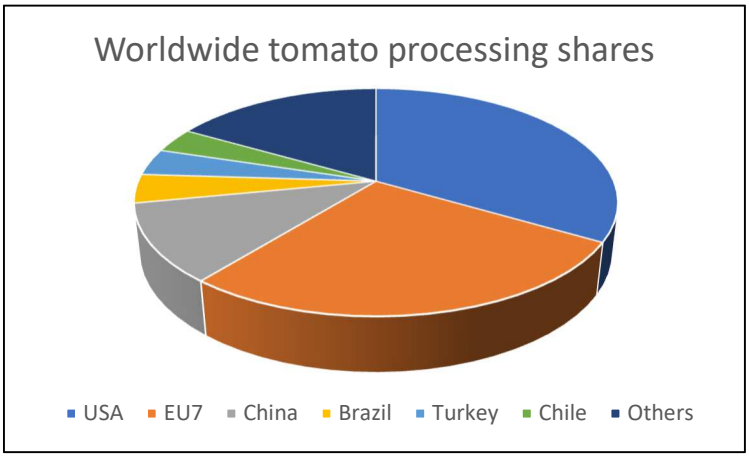
5. Tomato powder and tomato flakes.

    - Tomato powder can be used as a substitute of paprika, as a flavouring spice or to add a bit of red colour to the dish while tomato flakes are usually eaten just naturally as a snack.

3.8. Production

In 2018, 34.33 million tonnes of tomatoes were processed worldwide. Mainly in:[48]

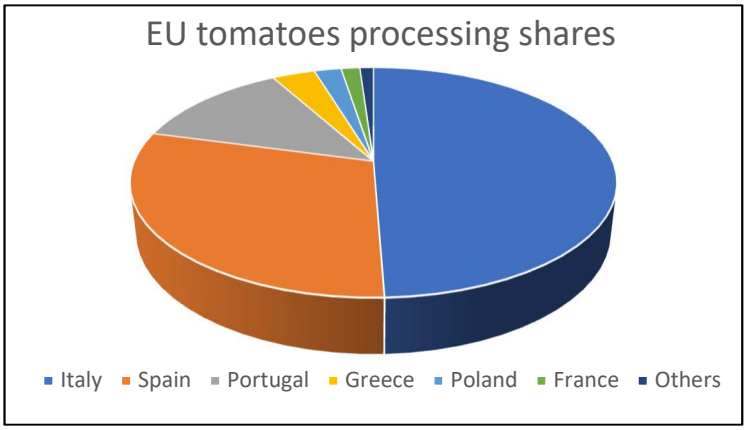
1) **United States of America:**
11.5 million tonnes (33.43% of share)
2) **European Union (TOP 7):**
9.41 million tonnes (27.41% of share)
3) **People's Republic of China:**
3.8 million tonnes (11.07% of share)
4) **Federative Republic of Brazil:**
1.4 million tonnes (4.08% of share)
5) **Republic of Turkey:**
1.3 million tonnes (3.79% of share)
6) **Republic of Chile:**
1.21 million tonnes (3.53% of share)



(Fig.21: Worldwide tomatoes processing)

These countries alone, accounted for 83.3% of the total production of tomato-based processed products worldwide. In 2018, in the EU, the main countries involved in the processing of tomatoes were:[48]

1) **Italian Republic:**
4.7 million tonnes (49.4% of the EU7 share)
2) **Kingdom of Spain:**
2.8 million tonnes (29.8% of the EU7 share)
3) **Portuguese Republic:**
1.2 million tonnes (12.7% of the EU7 share)
4) **Hellenic Republic:**
0.3 million tonnes (3.40% of the EU7 share)
5) **Republic of Poland:**
0.2 million tonnes (2.13% of the EU7 share)
5) **French Republic:**
0.14 million tonnes (1.49% of the EU7 share)



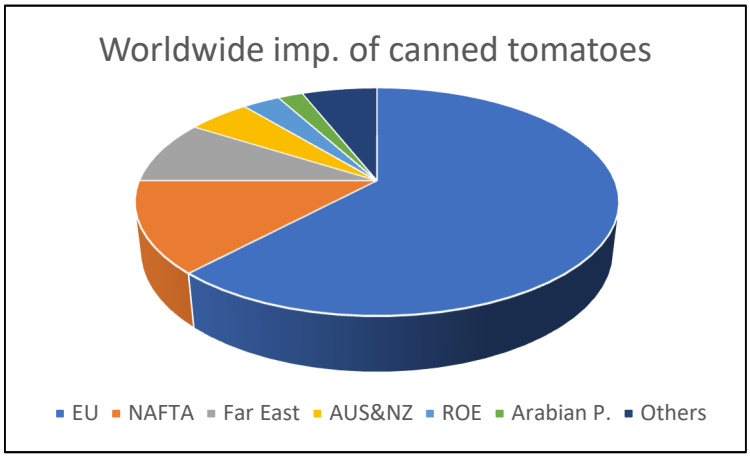
(Fig.22: EU tomatoes processing)

(Fig.23: Global tomato processing map for 2018)[48]

3.9.1. Import

In 2017, 1.59 million tonnes of canned tomatoes were imported worldwide. Main importers were:[49]

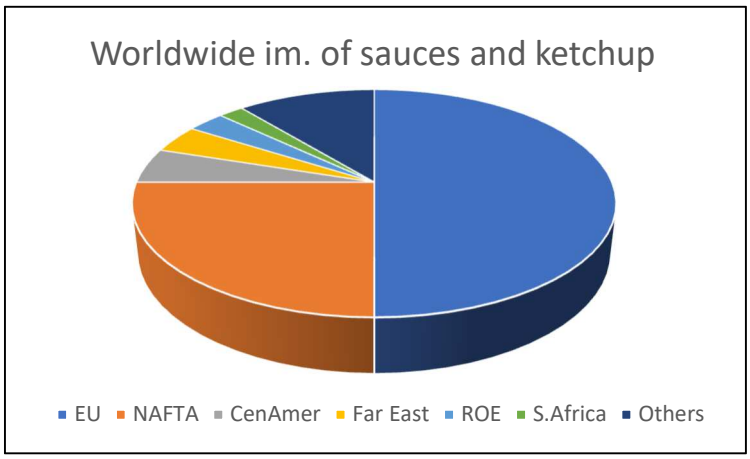
1) **European Union:**
0.99 million tonnes (62% of share)
2) **USA, Canada, Mexico (NAFTA):**
0.20 million tonnes (13% of share)
3) **Far East Countries:**
0.14 million tonnes (9% of share)
4) **Australia and New Zealand:**
0.08 million tonnes (5% of share)
5) **Rest of Europe (ROE):**
0.04 million tonnes (3% of share)
6) **Arabian Peninsula:**
0.03 million tonnes (2% of share)



(Fig.24: Worldwide import of canned tomatoes)

In 2017, 1.20 million tonnes of sauces and ketchup were imported worldwide. Main importers were:[49]

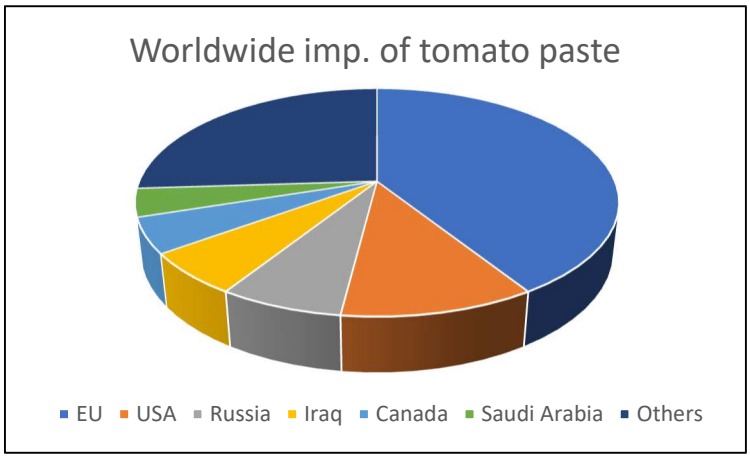
1) **European Union:**
0.60 million tonnes (50% of share)
2) **USA, Canada, Mexico (NAFTA):**
0.30 million tonnes (25% of share)
3) **Far East Countries:**
0.06 million tonnes (5% of share)
4) **Central America:**
0.05 million tonnes (4% of share)
5) **Rest of Europe (ROE):**
0.03 million tonnes (3% of share)
6) **Southern Africa:**
0.03 million tonnes (2% of share)



(Fig.25: Worldwide import of sauces and ketchup)

In 2017, 3.11 million tonnes of tomato paste were imported worldwide. Main importers were:[49]

1) **European Union:**
1.30 million tonnes (41% of share)
2) **West Africa:**
0.35 million tonnes (11% of share)
3) **Far East Countries:**
0.23 million tonnes (7% of share)
4) **North Africa:**
0.20 million tonnes (6% of share)
5) **Republic of Iraq:**
0.16 million tonnes (5% of share)
6) **USA, Canada, Mexico (NAFTA):**
0.14 million tonnes (4% of share)

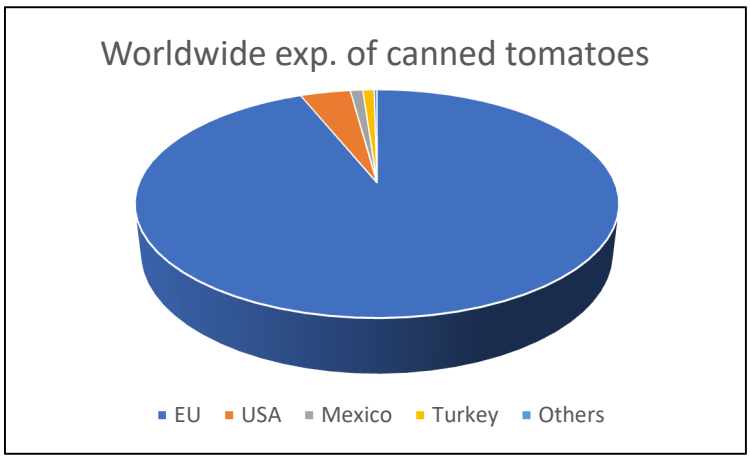


(Fig.26: Worldwide import of tomato paste)

3.9.2. Export

In 2017, 1.59 million tonnes of canned tomatoes were exported worldwide. Main exporters were:[49]

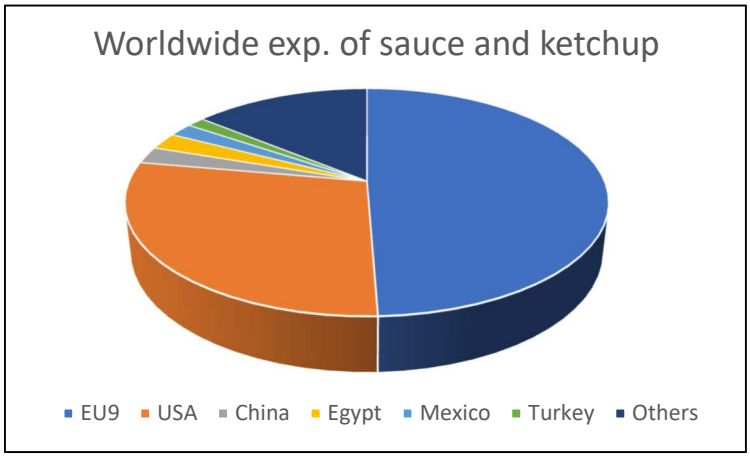
1) **European Union (TOP 5):**
1.50 million tonnes (93.87% of share)
2) **United States of America:**
0.07 million tonnes (4% of share)
3) **United Mexican States:**
0.02 million tonnes (1% of share)
4) **Republic of Turkey:**
0.01 million tonnes (0.9% of share)



(Fig.27: Worldwide canned tomatoes export)

In 2017, 1.20 million tonnes of sauces and ketchup were exported worldwide. Main exporters were:[49]

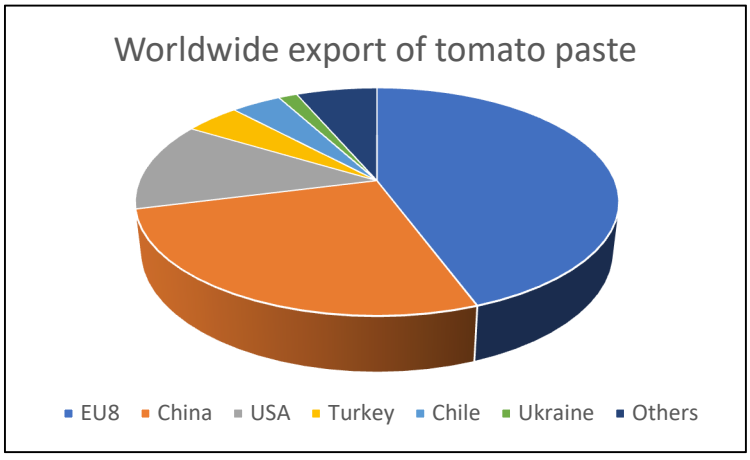
1) **European Union (TOP 9):**
0.67 million tonnes (49.4% of share)
2) **United States of America:**
0.38 million tonnes (28.4% of share)
3) **People's Republic of China:**
0.03 million tonnes (2.4% of share)
4) **Arab Republic of Egypt:**
0.03 million tonnes (2.4% of share)
5) **United Mexican States:**
0.03 million tonnes (1.9% of share)
6) **Republic of Turkey:**
0.02 million tonnes (1.4% of share)



(Fig.28: Worldwide tomato sauces and ketchup export)

In 2017, 3.11 million tonnes of tomato paste were exported worldwide. Main exporters were:[49]

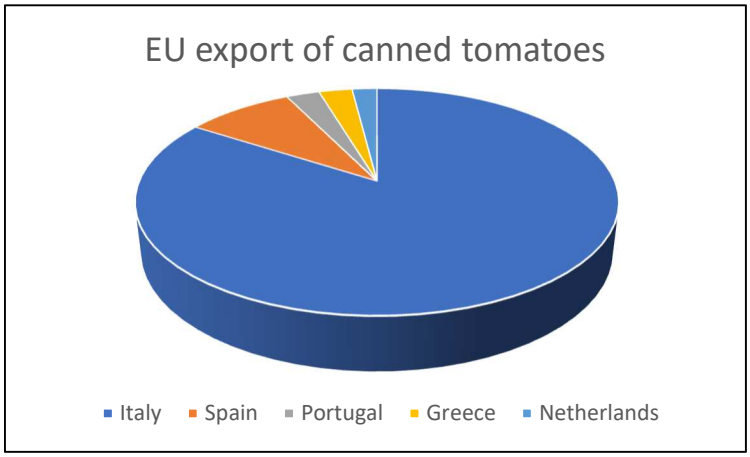
1) **European Union (TOP 8):**
1.38 million tonnes (44.34% of share)
2) **People's Republic of China:**
0.86 million tonnes (26.7% of share)
3) **United States of America:**
0.40 million tonnes (12.6% of share)
4) **Republic of Turkey:**
0.14 million tonnes (4.4% of share)
5) **Republic of Chile:**
0.13 million tonnes (4% of share)
6) **Ukraine:**
0.05 million tonnes (1.5% of share)



(Fig.29: Worldwide export of tomato paste)

Talking about the European Union situation, in 2017, main canned tomatoes exporters were:[49]

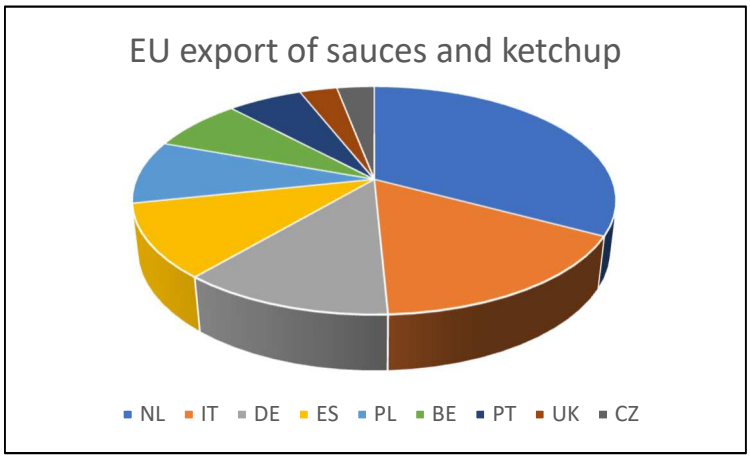
1) **Italian Republic:** 1.27 million tonnes
2) **Kingdom of Spain:** 0.13 million tonnes
3) **Portuguese Republic:** 0.04 million ton.
4) **Hellenic Republic:** 0.04 million tonnes
5) **Netherlands:** 0.03 million tonnes



(Fig.30: EU export of canned tomatoes)

Talking about the European Union situation, in 2017, main sauced and ketchup exporters were:[49]

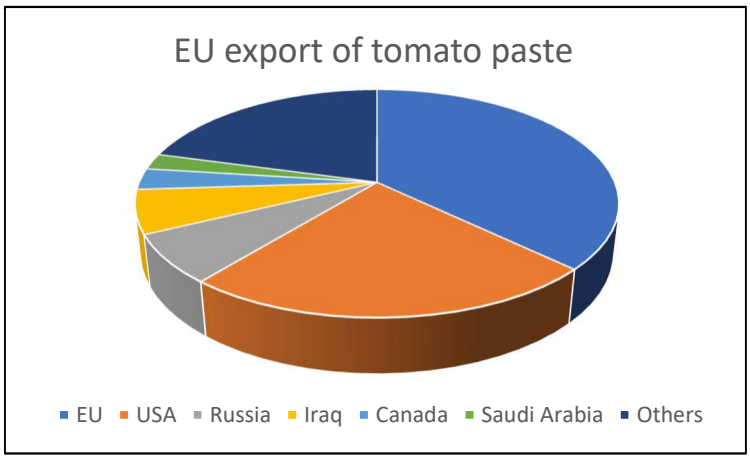
1) **Netherlands:** 0.22 million tonnes
2) **Italian Republic:** 0.11 million tonnes
3) **Fed. Rep. of Germany:** 0.08 million ton.
4) **Kingdom of Spain:** 0.07 million tonnes
5) **Republic of Poland:** 0.06 million tonnes
6) **Kingdom of Belgium:** 0.05 million ton.
7) **Portuguese Republic:** 0.04 million ton.
8) **United Kingdom:** 0.02 million tonnes
9) **Czech Republic:** 0.02 million tonnes



(Fig.31: EU export of sauces and ketchup)

Talking about the European Union situation, in 2017, main tomato paste exporters were:[49]

1) **Italian Republic:** 0.69 million tonnes
2) **Kingdom of Spain:** 0.32 million tonnes
3) **Portuguese Republic:** 0.26 million ton.
4) **Hellenic Republic:** 0.04 million tonnes
5) **Netherlands:** 0.02 million tonnes
6) **Fed. Rep. of Germany:** 0.02 million ton.
7) **Republic of Poland:** 0.01 million tonnes
8) **French Republic:** 0.01 million tonnes



(Fig.32: EU export of tomato paste)

4. The EU tomato supply chain

In the past two chapters a general understanding about tomato and tomato-based product has been provided while in this chapter the EU tomato supply chain itself will be investigated. The patterns and the flows which will be explored are based on the very interesting work called: "The German meat and EU tomato cases" written by Li Xue, Zhi Cao, Neele Prass, Gang Liu, Sebastian Gollnow, Jennifer Davis, Silvia Scherhaufer, Karin Östergren, Fabio De Menna, Laura García Herrero and Matteo Vittuari.[50]

A schematic representation of the trade-linked EU tomato supply chain is now presented:

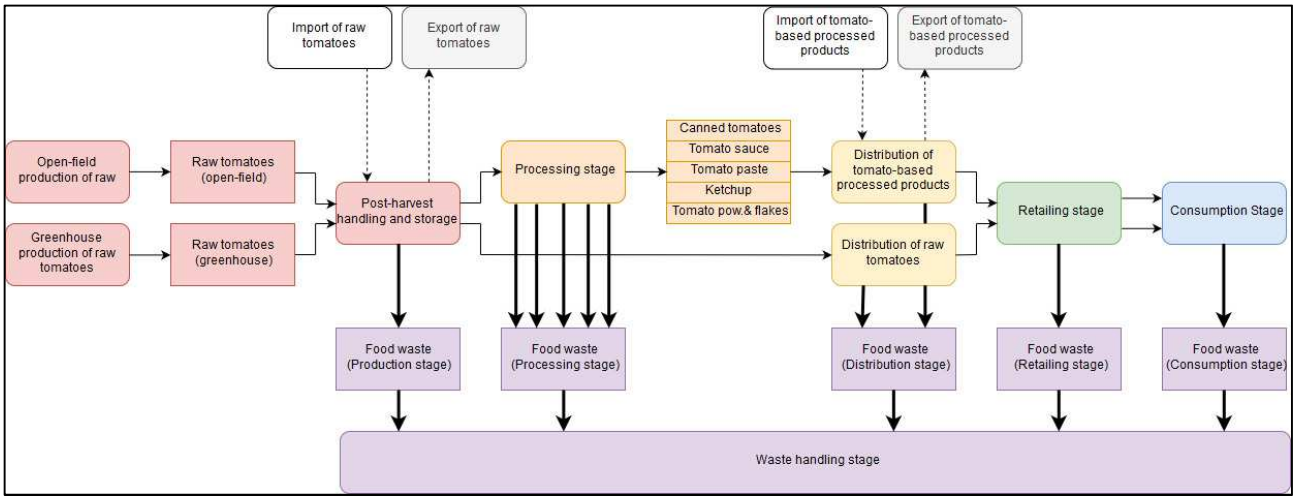
1. The rounded rectangles represent the various processes (such as the open-field and the greenhouse production, the retailing and so on) while the normal ones represent the products (such as raw tomatoes, ketchup, tomato sauce, tomato paste, canned tomatoes and so on)

2. The black thin arrows represent first the flows of open-field and greenhouse raw tomatoes and then the flows of tomato-based processed products while the black thick ones represent the flows of food waste. Import and export flows are represented by dashed arrows.

3. The colours which are applied both to products and processes represent:

    - Red: production stage (first stage)
    - Orange: processing stage (second stage)
    - Yellow: distribution stage (third stage)
    - Green: retailing stage (fourth stage)
    - Blue: consumption stage (fifth stage)
    - White: import stage (complementary stage)
    - Grey: export stage (complementary stage)
    - Violet: waste handling stage (complementary stage)

Import and export stages occur in two different main stages of the chain in fact they occur both in the post-harvest handling and storage (where raw tomatoes are imported and exported) and during the distribution stage in which tomato-based processed product are bought and sold before to be put in the retailing stage. It has to be said that the waste handling stage occurs in all the main five stage of the tomato supply chain.



(Fig.33: Schematic representation of the EU tomato supply chain)

4.1.1. The production stage

The production stage is the stage in which tomatoes are cultivated (the cultivation process has already been explained in the paragraph 2.1.). As we have seen in the Chapter 2, tomatoes can be cultivated both in open-field (mainly done in Southern Europe) and in greenhouses (which is preferred in Northern Europe). The description of the patterns and the flows of this stage may be summarized as follow:

1. Two flows of harvested tomatoes (from open-field and from greenhouse) go to the post-harvesting handling and storage stage (which is a part of the production stage itself). Raw tomatoes can also be imported and/or exported during this stage.

2. Two flows of harvested tomatoes go outside the production stage (one ends directly in the distribution stage while the other one ends in the processing stage). These two flows are a mixture of the previous two and they include the raw tomatoes which entered the system through the import while do not include the raw tomatoes which exited the system through the export. In few words, no matter if the tomatoes were cultivated in open fields, in greenhouses or imported; they all will be exported, processed, distributed or of course wasted.

In this stage, the waste generated (which will end in the waste handling stage through the "waste flow") is caused by several factors such as:

- Pest-infections, diseases and infections (Paragraph 2.3.)
- Environmental issues and extreme weather events
- Mechanical injuries occurred during the harvesting
- Poor transportation, handling and storage techniques
- Poor quality of tomato seeds

It has to be said that commonly, tomatoes that could be still eaten safely are sadly discarded just for market reasons because they do not have a perfect appearance (colour, shape, homogeneity, dimensions).

4.1.2. The processing stage

The processing stage is the stage in which tomatoes are processed in order to become tomato-based processed products. As we have seen in the Chapter 3, processing stage is where raw tomatoes are transformed in canned tomatoes, sauces, pastes, ketchup, powder or flakes. The input flow comes from the production stage while the output flows go to the distribution stage and to the waste handling stage.

In this stage, the waste generated (which will end in the waste handling stage through the "waste flow") is caused by several factors such as:

- Not-optimised techniques of cutting and/or peeling
- Old factories and/or obsolete machines
- Poor methods of processing
- Poor quality of the raw tomatoes

Apart from those factors which are related with factories (which unfortunately don't make enough investments to improve their techniques and equipment) it's clear that the quality of the raw product plays a key role in the final yield which is achievable in the processing stage.

4.1.3. The distribution stage

The distribution stage is the stage in which distributors (that since now are going to be called wholesalers) buy raw tomatoes from producers and tomato-based tomato products from processing industries. According to that (and for simplicity) we can imagine this stage as if it was split in two: one which deals with the distribution of raw tomatoes and another one which deals with the tomato-based products.

1. In the distribution stage which deals with raw tomatoes we have one input flow from the production stage and two output flows: one ends in the retailing stage while the other one ends, as expected, in the waste handling stage.

2. In the distribution stage which deals with tomato-based processed products we have one input flow from the processing stage (which is made up of the sum of all the single tomato-based processed products flows) and one input flow that shows the products entering the stage through the import. Furthermore, there are three output flows: the first one ends in the retailing stage (as it happened before with the previous distribution stage), the second shows the products which are exiting the system through the export and the last one ends in the waste handling stage.

The reason because import/export occurs with tomato-based processed products is that import/export of raw tomatoes already occurred in the production stage (post handling and storage stage). The factors that are involved in the production of waste in this stage are mainly related with the difficulty to match the demand with the supply, with mistakes during transportation and with poor techniques of storage.

4.1.4. The retailing stage

The retailing stage is the stage in which retailers buy raw tomatoes and tomato-based processed products from wholesalers and sell these to the final consumers. The input flows come from the distributions stages while the output flows end in the consumption stage and again in the waste handling stage.

In this stage, the waste generated is caused by several factors such as:

- Difficulty to match the demand with the supply
- Poor techniques of storage or not proper handling

Another quite impactive issue is the outdating of the products which is caused mainly by the bad habit of retailers who always want to show all their products at every time of the day to the consumers.

4.1.5. The consumption stage

The consumption stage is the stage in which final consumers buy the products from retailers in order to consume it. The input flow comes from the retailing stage while the output one goes to the waste handling stage. In this stage, the waste generated is caused by several factors such as:

- The bad habit of many consumers to buy more products than the ones they can consume
- Poor attention of the consumers due to the relatively low price of tomatoes
- Poor techniques of storage (especially improper conditions of refrigeration)
- Lack of cooking skills (especially cutting skills) of the consumers

4.2. Introduction about food waste

In the last paragraphs, food waste flows have been introduced. Food waste (sometimes also knows as food loss and/or food wastage) is the loss of edible food which would be suitable for human consumption.

It has to be said that some authors make a difference among food loss, food waste and food wastage and until now, the definition of food waste itself, appear far to be univocal. After this clarification, since now, the loss of edible food which would be suitable for human consumption will be defined as "food waste".

There are two categories of food waste:

1. Avoidable food waste which is, it was shown briefly in the past chapter the result of several contributing factors occurring in all the stage of the tomato supply chain:

    - Parts that could be eaten but they are currently not due to the wrong habits

    - Parts that could be eaten but they are lost due to obsolete processing machines, employment of unskilled workers, lack of use of "best methods and techniques", poor handling, cultivation, storage and transportation techniques.

    - Parts which nevertheless their safeness and their goodness are discarded just because their poor appearance (colour, shape, dimensions and so on).

2. Unavoidable food waste which is the result of several contributing factors:

    - Parts that cannot be eaten (such as skin, peels, leaves, seeds) or, and that's very important, which could be technically eaten but are currently not (or there is no proof that a consistent percentage of people is eating them). Maybe they are eaten by a restricted percentage of people, maybe they are eaten just during crises, maybe they were eaten in the past or maybe they will be eaten in the future. This part of the unavoidable food waste is of course influenced by both geographical, social, economic, religious, historical, cultural and temporal factors which are really hard to investigate, estimate and predict.

    - Parts that are lost due to the handling and processing methods nevertheless the use of best practice methods[51], most modern technologies and most skilled workers. In few words, this contribution is the result of both the technologic limits and the scientific ones (we cannot predict the technologies that will be available in the future but we can assume that if we will continue to eat for example peeled tomatoes there will be always peels to discard.)

    - Parts that are lost due their poor characteristics or their low quality. If it's true that vegetables with a poor appearance but which are good and safe could still be eaten, we cannot imagine to eat those products which are infected, not safe or with a bad taste. (Also if, as Latin said, "de gustibus non est disputandum" = taste is a matter of subjectivity).

Since now and unless otherwise indicated, the unavoidable food waste will be not considered anymore. According to that, food waste will be simply considered as the reasonably avoidable food waste.

4.2.1. The impact of food waste

Nowadays, food waste represents both one of the biggest environmental issue and one of the biggest socioeconomic ones. According to the Swedish Institute for Food and Biotechnology, more than 33% of all the food produced nowadays ends in waste[52] and there are estimates that raise this percentage up to 50%.

According to FAO, the economic impact of food waste appear to be huge:[53]

- 890 billion euros of direct costs
- 623 – 801 billion euros of indirect costs (environmental, public health costs)

The environmental impact seems to be quite impressive as well:

- It has been estimated that a percentage between 20% and 30% of the individual environmental impact is somehow related with food waste[53].
- Furthermore, it has been estimated that extensive agriculture techniques together with the land used by agricultural fields are the main responsible for both the degradation of ecosystems and for the loss of biodiversity.[54]
- 700 kg of $CO_{2\text{-eq/percapita}}$[55] emitted are a direct consequence of food waste.

The huge social impact of food waste has no further need to be underlined, in fact while at least one third of the total food production is wasted worldwide:

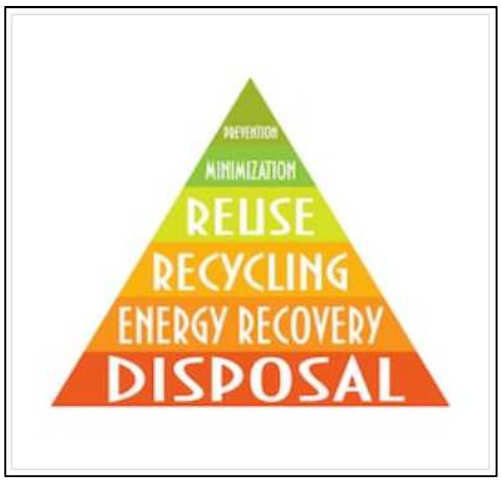
- According to FAO, in 2017, 821 million people were undernourished and furthermore, it has to be said that nowadays, the hunger is currently on rise (804 million people undernourished in 2016.)[56] This is clearly in contrast with the second "Sustainable Development Goal" whose aim is to defeat the hunger everywhere in the world in 2030.
- The human population is expected to raise up to 9.5 billion in 2050 [57] and up to almost 11 billion in 2100 [58]. If we assume that, in the "best" case scenario, the percentage of undernourished people will remain steady (around 11%) we will have to deal with more than 1.2 billion undernourished people (scenario in which growth is assumed steady).

According to the fact that, as it was said in Chapter 2, tomatoes represent a big percentage of the total vegetables which are consumed (and so wasted) worldwide, the understanding of the supply chain appears to be a fundamental priority in order to try to reduce the issues related with food waste.

(Fig.34: Food waste is both an environmental and a social issue)[o]

4.3. The food waste handling

Food waste is classified as organic waste. (Organic waste represents about the 70% of all the total waste.[59])



(Fig.35: Waste pyramid)[o]

As we have seen before, food waste is originated at every stage of the chain for the most various reasons and its generation has big impact both on the human beings and on the environment.

The waste pyramid (also known as the waste hierarchy) represents a useful tool in order to classify the various options available for the waste handling ordering them from the safest and the most sustainable for the environment to the least safe and sustainable one.

These options (ordered from the most favourable to the least one) are: prevention, minimization, reuse, recycling, energy recovery, disposal). Talking about organic waste, "recycling" can be considered the equivalent of "composting" (not only).

4.3.1. Prevention and minimization

Prevention and/or minimization of food waste (which as we have seen before occurs at every stage of the chain) would be the most favourable option. This, is generally, pretty obvious and it is linked to the fact that also recycling/waste handling plants have both direct (gas emissions, energy and material consumption, water use) and indirect (such as the land use change) impacts on the environment. The collection and the transportation of waste is also quite impactive due to the trucks used (generally supplied by fossil fuels.)

4.3.2. Reuse and composting

Food waste (depending by the type) can be sometimes used for both breeding and agricultural applications. Tomatoes, together with other types of organic waste can become food for animals (raw as they are or after some kind of processing): the idea is to consider them not as waste but as by-products. Furthermore, agricultural waste can be used (in right proportions) as fertilizer reducing the needs of the chemical ones.

One particular application of what we have just seen is the compost. Compost is a soil-conditioner that is obtained from the decomposition of a large variety of organic-based products (like for example food waste). It can be used as soil-conditioner, in gardening, and in organic farming especially for horticultural applications. The overall process can be summarized as follow:

- Collection and delivery: organic waste is first collected both from households and from industries and then delivered to the biogas processing plants.
- Sorting: organic waste is sorted together with the removal of any unwanted material
- Composting: organic matter is being decomposed in tanks in aerobic conditions. This decomposition occurs thanks to several organisms (worms, bacteria, protozoa, fungi and so on) that oxide the carbon-based material thanks to the oxygen with the help of water (that keeps the microorganisms' activity going, avoiding the anaerobic conditions) and nitrogen (which is necessary to oxidize more carbon and to grow more microorganisms).
- Storage and/or distribution: compost is stored locally and/or distributed to potential users.

Compost is similar to digestate (which is produced in anaerobic conditions) but it has more nutrients.

4.3.3. Production of biogas and biomethane

Organic waste can be used as main ingredient in the production of biogas and biomethane which are two environmentally friendly fuels. Biogas is produced through the digestion of the organic waste (which is carried out by several microorganisms) while biomethane is obtained from the purification of the biogas and can be considered almost equivalent to natural gas. The process[60] can be overall described as follow:

- Collection and delivery: organic waste is first collected both from households and from industries and then delivered to biogas processing plants.
- Sorting: organic waste is sorted together with the removal of any unwanted material
- Shredding and slurrification: organic waste is first shredded and then mixed with water (or other fluids) in order to give it a more fluid consistency (process of slurrification).
- Sanitization: organic waste is sanitized in order to eliminate all the harmful microbes.
- Digestion: the slurry is heated up to 37°C in order to activate the microorganisms and then put in large containers for about three weeks where the production of biogas takes place.
- Degasification and finishing: CO_2 is removed from the mixture and the so obtained biomethane is furtherly processed in order to remove all the impurities.
- Storage and/or distribution: biogas is stored locally and/or put in the distribution network.

The solid part which remains in the tank after the digestion process is called digestate and it can be used as fertilizer (due to its relatively high nitrogen content), in gardening or, most commonly, in dumps covering.

4.3.4. Production of syngas

Organic waste can be also used as main ingredient in the production of the syngas which is an environmentally friendly fuel produced through the partial combustion (with a lack of oxygen which doesn't allow the biomass to burn completely) of biomass. The process can be overall described as follow:

- Collection and delivery: organic waste is first collected both from households and from industries and then delivered to biogas processing plants.
- Sorting: organic waste is sorted together with the removal of any unwanted material
- Drying: organic waste is dried in order to make the water content lower
- Partial combustion: organic waste is combusted in an oxygen-deficient atmosphere
- Storage and/or distribution: syngas is stored locally and/or distributed to potential users.

Syngas cannot usually be put directly in the distribution network due to its different composition but it can be used in order to supply turbines, fuel cells, combustion engines or to be furtherly converted in methanol, hydrogen, dimethyl ether, biochar or several other mixture of useful alcohols.[61]

(Fig.36: Biogas production plant)[o]

4.3.5. Production of ethanol

Another product that can be manufactured using organic waste as basis is the ethanol. Ethanol, which is the result of the fermentation carried out by the action of several microorganisms, can be used as fuel. The process of production of ethanol fuel (from organic waste) can be described as follow[62]:

- Collection and delivery: organic waste is first collected both from households and from industries and then delivered to biogas processing plants.
- Sorting: organic waste is sorted together with the removal of any unwanted material
- Fermentation: sugars contained in the organic waste are converted in ethanol
- Distillation: water and yeast are removed from the mixture through the use of evaporators
- After this phase, a 95% ethanol mixture (called hydrous ethanol) is obtained
- Dehydration: through several processes the remaining water is removed from the mixture
- Storage and/or distribution: ethanol is stored locally and/or distributed to potential users

Ethanol fuel can be used pure (or mixed with gasoline) in the so-called flexible-fuel vehicles. (FLEX engines)

4.3.6. Production of biodiesel

Biodiesel represents another liquid fuel which can be synthesized using organic waste as starting ingredient through the transesterification and esterification processes.[63]

- Collection and delivery: organic waste is first collected both from households and from industries and then delivered to biogas processing plants.
- Sorting: organic waste is sorted together with the removal of any unwanted material
- Oil extraction: the oily part is extracted from organic waste
- Pre-treatments: organic oils are treated in order to remove both impurities and water
- Transesterification: during the transesterification, alcohol react with lipids in order to produce biodiesel together with glycerol
- Esterification: oils with a high content of acid can also react with alcohol to obtain biodiesel
- Separation and refining: by-products are removed and biodiesel is refined.
- Storage and/or distribution: biodiesel is stored locally and/or distributed to potential users

Biodiesel can be used (pure or mixed with classic diesel) in order to supply a large group of vehicles. The percentage of biodiesel in the mixture that is tolerated by the engine varies from engine to engine (technically this quantity can vary between 0% and 100% but more commonly the range is between 5% and 80%). This fuel can be also used in order to supply trains and its use for airplanes has been proposed as well. Furthermore, biodiesel can be safely used also as heating oil in both domestic and industrial application and as generator's fuel in order to produce electricity.

4.3.7. Production of solid fuels

Finally, organic waste can be also used as solid fuel. In order to do so, after collection, delivery and sorting, organic waste has to be first sanitized and then densified. After that, it can be burned in order to produce electricity and/or heat. It can also be pyrolyzed (combusted in an oxygen-deficient atmosphere) to obtain the biochar (with syngas). Biochar is a type of charcoal that is currently used for soil enrichment purposes.

4.3.8. Energy recovery

Organic waste can be incinerated in the so-called incineration plants. Incineration have two main advantages: it reduces twenty times the mass of waste and it can recover both energy and heat.[64]

(Fig.37: Waste incinerating plant, Biebesheim, Hesse, Germany)[o]

The main disadvantage of incinerating waste is that incineration does not allow any recovery of materials (if we exclude the ashes that, if not hazardous, may have some applications in road constructions or landfills covering.)

Incineration plants are claimed to be less polluting than landfills but it has to be said that in Southern Europe they are still controversial.

In Italy for example, there is a really big social opposition against the construction of new plants also considering that district heating is not so common and not so useful in these areas (due to the relatively high temperature during the year). On the other hand, in Northern Europe, incineration is very accepted.

4.3.9. Disposal

The last option of waste handling (in this case organic waste) is the landfilling. Landfills are large areas (which can be situated within the cities) in which waste is collected, managed, treated and dumped.[65]

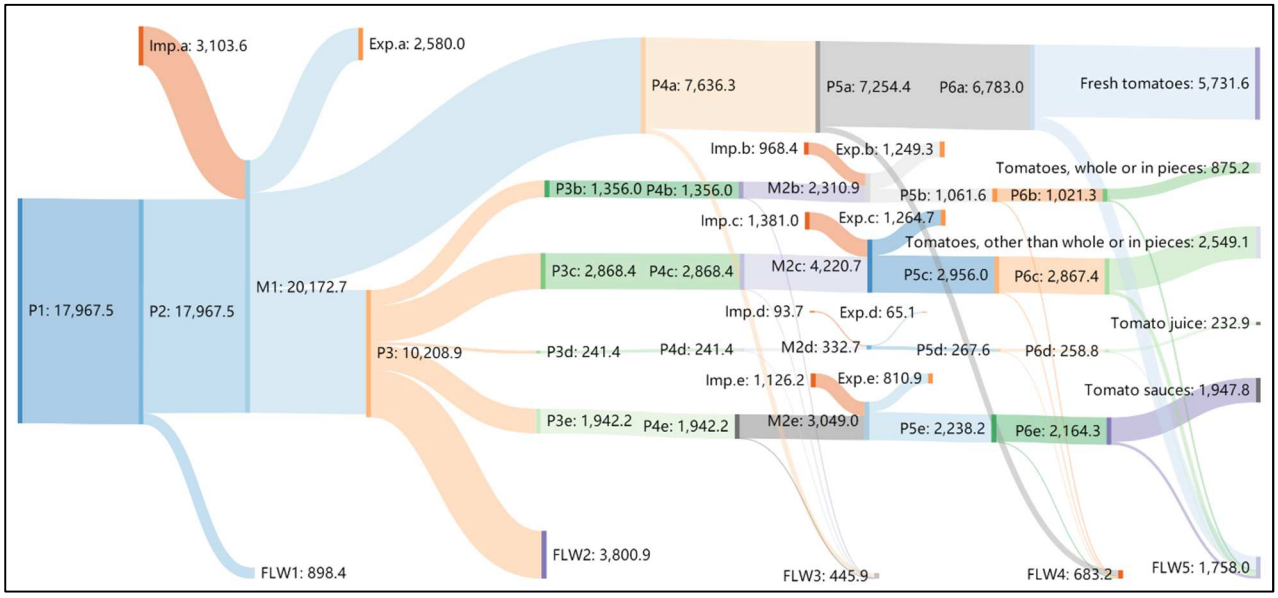
This way of waste handling is the oldest one and it does not bring any advantage because landfills do not allow the recovery neither of materials nor of energy.

(Fig.38: Example of dump: the least favourable option for handling waste)[o]

Apart from the land use, landfills have a big impact on the environment due to the methane emissions and the production of percolate which can pollute both the soil and the groundwater.

These problems can be limited through the installation of some kind of liner and collection systems, through a proper percolate management and the through the control of the storm water and of the methane (which can be both collected or more commonly locally burned). Furthermore, before establishing a landfill, complex studies regarding the water table have to be done in order to avoid contaminations.

4.4. Material flow analysis



(Fig.39: Material flow analysis of the EU tomato supply chain)[50]

Now that a general understanding about the tomato supply chain has been given, the material flow analysis of the EU tomato supply chain contained in "The German meat and EU tomato cases" can be presented. (Please note that units are expressed in thousands of tonnes) In detail:[50]

1. P1, which represents the flow of tomato production and P2 which represents the postharvest handling and storage one, are both referred to the production stage. FLW1 is the total food waste caused by the tomato loss in production stage. Flows representing import/export are visible as well

2. P3 is referred to the processing stage while FLW2 stands for the flow of the total amount of food waste which is caused by the tomato loss occurring during the processing stage.

3. P4 is referred to the distribution stage while FLW3 stands for the flow of total food waste caused by the tomato loss in the distribution stage.

4. P5 is referred to the retailing stage while FLW4 stands for the flow of the total amount of food waste which is caused by the tomato loss occurring during the retailing stage.

5. P6 is referred to the consumption stage while FLW5 stands for the flow of total food waste caused by the tomato loss in the consumption stage.

6. "a" stands for: raw tomatoes, "b" stands for: tomatoes, whole or in pieces, "c" stands for: tomato, other than whole or in piece, "d" stands for: tomato juice while "e" stands for: tomato sauces. Furthermore, M1 represents the fresh tomato market while M2 represents the tomato-based processed products one.

Since now, those mass flows which don't concern with food waste will not be considered anymore (since they are out of the scope of this thesis) while the data of the flows related with food waste will be furtherly used in the economic analysis (because they will be combined with the unitary cost of every kg of food waste in order to obtain the total amount of money which is lost due to the food waste in every stage of the EU tomato supply chain. These data are presented now and will be discussed later on.

4.4.1. Material flow analysis methodology

The tomato-based processed products (tomato whole or in pieces, tomato juice, tomato sauce, tomato other than whole or in pieces) have been converted into raw tomatoes equivalent in order to map the flows of both raw tomatoes and tomato-based processed products. Furthermore, two different markets (raw tomatoes and tomato-based processed products) with the related export and import flows have been quantified on the basis of trade statistics.[50]

In detail, data concerning the waste management and both the production of raw tomatoes and the one related to tomato-based processed products have been retrieved from EUROSTAT while the data related to trade have been retrieved from the UN-Comtrade database. All the data used are referred to 2016.[50]

The mass flow analysis started taking in consideration the raw tomatoes production (which is followed by the so-called postharvest handling and storage stage). The total amount of raw tomatoes which are available for consumption (and/or processing) has been quantified considering both the tomato loss rate at this stage and the import/export of raw tomatoes.[50]

Since raw tomatoes which are involved in the production of tomato-based processed products are available, the remaining part is represented by the consumption of raw tomatoes whose flow directly went to the distribution stage. Then, how much fresh tomatoes left this stage in order to go to the retailing and consumption stages were calculated based on the loss and food waste rates calculated at these stages and trough the mass balance principle. The remaining part represents what is actually eaten by consumers.[50]

4.4.2. Material flow analysis results[50]

1000 tonnes	Tomato loss in p.harv		Tomato loss in processing stage				Tomato loss in distribution stage				
	FLW1a	FLW1b	FLW2a	FLW2b	FLW2c	FLW2d	FLW3a	FLW3b	FLW3c	FLW3d	FLW3e
Italy	29,95	269,55	319,23	81,10	34,28	1571,70	25,30	10,80	0,80	1,50	18,80
France	33,12	8,28	2,52	0,97	12,17	4,33	41,30	0,00	0,20	1,60	0,50
Spain	130,85	130,85	201,74	6,44	594,92	327,20	96,20	2,10	0,10	4,80	4,50
Netherl.	44,50	0,00	0,00	0,00	0,00	0,00	6,70	0,00	0,00	1,60	0,00
EU	302,24	596,16	1114,73	203,06	1601,39	2205,52	292,30	13,60	2,40	19,40	28,70

(Tab.8: Results of the material flow analysis of the EU tomato supply chain first part)

Kilograms of food waste for all the products (raw tomatoes, canned tomatoes, tomato sauce, tomato juice, tomato other than whole and/or in pieces) for all the countries (Italy, France, Spain, Netherlands, EU) in production, processing and distribution stages; retrieved from the MFA are shown in the tab above while those kilograms of food waste which are related to all the products (raw tomatoes, canned tomatoes, tomato sauce, tomato juice, tomato other than whole and/or in pieces) for all the countries (Italy, France, Spain, Netherlands, EU) in retailing and consumption stages; retrieved from the MFA are shown in the tab below.

1000 tonnes	Tomato loss in retailing stage					Tomato waste in consumption stage				
	FLW4a	FLW4b	FLW4c	FLW4d	FLW4e	FLW5a	FLW5b	FLW5c	FLW5d	FLW5e
Italy	31,30	3,00	2,30	0,10	38,10	69,70	10,80	6,70	0,30	136,90
France	51,00	4,00	0,70	13,30	4,60	113,80	14,50	2,00	39,00	16,50
Spain	118,80	3,80	0,10	14,00	5,20	264,90	13,90	0,30	41,00	18,60
Netherl.	8,30	1,60	0,30	4,30	3,70	18,60	5,80	0,80	12,60	13,30
EU	361,00	41,10	8,40	65,70	79,00	805,00	148,60	24,80	192,60	283,60

(Tab.9: Results of the material flow analysis of the EU tomato supply chain second part)

In the MFA, it has been possible to read what is the percentage of tomatoes (for every country) that are going to be furtherly processed and what is the percentage of tomatoes that are going to enter directly the distribution stage. These percentages have been applied to the quantity of food waste in the production stage in order to obtain the quantity of food waste for both the fresh products and those which are going to be in the processing stage in order to be processed.

fresh	processing	tot EU
0,336423	**0,663577**	**1**
302,2426	596,1574	898,4

fresh	processing	tot ESP
0,5	**0,5**	**1,0**
130,85	130,85	261,7

fresh	processing	tot ITA
0,1	**0,9**	**1,0**
29,95	269,55	299,5

fresh	processing	tot FRA
0,8	**0,2**	**1,0**
33,12	8,28	41,4

(Tab.10: Index of the distribution between fresh products and those that are going to be processed)

In order to divide the waste flow of the processing stage in four different flows (every flow stands for one category of product), the following indexes have been developed. These indexes are based on an average of the distribution, consumption and retailing stages ones (for every country and for the European Union).

Italy	**canned**	**juice**	**sauce**	**other**	**tot**
distrib.	10,8	0,8	1,5	18,8	31,9
	0,338558	0,025078	0,047022	0,589342	1
retailing	3	2,3	0,1	38,1	43,5
	0,068966	0,052874	0,002299	0,875862	1
consum.	10,8	6,7	0,3	136,9	154,7
	0,069813	0,04331	0,001939	0,884939	1
process.	**0,159112**	**0,040421**	**0,017087**	**0,783381**	**2006,3**

EU	**canned**	**juice**	**sauce**	**other**	**tot**
distrib.	13,6	2,4	19,4	28,7	64,1
	0,212168	0,037441	0,302652	0,447738	1
retailing	41,1	8,4	65,7	79	194,2
	0,211637	0,043254	0,338311	0,406797	1
consum.	148,6	24,8	192,6	283,6	649,6
	0,228756	0,038177	0,29649	0,436576	1
process.	**0,217521**	**0,039624**	**0,312484**	**0,43037**	**5124,7**

France	**canned**	**juice**	**sauce**	**other**	**tot**
distrib.	**0**	**0,2**	**1,6**	**0,5**	**2,3**
	0	0,086957	0,695652	0,217391	1
retailing	**4**	**0,7**	**13,3**	**4,6**	**22,6**
	0,176991	0,030973	0,588496	0,20354	1
consum.	**14,5**	**2**	**39**	**16,5**	**72**
	0,201389	0,027778	0,541667	0,229167	1
process.	**0,126127**	**0,048569**	**0,608605**	**0,216699**	**20**

Spain	**canned**	**juice**	**sauce**	**other**	**tot**
distrib.	**2,1**	**0,1**	**4,8**	**4,5**	**11,5**
	0,182609	0,008696	0,417391	0,391304	1
retailing	**3,8**	**0,1**	**14**	**5,2**	**23,1**
	0,164502	0,004329	0,606061	0,225108	1
consum.	**13,9**	**0,3**	**41**	**18,6**	**73,8**
	0,188347	0,004065	0,555556	0,252033	1
process.	**0,178486**	**0,005697**	**0,526336**	**0,289482**	**1130,3**

(Tab.11: Index on the distribution of loss of the four categories of products in the processing stage)

5. Economic Analysis

An economic analysis has been carried out in order to quantify the cost of food waste (expressed in €/kg) for every product (raw tomatoes, canned tomatoes, tomato juice, tomato sauce, ketchup, tomato paste), for every stage (production stage, processing stage, distribution stage, retailing stage, consumption stage), both for every country (Italy, France, Spain, Netherlands) and for the entire European Union.

Some assumptions have been made:

- Tomato flakes and tomato powder have been not considered because of the lack of data and considering the fact that this category of tomato-based products is quantitively not relevant.
- "Canned tomatoes" is the equivalent category of "tomato whole or in pieces" in the MFA.
- "Ketchup and tomato paste" is the equivalent category of "tomato other than whole or in pieces".
- France, Italy, Spain and Netherlands are considered to be representative of the entire European Union for population and for both the production capacity and the processing one.

After these clarifications, a short comparison among economic analysis will be now presented. After that, the economic analysis which has been carried out will be investigated in detail.

5.1. Comparison among methods

The economic analysis of the food waste in the EU tomato supply chain can be done through several types of LCC life cycle cost methodologies which are methodologies whose aim is to calculate the overall costs of some services or some product during their entire life cycles or during their entire life spans.[66]

LCC methodologies can be divided in conventional LCC (C-LCC) which are those techniques that "are mainly applied in the framework of decisions over products or investments requiring high initial capital, such as buildings, energy systems, transport systems, military equipment, and durable goods in general, with the perspective of the producer or the consumer" and in the environmental life cycle costing (E-LCC) ones "which are those techniques whose aim is to be compatible with LCAs assessing the costs which occurr during the life span of services, technologies and products."[66]

Apart these two main LCC categories, there are other methodologies which take in consideration both the direct and the indirect social and/or environmental costs for the society such as the cost-benefit analysis, the full cost accounting and the social life cycle costing (S-LCC).

In detail:

1. The life cycle costing (LCC), according to the article 67 of the European Directive about procurements, is a methodology that should allow to estimate all the costs occurring during the entire life span of one service or product, from the production to the waste handling stage. These costs include installation and purchases, costs occurred due to the use of the products (such as those for gas, fuels, electricity, training, maintenance) and those related to the waste handling. [67] LCC can be calculated as follow: *LCC = purchase costs + repair and maintenance costs + energy and water consumption costs + replacement cost-residual value + waste handling costs*

2. The environmental life cycle costing (E-LCC) is a significant step forward in the assessment of costs if compared to the traditional version of LCC because it combines elements of LCC with some LCA-belonging ones. This methodology takes in consideration both the costs which are related to the life cycle of a product and those which are related to the externalities produced. In detail, all the costs concerning the externalities (occurring during all the stages) are quantified as internal processes and included among the other economic costs. There are several methods to quantify the environmental costs such as the "willingness to pay", the eco-costs or the external costs. [68]

3. The social life cycle costing (S-LCC) considers both the positive and the negative social impacts which are generated during the entire life cycle of a product or a service. This methodology is not completely standardized yet due to the lack of agreement about the choice of functional units and considering the fact that that usually, social impacts cannot be attributed just to the production processes (since they are often connected to the environment or to the shareholders' behaviour).[69]

4. The cost-benefit analysis is a methodology whose aim is to investigate the opportunity costs. It is used to determine how weak (or strong) is an alternative compared to the others trying in the end, to find the best and the most appropriated one (the most suitable for achieving the targets). It is used especially in order to compare different investments trying to assess their effectiveness.[70]

5. Finally, the full costing methodology try to assess the total costs assuming that all the fixed, and variable costs (such as raw materials and salaries) are directly assigned to the end product.

Nevertheless, both the environmental and the social aspects had been considered and briefly analysed and discussed, they have not directly been included in the economic analysis due to two main reasons:

- Lack of standardization: S-LCC are not uniquely standardized and the development of an appropriate and suitable method has been considered not feasible for the tomato supply chain.
- Lack of data and time shortage: also taking in consideration the possibility to carry a S-LCC, the average lack of data would have affected the general solidity and strength of the model (while the data gaps of the model chosen do not affect sensibly the overall strength of the model). Furthermore, the investigation of the literature would have required a time several times bigger than the time (one semester) that has been given in order to complete the study project.

Time shortage and the lack of data together with the difficulty to take in consideration all the possible rebound effects are the main reasons which made the realization of a complete LCC not possible.

Cost-benefit analysis has not been considered suitable for the investigation considering the fact that the there is just one situation (and not two or more that need to be investigated): the production of waste in the EU tomato supply chain (for every category of product, for every country, for every stage).

In the end, the model chosen, as it will be shown after, is more similar to a full cost analysis (applied to the waste flows, in every stage) in which the opportunity costs of the missed sales are considered as well.

The methodology chosen will be now presented first in a general form (introducing some key concepts together with some explicative examples) and then in a more detailed form in which every stage of the European tomato supply chain will be investigated in order to find the overall total cost of food waste coming both from tomato and tomato-based processed products.

5.2. Methodology chosen

The methodology chosen for the economic analysis can be summarized as follow:

1. Retrieve, calculate or (as last option) reasonably assume the total cost of every kilogram of the tomato-based waste, in every stage of the EU tomato supply chain (production stage, processing stage, distribution stage, retailing stage, consumption stage), for each country (Italy, France, Netherlands, Spain), for each product (raw tomatoes, canned tomatoes, tomato juice, tomato sauce, tomato paste, ketchup). This amount of money represents the actual amount of money which has been lost in producing something that will be then not sold.

2. Retrieve, calculate or (as last option) reasonably assume the total gross margin of every kilogram of the tomato-based waste, in every stage of the EU tomato supply chain (production stage, processing stage, distribution stage, retailing stage, consumption stage), for each country (Italy, France, Netherlands, Spain), for each product (raw tomatoes, canned tomatoes, tomato juice, tomato sauce, tomato paste, ketchup). This gross margin will be assumed as an "opportunity cost" which represents the amount of money which has been lost due to the missed sales.

3. If they were not already combined (often, costs and gross margins were already available combined and retrieved in this form) 1. and 2. are combined in order to obtain a "cost" which include both.

4. Remove the influence of the taxation focusing in particular on the so-called VAT (value added tax) from this obtained "cost" of every kilogram of tomato-based waste, in every stage of the trade-linked tomato supply chain (production stage, processing stage, distribution stage, retailing stage, consumption stage), for each country (Italy, France, Netherlands, Spain), for each product (raw tomatoes, canned tomatoes, tomato juice, tomato sauce, tomato paste, ketchup).

5. Combine these cluster of national data in order to obtain a European cluster of data.
(This combination will be made in several ways which will be investigated later on)

6. Retrieve data about the kilograms of every waste flow from the material flow analysis (paragraph 4.4.) for every stage of the EU tomato supply chain (production stage, processing stage, distribution stage, retailing stage, consumption stage), for each country (Italy, France, Netherlands, Spain), for all the European Union (considered one country) for each product (raw tomatoes, canned tomatoes, tomato juice, tomato sauce, tomato paste, ketchup).

7. Combine economic data from 4. (concerning countries) and 5. (concerning European Union) with 6. (material flow analysis) in order to obtain the total amount of money which is lost, according to the methodology chosen, for every stage of the EU tomato supply chain (production stage, processing stage, distribution stage, retailing stage, consumption stage), for each country (Italy, France, Netherlands, Spain), for all the European Union (considered one country) for each product (raw tomatoes, canned tomatoes, tomato juice, tomato sauce, tomato paste, ketchup).

According to this, a summary about some key concepts such as costs, margins, prices, taxes will be now presented. Then, after these clarifications, the application of the methodology to every stage of the trade-linked tomato supply chain (production stage, processing stage, distribution stage, retailing stage, consumption stage), for each country (Italy, France, Netherlands, Spain), for all the European Union (considered one country) for each product will be presented and explained in detail.

5.2.1. Cost and profit

In accounting, costs are defined as the amount of money which has to be spent in order to deliver a service or to produce something. There are several types of costs:

1. Manufacturing costs (costs which are involved in manufacturing in a direct way)

    - Direct labour costs: those costs are related with the employees (They have to receive money for producing something or for providing a service) and can be calculated as follow: $Direct\ labour\ costs = hourly\ wage * working\ hours\ needed$ [71]
    - Direct materials costs: those costs are related with the materials (including energy) which are needed in order to manufacture a product. They can be calculated as follow: $Direct\ material\ costs = raw\ materials\ needed\ per\ unit * units\ produced$
    - Manufacturing overhead costs: those costs are not related neither with direct labour costs, nor with direct material costs and they include plant repairs, insurances, maintenance, cleaning, lighting, rents, property taxes, lubricants and so on.[72]

2. Non-manufacturing costs: (costs which are not involved in manufacturing in a direct way)

    - Administrative costs: marketing, project management, finance, accounting and so on
    - Distribution costs: (for example the salaries of salesmen)

3. Other costs:

    - Indirect labour costs: taxes, insurances, vacation payments
    - Other: training costs, working clothes, protection of the environment and so on

Costs can be also divided in variable costs and fixed costs:

1. Fixed costs: those costs are not related with the quantity of products which are manufactured (or from the services which are provided). Fixed costs include utilities bills, rent, administrative costs, some marketing costs, interests and so on.

2. Variable costs: those costs are related with the quantity of goods which is produced.

Often variable costs can be related with manufacturing costs (direct costs) while fixed costs can be related with non-manufacturing costs but that's a simplification which is not always valid: for example, marketing cost (which is a NM cost) is both a variable and a fixed cost[73]. Another example is about manufacturing overhead costs: they are manufacturing costs but they are also fixed costs.

Few words have to be spent also on the opportunity cost which is the cost of choosing something in a range of available options. This is the cost related to the not enjoyed benefit that the option which was not chosen was carrying with it or in other words the missed potential gain from the other alternatives.[74] [75]

The profit is the amount of money which is earned by a shareholder. The gross profit may be calculated as follow: $Gross\ profit = sales - costs$. (There are other economic indicators such as EBT, EBIT, EBITDA and so on which may be useful but their application is beyond the scope of this Master Thesis.)

5.2.2. VAT: The value-added tax

The value-added tax is a tax which is related on the increment of value of a product (or a service). Nowadays, it is applied with various rates between 2% (Aruba) and 27% (Hungary) in many countries[76]. According to the economic theory[77], VAT is a fiscal policy which represents a sort of compensation for the state-founded infrastructures and services which were reasonably involved in the production process.

Every country can apply different rates to different categories of products. For example, unprocessed food (vegetables, fruit, meat, fish, eggs, milk and so on), medicines, books and newspapers are often VAT-exempted while processed food or some other necessary goods (such as soaps, detergents, electricity, insurances) are often sold with a reduced VAT rate. This is made in order to try to keep the price of necessary goods and services as low as possible. Sometimes renovations, tourism and restoration-related services have a low VAT rate in order to boost economic sectors such as construction and tourism.
Some particular goods (such as wine or truffles in Italy) have small VAT rates in order to facilitate the exportation of these products and in general, exported products may be VAT-exempted (duty-free).

There are several criticisms regarding the value-added tax:

1. Some necessary goods, in some countries, are sold with the maximum VAT rate while some others which can be consider luxury goods are exempted (or sold with a low VAT rate). For example, in Italy, gold is VAT-exempted but tampons and diapers have a 22% VAT rate.

2. In countries like Hungary, VAT is very high and this is partly done in order to compensate the low- and flat-income tax. Doing so, the poorest part of the population pays as the richest one and there is no progressivity in taxation. In general, VAT is a flat tax which doesn't take in consideration the income of the taxpayer. (Different rates of VAT try in theory to reduce the inequalities making the necessary goods cheaper for everyone and the luxury goods more expensive for everyone.)

3. VAT is technically applied in every stage of the supply chain but in practise, the final consumer is the only one to pay for it. That can be easily explained:

    - In the first stage, the producer pays the VAT but then sells the product to the those who are going to process the product charging them for the VAT paid. This process continues until the end consumer which cannot charge anyone except himself.
    - Very often businessmen can have the VAT paid back from the State (and this may be considered illegal if they already covered their VAT expenses, charging the other stages of the supply chain). Furthermore, in international trade practice, many products are VAT-exempted, making wholesalers and distributors not paying the VAT.
      Again, VAT can be avoided in every stage of the chain, apart the last one.

4. As it was partly explained in the point 3, VAT is often involved in frauds and in both national and international tax evasion. According to the European Commission, just in 2018, 147.1 billion euro of VAT were evaded. This amount of money corresponds to the 12.3% of the total VAT of European Union with the evasion rate that oscillated between 0.85% in Luxembourg and 35.88% in Romania. Such a various range can be explained both with the not harmonized ways to produce statistics in member states and with the different situations about insolvencies, bankruptcies, avoidances, frauds and tax loyalty which can be currently found across the member states[78].

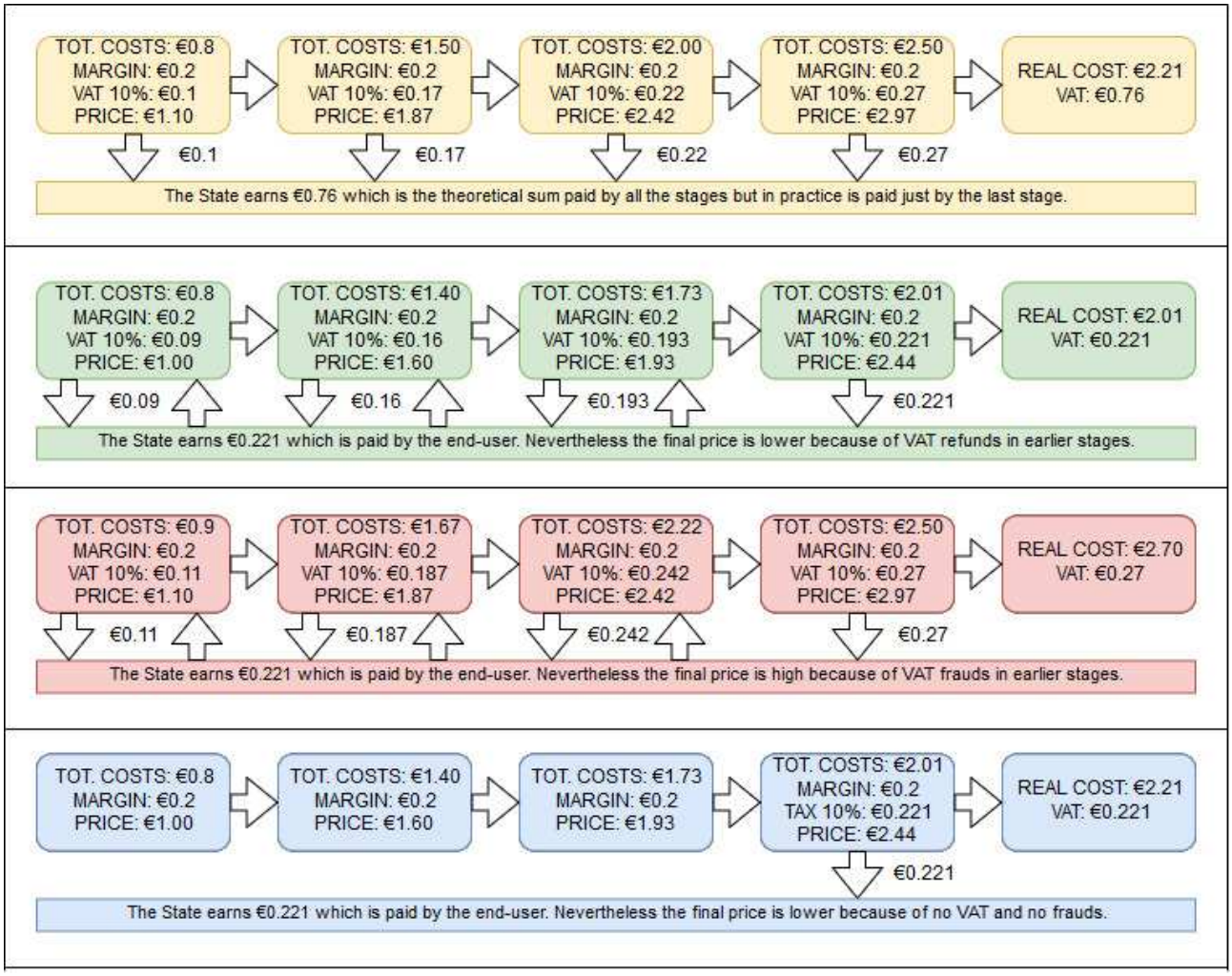
The following scheme summarizes the application of VAT to a product or a service. This scheme considers just the easiest situations with a VAT fixed-rate and with fixed margins. There are 4 main situations:

1. The first situation, represented in yellow, is the one in which the producer charges the following stages (and so on) after having established the costs and the desired gross margin. Without considering any rebound effect, we can say that the State keeps the biggest advantage while for the entrepreneurs almost nothing changes. It's clear that all the VAT cost is paid by the consumers.

2. In the second situation, represented in green, entrepreneurs in all the stages are refunded by the State for the VAT they paid and in this way the final price can be lower. Without considering any rebound effect, we can say that the end-users keep the biggest advantage while for the entrepreneurs almost nothing changes. It's clear that all the VAT cost is paid by the State.

3. In the third situation, represented in red, entrepreneurs make the VAT they should pay appear like a cost and then apply the, in this case fixed, margin. After this, they calculate the VAT which will be refunded by the State. This is obviously a fraud in which entrepreneurs keeps the big advantage while consumers pay the highest price and the country does not earn much taxes.

4. The fourth situation is the one in which VAT doesn't exist and only a sale tax is applied in the final stage. Theoretically speaking, this situation is analogous to the second one but compared to that solution is a lot easier to apply. The biggest disadvantage is that in this case, tax evasion is very easy



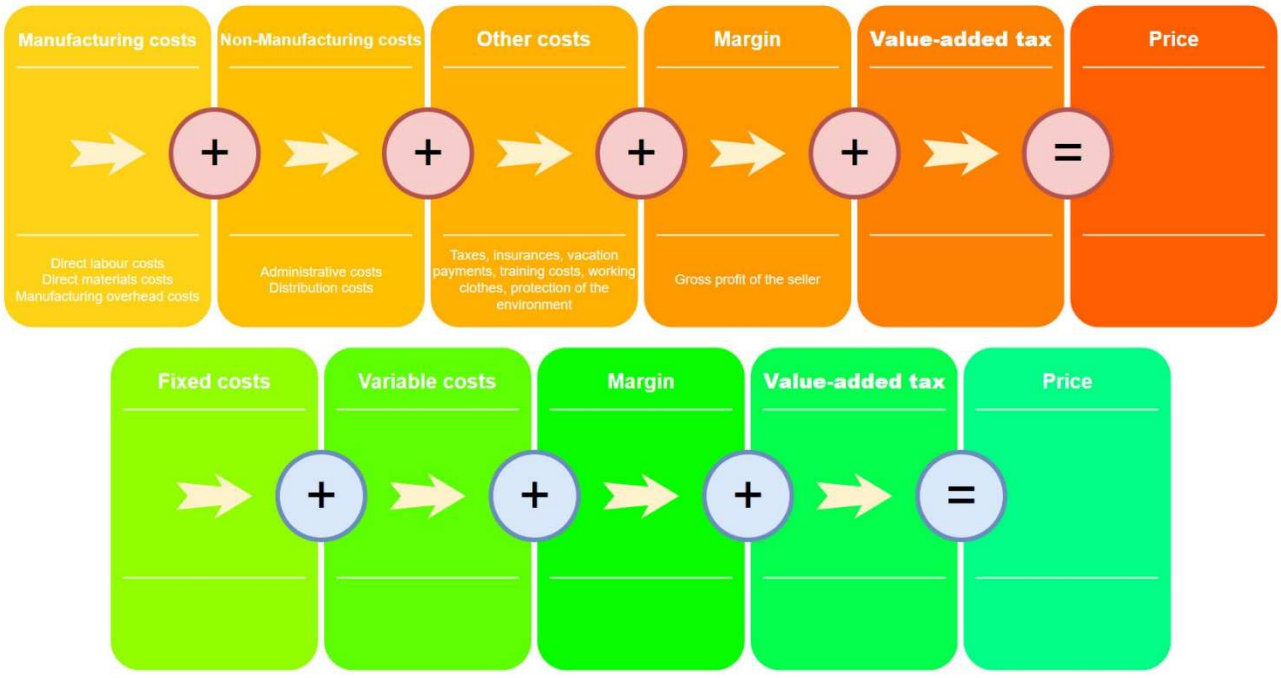
(Fig.40: VAT application: four different scenarios)

5.2.3. Price

According to BD (the Online Business Dictionary) selling price is: "*The market value, or agreed exchange value, that will purchase a definite quantity, weight, or other measure of a good or service. As the consideration given in exchange for transfer of ownership, price forms the essential basis of commercial transactions. It may be fixed by a contract (such as sale of goods contract), left to be determined by an agreed upon formula at a future date, or discovered or negotiated during the course of dealings between the parties involved. In commerce, it boils down to what (1) a buyer is willing to pay, (2) a seller is willing to accept, and (3) the competition is allowing to be charged. With product, promotion and place of marketing mix, it is one of the business variables over which a company can exercise some degree of control. It is a criminal offence to manipulate prices [...] in collusion with other suppliers, and to give a misleading indication of price such as charging for items that are reasonably expected to be included in the advertised, list, or quoted price. Also called sale price and price.*[79]"

In other words, the selling price is the amount of money which is required to buy a product. This price generally includes the total costs which were paid by the seller in order to purchase, produce and/or manufacture the product, the gross margin which as it was said before is the profit of the seller and the VAT (if applicable) which as we have seen is, in the end, paid entirely just by the consumer. The selling price can be calculated as follow: $Selling\ price = total\ cost\ per\ unit + margin\ per\ unit + value\ added\ tax$

The following scheme summarize the concept of selling price showing its composition in two different scenarios: in the first one, costs follow the MC/NMC classification while in the second one, they follow the FC/VC one. (Please note that the scheme is not scale-based and the width of the columns is not a representation of how much the single categories impact on the final selling price).

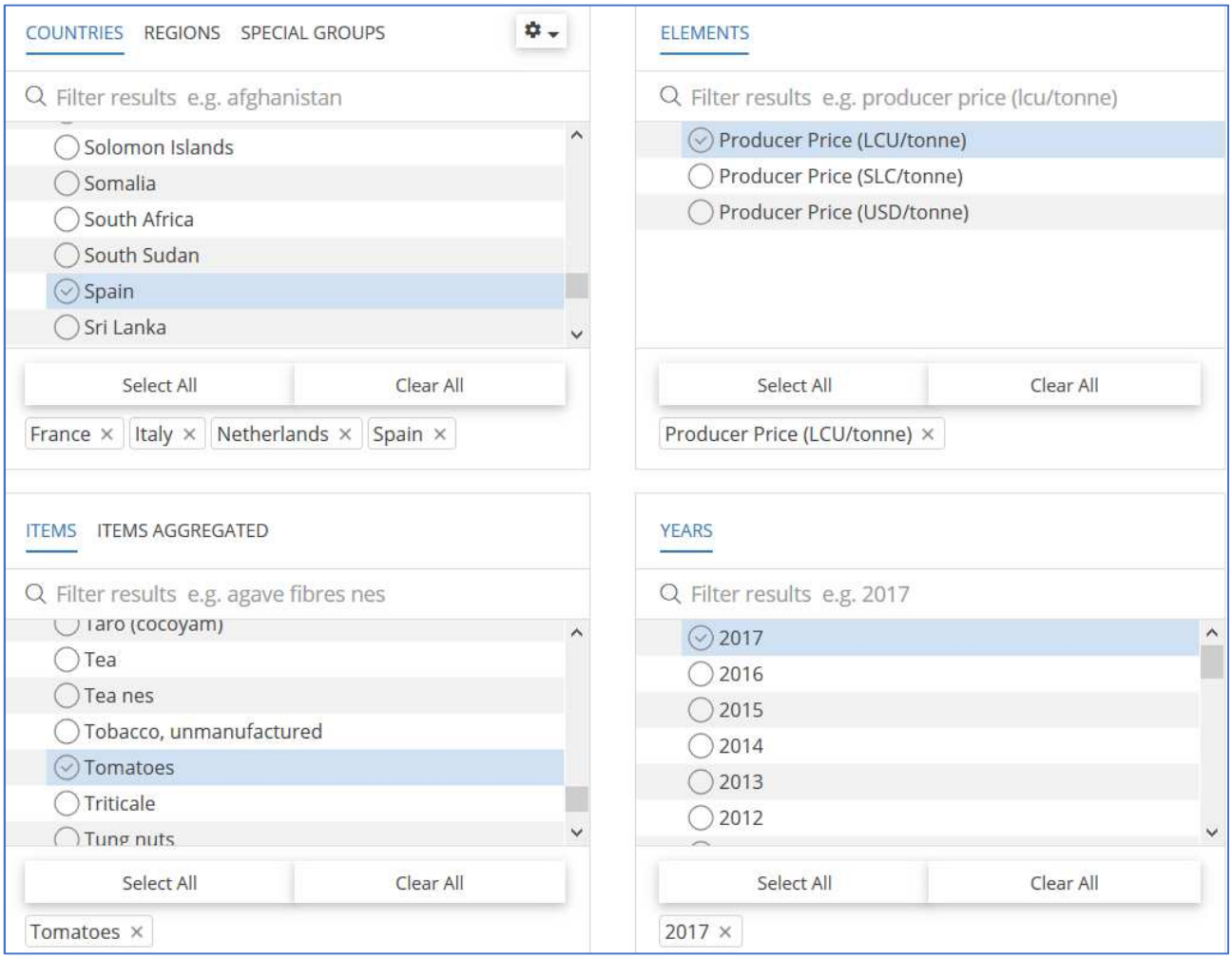


(Fig.41: composition of selling price according to the MC/NMC and FC/VC definitions)

5.2.4. Production stage

For the production stage, two different methodologies (one for those tomatoes that are going to be distributed and consumed as they are (raw products) and one for those tomatoes which will be furtherly processed in order to become tomato-based processed products; have been used.

Data concerning the first category were available in the FAO dataset named “producer prices”.[80] These prices which already include both the costs and the gross margin do not consider the VAT. These data are referred to 2017 and are available for all the four countries taken in consideration.



(Fig.42: Setup used in order to investigate the FAO dataset)

Domain Code	Domain	Area Code	Area	Element Code	Element	Item Code	Item	Year Code	Year	Unit	Value	Flag	Flag Descripti
PP	Producer Prices - Annual	68	France	5530	Producer Price (LCU/tonne)	388	Tomatoes	2017	2017	LCU	812.3		Official data
PP	Producer Prices - Annual	106	Italy	5530	Producer Price (LCU/tonne)	388	Tomatoes	2017	2017	LCU	792.5		Official data
PP	Producer Prices - Annual	150	Netherlands	5530	Producer Price (LCU/tonne)	388	Tomatoes	2017	2017	LCU	732		Official data
PP	Producer Prices - Annual	203	Spain	5530	Producer Price (LCU/tonne)	388	Tomatoes	2017	2017	LCU	388.8		Official data

(Fig.43: Results retrieved from the FAO dataset; producers prices)

Data concerning the second category have been retrieved from literature. These prices which already include both the costs and the gross margin do not consider the VAT [81]. Data are referred to 2018 to France, Spain and Italy (a simple average between Italy North and Italy South has been carried out). Unfortunately, no data about the Dutch situation have been found.

Prices of Raw Material, per mT

	2017	2018		
California	77,7	80,8	USD	4%
China	410,0	400,0	CNY	-2%
France	79,0	79,0	EURO	0%
Greece	84,0	82,5	EURO	-2%
Italy North	79,5	79,75	EURO	0,3%
Italy South	87,0	87,0	EURO	0,0%
Poland	410,0	400,0	PLN	-2%
Portugal	70,5	70,0	EURO	-1%
Spain	71,4	69,0	EURO	-3%
Tunisia	147,0	170,0	DT	16%
Turkey	*250,0*	*350,0*	*TL*	*50%*

in national currencies

(Fig.44: Results retrieved from "Tomato news"; producers prices)

The EU cluster of data concerning for those tomatoes that are going to be distributed and consumed as they are (raw products) has been built through a weighted average expressed by the following formula: $EU\ \left[\frac{€}{kg}\right] = a * Italy\ \left[\frac{€}{kg}\right] + b * France\ \left[\frac{€}{kg}\right] + c * Spain\ \left[\frac{€}{kg}\right] + d * Netherlands\ \left[\frac{€}{kg}\right]$ where: a + b + c + d = 1 and a = 0,145251 = Italian share of the production of this category of tomatoes among the four countries, b = 0,145251 = French share of the production of this category of tomatoes among the four countries, c = 0.519533 = Spanish share of the production of this category of tomatoes among the four countries, d = 0.18994 = Dutch share of the production of this category of tomatoes among the countries.[27]

The EU cluster of data concerning those tomatoes which will be furtherly processed in order to become tomato-based processed products has been built through a weighted average expressed by the following formula: $EU\ \left[\frac{€}{kg}\right] = a * Italy\ \left[\frac{€}{kg}\right] + b * France\ \left[\frac{€}{kg}\right] + c * Spain$. Where a + b + c = 1 and a = 0,656891496 = Italian share of the production of this category of tomatoes among the three countries, b = 0,020527859 = French share of the production of this category of tomatoes among the three countries, c = 0.322581 = Spanish share of the production of this category of tomatoes among the three countries.[27]

The results are presented in the following tab where on the x-axis are placed the categories of products (for the production stage) while on the y-axis are placed both the countries (Italy, France, Spain, Netherlands) and the European Union itself (considered as one single country). The prices are expressed in euro/kg and The yellow boxes indicate those values that have been calculated through extrapolation and averages while the green boxes indicate those values that have been retrieved, without data gaps, from reliable sources.

€/kg	Tomato loss in p.harv	
	FLW1a	FLW1b
Italy	0,79	0,08
France	0,81	0,08
Spain	0,39	0,07
Netherl.	0,73	*0,08*
EU	0,57	*0,08*

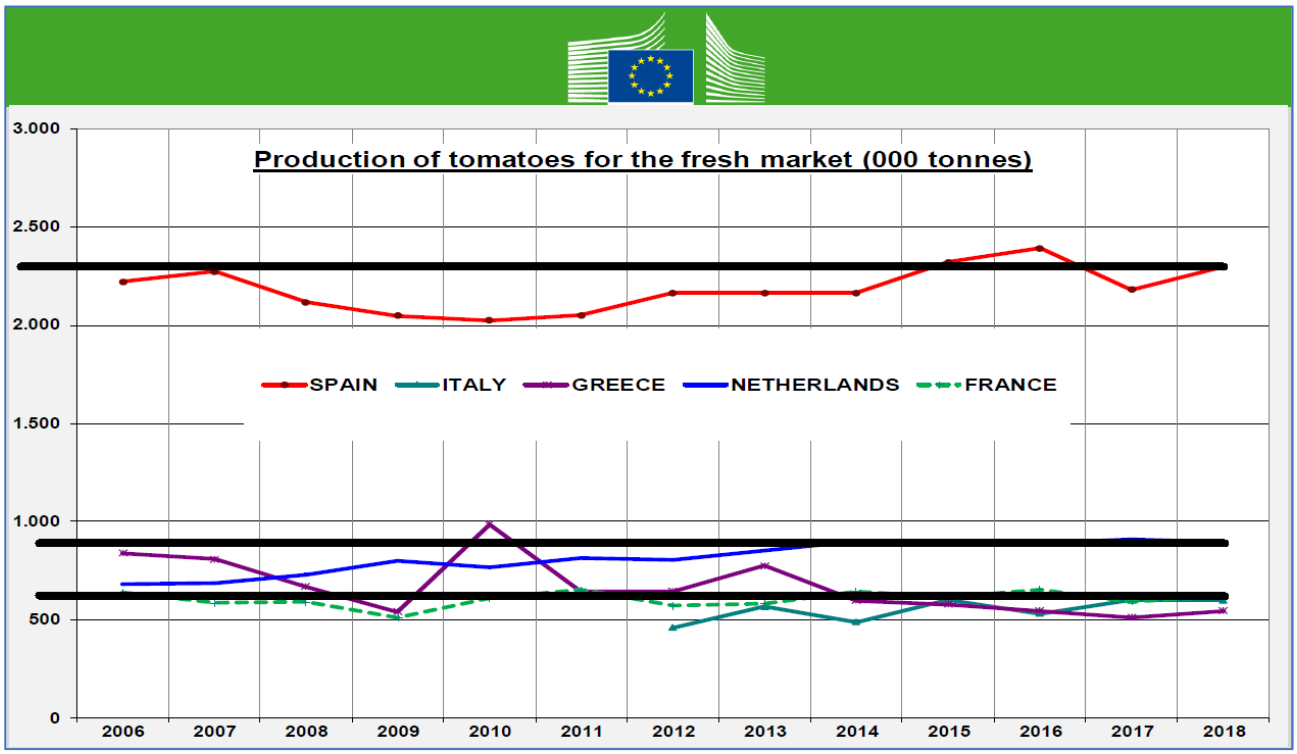
(Tab.14: Results [€/kg], production stage)

Italy[27]	5600000	0,656891	Index based on the production (tomatoes for processing): used in the **production stage-based** calculations about the European Union situation.
France[27]	175000	0,020528	
Spain[27]	2750000	0,322581	
Nether.	-		
Total	8525000	1	

(Tab.12: Production shares of tomatoes among countries, second category)

Italy[27]	650000	0,145251	Index based on the production (fresh tomatoes): used in the **production stage-based** calculations about the European Union situation.
France[27]	650000	0,145251	
Spain[27]	2325000	0,519553	
Nether.[27]	850000	0,189944	
Total	4475000	1	

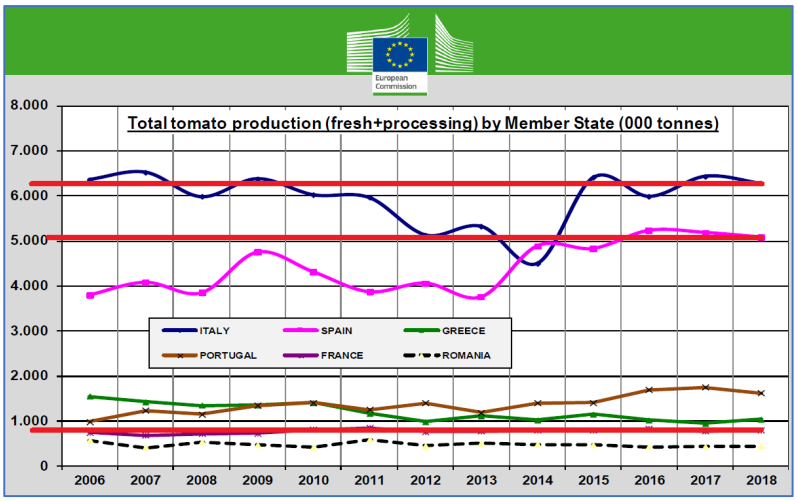
(Tab.13: Production shares of tomatoes among countries, first category)



(Fig.45: Graphic way to determine the production of tomatoes)

Few words have to be spent about the method which was used in order to quantify the production of tomatoes: 10 millimetres on the graph (which is here scale-sized) stand for a range of 500000 tonnes. In detail, drawing a line from the end of the curve (which is referred to 2018) it's possible to have useful information on the y-axis. In particular using this graph released by the European Commission it has been possible to retrieve the production of fresh tomatoes for the four countries.

- The Spanish production of tomatoes resulted to be: 2325000 tonnes
- The Dutch production of tomatoes resulted to be: 850000 tonnes
- The Spanish production of tomatoes resulted to be: 650000 tonnes
- The Spanish production of tomatoes resulted to be: 650000 tonnes

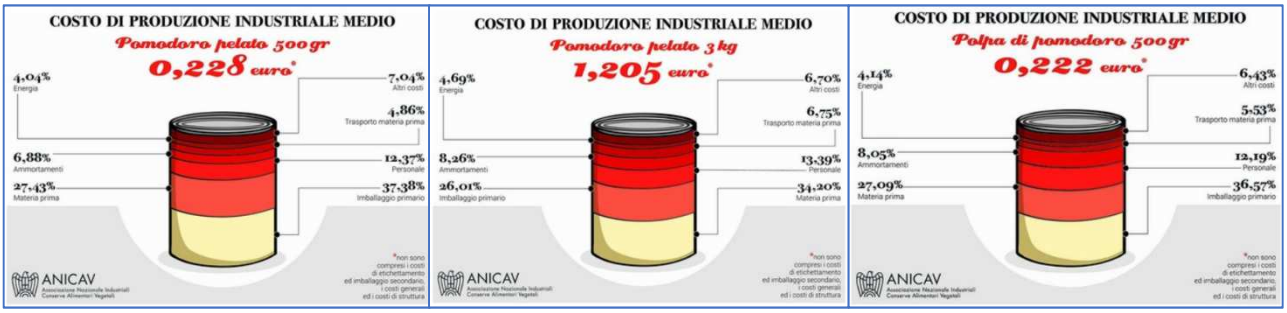


(Fig.46: Graphic way to determine the production of tomatoes for processing)

14 millimetres on the graph (which is here scale-sized) stand for a range of 1000000 tonnes. Drawing a line from the end of the curve (which is referred to 2018) it's possible to have useful information on the y-axis. In detail:
14 : 1000000 = 1 : 75000 (Spain)
14 : 1000000 = 3.5 : 250000 (Italy)
14 : 1000000 = 2.5 : 175000 (France)
5000 (from the graph) + 75 = 5075
6000 (from the graph) + 250 = 6250
800 (from the graph) + 25 = 825
Subtracting the fresh production, the production for processing is obtained.

5.2.5. Processing stage[81] [82] [83]

For the processing stage, data concerning canned tomatoes were available in "Canned and Tomato, IEG Vu Agribusiness Intelligence" and "Analisi del costo industriale nel settore delle conserve di pomodoro" which are two reports dedicated to canned food, tomatoes and vegetables in general. These data are referred to 2018 to Italy and Spain. Unfortunately, no data about the French and the Dutch situations have been found.



(Fig.47: Production costs of canned tomatoes in Italy)

In "Analisi del costo industriale nel settore delle conserve di pomodoro", three different types of canned tomatoes have been analysed:

- Whole tomatoes, 500 grams: €0.228 (and so €0.456 for one kilogram)
- Whole tomatoes, 3 kg: €1.205 (and so €0.402 for one kilogram)
- Tomatoes in pieces, 500 grams: €0.222 (and so €0.444 for one kilogram)

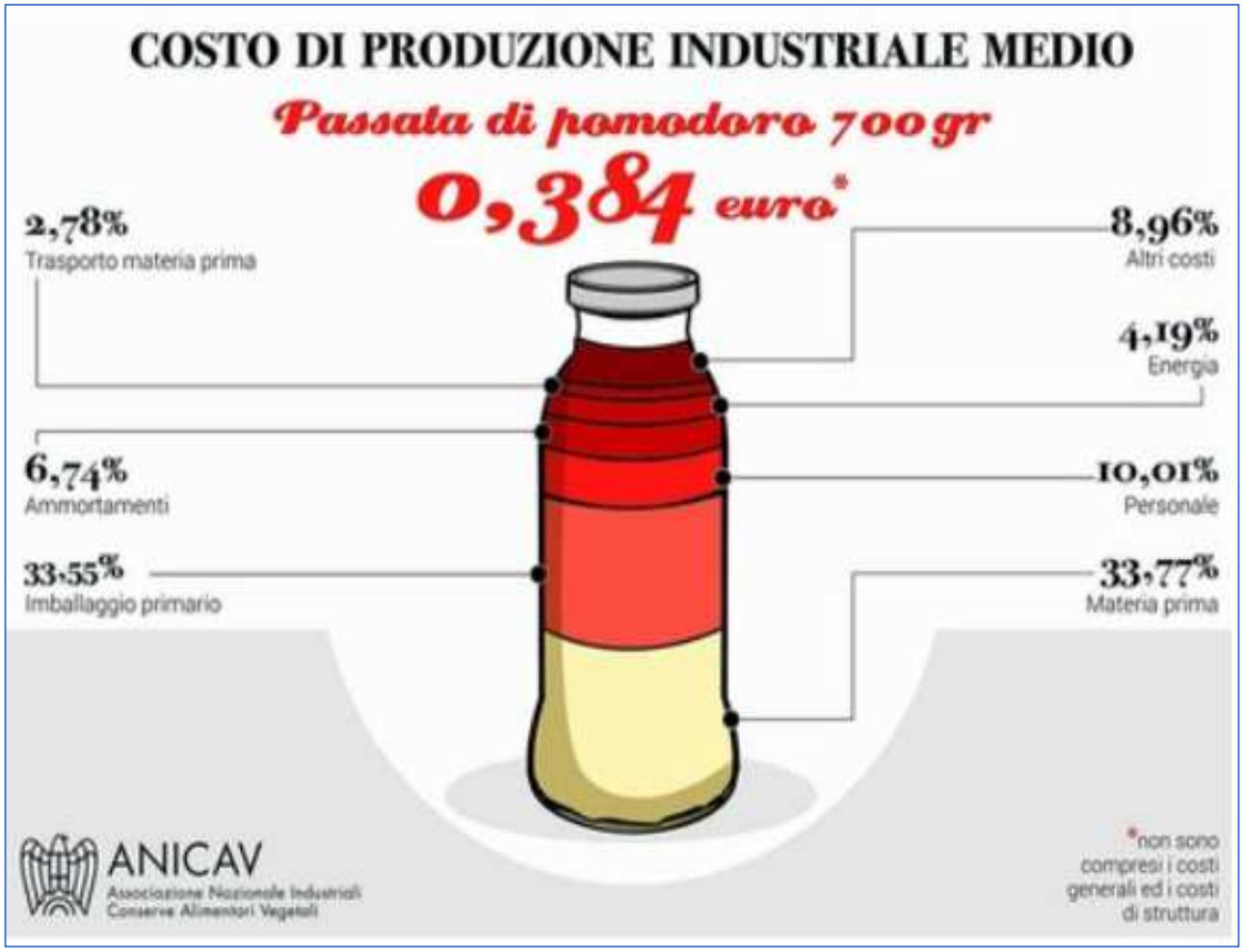
First, a simple average among these three prices has been made: (€0.456 + €0.402 + €0.222)/3 = €0.434
Then, another 6.5% which represents the cost of management, infrastructures, insurances and marketing has been added: €0.434 + 0.0065*€0.434 = €0.437.

In "Canned and Tomato, IEG Vu Agribusiness Intelligence" selling price of canned tomatoes is considered to be €0.68. Combining the two data it's possible to assume that the selling price of canned tomatoes in Italy, is €0.68 (€0.437 of costs and €0.243 of gross margin).

In “Analisi del costo industriale nel settore delle conserve di pomodoro”, it was also possible to retrieve those data regarding tomato sauce (but unfortunately, these data are referred just to Italy). In detail, the cost for 700 grams of tomato sauce has been estimated to be €0.384 (and so €0.549 for one kilogram). This cost (€0.549) is structured in the following way:

- €0.1854 is the cost of the raw matter (33.77% of the total cost)
- €0.1842 is the cost of the primary packing (33.55% of the total cost)
- €0.0550 is the cost of the workforce (10.01% of the total cost)
- €0.0370 is the cost of depreciation (6.74% of the total cost)
- €0.0230 is the cost of energy (4.19% of the total cost)
- €0.0153 is the cost of transportation of the raw matter (2.78% of the total cost)
- €0.0492 is the cost classified as other costs (8.96% of the total cost)

Furthermore another 6.5% which represents the cost of management, infrastructures, insurances and marketing has to be added: €0.549 + 0.0065*€0.549 = €0.5526. The selling price after the processing stage of tomato sauce, in Italy, is estimated to be €0.76 (€0.55 of costs and €0.21 of assumed gross margin).



(Fig.48: Production costs of tomato sauce in Italy)

In “Canned and Tomato, 2018, IEG Vu Agribusiness Intelligence”, it was possible to retrieve also the data concerning the tomato paste (unfortunately, again, just for Italy and Spain).

(Fig.49: Results retrieved from "Canned and Tomato 2018"; tomato paste prices in Italy and Spain)

The main issue of the processing stage economic analysis has been that no data about tomato juice have been found. The price of it was assumed to be a simple average between the other prices available:

- Tomato juice, Italy, processing stage = (0.68 + 0.68 + 0.76)/3 ≃ €0.70
- Tomato juice, Spain, processing stage = (0.45 + 0.60)/2 ≃ €0.53

€/kg	Tomato loss in processing stage			
	FLW2a	FLW2b	FLW2c	FLW2d
Italy	0,68	0,70	0,76	0,68
France	*0,59*	***0,64***	*0,76*	*0,65*
Spain	0,45	0,53	*0,76*	0,60
Netherl.	*0,59*	***0,64***	*0,76*	*0,65*
EU	*0,59*	***0,64***	*0,76*	*0,65*

(Tab.15: Results [€/kg], processing stage)

Legend:
FLW2a = cost of the loss of tomato whole or in pieces during the processing stage
FLW2b = cost of the loss of tomato juice during the processing stage
FLW2c = cost of the loss of tomato sauce during the processing stage
FLW2d = cost of the loss of tomato other than whole or in pieces during the processing stage
= balanced, reliable sources, no data gaps
= balanced through extrapolations, reliable sources, few/some data gaps
= balanced through assumptions and extrap., many data gaps

The EU cluster of data has been built through a weighted average expressed by the following formula:

$$EU\left[\frac{€}{kg}\right] = a * Italy\left[\frac{€}{kg}\right] + b * Spain\left[\frac{€}{kg}\right]$$

Where a + b = 1 and a = 0.6233 = Italian production of tomato-based products/total production in Italy and Spain, b = 0.3767 = Spanish production of tomato-based products/total production in Italy and. These countries represent alone the 77% (Italy 48%, Spain 29%) of the total EU production of tomato-based processed products and according to that, the averaged results obtained by these two countries are assumed extended through extrapolation to the entire EU.[84] [85]

Italy	0,48	0,6233	Index based on the processing: used in the **processing stage-based** calculations about the European Union situation.
Spain	0,29	0,3767	

(Tab.16: Processing shares of tomatoes among countries)

5.2.6. Distribution stage

For the distribution stage stage, two different methodologies (one for the raw products and one for the tomato-based processed ones) have been used in order to find out the desired data (selling prices).

Data concerning the first category were available in "Tridge: Smarter global sourcing" [86] which is a global online platform whose aim is to build an international network among buyers and sellers. As shown in the appendix, data are referred to 2018 and are available for all the four countries taken in consideration.

Unfortunately, no data concerning the second category seemed to be available in the literature. Several tries have been made (searching among online dedicated literature, market researches, studies, grey literature, Danish, German and Italian libraries) but no results have been successfully retrieved.

In order to get rid of this data gap, which represented one of the biggest source of uncertainty, it was assumed that prices of retailers are 65% higher compared of the distributors ones.[87] This 65% includes the 35% gross margin which was retrieved from literature and the 30% of costs during the retailing stage which have been assumed. As it will be shown later, data about retailers have been successfully retrieved so the selling prices concerning the tomato-based processed products have been calculated as follow:

$$prices\ in\ distribution\ stage = prices\ in\ retailing\ stage * 0.65$$

€/kg	Tomato loss in distribution stage				
	FLW3a	FLW3b	FLW3c	FLW3d	FLW3e
Italy	1,64	1,97	1,90	1,34	4,15
France	1,59	1,64	0,84	1,93	3,28
Spain	0,91	1,14	0,95	1,32	1,99
Netherl.	1,06	1,26	0,98	1,64	2,71
EU	1,39	1,59	1,21	1,57	3,19

(Tab.17: Results [€/kg], distribution stage)

Legend:
FLW3a = cost of the loss of tomatoes used for direct distribution (no processing); distribution stage.
FLW3b = cost of the loss of tomato whole or in pieces; distribution stage.
FLW3c = cost of the loss of tomato juice; distribution stage.
FLW3d = cost of the loss of tomato sauce; distribution stage
FLW3e = cost of the loss of tomato other than whole or in pieces; distribution stage

= balanced, reliable sources, no data gaps; = balanced through extrapolations, reliable sources, few/some data gaps; = balanced through assumptions and extrapolations, many data gaps

The EU cluster of data has been built through a weighted average expressed by the following formula:

$$EU\ \left[\frac{€}{kg}\right] = a * Italy\ \left[\frac{€}{kg}\right] + b * France\ \left[\frac{€}{kg}\right] + c * Spain\ \left[\frac{€}{kg}\right] + d * Netherlands\ \left[\frac{€}{kg}\right]$$

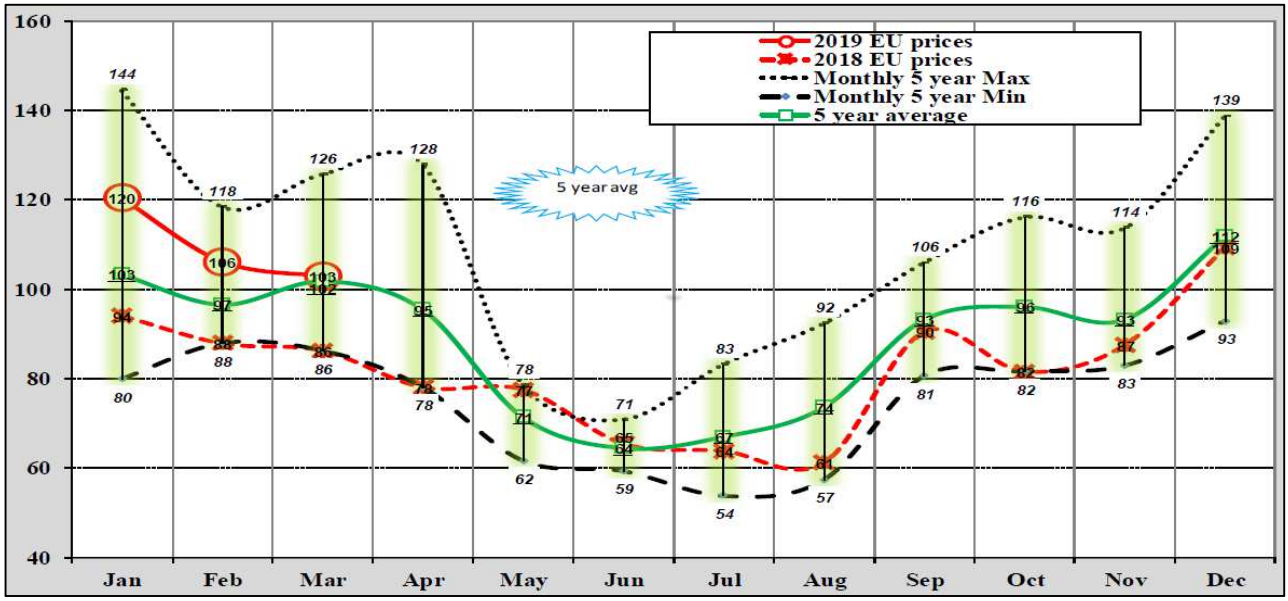
Where a[88] + b[89] + c[90] +d[91] = 1 and a = population of Italy/sum of the population of the four countries, a = 0.315229 = population of Italy/sum of the population of the four countries, b = 0.351003 = population of France/sum of the population of the four countries, c = 0.243562 = population of Spain/sum of the population of the four countries and d = 0.090206 = population of Netherlands/sum of the population of the four countries. These countries represent alone the 37% of the total EU population and according to that, the averaged results obtained by the four countries are assumed extended through extrapolation to the entire European Union.[92]

5.2.7. Retailing stage

For the retailing stage, two different methodologies (one for the raw products[27] and one for the tomato-based processed ones) have been used in order to find out the desired data (selling prices).

Selling prices of raw products (which already included both the total costs and the gross margin) were retrieved from "DGAGRIDASHBOARD: TOMATOES" that has been distributed by European Commission in 2019. There was no necessity to make any calculation about VAT and taxation because these data were already released in a "excluding VAT" form.

The average price of one kilo of raw tomatoes in the EU for 2018 has been €0.82. This price fluctuated between €0.61/kg in August and €1.09/kg in December (when due to the unfavourable weather conditions the availability of tomatoes was at its minimum). A 5-years average (2014 – 2018) showed that the average price of one kilo of tomatoes in the EU during that period has been €0.89 (with a fluctuation between €0.64 in June and €1.12 in December).

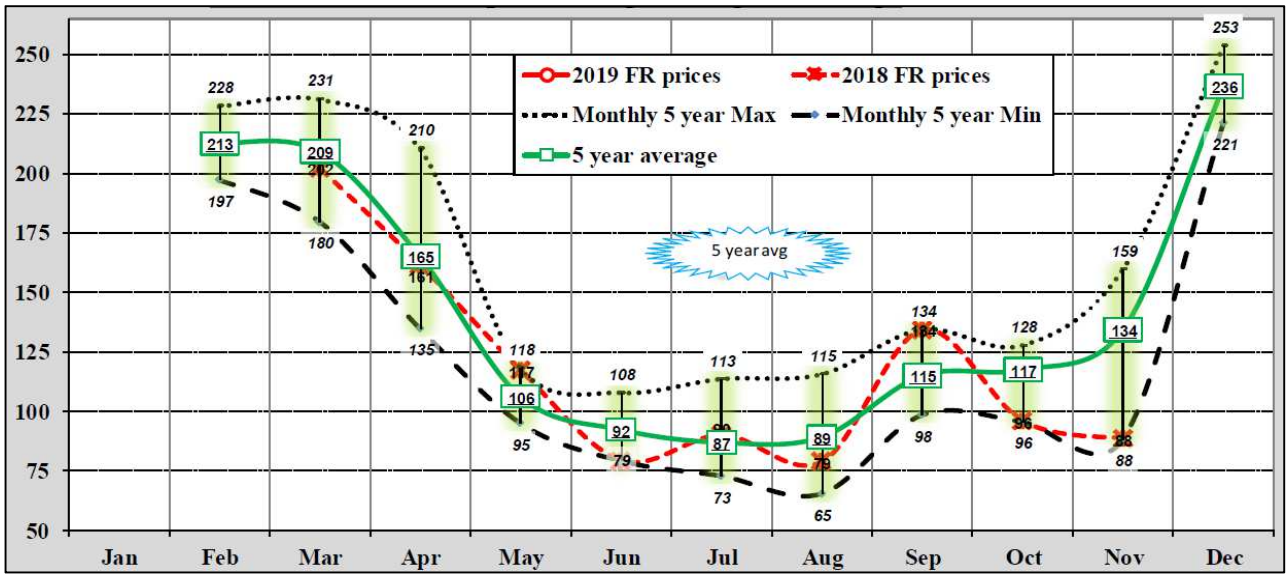


(Fig.50: Trends and fluctuations of tomatoes selling prices in the EU)

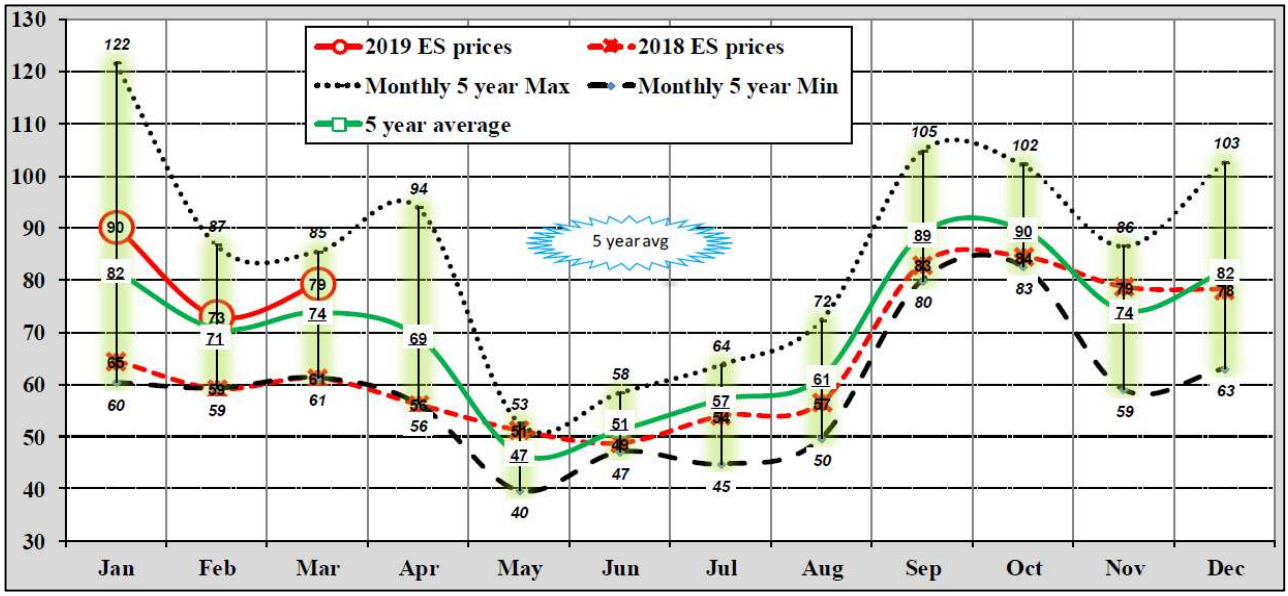
Focusing on the single countries it has been discovered that:

1. In Italy, the average price of one kilo of tomatoes in 2018 has been €1.00 (with a fluctuation between €0.71 in August and €1.62 in December). A 5-years average (2014 – 2018) showed that the average price of one kilo of tomatoes in Italy during that period has been €1.08 (with a fluctuation between €0.80 in June and €1.35 in December).
2. In France, the average price of one kilo of tomatoes in 2018 has been €1.16 (with a fluctuation between €0.79 in June and August and €2.02 in March). A 5-years average (2014 – 2018) showed that the average price of one kilo of tomatoes in France during that period has been €1.42 (with a fluctuation between €0.87 in July and €2.36 in December).
3. In Spain, the average price of one kilo of tomatoes in 2018 has been €0.65 (with a fluctuation between €0.49 in June and €0.84 in October). A 5-years average (2014 – 2018) showed that the average price of one kilo of tomatoes in Spain during that period has been €0.71 (with a fluctuation between €0.47 in May and €0.90 in October).
4. In Netherlands, the average price of one kilo of tomatoes in 2018 has been €0.76 (with a fluctuation between €0.29 in July and €1.29 in January). A 5-years average (2014 – 2018) showed that the average price of one kilo of tomatoes in Netherlands during that period has been €0.85 (with a fluctuation between €0.48 in June and €1.50 in February).

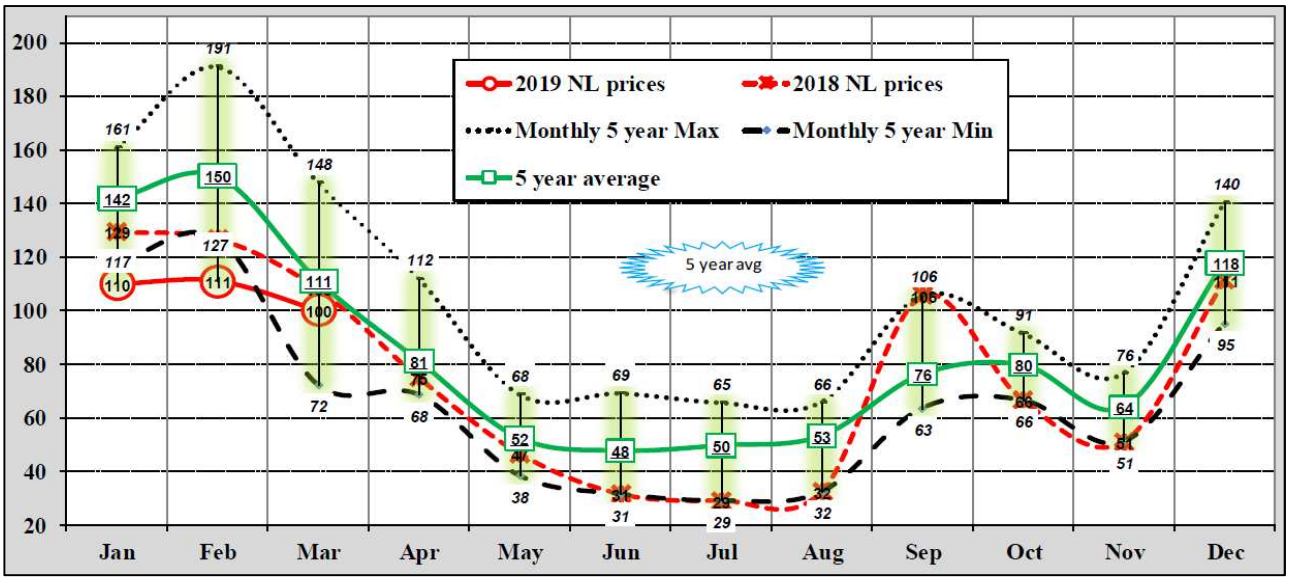
(Fig.51: Trends and fluctuations of tomatoes selling prices in Italy)



(Fig.52: Trends and fluctuations of tomatoes selling prices in France)



(Fig.53: Trends and fluctuations of tomatoes selling prices in Spain)



(Fig.54: Trends and fluctuations of tomatoes selling prices in the Netherlands)

The situation about selling price is well summarized in the following tab:

€/kg of tomatoes		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
EU	2008	0,94	0,88	0,86	0,78	0,77	0,65	0,64	0,61	0,90	0,82	0,87	1,09	0,82
	2008 -2014	1,03	0,97	1,02	0,95	0,71	0,64	0,67	0,74	0,93	0,96	0,93	1,12	0,89
Italy	2008	1,28	1,18	0,77	0,73	1,14	0,96	0,83	0,71	0,78	0,75	1,21	1,62	1,00
	2008 -2014	1,27	1,06	1,00	1,05	0,97	0,80	0,83	1,02	1,14	1,17	1,29	1,35	1,08
France	2008	-	-	2,02	1,61	1,17	0,79	0,90	0,79	1,34	0,96	0,88	-	1,16
	2008 -2014		2,13	2,09	1,65	1,06	0,92	0,87	0,89	1,15	1,17	1,34	2,36	1,42
Spain	2008	0,65	0,59	0,61	0,56	0,51	0,49	0,54	0,57	0,83	0,84	0,79	0,78	0,65
	2008 -2014	0,82	0,71	0,74	0,69	0,47	0,51	0,57	0,61	0,89	0,90	0,74	0,82	0,71
Nether.	2008	1,29	1,27	1,11	0,75	0,47	0,31	0,29	0,32	1,06	0,66	0,51	1,11	0,76
	2008 -2014	1,42	1,50	1,11	0,81	0,52	0,48	0,50	0,53	0,76	0,80	0,64	1,18	0,85

(Tab.18: Summary tab about tomatoes selling prices in the four selected countries and in the EU)

After this investigation which has been done to see in practise how the markets really work (chapter 2.9.); prices which have been in taken in consideration were those related to “December five year maximum”.

This choice has been made for three main reasons which can be summarized as follow:

1. Both data referring to the tomato-based products in the retailing stage and data referring to the distribution stage were not time average-based and so the use of time average-based data in just one part of one stage has not been considered to be suitable due to the possibility of bias results.

2. Prices in December were high enough to consider a situation of “worst case scenario” but still relatable to averaged data. Furthermore ,these appeared to be the most coherent with those data that have been retrieved from other sources concerning the other stages.

3. Prices in December appeared to be globally one of the most complete and coherent cluster of data with relatively small fluctuations among countries and in relation with the other periods of the year. Furthermore, these data have always shown quite clear and predictable trends.

Data gaps and the hypothetical possibility to carry a sensitivity analysis will be both discussed later on.

Selling prices of tomato-based processed products (which already included both the total costs and the gross margin) were retrieved from a market investigation which has been carried as follow:

1. For every country (Italy, France, Spain, Netherlands) five distribution chains were identified. These distribution chains have been chosen due their big availability of data and their popularity.

2. For every country (Italy, France, Spain, Netherlands) five brands of tomato-based processed products were identified. These brands have been chosen because of their relatively high market share[98] and due both their spread and their popularity. [99] [100] [101] [102] [103] [104] [105] [106] [107]
   When possible, two discounts distribution chains, two normal-priced distribution chains and one high-quality/biologic distribution chain (for every country) have been considered.

3. The selling price of every category of tomato-based processed products (canned tomatoes, tomato juice, tomato paste, tomato sauce, ketchup) related to every brand, to every distribution chain and to every country has been retrieved. Selling price of similar products of the same brand, sold by the same distribution chain, in the same country have been averaged.

The averages have been calculated through the following formula: $\mu = \frac{1}{m}\sum_{j=1}^{m}(\frac{1}{n}\sum_{i=1}^{n} Xi)$j
where "m" stands for the number of boxes in the same category of products, in the same country while "n" stands for the number of products present in every box (in every m) and Xi stands for the single values taken singularly.

The standard deviations have been calculated through the following formula: $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\mu)^2}{n}}$

where "n" stands for the number of products in the same category and same in the same country, μ stands for the mean value and Xi stands for the single values taken singularly.

$$Number\ of\ data = similar\ products * categories * brands * distribution\ chain * countries$$
$Max\ total\ number\ of\ data = 3 * 6 * 5 * 5 * 4 = 1800$ (348 in practice due to the data gaps)
$Max\ total\ number\ of\ data\ for\ category = 3 * 5 * 5 * 4 = 300$ (from 33 to 114 in practice)
$Max\ total\ number\ of\ data\ for\ category\ for\ country = 3 * 5 * 5 = 75$ (from 3 to 43 in pract.)

From the calculations of the standard deviations done on 348 data it has been observed that the relative error associated with the standard deviation is ±46.97% which is relatively high but because we are talking about prices about which are affected from huge fluctuations (both in space and in time) these results were quite predictable and have been considered to be sufficiently reliable.

Anyway, it is possible to calculate how big the size of the cluster of data should had been in order to have a ±5% of relative error (with a confidence interval of 95%). For each category[108]:

$Sample\ size\ "n" \geq \left(\frac{1.96(Xi)}{0.05*Xi}\right)$ where 1.96 = z+ which is associated with a CI of 95%.

From calculations "n" ≥ 1537 for every category, for every country.
Overall around 25000 (1537*16 categories) data would be needed in order to have an error of ±5%.
This is of course almost impossible to achieve for two reasons:

- It would very difficult to find enough reliable source to build such a big cluster of data.
- The time available is not enough to build such a complex system.

€/kg	Tomato whole or in pieces			Tomato juice			Tomato sauces			Tomato other than whole or in pieces					
	cann. 1	cann. 2	cann. 3	juice 1	juice 2	juice 3	sauce 1	sauce 2	sauce 3	paste 1	paste 2	paste 3	ketchup 1	ketchup 2	ketchup 3
Cirio	3,98	3,42	2,84	-	3,24	-	2,12	2,09	2,24	7,07	7,95	-	6,03	-	-
Divella	-	-	1,53	-	-	-	-	-	1,38	-	-	-	-	-	-
Mutti	4,07	3,80	2,48	-	-	-	2,40	2,43	1,50	6,55	8,42	6,85	-	4,38	-
Pomì	-	-	-	-	-	-	-	2,87	2,34	-	-	-	-	-	-
Star	-	-	-	-	-	-	1,79	3,20	1,41	-	-	-	-	-	
Average	**3,16**			**3,24**			**2,15**			**6,75**					
St.Dev.	*0,86*			*0,00*			*0,54*			*1,23*					

€/kg	Tomato whole or in pieces			Tomato juice			Tomato sauces			Tomato other than whole or in pieces					
	cann. 1	cann. 2	cann. 3	juice 1	juice 2	juice 3	sauce 1	sauce 2	sauce 3	paste 1	paste 2	paste 3	ketchup 1	ketchup 2	ketchup 3
Carrefour	1,57	1,56	-	1,22	2,02	-	2,93	1,24	-	-	-	-	1,67	1,44	-
Apis	2,57	2,23	1,88	-	-	-	-	2,04	2,32	-	-	-	-	-	-
Mensajero	1,39	1,31	-	-	-	-	-	2,79	-	-	-	-	-	-	-
Hida	-	2,19	2,00	-	-	-	-	2,19	2,93	5,24	4,88	5,00	-	-	-
Orlando	2,70	1,47	2,48	-	-	-	2,16	1,89	2,01	-	-	-	2,73	2,86	3,36
Average	**1,95**			**1,62**			**2,25**			**3,40**					
St.Dev.	*0,47*			*0,40*			*0,50*			*1,40*					

€/kg	Tomato whole or in pieces			Tomato juice			Tomato sauces			Tomato other than whole or in pieces					
	cann. 1	cann. 2	cann. 3	juice 1	juice 2	juice 3	sauce 1	sauce 2	sauce 3	paste 1	paste 2	paste 3	ketchup 1	ketchup 2	ketchup 3
Auchan	2,38	-	-	1,54	1,31	-	3,69	-	-	4,64	-	-	7,12	-	-
Panzani	-	-	-	-	-	-	3,29	2,67	2,81	-	-	-	-	-	-
Jardin Bio	-	2,78	3,61	-	-	-	-	-	5,12	8,21	6,07	8,83	5,14	4,45	-
Carrefour	-	1,95	-	-	-	-	-	2,24	-	-	3,81	-	-	2,18	-
D'Aucy	2,61	2,99	3,34	-	-	-	-	-	-	-	-	-	-	-	-
Average	**2,81**			**1,43**			**3,30**			**5,61**					
St.Dev.	*0,52*			*0,12*			*0,93*			*2,03*					

€/kg	Tomato whole or in pieces			Tomato juice			Tomato sauces			Tomato other than whole or in pieces					
	cann. 1	cann. 2	cann. 3	juice 1	juice 2	juice 3	sauce 1	sauce 2	sauce 3	paste 1	paste 2	paste 3	ketchup 1	ketchup 2	ketchup 3
AH	1,65	-	-	0,88	-	-	1,91	-	-	3,51	-	-	1,61	-	-
Jumbo	-	-	1,13	-	-	0,87	-	-	1,58	-	-	3,29	-	-	1,81
Heinz	2,83	2,03	2,02	-	-	-	2,49	3,48	-	6,14	6,14	5,86	3,91	3,81	3,44
Smaakt	-	3,63	-	2,32	2,73	2,23	-	5,81	-	-	12,17	-	-	7,34	-
g'woon	-	1,65	-	-	0,88	-	-	1,43	-	-	3,38	-	-	1,66	-
Average	**2,13**			**1,65**			**2,78**			**4,58**					
St.Dev.	*0,78*			*0,79*			*1,52*			*2,56*					

(Tab.19: Summary tab about tomato-based products prices in the four countries in retailing stage)

4. The obtained values had to been recalculated in order to exclude the VAT (Chapter 5.2.2.). This calculation is not immediately understandable in fact every country has its own VAT rates and those rates are different for every category of product. In detail:

   a. In Italy[93] [94], there are four VAT rates:

      - 4% which is applied to basic necessities and essential goods (some kind of food, newspapers, etc.). In our case, the 4% VAT rate is applied to canned tomatoes, tomato sauce and tomato paste.
      - 5% which is applied to some culinary herbs and some transportation services
      - 10% which is applied to some services and some goods (insurances, restaurants, hotel, constructions, some kind of processed food etc.) In our case, the 10% VAT rate is applied to tomato juice and to ketchup.
      - 22% which is applied to all the other goods and services.

   b. In France[95], there are four VAT rates:

      - 2.1% which is applied to essential goods such as medicines and newspapers.
      - 5.5% which is applied to some services and some goods (cinema and theatre tickets, electricity and heat from renewable energies, housing, etc.)
      - 10% which is applied to some services and some goods (restaurants, transportation, firewood, some kind of food). In our case, the 10% VAT rat is applied to canned tomato, tomato juice, tomato sauce, tomato paste and ketchup).
      - 20% which is applied to all the other goods and service.

   c. In Spain[96], there are three* VAT rates:

      - 4% which is applied to essential goods (some kind of food, newspapers, etc.)
      - 10% which is applied to some services and some goods (restaurants, hotels, entertainment, some kind of food, etc.) In our case, the 10% VAT rat is applied to canned tomato, tomato juice, tomato sauce, tomato paste and ketchup).
      - 21% which is applied to all the other goods and service.

      * the fourth rate (7%) which is applied in Canary Islands has not been considered.

   d. In the Netherlands[97], there are three VAT rates:

      - 0% which is applied to essential goods and to import/export.
      - 9% which is applied to some services and some goods (food, beverages, medicines, newspapers, etc.) In our case, the 9% VAT rat is applied to canned tomato, tomato juice, tomato sauce, tomato paste and ketchup).
      - 21% which is applied to all the other goods and services.

5. The obtained values regarding the four countries have been then averaged in order to obtain a cluster of data suitable for the entire European Union. This average is based on the population of the four countries (which has been retrieved from reliable data) and extrapolated for all the EU.

The results are presented in the following tab where on the x-axis are placed the categories of products (for every stage) while on the y-axis are placed both the countries (Italy, France, Spain, Netherlands) and the European Union itself (considered as one single country). The prices are expressed in euro/kg.

€/kg	Tomato loss in retailing stage				
	FLW4a[27]	FLW4b*	FLW4c*	FLW4d*	FLW4e*
Italy	1,94	3,03	2,92	2,06	6,39
France	2,53	2,53	1,29	2,97	5,05
Spain	1,03	1,76	1,46	2,03	3,06
Netherl.	1,40	1,94	1,50	2,53	4,17
EU	1,88	2,45	1,86	2,41	4,91

(Tab.20:Results [€/kg], retailing stage)

Legend:
FLW4a = cost of the loss of tomatoes used for direct distribution (no processing) in the retailing stage.
FLW4b = cost of the loss of tomato whole or in pieces in the retailing stage.
FLW4c = cost of the loss of tomato juice in the retailing stage.
FLW4d = cost of the loss of tomato sauce in the retailing stage.
FLW4e = cost of the loss of tomato other than whole or in pieces in retailing stage.
* = Retrieved from fig.53

= balanced, reliable sources, no data gaps; = balanced through extrapolations, reliable sources, few/some data gaps; = balanced through assumptions and extrapolations, many data gaps.

The EU cluster of data has been built through a weighted average expressed by the following formula:

$$EU\ \left[\frac{€}{kg}\right] = a * Italy\ \left[\frac{€}{kg}\right] + b * France\ \left[\frac{€}{kg}\right] + c * Spain\ \left[\frac{€}{kg}\right] + d * Netherlands\ \left[\frac{€}{kg}\right]$$

Where a + b + c + d = 1 and a = population of Italy/sum of the population of the four countries, a = 0.315229 = population of Italy/sum of the population of the four countries, b = 0.351003 = population of France/sum of the population of the four countries, c = 0.243562 = population of Spain/sum of the population of the four countries and d = 0.090206 = population of Netherlands/sum of the population of the four countries. These countries represent alone the 37% of the total EU population and according to that the averaged results obtained by the four countries are assumed extended through extrapolation to the entire European Union.

5.2.8. Consumption stage

Obviously, the consumption stage presents exactly the same situation of the retailing stage: consumers buy products by the retailers paying the selling price which they have set previously and according to this, it's clear that there are no quantitatively differences in the amount of money which is lost for every kg of product lost although a small theoretical difference can be actually found:

While the amount of money which is lost by the consumers is made up of just the cost (in the strictest definition of the word); the amount of money which is lost by the retailers is, how it has been shown previously in Chapter 5.2.3., the total costs plus the gross margin (and so it's actually a loss of "real" money plus the "opportunity cost" concerning the missed sales).

Furthermore, assuming that the operations regarding taxes are carried out according to the second way of VAT treatment, it has not to be forgotten that also if it's not considered, consumers have to pay the VAT so in practice the amount of money which will be lost with the food waste will be higher.

This consideration is also valid for all the other VAT-related cases that have been taken in consideration.

5.3. Results

Million €	Tomato loss in p.harv		Tomato loss in processing stage				Tomato loss in distribution stage				
	FLW1a[1]	FLW1b[2]	FLW2a[3 4]	FLW2b[2]	FLW2c[4]	FLW2d[3]	FLW3a[5]	FLW3b[6]	FLW3c	FLW3d[6]	FLW3e[6]
Italy	23,74	22,47	215,48	57,04	26,05	1060,90	41,38	21,30	1,52	2,01	78,10
France	26,90	0,65	1,49	0,62	9,25	2,82	65,71	0,00	0,17	3,09	1,64
Spain	50,77	9,03	90,99	3,38	452,14	196,32	87,22	2,40	0,09	6,32	8,95
Netherl.	32,57	0,00	0,00	0,00	0,00	0,00	7,09	0,00	0,00	2,63	0,00
EU	172,28	47,69	657,69	129,96	1217,06	1433,59	406,30	21,62	2,90	30,46	91,55

Million €	Tomato loss in retailing stage					Tomato waste in consumption stage				
	FLW4a[7]	FLW4b[8]	FLW4c[8]	FLW4d[8]	FLW4e[8]	FLW5a[7]	FLW5b[8]	FLW5c[8]	FLW5d[8]	FLW5e[8]
Italy	60,72	9,10	6,71	0,21	243,49	135,22	32,76	19,54	0,62	874,90
France	129,03	10,12	0,90	39,50	23,23	287,91	36,67	2,57	115,83	83,31
Spain	122,36	6,67	0,15	28,35	15,91	272,85	24,39	0,44	83,03	56,92
Netherl.	11,62	3,10	0,45	10,88	15,42	26,04	11,24	1,20	31,88	55,43
EU	678,68	100,70	15,62	158,34	387,89	1513,40	364,07	46,13	464,17	1392,48

Italy	Million € loss in post harv. Stage	Million € loss in processing stage	Million € loss in distribution stage
	46,21	1359,46	144,30
France	Million € loss in post harv. Stage	Million € loss in processing stage	Million € loss in distribution stage
	27,56	14,18	70,61
Spain	Million € loss in post harv. Stage	Million € loss in processing stage	Million € loss in distribution stage
	59,80	742,83	104,98
Netherl.	Million € loss in post harv. Stage	Million € loss in processing stage	Million € loss in distribution stage
	32,57	0,00	9,72
EU	Million € loss in post harv. Stage	Million € loss in processing stage	Million € loss in distribution stage
	219,97	3438,29	552,84

Italy	Million € loss in retailing stage	Million € loss in consumption stage	Total loss
	320,22	1063,03	2933,23
France	Million € loss in retailing stage	Million € loss in consumption stage	Total loss
	202,77	526,30	841,42
Spain	Million € loss in retailing stage	Million € loss in consumption stage	Total loss
	173,44	437,62	1518,67
Netherl.	Million € loss in retailing stage	Million € loss in consumption stage	Total loss
	41,47	125,79	209,55
EU	Million € loss in retailing stage	Million € loss in consumption stage	Total loss
	1341,23	3780,24	9332,57

(Tab.21: Final results of the economic analysis)

The results of the economic analysis are now presented: the total cost of the tomato-related food waste (tax excluded) generated in every stage, for every product, in the European Union seems to be €9.3 billion.

6. Social analysis

Overall, the relatively low selling price of tomatoes and tomato-based processed products do not allow the producers to receive a proper remuneration for their work. This is especially evident in Italy where large retailers together with entrepreneurs make the price so low to make all the chain not-sustainable.

As it was shown before, from the field to the consumer, the selling price of tomatoes can increase more than ten times and that can be explained by considering all the operations which are carried out (collection, sorting, washing, processing, packaging, labelling, transportation, marketing etc.) but the main point is to make the agricultural production phase profitable as well.

In Netherlands, this has been partly achieved through the reduction of arable land, using advanced greenhouses and modern agricultural techniques that are linked to a complete mechanization of each phase and to a strict cost optimization.

6.1. The phenomenon of "caporalato"

The world "caporalato" comes from the Italian word "caporale" which means "corporal".
In Italy, "caporalato" is the unlawful organization of teams of illegals workers where each time is controlled by a corporal who is responsible for the organization and the recruitment of workers in agriculture and who represents the link between the labour supply (entrepreneurs) and the labour demand (workers).

The working conditions applied by the corporals are very harsh:

- Usually the daily working time is between 10 and 12 hours (where the law permits max. 8 hours).
- Usually the hourly wage is between €0.85 and €2.50 (where the law requires at least €7.13).
- Workers have to live in slums with no sanitary facilities often without electricity or running water.
- Workers have to pay the corporals for the transportation from the slums to the field, for the food, for the water and for living. These expenses are mandatorily claimed by the corporals.
- Workers do not have rights or insurances (where the law provides 2 days of rest every 14 days worked, 11 hours at least of daily rest, 4 weeks of full-paid vacations, 180 days of full-paid rest in case of accidents or illness, the rights to strike and to join a trade union, maternity/paternity permits, wedding permits, the right to work in a safe environment; just to quote the main ones).

These workers are mostly illegal immigrants coming from the Sub-Saharan Africa who accept to work in these conditions in order to earn something and because they don't have any other option to survive.
This phenomenon is caused from the avarice of unscrupulous entrepreneurs who want to earn not honestly and by the corporals who decide to enslave the other workers in exchange of a good pay. Furthermore, corporals are often affiliated with mafia organizations which makes this phenomenon even harder to die.

After the death of several workers and after big strikes, the law "LEGGE 29 ottobre 2016, n. 199" has been approved. Since then, whoever is caught to be a corporal in Italy, faces up to 12 years of prison and up to €2000 of fines for every illegal worker recruited while entrepreneurs face the confiscation of their assets.

Nevertheless, this phenomenon is still sadly spread especially in the south of Italy and this could be easily explained with the workers who are scared to denounce the entrepreneurs and the corporals (because of the violence of the corporals who may wound or kill the workers, because of their extreme miserable living conditions and because they are scared to be expelled by the country due to their illegal conditions).

7. Environmental analysis

According to A. Del Borghi, M. Gallo, C. Strazza, M. Del Borghi[109] the main things which have to be considered in order to make a life cycle assessment of the tomato-based processed products are:

- Fresh tomatoes [expressed in kg] which are obviously the main ingredients
- Salt [expressed in kg] which is, as we have seen in Chapter 3 added in several preparations
- Citric acid [expressed in kg] which is used as food additive, emulsifier and/or preservative
- Electricity [expressed in kWh] which is used in every stage (especially during the processing stage)
- Fuel [expressed in MJ] which is used for transportation in every stage

Furthermore, packaging has to be considered as well (glass bottles with metal lids, carton-based containers, carton-based containers with plastic cups and open top tin-plated steel cans and lids).

Using CML 2001 which is a LCIA methodology, it has been possible to assess that:

- The production stage and the packaging phase are the most fuel and electricity consuming.
- Carton containers are more environmentally friendly (less carbon dioxide emissions) if compared to the glass and the metal ones due to their less need of resources consumption (ferronickel, iron ore, limestone, silica sand, dolomite etc.)
- The production stage and the packaging phase are the most impacting categories talking about sulphur dioxide and hydrocarbons emissions (which contribute to acidification and oxidation).
- The average land use is equal to 3.55 m^2a per every kilogram of tomatoes.
- Pesticides have quite a large impacts in the production stage also if further studies are needed.

The production of waste (in every stage of the tomato supply chain) appears to be the main economic and environmental issue of the tomato supply chain in fact, the disposal of the food waste generated by the tomato industry is costly (and has the greatest negative impact on its sustainability).

On the other hand, waste may also be considered as a quite important resource considering the fact that this waste represents a renewable and cheap biomass which can be used for the production of biofuels, energy and/or for the extraction of several chemicals (contributing to the sustainability of the chain).[110]

Considering the first ten countries for tomato production and processing capacity, the biggest amount of GHG emissions coming from the waste handling (consumption stage) occurs in landfills (79 kt CO2-eq) while the impact of the remaining eighteen European countries taken together is way less (15 kt CO_2-eq).[50] Considering again the first ten countries for tomato production and processing capacity, the second biggest amount of GHG emissions coming from waste handling occurs during the anaerobic digestion (12 kt CO_2-eq)

Compared to the overall GHG emission occurring in the entire tomato supply chain (which are not so high, overall) the GHG emissions occurring during the waste handling stage are almost not so relevant.
Overall, the GHG emissions, in the first ten countries are distributed as follow:[50]

- Production in greenhouses is almost everywhere the most impactive.
- As predictable, import of tomatoes is the most impactive in Germany and UK (the main importers)
- In the two processing countries (Spain and Italy) the processing stage is respectively the third and the first most impactive stage
- Post harvesting and storage stage and retailing have, everywhere, the smallest GHG impact

8. Interpretation and general discussion

The total cost of the waste generated in every stage of the EU tomato supply chain seems to be around of €9.3 billion which is quite a relevant amount of money (for comparison, the annual GDP of Haiti is around €8.5 billion [111]). If we imagine to extend this result to the entire vegetable sector (of which tomatoes represent around the 19%-25%) we could assume that in the entire European Union, the food waste related to vegetables could be around €40-€50 billion (for comparison the annual GDPs of Lebanon, Macau, Slovenia, Lithuania, Serbia and Azerbaijan are between €40 and €50 billion each[111]).

- In Italy and in Spain which are the countries with the biggest processing capacity, the largest amount of money related to food waste is lost, clearly, during the processing stage (€1.4 billion, the 46.24%, in Italy and €0.7 billion, the 48.91%, in Spain). As we have seen before, the processing stage is quite costly because of both the fuel and the electricity which are there required.

- Apart from the processing stage in those countries which have a big processing capacity, the consumption stage appeared to be the most costly one and this could be easily explained both considering that it is in the end of the chain (maximizing the electricity and the fuel consumption) and also because of the behaviour of the consumers which is often distracted and not so diligent.

- The production stage, as predictable, appeared to be the least costly and that can be explained taking in consideration that at that stage the product does not have any added value yet. Furthermore, for the same reason, it is possible to say that in these countries (such as the Netherlands) in which the production occurs mainly in greenhouses, the stage is more costly if compared to those countries in which the production occurs mainly in open fields.

8.1. Sensitivity analysis

A sensitivity analysis of problematic parameters has been carried out trying to assess the overall strength of the model and to investigate how the model is affected from the fluctuations of these parameters.

The parameters that have been tested are “FLW3b”, “FLW3c”, “FLW3d”, “FLW3e” (which represent the unitary costs [€/kg] of the food waste flows coming from tomato-based processed products in the distribution stage, in every country and in the EU) and “FLW2b” (which represents the unitary cost [€/kg] of the food waste flow coming from tomato juice in the processing stage, in every country and in the EU). These parameters have been varied applying a factor of ±46.97 (which represents the maximum relative error statistically calculated in the retailing stage and two “extreme” situations have been developed:

1. In the first one, all the parameteres taken in consideration (FLW3b, FLW3c, FLW3d, FLW3e and FLW2b) have been at the same time reduced by a factor of 46.97. In detail: the model is still valid (because the prices of distribution stage do still fit between those in the processing stage and those in the retailing stage) and the total food waste cost varies of just 129.88 million (just the 1.40%)
2. In the second one, all the parameteres taken in consideration (FLW3b, FLW3c, FLW3d, FLW3e and FLW2b) have been at the same time raised by a factor of 46.97. In detail: the model is still valid (because the prices of distribution stage do still fit between those in the processing stage and those in the retailing stage) and the total food waste cost varies of just 129.88 million (just the 1.40%)

In the end, also applying a quite large distortion (which anyway cannot be greater, considering that prices in the distribution stage have to be below the ones in the retailing stage and above the ones in the processing stage and that already almost happens applying a distortion of 46.97%) results do not change.

8.2. Possible improvements scenarios

Without considering the possible rebound effects on the employment rate (as the reduction of waste could technically leads to a reduction of the production and of the employment), it is clear that a minimum optimization of the EU tomato supply chain could lead to great positive effects: a reduction of 10% of the tomato-related food waste should be enough to save €1 billion every year in the European Union.
Every stage could be in fact optimized (and of course cost-benefit analysis should be carried out in order to assess the effectiveness of these actions) with positive environmental and socioeconomic effects. In detail:

1. Import and export should be limited as much as possible as it seems that producing tomatoes in greenhouses is still more sustainable compared to import them. Furthermore, no reliable studies about transportation have still been made and so the import/export stages could represent a source of greenhouse gas emissions bigger and more dangerous than what it was thought before.

2. The use of renewable energy and biofuels in the supply chain will greatly lower the GHG emissions because how it has been shown before, they represent the main source of GHG in the chain. Anyway, biofuels should come from the by-products in order not to have a negative land use change: actually, by-products coming from the chain itself could be used to supply partly this need.

3. A particular attention should be dedicated to the consumers behaviour (and all the efforts should be done in order to improve their awareness) because the main losses occur during this stage

    - Economic incentives should be available in order to allow the consumers to afford smart fridges, smart ovens and smart cupboards which may help to store the food properly.

    - Apps (and/or leaflets) should be available to help consumers to develop proper cooking, storing and scheduling skills (which are necessary in order to reduce the waste) and both supermarkets, schools, volunteers and local authorities should be involved in this process.

4. The adoption of advanced peeling protocols during the processing stage could surely be helpful in reducing the waste which is directly linked with the peeling considering that peels represent a percentage of waste between 7% (optimal) and 25% (worse case scenario). These numbers show how large are the possibilities of improvement.[112]

5. As we have seen before, tonnes of tomatoes are discarded every year just because of their appearance (or because of their non standardized shape, colour and size). This situation could be improved with a synchronized action of consumers, retailers and lawmakers. In detail:

    - European lawmakers should change the European directives regarding the standardization of vegetables (which were approved when the single market born)

    - Retailers should encourage the consumers to buy those both safe and good products (which are perfectly suitable for human consumption also if they may not have a perfect appearance) applying discounts and informing consumers through awareness campaigns.

    - Consumers on their hand, should change their habits, trying to understand that if a tomato is over (or under) sized or if its colour is not perfect, it is still perfectly safe and good to eat and there is absolutely no reason for this product to be thrown away.

9. Conclusions, recommendations and limitations

In the end of this study, it is clear that the tomato supply chain presents several issues which are both economic, environmental and social where the social ones are mainly related to the exploitation of workers in the production stage: as we have seen, this situation may be solved if the tomato harvesting would be entirely mechanized and optimised also if on the other hand this may lead to an increment of the GHG emissions due to the use of machines and/or greenhouses. Further studies are needed in order to assess it.

Talking about the GHG emissions, they overall appear to be not so high and anyway the ones related to the waste handling stage are almost neglectable if compared to the entire supply chain. For sure, as it was shown, they could be easily reduced and the overall efficiency of the chain could be furtherly improved.

The economic impact of the waste appears to be the main impact. This loss of money seems to be for sure consistently as it occurs at every stage of the chain, in every country, for every category of products. Several efforts have to be made in order to reduce the generation of waste, which is very costly and moderate polluting (especially if by-products are not re-used and if the waste is disposed in landfills which may have also quite a big social impact if they are built next to residential areas).

The research presents some data gaps and some assumptions that should be investigated more:

- The data about the cost [€/kg] of tomato juice during the processing weren't available.
- Data about canned tomatoes, and tomato paste were available just for Italy and Spain (which anyway are the main processing countries) while those related to tomato sauce were available just for Italy. Furthermore, data about the production of tomatoes for the processing market in Netherlands were not available as well.
- One of the main issue has been the lack of data about the cost of waste in the distribution stage.
- The data about tomato flakes and tomato powder weren't available also if the quantity on the market of these products appears to be neglectable.
- The analysis has been carried out and based on 4 countries out of 28 (which alone represent the 37% of the EU population, the 77% of the processing market and almost all the production market).
- Social and environmental costs have been discussed but not quantified.
- Taxes have been investigated but then not taken in account in the consumption stage.

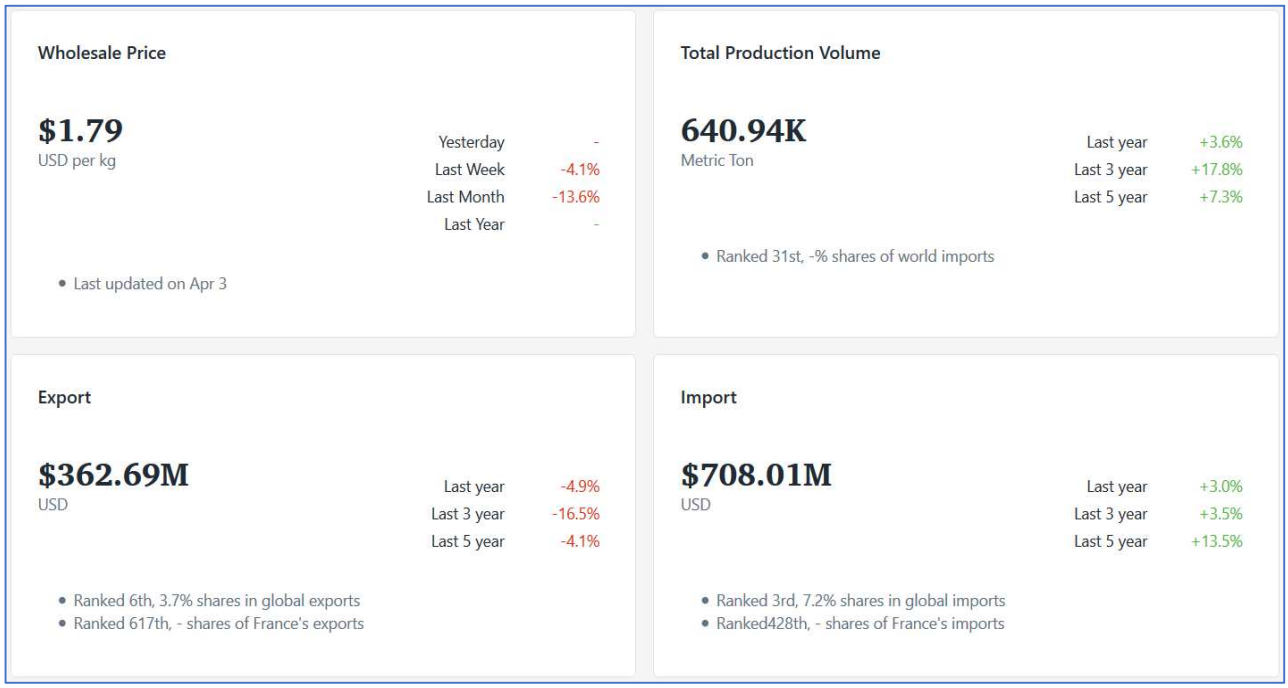
This study could be the basis of a more detailed study on the EU tomato supply chain in which the analysis is carried out on all the 28 countries (also considering that the MFA is already available for the 28 countries) and/or as a basis for a study about the other most common fruits and vegetables produced, processed and consumed in the European Union. The approach could be easily applied to other vegetable-based products.

Furthermore, the social and the environmental costs should be investigated, quantified and included together with the costs and the impacts occurring due both the transportation (occurring among the stages) and the import/export which should be investigated more as well.

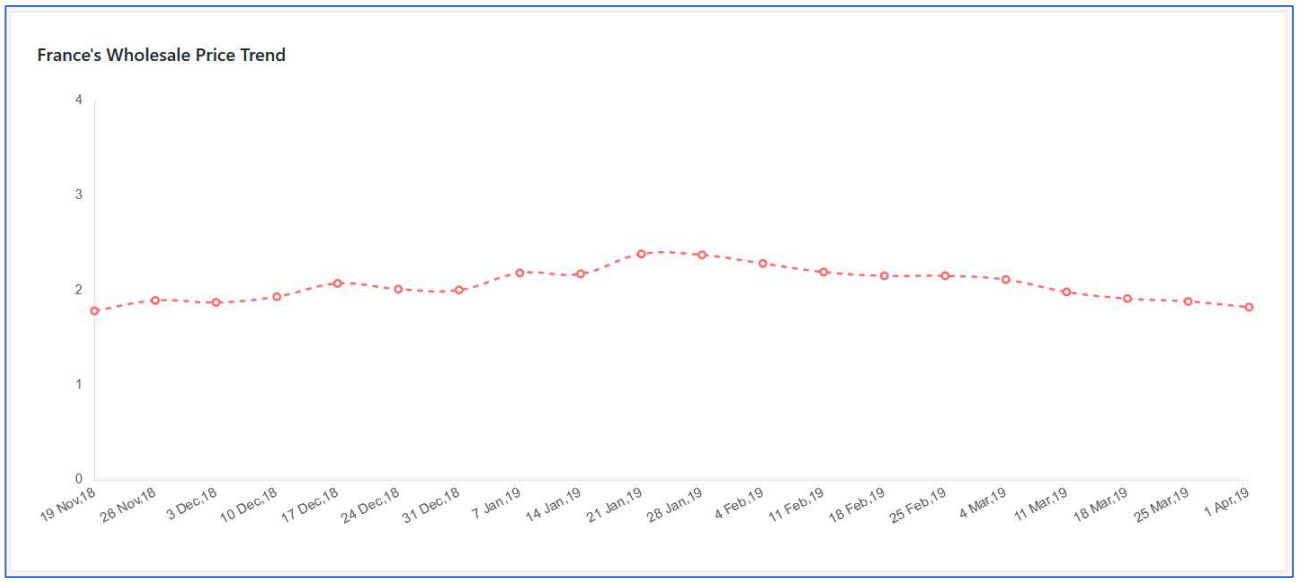
As it was shown in chapter 5, a larger sample about selling prices in the consumption stage has to be taken in consideration in order to reduce the relative error and overall, data about prices should be available for longer periods of time in order to develop better averages and reduce the time-related uncertainties. Finally, further studies about food waste appear to be needed, considering the fact that the literature is mainly based on secondary data and that some data were available just in the grey literature.

10. Appendix

(Fig.55: French tomatoes general information)[86]



(Fig.56: Wholesale price, total production volume, import/export regarding France)[86]



(Fig.57: French wholesale price trend)[86]

Top Export Destinations from France

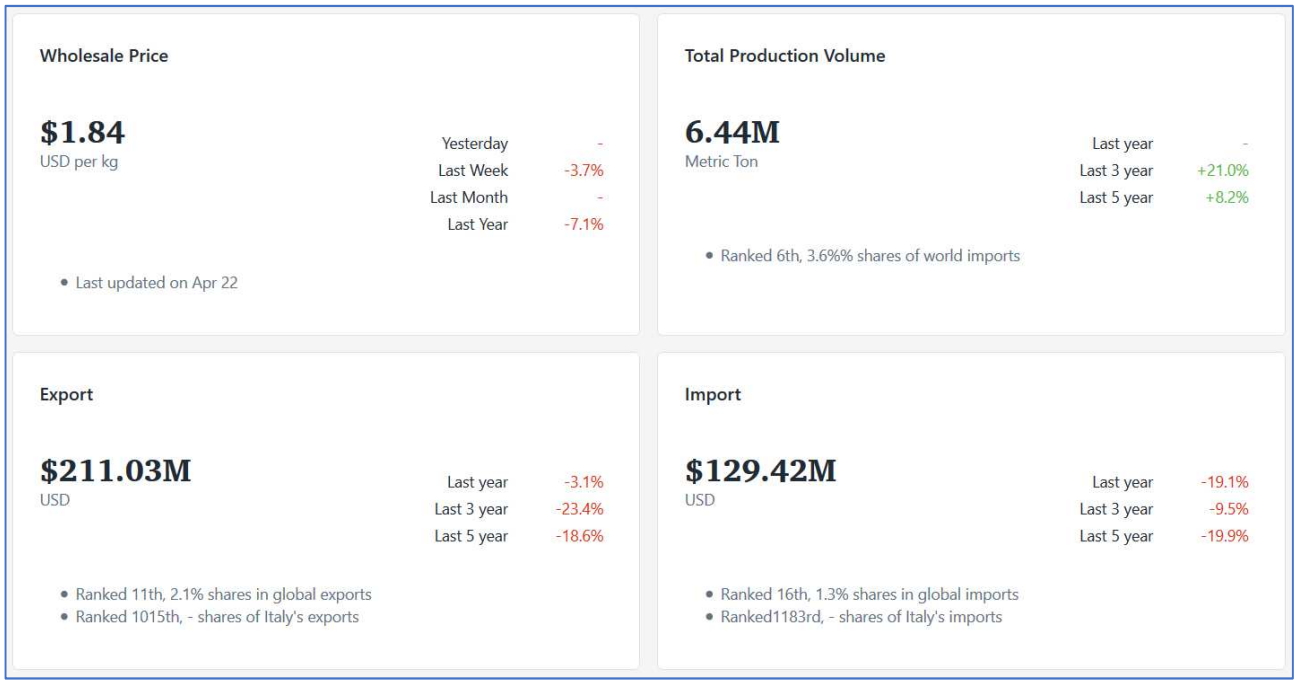
Rank	Country	Export Value in 2016 USD	Shares in Export %	1-Year Growth in Value %	3-Year Growth in Value %
1	Germany	$126.00M	34.7%	-1.8%	-22.6%
2	Belgium	$50.96M	14.1%	+8.6%	-4.3%
3	United Kingdor	$35.55M	9.8%	+19.0%	+4.3%
4	Netherlands	$31.12M	8.6%	+14.8%	-4.5%
5	Switzerland	$17.43M	4.8%	+21.4%	+18.1%
6	Poland	$17.21M	4.7%	-18.9%	-15.4%
7	Italy	$14.88M	4.1%	-34.5%	-35.3%
8	Sweden	$14.21M	3.9%	+2.9%	-12.2%
9	Czechia	$13.82M	3.8%	+27.1%	-21.8%
10	Spain	$12.99M	3.6%	-	-2.1%
11	Denmark	$6.60M	1.8%	+32.4%	+4.4%
12	Austria	$5.31M	1.5%	+3.8%	+10.2%

Top Import Origins of France

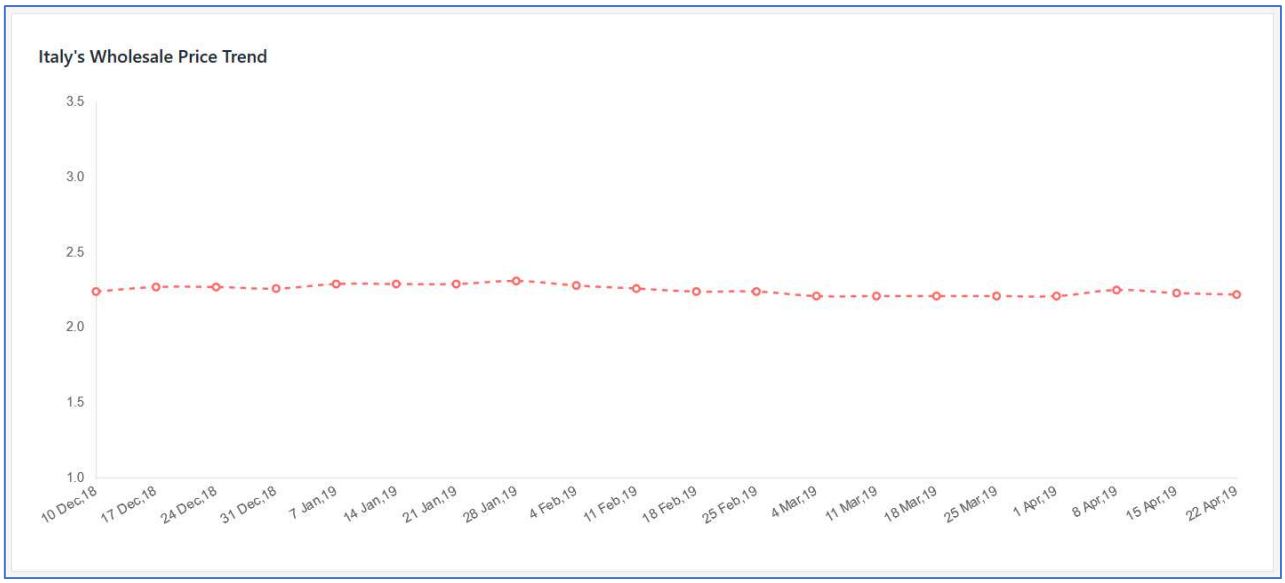
Rank	Country	Import Value in 2016 USD	Shares in Import %	1-Year Growth in Value %	Gro
1	Morocco	$387.10M	54.7%	+11.7%	+
2	Spain	$143.05M	20.2%	+1.7%	-
3	Belgium	$92.79M	13.1%	-3.4%	
4	Netherlands	$42.05M	5.9%	+9.1%	
5	Italy	$12.71M	1.8%	-5.3%	-
6	Tunisia	$10.41M	1.5%	+32.1%	
7	Poland	$5.43M	-	+21.1%	+5
8	Germany	$4.64M	-	+6.2%	
9	Senegal	$3.62M	-	-23.5%	
10	Dominican Rep	$2.19M	-	+60.0%	
11	Portugal	$1.22M	-	-25.0%	-
12	Luxembourg	$729.32K	-	+25.8%	+

(Fig.58: List of countries for import/export regarding France)[86]

(Fig.59: Italian tomatoes general information)[86]



(Fig.60: Wholesale price, total production volume, import/export regarding Italy)[86]



(Fig.61: Italian wholesale price trend)[86]

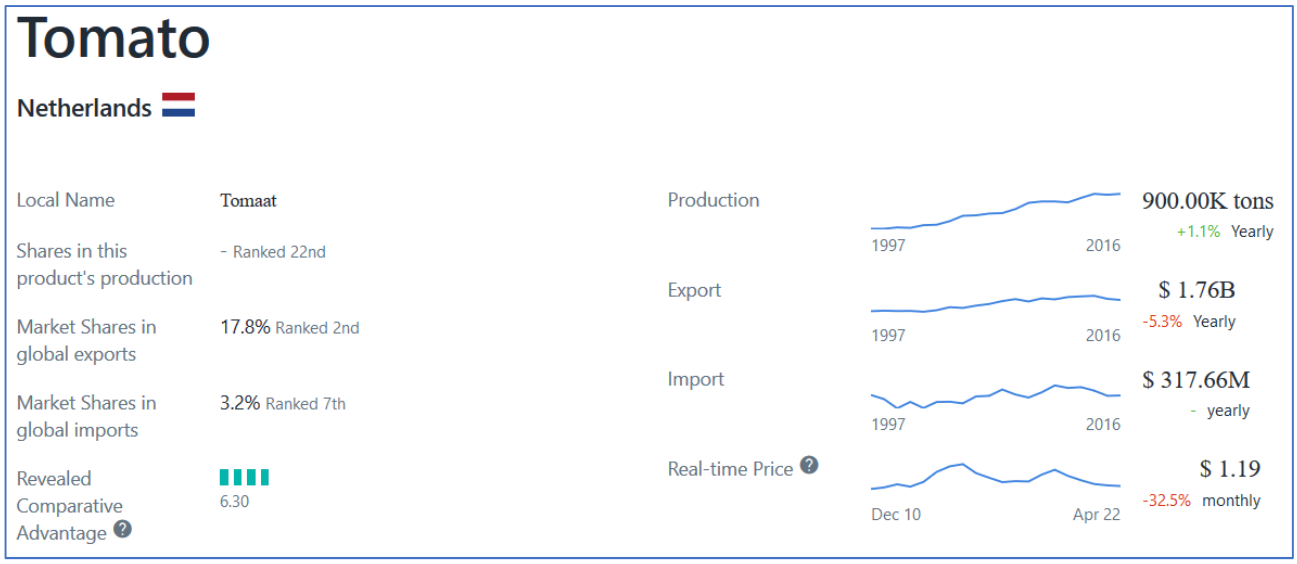
Top Export Destinations from Italy

Rank	Country	Export Value in 2016 USD	Shares in Export %	1-Year Growth in Value %	3-Year Growth in Value %
1	Germany	$53.61M	25.4%	-13.4%	-40.0%
2	Austria	$36.51M	17.3%	-	-14.0%
3	Switzerland	$24.45M	11.6%	+12.0%	+2.6%
4	United Kingdor	$20.06M	9.5%	7.7%	23.0%
5	France	$12.71M	6.0%	-5.3%	-15.4%
6	Romania	$11.16M	5.3%	+76.8%	+35.8%
7	Poland	$6.60M	3.1%	-21.0%	-34.9%
8	Czechia	$5.68M	2.7%	+35.2%	-16.9%
9	Slovenia	$5.39M	2.6%	-6.7%	-8.3%
10	Netherlands	$4.46M	2.1%	-18.4%	-42.2%
11	Denmark	$4.41M	2.1%	-1.4%	-30.9%
12	Slovakia	$3.88M	1.8%	+33.5%	+3.2%

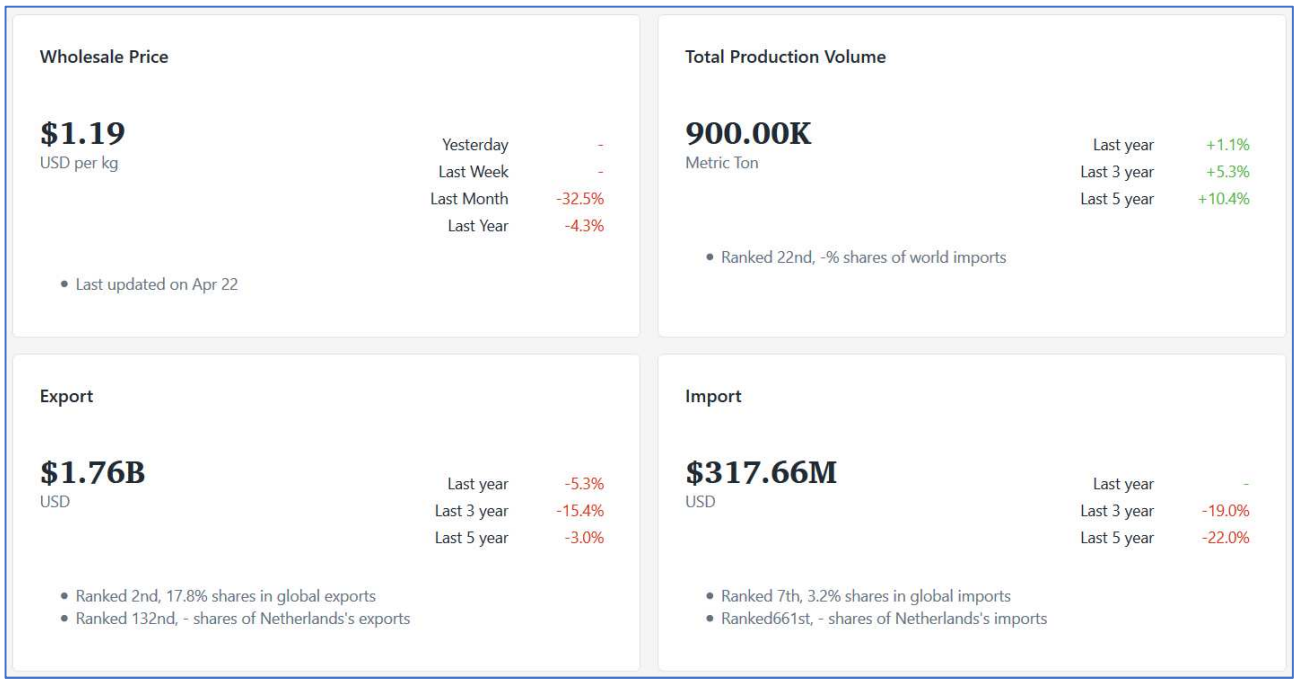
Top Import Origins of Italy

Rank	Country	Import Value in 2016 USD	Shares in Import %	1-Year Growth in Value %	3-Ye Grow Valu
1	Netherlands	$59.00M	45.6%	-15.6%	+21.8
2	Spain	$28.79M	22.2%	-32.6%	-37.3
3	France	$14.88M	11.5%	-34.5%	-35.3
4	Belgium	$9.37M	7.2%	12.7%	46.8
5	Germany	$7.38M	5.7%	-10.0%	-44.7
6	Morocco	$3.07M	2.4%	+1590.8%	+382.9
7	Poland	$2.87M	2.2%	-26.7%	+177.1
8	Tunisia	$2.57M	2.0%	-5.8%	+1.8
9	Austria	$630.33K	-	+23.5%	+24.2
10	Egypt	$455.07K	-	+466.8%	+60.5
11	Slovenia	$145.90K	-	+80.5%	+67.9
12	Croatia	$50.45K	-	-6.2%	+116.5

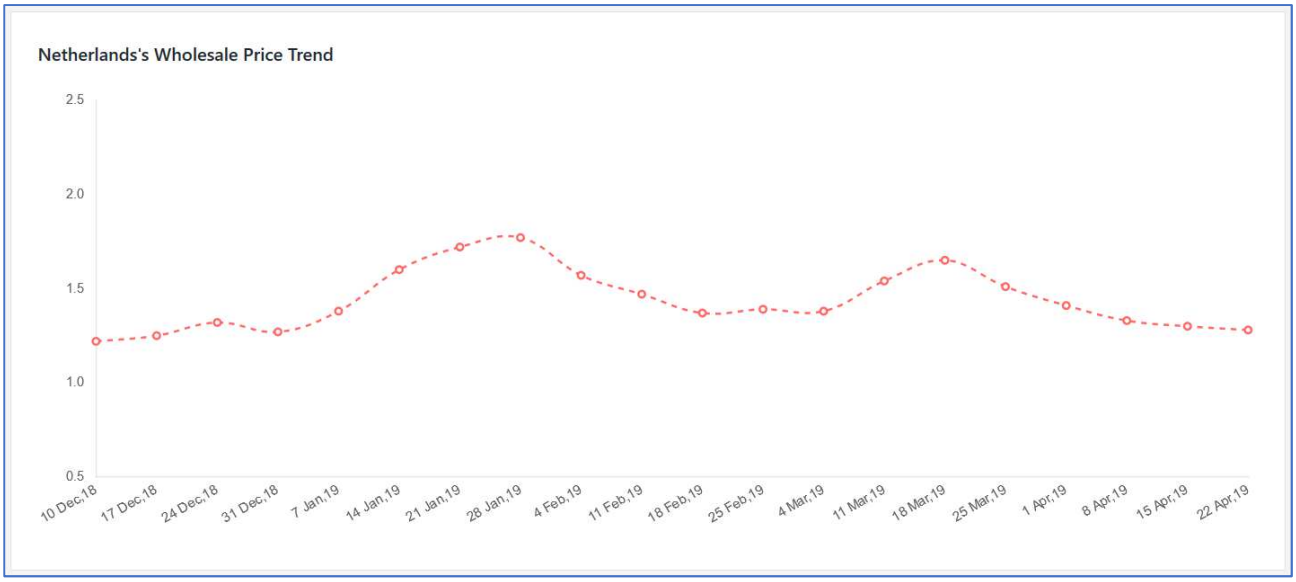
(Fig.62: List of countries for import/export regarding Italy)[86]



(Fig.63: Dutch tomatoes general information)[86]



(Fig.64: Wholesale price, total production volume, import/export regarding the Netherlands)[86]



(Fig.65: Dutch wholesale price trend)[86]

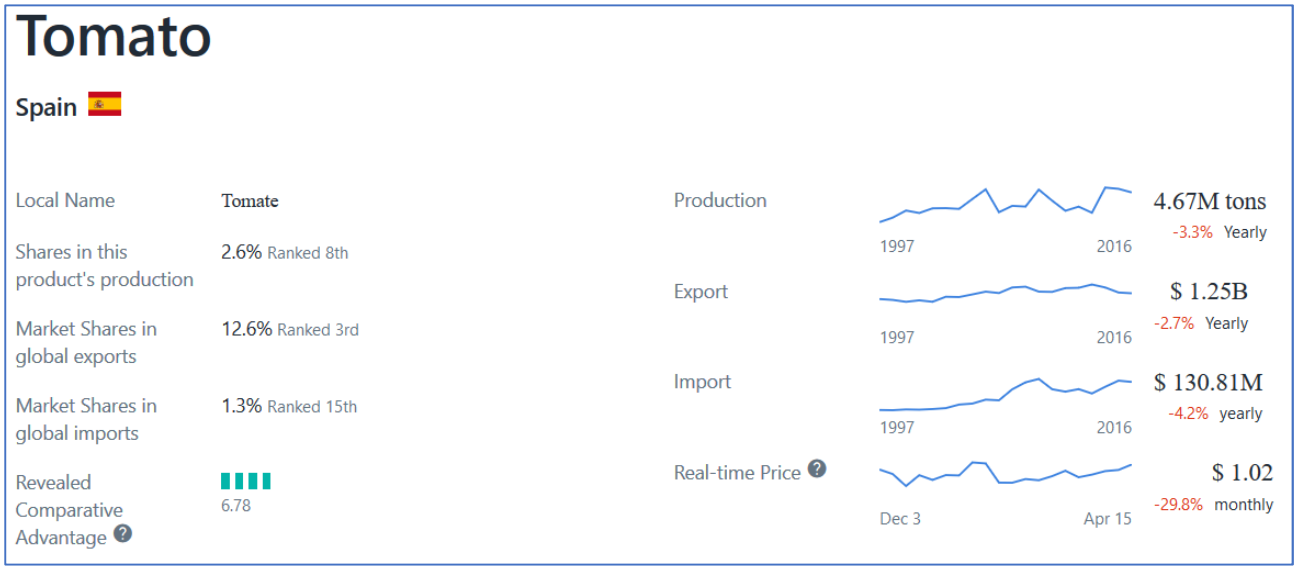
Top Export Destinations from Netherlands

Rank	Country	Export Value in 2016 USD	Shares in Export %	1-Year Growth in Value %	3-Year Growth in Value %
1	Germany	$867.70M	49.2%	-	-3.2%
2	United Kingdor	$256.26M	14.5%	-14.2%	-14.0%
3	Sweden	$89.13M	5.1%	+2.7%	-9.2%
4	Italy	$59.00M	3.3%	-15.6%	+21.8%
5	Belgium	$58.82M	3.3%	-11.3%	-24.7%
6	Poland	$44.41M	2.5%	+2.5%	-5.4%
7	Norway	$43.75M	2.5%	-17.1%	-22.8%
8	France	$42.05M	2.4%	+9.1%	+1.9%
9	Denmark	$36.28M	2.1%	+2.4%	-1.4%
10	Czechia	$34.77M	2.0%	-9.9%	-8.0%
11	Spain	$29.95M	1.7%	-1.7%	+128.4%
12	Ireland	$26.90M	1.5%	-10.9%	-23.5%

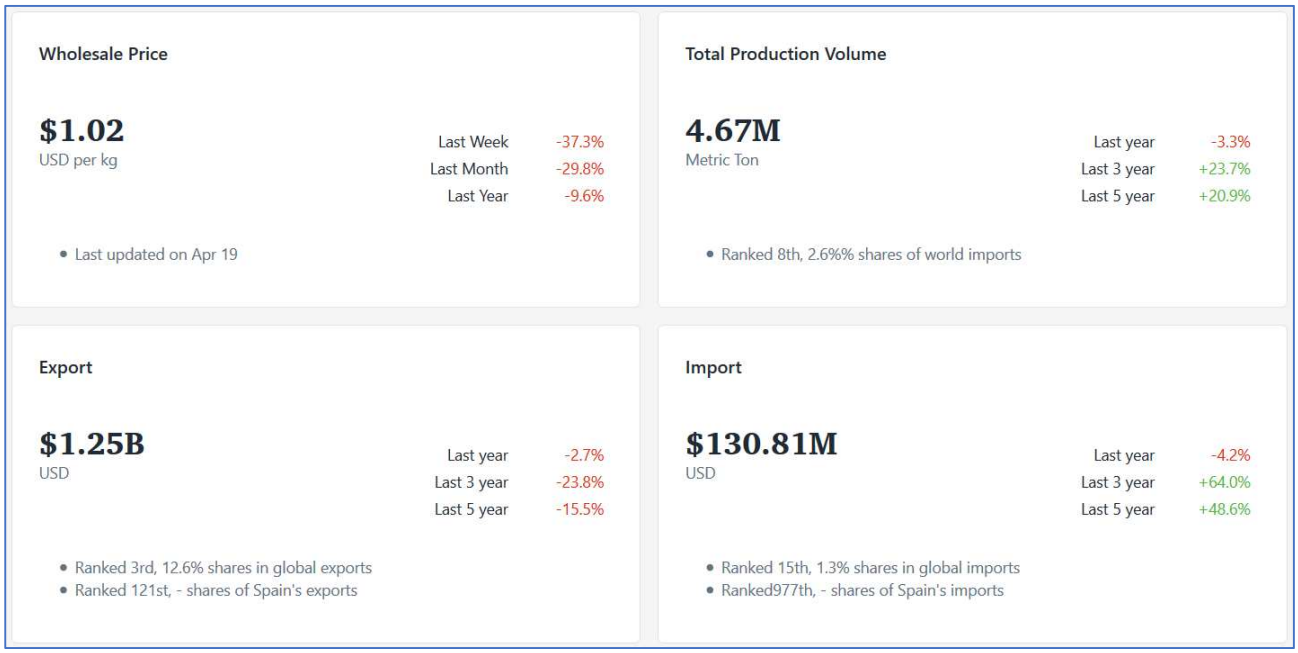
Top Import Origins of Netherlands

Rank	Country	Import Value in 2016 USD	Shares in Import %	1-Year Growth in Value %	3-Y Growt Va
1	Spain	$138.21M	43.5%	-8.5%	-43
2	Belgium	$53.12M	16.7%	-6.3%	+15
3	France	$31.12M	9.8%	+14.8%	-4
4	Morocco	$24.74M	7.8%	+19.4%	+50
5	Germany	$24.44M	7.7%	+28.4%	+111
6	Portugal	$6.49M	2.0%	-13.9%	+207
7	Senegal	$6.34M	2.0%	+36.2%	+28
8	Poland	$4.84M	1.5%	+55.1%	+610
9	Italy	$4.46M	1.4%	-18.4%	-42
10	Turkey	$4.40M	1.4%	+85.4%	+44
11	Tunisia	$4.23M	1.3%	+14.4%	+198
12	United Kingdor	$3.14M	-	-16.0%	-33

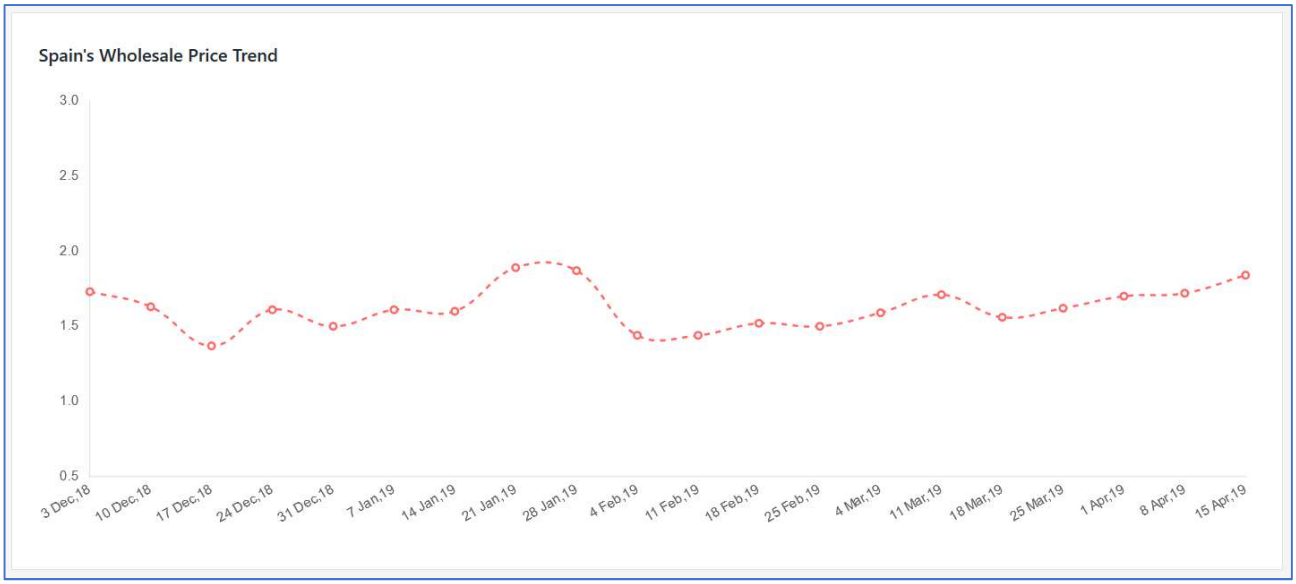
(Fig.66: List of countries for import/export regarding the Netherlands)[86]



(Fig.67: Spanish tomatoes general information)[86]



(Fig.68: Wholesale price, total production volume, import/export regarding Spain)[86]



(Fig.69: Spanish wholesale price trend)[86]

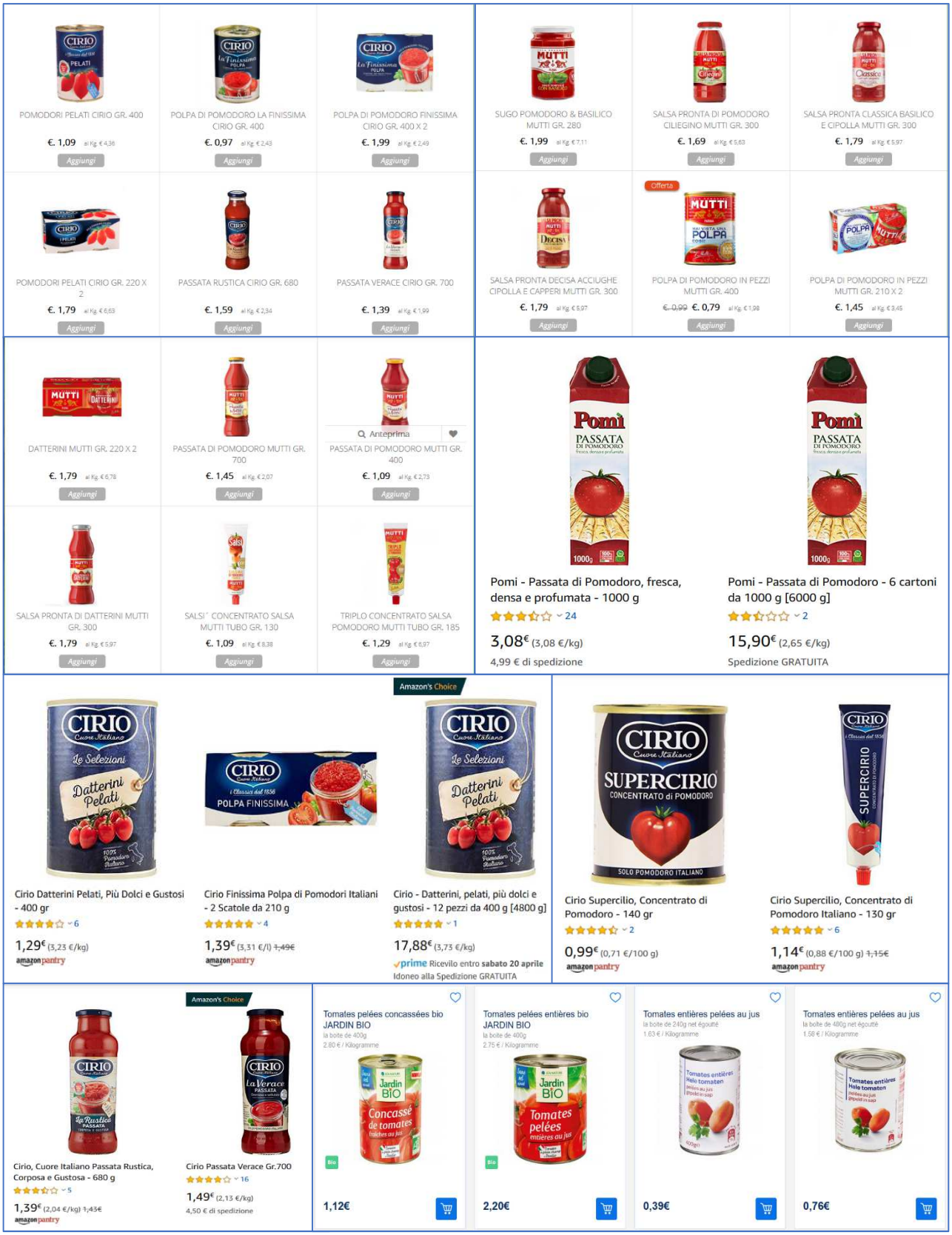
Top Export Destinations from Spain

Rank	Country	Export Value in 2016 USD	Shares in Export %	1-Year Growth in Value %	3-Year Growth in Value %
1	Germany	$323.90M	26.0%	+9.9%	-5.7%
2	United Kingdor	$198.83M	16.0%	-1.7%	-7.8%
3	France	$143.05M	11.5%	+1.7%	-18.9%
4	Netherlands	$138.21M	11.1%	-8.5%	-43.6%
5	Poland	$62.28M	5.0%	-12.3%	-27.2%
6	Sweden	$49.08M	3.9%	-2.2%	+6.4%
7	Switzerland	$33.72M	2.7%	+2.7%	+6.3%
8	Finland	$31.47M	2.5%	+12.5%	+8.6%
9	Italy	$28.79M	2.3%	-32.6%	-37.3%
10	Norway	$27.18M	2.2%	+3.6%	+21.7%
11	Belgium	$25.90M	2.1%	-2.9%	-32.6%
12	Portugal	$25.56M	2.1%	+8.2%	-10.0%

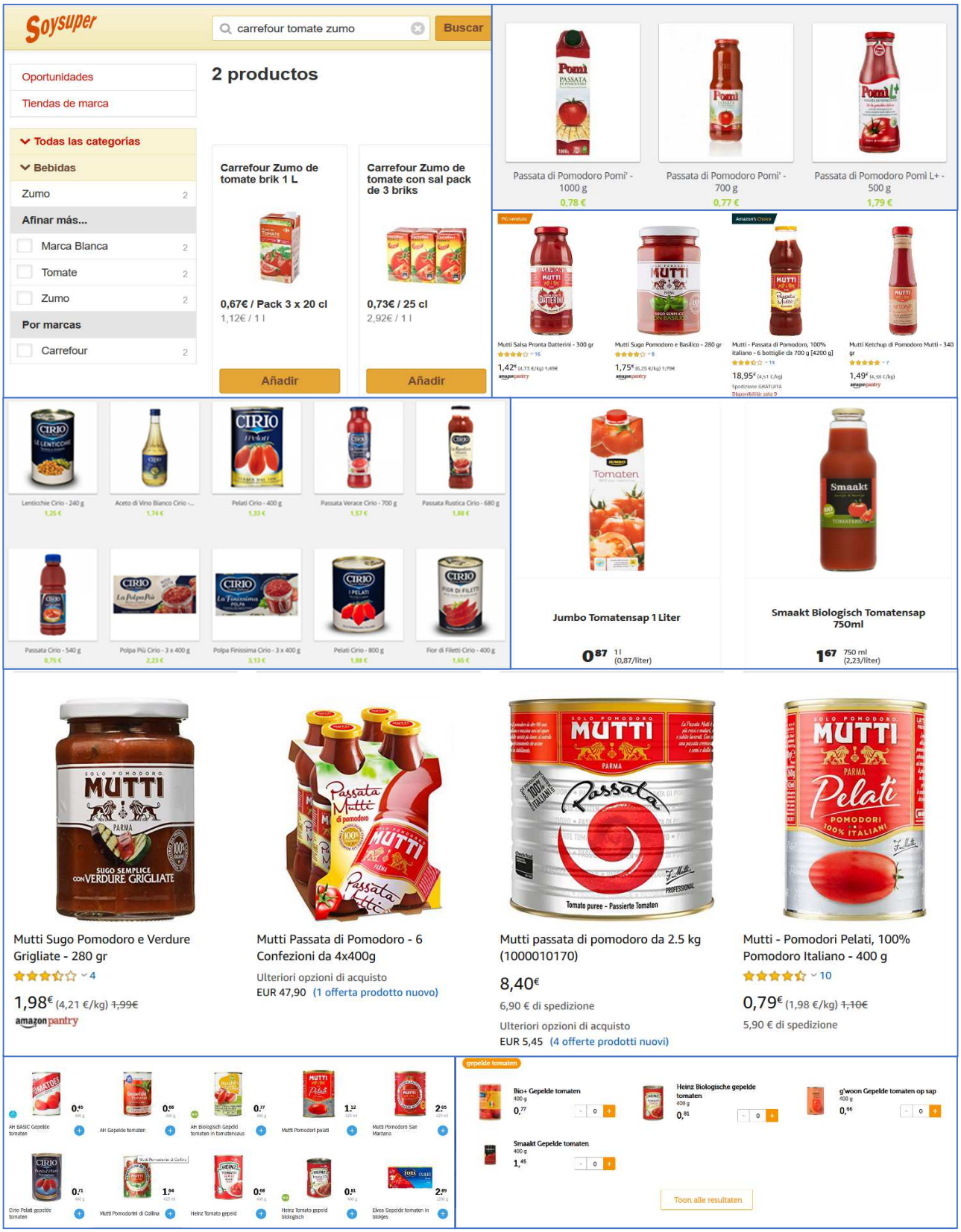
Top Import Origins of Spain

Rank	Country	Import Value in 2016 USD	Shares in Import %	1-Year Growth in Value %	3-Growt V
1	Morocco	$35.87M	27.4%	+26.2%	+6
2	Portugal	$33.90M	25.9%	-11.9%	+5
3	Netherlands	$29.95M	22.9%	-1.7%	+12
4	France	$12.99M	9.9%	-	-
5	Belgium	$6.02M	4.6%	-18.7%	+9
6	Poland	$5.86M	4.5%	-38.8%	+20
7	Germany	$3.79M	2.9%	+39.7%	+56
8	United Kingdor	$741.09K	-	-78.5%	-7
9	South Africa	$411.52K	-	+3647.9%	
10	Italy	$369.62K	-	-54.9%	-2
11	Denmark	$273.03K	-	+615.5%	+72
12	Slovenia	$78.14K	-	-53.1%	+33

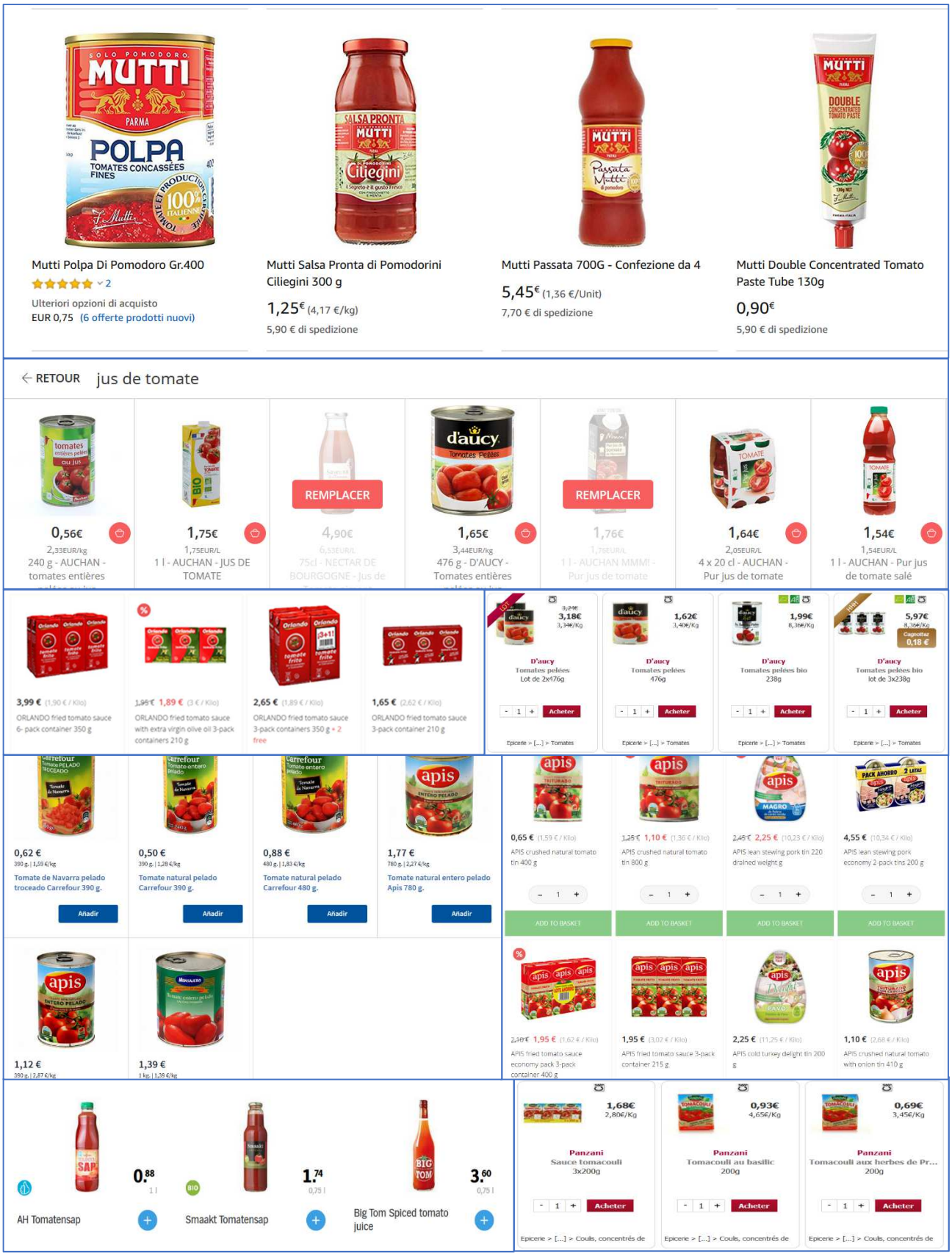
(Fig.70: List of countries for import/export regarding Spain)[86]



(Fig.71: First example of websites from which data about retailing stage have been retrieved)



(Fig.72: Second example of websites from which data about retailing stage have been retrieved)



(Fig.73: Third example of websites from which data about retailing stage have been retrieved)

11. References and bibliography

[0] Shutterstock, https://www.shutterstock.com/it/
[1] Solanum lycopersicum – “Tomato". Encyclopedia of Life.
[2] "Lycopersicon esculentum". International Plant Name Index
[3] “Tomato". Etymology Online Dictionary. 2018
[4] https://www.eurofresh-distribution.com/news/around-world-tomatoes
[5] Frankie, Gordon; Thorp, Robbin; Coville, Rollin; barbara, Ertter; California Native Plant Society (2014). California bees & blooms: a guide for gardeners and naturalists. Berkeley, CA: Heydey. *ISBN 9781597142946*.
[6] Bittman, Mark (14 June 2011). "The True Cost of Tomatoes". New York Times.
[7] FAOSTAT: Production-Crops, 2012 data". Food and Agriculture Organization of the United Nations.
[8] Acquaah, G. (2002). Horticulture: Principles and Practices. New Jersey: Prentice Hall.
[9] BBC - Food - Cherry tomatoes recipes".
[10] "The Purple Tomato FAQ | Department of Horticulture | Oregon State University"
[11] Lorena Lombroso, Il libro completo del giardinaggio, Gribaudo, 2010
[12] Pomodoro grinzoso sanminiatese Prodotti Agroalimentari Tradizionali della Toscana
[13] http://theseedsmaster.blogspot.com/2016/02/top-3-heirloom-tomato-varieties-to-grow.html
[14] Storia del pomodoro, su baroque.it. 2015
[15] R. Dondarini, M. Dondini, 2007 “Il pomodoro”, Coltura e Cultura).
[16] USDA Nutrient Database
[17] Burton-Freeman B, Sesso HD (2014). "Whole food versus supplement: comparing the clinical evidence of tomato intake and lycopene supplementation on cardiovascular risk factors". Adv Nutr. 5 (5): 457–85. doi:10.3945/an.114.005231. PMC 4188219. PMID 25469376.
[18] Hackshaw-McGeagh LE, Perry RE, Leach VA, Qandil S, Jeffreys M, Martin RM, Lane JA (2015). "A systematic review of dietary, nutritional, and physical activity interventions for the prevention of prostate cancer progression and mortality". Cancer Causes Control. 26 (11): 1521–50. doi:10.1007/s10552-015-0659-4. PMC 4596907. PMID 26354897.
[19] European Food Safety Authority (2011). "Scientific Opinion on the substantiation of health claims related to lycopene and protection of DNA, proteins and lipids from oxidative damage (ID 1608, 1609, 1611, 1662, 1663, 1664, 1899, 1942, 2081, 2082, 2142, 2374), protection of the skin from UV-induced (including photo-oxidative) damage (ID 1259, 1607, 1665, 2143, 2262, 2373), contribution to normal cardiac function (ID 1610, 2372), and maintenance of normal vision (ID 1827) pursuant to Article 13(1) of Regulation (EC) No 1924/2006". EFSA Journal. 9 (4): 2031. doi:10.2903/j.efsa.2011.2031.
[20] About Reynoldsburg. ci.reynoldsburg.oh.us
[21] international.sp.nl
[22] The country's only single vine "tomato tree" growing in The Land pavilion at Epcot. Walt Disney World News
[23] Production of tomatoes, 2016. FAOSTAT of the United Nations.
[24] FAO, http://www.fao.org/faostat/en/#data/CC
[25] https://www.hortidaily.com/article/6025804/europe-tomato-production-rises-consumption-falls/
[26] https://www.freshplaza.com/article/2197844/overview-global-tomato-market/
[27] TOMATOES, European Commission, 2019
[28] https://www.tridge.com/intelligences/tomato/export
[29] The Cosmopolitan Condiment". slate.com. Retrieved January 30, 2015.
[30] Lyn Rutherford, Patrick McLeavey -The Book of Antipasti - Page 8 1992 "Sun-dried tomato paste — with a richer flavour than ordinary tomato paste, sun-dried tomato paste is a really useful cupboard ingredient."

[31] “pomodoro”, Coltura e Cultura
[32] https://steemit.com/technology/@yo117/this-machine-sorts-the-tomatoes-at-an-extreme-rate
[33] http://www.potatodryer.com/production-line-equipment/Tomato-Washing-Machine.html
[34] http://www.fenco.it/it/linee-complete-di-processo-pomodoro/macchine-per-la-produzione-di-pomodoro-pelato/
[35] http://www.directindustry.it/prod/navatta-group-food-processing-srl/product-193690-2019376.html
[36] http://www.madehow.com/Volume-2/Ketchup.html
[37] FENCO, http://www.fenco.it/tomato-processing-lines/equipment-for-tomato-paste-production/
[38] http://www.toponemachine.com/html_products/tomato-paste-production-line-27.html
[39] http://www.fenco.it/it/linee-complete-di-processo-pomodoro/impianti-per-la-produzione-di-succo-bevibile-di-pomodoro/
[40] Fruit and vegetable juice processing technology Tressler, Joslyn, 1971 Avi Pub. Co.
[41] https://www.ilpomodoropetti.com/en/production-process
[42] https://www.lastampa.it/2013/07/22/italia/nei-barattoli-della-nonna-la-tossina-che-pu-uccidere-v62QBVOA1LxUYdlZt8SsjP/pagina.html
[43] https://viverepiusani.it/cibo-in-scatola-sicuro-per-salute/
[44] https://pomodoro.museidelcibo.it/il-prodotto/storia/la-lunga-avventura-della-conserva/
[45] https://fdc.nal.usda.gov/fdc-app.html#/?query=ndbNumber:43217
[46] Amy Bentley, How Ketchup Became the Great Equalizer
[47] Enciclopedia dei Ragazzi – Treccani
[48] http://www.tomatonews.com/en/background_47.html
[49] http://www.tomatonews.com/en/trade_46.html
[50] “The German meat and EU tomato cases” written by Li Xue, Zhi Cao, Neele Prass, Gang Liu, Sebastian Gollnow, Jennifer Davis, Silvia Scherhaufer, Karin Östergren, Fabio De Menna, Laura García Herrero and Matteo Vittuari.
[51] Environmental Impacts and Hotspots of Food Losses: Value Chain Analysis of Swiss Food Consumption. Claudio Beretta, Matthias Stucki and Stefanie Hellweg. ETH Zurich, Institute of Environmental Engineering, John-von-Neumann-Weg 9, 8093 Zurich, Switzerland. ZHAW Institute of Natural Resource Sciences, Zurich University of Applied Sciences, 8820 Wadenswil, Switzerland
[52] Gustavsson, J.; Cederberg, C. Global food losses and food waste; extent, causes and prevention; Swedish Institute for Food and Biotechnology (SIK): Gothenburg (Sweden), and FAO, Rome (Italy), 2011
[53] FAO. Food Wastage Footprint - Impacts on Natural Resources. Summary Report, FAO, Rome, 2013. http://www.fao.org/docrep/018/i3347e/i3347e.pdf
[54] Donald, P. F.; Evans, A. F. Habitat Connectivity and Matrix Restoration: The Wider Implications of Agri Environment Schemes. J.Appl. Ecol.2006,43(2), 209 – 218 2006
[55] Tukker, A., Gjalt, H., Jeroen, G., Reinout, H.; Koning, A. Environmental Impact of Products (EIPRO), Analysis of the life cycle environmental impacts related to the final consumption of the EU-25, Main Report; Leiden University: the Netherlands, 2006
[56] http://www.fao.org/state-of-food-security-nutrition/en/
[57] "World Population – Total Midyear Population for the World: 1950–2050". Census.gov. July 2015. Retrieved March 7, 2016.
[58] Sebastien von Hoerner (1975). "Population Explosion and Interstellar Expansion". Journal of the British Interplanetary Society (28): 691–712.
[59] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/organic-waste
[60] https://www.gasum.com/en/About-gas/biogas/Biogas/how-is-biogas-produced/
[61] Evans, G. "Liquid Transport Biofuels - Technology Status Report", *National Non-Food Crops Centre*, 2008-04-14. Retrieved on 2009-05-11
[62] Ethanol". University of Illinois Extension. Retrieved 10 July 2017.

[63] Transesterification of Vegetable Oils with Ethanol and Characterization of the Key Fuel Properties of Ethyl Esters
[64] http://www.wrfound.org.uk/articles/incineration.html
[65] http://www.wrfound.org.uk/articles/landfill.html
[66] Methodology for evaluating LCC, F. De Menna, M. Loubiere, J. Dietershagen, N. Unger, M. Vittuari
[67] https://ambiente.regione.emilia-romagna.it/it/sviluppo-sostenibile/temi-1/sviluppo-sostenibile/green-public-procurement/faq-gpp/che-cosa-e-il-life-cycle-costing-lcc
[68] Environmental Life Cycle Costing: una valutazione economica degli impatti ambientali. Caso di studio su un'azienda operante nel settore dei materiali inerti, Antonio Manea, Università Ca' Foscari Venezia
[69] https://www.unirc.it/documentazione/materiale_didattico/1462_2016_414_25080.pdf
[70] D.Rodreck; P.Ngulube; A.Dube "A cost–benefit analysis of document management strategies used at a financial institution in Zimbabwe: A case study". SA Journal of Information Management.
[71] Ostwald, P. F., McLaren, T. S. *Cost Analysis and Estimating for Engineering and Management*, Prentice Hall, 2004
[72] Cornerstones of Managerial Accounting 4th edition-Chapter 2: Depreciation on plant buildings and equipment, janitorial and maintenance labour, plant supervision, materials handling, power for plant utilities, and plant property taxes.
[73] Farris, Paul W.; Neil T. Bendle; Phillip E. Pfeifer; David J. Reibstein (2010). Marketing Metrics: The Definitive Guide to Measuring Marketing Performance. Upper Saddle River, New Jersey: Pearson Education, Inc. ISBN 0-13-705829-2. Content used from this source has been licensed under CC-By-SA and GFDL and may be reproduced verbatim. The Marketing Accountability Standards Board (MASB) endorses the definitions, purposes, and constructs of classes of measures that appear in *Marketing Metrics* as part of its ongoing Common Language in Marketing Project.
[74] "Opportunity Cost". Investopedia. Retrieved 2010-09-18.
[75] James M. Buchanan (2008). "Opportunity cost". The New Palgrave Dictionary of Economics Online
[76] Consumption Tax Trends 2018: VAT/GST and excise rates, trends and policy issues. Consumption Tax Trends. Secretary-General of the OECD. 2016. *doi*:*10.1787/ctt-2018-en*. *ISBN 978-92-64-22394-3. Retrieved* 24 September *2016.*
[77] https://www.uscib.org/value-added-tax-rates-vat-by-country/
[78] https://ec.europa.eu/taxation_customs/business/tax-cooperation-control/vat-gap_en
[79] http://www.businessdictionary.com/definition/selling-price.html
[80] FAOSTAT, 2017; http://www.fao.org/faostat/en/#data/PP
[81] Tomato news, 2018; http://www.tomatonews.com/en/2018-a-slight-increase-in-this-years-prices_2_494.html
[82] Canned and Tomato, 2018, IEG Vu Agribusiness Intelligence
[83] [Analisi del costo industriale nel settore delle conserve di pomodoro, Francesco Gangi, Eugenio D'Angelo]
[84] Italian Processed Tomato Overview, Ornella Bettini, 2016
[85] Tomato news, 2017; http://www.tomatonews.com/en/spain-the-other-european-giant_2_264.html
[86] Tridge - Find The World's Most Competitive Suppliers, 2018; https://www.tridge.com/
[87] : https://exportlinked.com/importatori-distributori-rivenditori-esteri-il-giusto-prezzo-per-attrarli/
[88] National demographic estimate, December 2017, ISTAT, 2017
[89] Population Figures at 01 July 2018. Migrations Statistics. First half of 2018, INE, 2018
[90] Demography - Population at the beginning of the month - France, INSEE, 2018
[91] Population counter, Centraal Bureau voor de Statistiek, 2019
[92] Eurostat – Population on 1 January 2018". European Commission
[93] http://www.intrage.it/Fisco/aliquote_iva
[94] https://www.ecnews.it/aliquote-iva-sterilizzate-per-lanno-2019/

[95] https://www.economie.gouv.fr/cedef/taux-tva-france-et-union-europeenne
[96] https://www.strongabogados.com/vat-tax.php
[97] https://www.belastingdienst.nl/wps/wcm/connect/bldcontenten/belastingdienst/business/
[98] http://www.tomatonews.com/en/italy-the-industry-is-pursuing-its-reorganization_2_177.html
[99] https://www.auchan.fr/
[100] https://www.carrefour.fr/
[101] https://www.houra.fr/
[102] https://www.ah.nl/
[103] https://www.coop.nl/
[104] https://www.jumbo.com/
[105] https://www.elcorteingles.es/
[106] https://soysuper.com/
[107] http://spesadoc.com
[108] https://www.dummies.com/education/math/statistics/how-to-determine-the-minimum-size-needed-for-a-statistical-sample/
[109] An evaluation of environmental sustainability in the food industry through Life Cycle Assessment the case study of tomato products, A. Del Borghi, M. Gallo, C. Strazza, M. Del Borghi
[110] Food Waste And Bio-Economy: A scenario for the Italian Tomato Market Flavio Boccia, Paola Di Donato, Daniela Covino, Annarita Poli
[111] "World Economic Outlook Database". International Monetary Fund
[112] Understanding Tomato Peelability, Huseyin Ayvaz, Alejandra M. Santos, and Luis E. Rodriguez-Saona, 2016 Institute of Food Technologists https://onlinelibrary.wiley.com/doi/pdf/10.1111/1541-4337.12195

11.1. Further readings

"Valorisation of surplus food in the French retail sector: Environmental and economic impacts" Paola Federica Albizzati, Davide Tonini, Charlotte Boyer Chammard, Thomas Fruergaard Astrup

"The Climate Change and Economic Impacts of Food Waste in the United States", Kumar Venkat

"Farm costs and food miles: An assessment of the full cost of the UK weekly food basket", J.N. Pretty, A.S. Ball, T. Lang, J.I.L. Morison

"The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States", Jean C. Buzby, Hodan F. Wells, and Jeffrey Hyman

"Reusing Food Waste in Food Manufacturing Companies: The Case of the Tomato-Sauce Supply Chain", Luca Secondi, Ludovica Principato, Luca Ruini, Matteo Guidi

"Carbon footprint and cumulative energy demand of greenhouse and open-field tomato cultivation systems" Georgios K. Ntinas, Maximilian Neumair, Christos D. Tsadilas, Joachim Meyer

"Energy utilization and carbon dioxide emission in the fresh, paste, whole-peeled, diced, and juiced tomato production processes" Ahmet Karakaya, Mustafa Özilgen

"Environmental Impacts and Hotspots of Food Losses Value Chain Analysis of Swiss Food Consumption" Claudio Beretta, Matthias Stucki, Stefanie Hellweg

12. Acknowledgments

Firstly, I would like to thank Professor Gang Liu who guided me along this path with his work, his experience and his knowledge; Zhi Cao and Li Xue for their collaboration and for their help, all the Professors and all the colleagues who sincerely inspired me, the University of Southern Denmark which provided me a first-class education for free and both the Kingdom of Denmark and the City of Odense, which welcomed me.

I would also like to make a special thanks to the Karlsruhe Institute of Technology (in which I've spent one semester) for the knowledge which it provided me, to the City of Karlsruhe which gave me the possibility to meet so many amazingly beautiful people and to the Federal Republic of Germany which welcomed me and treated me with love, kindness and great respect making me feel as one of its best children.

I would like to thank those in my family who financially supported me and those who really believed in me. I would also like to thank those employees whose work has allowed me, for the most various reasons, to achieve this and all the people who helped me at some point of my life as I am deeply convinced that nobody can do anything really important alone on its own as the Ubuntu theory (I am because we are) says.

I would like to say the biggest "thank you" ever to the true lights of my life: my friends. I would like to thank both the lifelong ones and those who I had the honour to meet during the past two years. I am grateful and I feel privileged for all the love, the support and the patience they gave to me also when I didn't really deserve it. I am deeply thankful for all the time, the life and the memories they decided to share with me.

Finally, I would like to thank all the people who never believed in me because they made me work harder.

This Master Thesis is dedicated to my beloved grandmother who unfortunately is no longer with me.
She has been my guiding star for many years and somehow she is still the brightest star in my sky.
I hope I made her proud of me. *That's for you nonna, I miss you and I love you so much.*

“And once the storm is over you won't remember how you made it through,
how you managed to survive.
You won't even be sure, in fact, whether the storm is really over.
But one thing is certain.
When you come out of the storm you won't be the same person who walked in."

(Haruki Murakami)

“Remember to look up at the stars and not down at your feet.
Try to make sense of what you see and wonder about what makes the Universe exist.
Be curious.
And however difficult life may seem,
there is always something you can do and succeed at.
It matters that you don't just give up.
While there's life, there is hope”

(Professor Stephen William Hawking)

"I have never let my schooling interfere with my education."

(Mark Twain)