CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE
Faculty of Tropical Agrisciences

Faculty of Tropical AgriSciences

A systematic review of cascara – an important coffee by-product

Bachelor´s thesis

Prague 2023

Author: Lucie Hadamovská

Supervisor: Ing. Olga Leuner Ph.D.

Declaration

I hereby declare that I have done this thesis entitled Cascara, an important coffee by-product, all texts in this thesis are original, and all the sources have been quoted and acknowledged using complete references and according to the Citation rules of the FTA.

In Prague 14.4. 2023

....

Lucie Hadamovská

Acknowledgements

First, I would like to thank my supervisor Ing. Olga Leuner, Ph.D. for her help, beneficial advice, and patience during the time of preparation of my bachelor thesis. I would also like to thank my work colleagues, who were always willing to take my shifts when I needed to write. Finally, I would like to thank my classmates, for their mutual support during this tense time. Last but not least there is one huge thank to give to my other half of the same damaged brain, which was there for me when I needed help.

Abstract

Coffee is one of the most popular beverages worldwide. Its harvesting and processing create millions of tons of various by-products every year. As the production of coffee is increasing so does the number of by-products, that come within, and they all have the potential to be reused. Those are for example coffee flowers, leaves and wood, parchment, and last but not least silver skin.

Cascara, the dried coffee husk and pulp of coffee fruits, is an abundant and underutilized by-product of coffee processing. The coffee industry generates tons of cascara annually, most of which is discarded or used as a low-value input in agriculture or energy production in coffee farms. However, cascara has recently attracted attention as a potential source of value-added products due to its rich bioactive composition and sustainable sourcing. The main potential is now seen in the food and beverage industry due to its unique taste profile, and anti-inflammatory and antioxidant properties. However, cascara can be used in other fields, such as manufacturing, cosmetics, agriculture, biomass energy, and substrate for the cultivation of fungi and yeasts.

Key words: *Coffea arabica*, sustainability, beverages, coffee cherry tea, novel food

Abstrakt

Káva je jedním z nejoblíbenějších nápojů na celém světě. Při její sklizni a zpracování vznikají ročně miliony tun různých vedlejších produktů. S rostoucí produkcí kávy roste i jejich množství, přičemž všechny mají potenciál být znovu využity. Jsou to na příklad kávové květy, listy a dřevo, parchment a v neposlední řadě silver skin.

Cascara, sušené kávové slupky a dužina kávových plodů, je hojným a nedostatečně využívaným vedlejším produktem zpracování kávy. V kávovém průmyslu se ročně vyprodukují tuny cascary, z nichž se většina vyhodí nebo se použije jako málo hodnotný vstup do zemědělství nebo na výrobu energie v kávových farmách. Cascara však v poslední době přitahuje pozornost jako potenciální zdroj produktů s přidanou hodnotou díky svému bohatému bioaktivnímu složení a udržitelné produkci. Hlavní potenciál je nyní spatřován v potravinářském a nápojovém průmyslu, díky jejímu jedinečnému chuťovému profilu a protizánětlivým a antioxidačním účinkům. Cacscaru však lze využít i v dalších odvětvích, například ve výrobě dalších produktů, kosmetice, zemědělství, při výrobě energie z biomasy a jako substrát pro kultivaci hub a kvasinek.

Klíčová slova: *Coffea arabica*, udržitelnost, nápoje, čaj z kávových třešní, novel food

Content

List of tables

List of figures

List of abbreviations used in thesis

EFSA - European Food Safety Authority

EU - European Union

EGCG - epigallocatechin gallate

1. Introduction

Coffee is one of the most widely consumed beverages in the world. However, the global coffee industry is facing significant sustainability challenges: environmental degradation, social inequality, and economic instability. To ensure the long-term viability of the coffee sector, it is essential to adopt sustainable practices that balance economic, social, and environmental objectives (Van der Vossen 2005). These challenges are driven by a complex set of factors, including climate change, globalization, and the uneven distribution of power within the industry.

The concept of sustainability has become increasingly important in the coffee industry, as more and more consumers demand products that are produced in an environmentally and socially responsible manner (Murthy & Madhava Naidu 2012). This trend has led to the emergence of sustainability initiatives and certification programs that aim to promote sustainable practices in coffee production and trade. Moreover, the coffee industry generates a number of by-products that can have both positive and negative impacts on sustainability. These by-products include coffee grounds, coffee pulp, and coffee husks, which can be used for various purposes, such as energy production, composting, and animal feed (Klingel et al. 2020).

Cascara is an often-overlooked by-product of the coffee industry. Cascara consists of the dried skins of coffee cherries, coffee husks, and pulp. Despite its long history of use in coffee-growing regions, cascara has only recently started to gain attention in the specialty coffee industry as a potential value-added product (Vilela et al. 2001). This product has recently gained attention as a potential source of sustainable income for coffee farmers. Traditionally, cascara was considered a waste product of the coffee industry. But now it is being seen from another perspective. Cascara has a flavourful profile that includes notes of dried fruit, caramel, and hibiscus, making it a popular ingredient not only in coffee shops and specialty cafes.

There is a growing interest in cascara as an ingredient in various products, such as tea blends, energy drinks, alcoholic beverages, and even cosmetics (Hidayah Base et al. 2022). In addition to its flavour profile, cascara is also rich in antioxidants and other beneficial compounds, which make it a potential candidate for various health applications (Turck et al. 2022).

Cascara also has several potential uses beyond its traditional use as a beverage. These include its use as a natural sweetener, composting, biomass energy, cosmetics, fertilizer, animal feed, and natural dye (Matos 2008). The use of cascara in these applications can provide additional economic and environmental benefits while promoting sustainable practices.

2. Aim of the thesis

This thesis aims to introduce and summarize most of the information about cascara such as its use (including health benefits), chemical characteristics, and production.

3. Methodology

The data focusing on the genus *Coffea* were found in scientific databases (Web of Science, Google Scholar, and PubMed), while using keywords such as: *Coffea arabica*, *Coffea Canephora*, production, methods of processing or caffeine. Details about plants were found in online databases World Flora Online and Useful Tropical Plants and in several books.

All the data on cascara (history, use, chemical compounds etc.) were collected from scientific databases (Web of Science, Google Scholar, and PubMed) using the variation of following keywords: cascara, by-product, novel food, sustainability, beverages, coffee cherry tea.

The data for other coffee by-products were also collected from scientific online databases with use of key words such as: parchment, coffee spent ground, green coffee, coffee leaves or flowers, silver skin.

4. Literature review

5. General information about the coffee plant

While drinking a cup of coffee we do not usually imagine the plant that produces the coffee beans and the hard work of many people that stands behind it. For several years coffee drinks belong to one the most favourite drinks drunk all over the world.

5.1. Coffee plants from the botanical point of view

The coffee tree is part of the subkingdom known as *Angiospermae* – which means that the plant is reproducing by using seeds, which are closed in the ovary, at the very base of the flower (Farah & Dos Santos 2015). The coffee plant is a member of the genus *Coffea* which belongs to the family *Rubiaceae,* which is one of the largest flowering families with circa 500 genera and 6000 species (Teketay 1999). Over ninety species were described within the *Coffea* genus (25 were more detail described), but only two of them are considered to have major commercial importance: *Coffea arabica* (see Fig 1) and *Coffea canephora* (Davis et al. 2007).

Figure 1 *Coffea arabica*. Source: Iseli 2020

The coffee plant is evergreen woody species, that can grow up to 1,5 to 15 meters – they can be referred to as bushes and sometimes even as trees (Veselá 2016). At plantations can be found shorter coffee plants, mainly because of the easiest way for harvesting. The characteristics of the plant are influenced by the conditions of the environment, where the plants grow. They are mainly influenced by the type of soil, latitude, and humidity (Teketay 1999). Another important influence is sunlight. They can grow in the undergrowth of taller trees, where they are hidden from direct sunlight, or in direct sunlight, where the sun does not have such strength. (Augustín 2016)

The best conditions for cultivating coffee plants can be found in countries in subtropical and tropical climate zone. It is planted in more than 70 countries in the world. In general coffee, plants need a more stable and warmer climate. The ideal amount of yearly rainfall is over 1500 mm, which is why the plantains are embedded with other different species of trees, that can hold the water in the soil. Plantains can also be found without trees, but these kinds are located in lower latitudes, where the risk of sunburn of leaves is not that risky and the rainfall is more regular. A very important role in the quality of coffee beans plays the soil quality. If the soil is slightly alkaline, the coffee plant grows slower in the reverse case, when the soil is more acidic, the plant dies (Burda 2013).

5.1.1. Anatomy of the coffee fruit

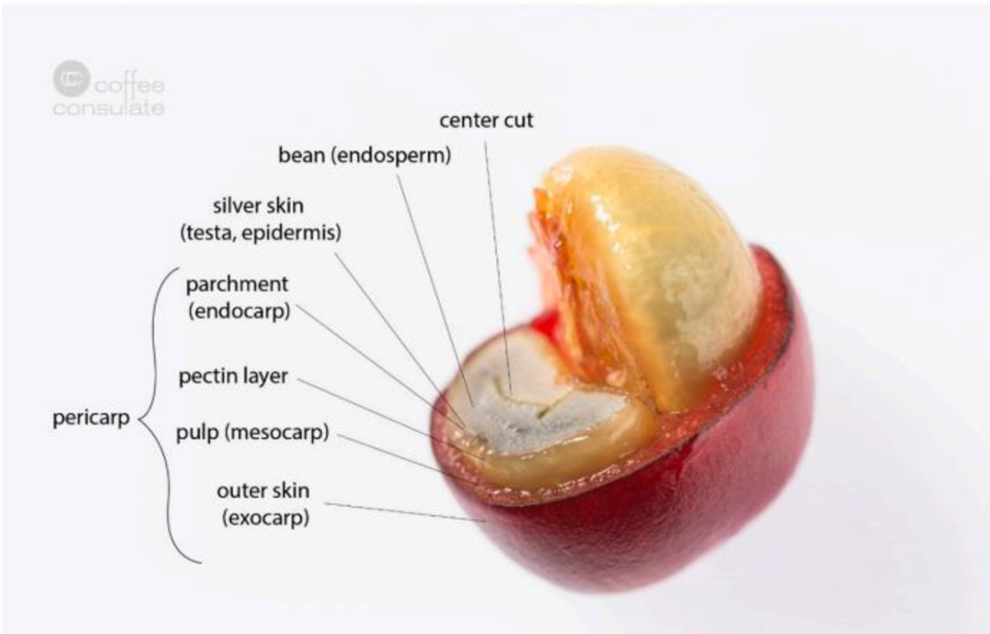

Figure 2 Anatomy of the coffee fruit. Source: Klingel et al. 2020

The fruit that comes from a coffee plant is called a drupe. It is usually fleshy and contains two sometimes only one coriaceous, and one-seeded pyrenes (Teketay 1999.). The coffee fruit has three main layers the exocarp, the mesocarp, and the endocarp (see Fig 2).

The skin on the coffee cherry is called the exocarp. It is thin, and tough, and covers the entire surface of the fruit. It is green until it ripens to a red, yellow, shades of orange, or sometimes even a pink, depending on the variety. Beneath this part is a thin layer called the mesocarp, known as the pulp. The mesocarp also contains a significant amount of water, which can affect the weight and quality of the coffee beans. The inner part of the pulp is called mucilage. These are the layers full of sugar and acids, that play an essential role in the processing of green coffee beans – in the fermentation (Farah & Dos Santos 2015). Mucilage is a sticky, gluey substance that covers both seeds inside the cherry. The see is covered by a thin layer called silver skin (testa) which comes off during the roasting. The coffee seed or mostly called the coffee bean, the most prized product of the coffee plant. Inside the coffee fruit, there are usually two coffee seeds, however, sometimes that there is only one seed inside the cherry - called a peaberry. The seeds are oblong in shape and have a flat side and a rounded side. The flat side is known as the ventral side, while the rounded side is called the dorsal side (Hoseini et al. 2021).

Figure 3 Coffee fruits. 1. Pulp, 2. Bean coated by mucilage and parchment coat.
Source: Poltronieri et al. 2016

Understanding the anatomy of coffee fruit is critical for coffee farmers, processors, and roasters to produce high-quality coffee beans. The outer layer, middle layer, inner layer, and seed all play an essential role in determining the flavour, aroma, and quality of coffee.

By carefully controlling the processing of the coffee cherry, coffee professionals can unlock the unique flavours and characteristics of each variety of coffee.

5.2. Main species of coffee plants

As was mentioned before there are many species of coffee plants in the world. However, the most commercially important species are *Coffea arabica* and *Coffea canephora*.

5.2.1. *Coffea arabica*

Coffea arabica is referred to as the better coffee in terms of the quality of the beans and taste. That is why it makes up 64% of the world´s production of coffee (Campuzano-Duque et al. 2021). It is believed to have originated in Ethiopia and is now growing in many countries. This variety of coffee plants is more challenging to grow. The first harvest comes after 5 years and the plant itself is less self-resistant against parasites and diseases. On the other hand, it does not mind the weather changes, just the opposite (Veselá 2016).

Coffea arabica has specific characteristics in terms of taste, which is influenced mainly by the type of soil, fertilizing, sunlight, and the amount of rain (Bisht & Sisodia 2010). Another huge influence on taste is the method of processing coffee beans, which will be discussed later, and roasting. Beans from *Coffea arabica* are usually roasted at a lower temperature than *Coffea canephora*, which gives them a lighter colour and more complex flavour profile.

5.2.1. *Coffea canephora*

Coffea canephora, sometimes referred to as *Coffea robusta*, has its origin in Congo and Uganda, so it comes from the African continent. Firstly, it was mentioned in the 60s in the 19th century. It is the second most widely cultivated species of coffee in the world. It is a prominent cash crop in several countries, including Vietnam, Brazil, and Indonesia. *Coffea canephora* is best grown in uplands and lowlands, so in areas 600 meters above the sea– it needs lower highs than *Coffea arabica*. The harvesting can start even after the second or third year of planting the seed (Veselá 2016).

Coffea canephora can have to double the number of coffee cherries per year than arabica and contain almost double the amount of coffee. This variety of coffee plants is also more resistant to parasites that regularly destroy the plantains of *Coffea arabica*. From an economic point of view is better to grow *Coffea canephora* plants, but when we discuss popularity, the more popular is without a doubt *Coffea arabica*. Robusta coffee is generally cheaper than arabica coffee, making it a popular choice for many larger companies to use these seeds to fill packages of lower-quality coffees and are also used in most instant coffees (Campuzano-Duque et al. 2021). It is also used in blends with arabica coffee to add body and flavour.

Table 1: The differences between *Coffea arabica* and *Coffea canephora*

	Coffea arabica	*Coffea canephora*
Latitude	Higher (600–2000 m.a.s.l.)	Lower (0–600 m.a.s.l.)
Climate	Mild (15–24 °C)	Warm (24–29 °C)
First harvesting	After 5 or 6 years	After 2 or 3 years
Taste	More acidic	Bitter
Caffeine content	Lower	Higher
World production	64 %	36 %

5.4. Harvesting and processing

After the coffee has ripened, it is the right time to start harvesting. Harvesting plays an important role in the final price of green coffee. The harvesting time depends on the geographical location. In countries around the equator, where the climate is very stable, coffee can be harvested throughout the year. North of the equator, harvesting takes place mostly from September to December, while in the south it is mainly from April to May (Veselá 2016).

Harvesting begins at lower altitudes, as the coffee cherries ripen much faster than elsewhere. After that pickers slowly move up to higher altitudes. Coffees from lower altitudes are cheaper but do not reach the best quality. At higher altitudes, coffee cherries ripen more slowly, so different substances (for example sugar) have more time to be absorbed into the beans and that is why they reach better quality (Farah & Dos Santos 2015).

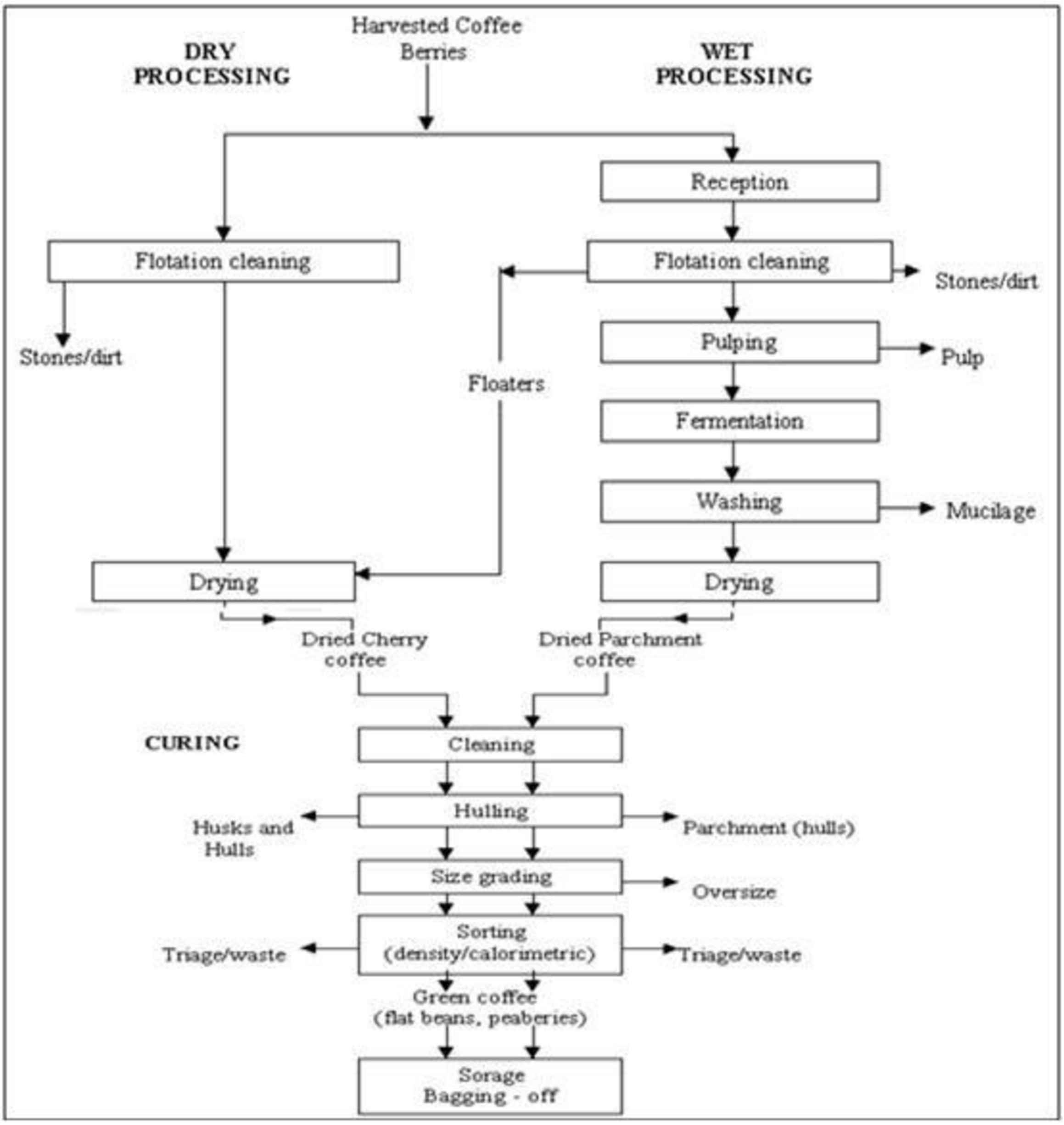

Figure 4 Flow sheet illustrating the stages of wet and dry processing.
Source: Ogundeji et al. 2019

The major impact on the coffee taste and price has its processing. That is why now both of these actions are so important for the coffee chain (Hoffmann 2014). Coffee plants differ from other fruit trees in that once the ripe fruit is harvested, coffee trees begin to flower and start producing brand-new cherries, even on the same branches. This brings both – higher profits but also more labour. For example, the average yield of a single coffee tree can be up to 1.4 kilograms of green coffee beans (Farah & Dos Santos 2015).

After the coffee cherries are picked, the processing (see Fig 4) can begin the sooner the better, because the coffee cherries and other fruits can get spoiled quickly. The most used processing of coffee cherries is dry, washed, and semi-washed. There are many differences in those processes. These methods differ not only in their processing techniques but above all in their varying degrees of intensity of labour and energy (Bastian et al. 2021).

5.4.1. Dry method

The dry method is considered to be the easiest and at the same time the most cost-effective. It is also considered to be the oldest method of processing coffee beans (Bastian et al. 2021). Sometimes it is also named natural or dry-processed. The most significant advantage of the process is that it does not need water, so it is mostly used in the countries dealing with water scarcity. Most often in African countries, water is primarily used to provide the necessities of life and cannot be wasted on processing coffee beans (Ghosh & Venkatachalapathy 2014).

The process starts with laying coffee cherries in thin layers either on the ground or on the African beds and the cherries are dried in the sun with the pulp, which is removed mechanically or by hand (Veselá 2016). The coffee berries are raked at regular intervals using specially adapted tools, horse-drawn carts (this is not used as much, because horses deform a large part of harvest with their hooves), and small tractors (Bastian et al. 2021).

The whole drying process takes about four weeks; during this time, farmers must ensure turning, direct sunlight, and cover the beans overnight to prevent moisture; otherwise, fermentation can be found (Várady et al. 2022). Once the drying is finished it is the right time to peel off the dry skins. This work is done mainly by women, where their job is to separate the husk from the beans and then the beans are sorted according to their size and quality.

Dry processed beans have a specific fruity taste and tend to be less acidic. The beans made with this method also have a stronger body, because the various substances from the skin and the flash gradually penetrate the beans. In those coffees, we find the sweet taste, honey, nutty flavours, and a hint of chocolate with alcohol (Ghosh & Venkatachalapathy 2014). It is challenging for farmers to make perfectly dry coffee because it takes a lot of time and energy, as mould, rot, and similar defects carry repulsive flavours that tend to take up residence among the warm and wet coffee (Veselá 2016). In recent years, the popularity of the dry method has increased among specialty coffee producers and roasters, who value the unique flavour profile and sustainability benefits of this method (Bastian et al. 2021).

5.4.2. Wet method

The wet-processing method is often referred to as fully washed, and its difficulty lies mainly in water recourses and finances. When you look at the African continent, with many coffee plantations in about every other country, this method becomes very questionable. The inhabitants have difficulty finding water or using it to grow crops for their living and of course, on the other hand, they waste water on coffee cherries (Bastian et al. 2021).

At the very beginning of the process, the coffee cherries are washed with water in special tanks. In doing so, the light, shrivelled and immature fruits are separated from the ripe and heavy fruits. Immediately after washing in water baths and selection, the top skin and some of the flashes are removed in this processing method (Gebremariam Woldesenbet et al. 2014). It is important that the peeling takes place within 24 hours of harvest. Later, the skin and pulp adhere to the grains and are much harder to remove. Even then, peeling can damage the grains (Ghosh & Venkatachalapathy 2014). Coffee beans are being peeled by special peeling machines.

The coffee is then moved into vats or troughs of water where is it left to ferment. The fermentation time and the amount of used water vary from region to region and farmer to farmer, but the basic aim is still the same: to remove the cherry pulp residue from the bean. After fermentation, the pericarp is so disturbed that it can be washed away with water (Bastian et al. 2021). The cleaned grains are then removed from the water and left to dry in the sun. It is also necessary to rake them regularly so that they dry evenly and slowly (Gebremariam Woldesenbet et al. 2014).

5.4.3. Honey method

This method was invented in Brazil and has taken hold in Central and South America. It combines steps from both – wet and dry processing methods (Bastian et al. 2021).In this method, the coffee cherries are pulped to remove the outer fruit layer, but some or all of the mucilage or honey-like substance is left on the beans during the drying process (Poltronieri & Rossi 2016).

Figure 5 Appearance of honey process coffee beans. Source: Poltronieri et al. 2016

There are different variations of the honey method, including white honey, yellow honey, and red honey, depending on the amount of mucilage left on the beans and the length of the drying process (see Fig 5). Generally, the more mucilage left on the beans and the longer the drying time, the more complex and fruitier the resulting coffee is likely to be (Kleinwächter et al. 2015).

This method is most popular in Central America and South America, as it can produce unique and complex flavour profiles that are highly sought after by specialty coffee roasters and enthusiasts. However, it can also be more labour-intensive and challenging to manage than other processing methods, as the beans must be carefully monitored and rotated during the drying process to prevent spoilage or uneven drying (Bastian et al. 2021).

5.4.4. Anaerobic method of processing coffee beans

Modern coffee processing methods include the processing of green beans. The trend now is to experiment with green beans and see how the taste of the coffee will change.

The most favourite newly used method is called anaerobic, which combines several practices applied in the methods described above. The fermentation process begins as soon as the coffee cherry is picked because it contains sugar, water, bacteria, and yeast (The Roasters Pack 2022). The acids and sugars in the coffee's mucilage are then converted into CO_2, ethyl alcohol, different acids, and other compounds. The anaerobic processing differs itself in lack of oxygen. The vessels in which the coffee cherries are fermented do not contain or let any oxygen in. First, the beans are put into the vessels and then the oxygen is removed. Valves on the tank keep oxygen from seeping in during the process while also letting the CO_2 out as it builds up during the fermentation (Girma & Sualeh 2022).

The whole process of the anaerobic method starts with pulping the coffee. The beans are removed from the coffee and added to the tank. The next step is to obtain mucilage – this part is squashed down to a very thick and viscous gel, that is spread over the top of beans. Then the producers put the lid on top of the tanks and the fermentation process begins. The whole process usually takes from 24 to 90 hours (The Roasters Pack 2022).

The most valid benefit is that the producers have a lot more control over the whole fermentation process – because there is the minimum influence of the outside environment (such as quality of air, humidity, etc.). The final taste of coffee can be fruitier and juicier, has a more complex body, and is funkier (Girma & Sualeh 2022).

6. Cascara

The processing of coffee gives rise to a large volume of waste, whose use has been the subject of several latest studies (Vilela et al. 2001). In the past (the first half of 20^{th} century) the waste from the coffee-producing industry was sometimes destroyed simply by burning or dumping overboard. But nowadays, the concern with environmental problems has led to an increased interest in the destination of residues generated in the agro-industrial processing of coffee, and a greater knowledge of the composition of these residues, resulting from scientific studies, has made it possible to expand the range of economic application (Luis et al. 1994).

The word "cáscara" originates in Spanish and means the skin or husk of any fruit. Cascara is the dried skin of coffee fruits (Klingel et al. 2020). Coffee fruits are harvested, and the seeds are extracted from the inside of the fruit for coffee production. The remaining fruit, including is discarded as waste. However, this discarded fruit can be dried and used to make cascara (see Fig6).

Figure 6 Dried cascara. Source: Zeckel et al. 2019

One of the benefits of cascara is that it contains antioxidants, which are believed to have a range of health benefits, including reducing inflammation and protecting against certain diseases (Lachenmeier et al. 2022). Cascara also contains lower levels of caffeine compared to coffee, which some people prefer for a gentler energy boost.

What is also making cascara more and more popular is also the taste. Without the high acidity and bitterness, that can coffee beverages contain, cascara preferred among the wider population, including the younger and older population. It has a fruity and slightly naturally sweet flavour with a hint of coffee. It is often compared to a cross between raisins, rosehip, hibiscus, and cherry. The flavour profile can vary depending on the type of coffee cherry used and the processing methods used to dry and prepare the cascara (Klingel et al. 2020).

6.1. History and the use of cascara

The history of cascara as a by-product of coffee production is complex and varied, with cultural and economic influences shaping its use over time. Coffee husks as a drink was first drunk in Ethiopia and Yemen followed by consumption in other coffee-producing countries, and it is still slowly finding consumers across the world.

6.1.1. First beverages from cascara

While coffee husks were considered by most countries to be a useless waste, in Yemen they are useful and valid for a long time. The population uses the coffee husk to produce a variety of tea, called qishr. Qishr is considered to be the first known beverage made from cascara. The name comes from the Arabic word for "husk" or "skin". It was found out in Yemen even before the cascara tea was ever prepared (Muzaifa et al. 2021). Briefly described it is a traditional warm drink that is made from coffee husks with additional spices such as ginger and sometimes cinnamon. It has a light, zesty, sweet, and spicy taste, which makes the drink ideal for mornings to wake you up, although, if it is served with milk, it can make a great night drink too, because of that not so high content of caffeine.

It has a long history, especially in Yemen culture where it is used as a drink to welcome your quest. Each guest is usually welcome with two cups of qishr after entering the host house. Qishr was also called Yemenies beverage made from the pulp of fermented coffee cherries, and it was used during religious ceremonies (Pendergrast Mark 2010).

Historically, cascara was used as food and medicine. In Ethiopia, where coffee is believed to have originated, cascara was consumed as a tea or mixed with other spices and honey to create a sweet and refreshing drink. The tea was also used to treat a variety of ailments, including stomach problems, fevers, and headaches. Nutmeg is sometimes added to the beverage and the drink is called "hashara" (Muzaifa et al. 2021).

6.1.2. Aida Batlle

A huge role in introducing cascara to the wider population played by Aida Batlle. Aida Batlle is a renowned coffee producer from El Salvador who has gained international recognition for her high-quality coffee beans. She comes from a family of coffee producers and has been involved in the coffee industry for over two decades (Zeckel et al. 2019). One of her latest contributions to the coffee industry has been her work with cascara, as she saw its potential as a by-product and began experimenting with different ways to use it. She is the first ever producer of cascara in Latin America and she is also responsible for coming up with the name "cáscara" as it is known today (Zeckel et al. 2019).

Her work with cascara has not only helped to reduce waste in the coffee industry but has also created a new revenue stream for coffee farmers. By selling cascara as a separate product, farmers can earn additional income and improve their livelihoods. Overall, Aida Batlle's innovative work with cascara highlights the potential for creativity and sustainability within the coffee industry and serves as an inspiration to coffee producers and enthusiasts around the world (Michelman & Carlsen 2018).

6.1.3. Cascara as a novel food in European Union

In recent years, there has been a growing interest in novel foods, which are defined as foods that were not commonly consumed by humans in the European Union (EU) before May 15, 1997 (Turck et al. 2022). The EU regulates the approval of novel foods to ensure their safety and to protect consumer health. One such novel food that has gained attention in latest years is also cascara.

As mentioned, cascara is considered a novel food in the EU because it was not commonly consumed in the region before May 15, 1997. While cascara has been consumed in certain countries for centuries, it has only recently gained popularity in other parts of the world (DePaula et al. 2022). In order for cascara to be approved as a novel food in the EU, it must undergo a safety assessment by EFSA, the European Food Safety Authority (Turck et al. 2022). This assessment includes a review of available data on the food's composition, potential allergenicity, and potential adverse effects. Once a novel food has been approved by the EFSA, it can be placed on the EU market. However, novel foods are subject to strict labelling requirements to ensure that consumers are aware of the food's novel status (Klingel et al. 2020). In the case of cascara, products containing the ingredient must be labelled as a "novel food" on the packing.

6.2. Processing of cascara

Cascara is usually produced while producing coffee either by the dry or wet method. The dry process is recommended for less advanced farms because it is much less disposed to contamination than moulding. While producing cascara from the dry method, there is also parchment attached to the final product (Klingel et al. 2020). After harvesting coffee fruits, the cherries are then spread out on a flat surface to dry in the sun. The fruits are left to dry in the sun for several days, during which time they are turned regularly to ensure even drying (Poltronieri & Rossi 2016). As the cherries dry the husks become brittle and start to separate from the beans inside. Once the cherries are fully dried, they are taken to the mill where the outer husks are removed from the beans. That is usually done using a machine that crushes the dried cherries, separating the beans from the husks (Lachenmeier et al. 2022). The next step is to sort and clean the dried husks to remove any remaining impurities or debris. This is typically done by hand.

Figure 7 Production of cascara. Source: Klingel et al. 2020

The more challenging processing of cascara is while using the wet method of production - where the combination of water and sugars from the fruit can occur. The main infection place for microorganisms is the pulper because it is hard to keep the pulper free from contamination (Lachenmeier et al. 2022). The production of cascara begins with the harvesting of coffee fruits. Once the coffee beans are removed from the cherries, the remaining fruit and pulp are separated from the coffee seeds through a process called depulping (Poltronieri & Rossi 2016). The resulting wet pulp is then either discarded, composed, or used as animal feed. However, to produce cascara, the pulp is set aside to dry. Traditionally, the pulp is left to dry in the sun, but in modern production, it is often dried using mechanical dryers. The drying process is crucial to the production of cascara, as improper drying can lead to the growth of mould and other harmful microorganisms (Klingel et al. 2020). In addition, the length of the drying process can affect the flavour profile of the cascara, with longer drying times resulting in a more intense, fruity flavour. Once cascara is fully dried, it is sorted and graded by size and quality. The cascara is then typically packaged in bags or containers for shipment to manufacturers, where it can be further processed into cascara tea or used as a flavouring in other food and beverage products.

While producing coffee beans by the dry method every ton of fresh coffee fruit produces 120 - 180 kilograms of coffee husk and 500 kilograms of coffee pulp with the wet method (Hoseini et al. 2021).

Overall, the production of cascara is a relatively simple process, but one that requires careful attention to detail to ensure quality and safety. As cascara continues to gain popularity as a food and beverage ingredient, it is likely that we will see further experimentation and innovation in the process to further enhance its flavour and versatility.

6.3. The chemical composition of cascara

The chemical composition of cascara can vary depending on the specific variety of coffee plants and the processing method used, but in general, it contains the following compounds.

Coffee husks and pulp are made of organic matter and nutrients, in addition, to contain compounds such as caffeine, which is one of the most common central nervous system stimulants, is present in coffee peels at approximately 1.3% concentration in dry matter, which is about a half lower amount than in coffee beans (Gouvea et al. 2009).

Cascara is a rich source of carbohydrates, including sugars like glucose, fructose, and sucrose (Pleissner et al. 2016).

Table 2 Chemical composition of cascara (source: Pleisner et al. 2016)

Chemical compounds	Content in %
Protein	9 – 11
Lipid	2 – 17
Tannin	4.5
Non-nitrogen extracts	57 – 63
Cellulose	13 – 27
Pectin matter	6.5

Also, it encompasses anthocyanidins, chlorogenic acid, and flavanols. Cascara contains various polyphenolic compounds, including flavonoids, catechins, and phenolic acids. These compounds have antioxidant properties (Manasa et al. 2021). One of the antioxidants appearing in cascara is epigallocatechin gallate (EGCG). It is probably the best-known antioxidant in green tea. Because of its structure, it is referred to as polyphenol and catechin. Other effects that EGCG has on the human body are anti-inflammatory effects and the reduction of blood pressure and blood cholesterol (Eckhardt et al. 2022). Cascara also contains various minerals, including potassium, magnesium, and calcium (Iriondo-DeHond et al. 2020).

A large amount of the coffee pulp that is made while producing coffee is usually thrown into waste disposal sites or river streams without any further treatment (Geremu et al. 2016). That can cause problems, such as contamination and environmental issues if the waste is not managed as it should be, mainly because the coffee pulp contains caffeine, tannin, and polyphenol (Murthy & Madhava Naidu 2012; Alves et al. 2017). Likewise, it can be harmful to the soil quality when it is mixed with animal fodder (Arya et al. 2022).

6.4. Food products made with cascara

The dried husk of the coffee cherry has a unique flavour profile, with notes of cherry, raisins, and hibiscus. This profile has led to the development of cascara-based food products, including energy bars chocolates, and even beer.

One of the most popular cascara food products is cascara tea, which is made by steeping the dried husks in hot water. Cascara tea is a popular beverage in coffee-producing regions such as Yemen and Ethiopia. In addition to its unique flavour, cascara tea is also rich in antioxidants and may have a variety of health benefits – such as reducing inflammation and improving digestion (DePaula et al. 2022). The most common recipe how to make cascara tea is to use 65.5 grams of dried cascara, brewed in 1 liter of 90°C water for 6.5 minutes (Eckhardt et al. 2022).

Another cascara-based food product is cascara energy bars. These bars are made by combining cascara with nuts, seeds, and dried fruit to create a nutritious and energy-packed snack. Cascara is also used in the production of chocolate. The dried husks are ground into a powder and added to the chocolate mixture, giving it a unique fruity flavour. Cascara has a unique flavour profile that is sweet and fruity and pairs well with the rich and complex flavours of chocolate. Cascara chocolate is becoming increasingly popular among artisanal chocolatiers, who are always looking for new and unique flavour combinations.

Another option for use of cascara is flour. The bread with some replacement of cascara flour has a higher crumb elasticity and the colour is like wholewheat bread. Cascara flour is also rich in antioxidants and fiber. Almost 2.5% can be replaced by cascara extract without a negative influence on the sensory results of bread and the baking procedure (Eckhardt et al. 2022).

Cascara has even been used in the production of beer. Cascara imparts a unique flavour to beer, with notes of dried fruit, berries, and tea. It also adds a subtle sweetness and complexity to the flavour profile. Some craft breweries are experimenting with using cascara as a flavouring agent in their beers, creating unique and innovative brews with hints of coffee and fruit (Arpi et al. 2021).

Cascara is also used in the production of gin, cascara syrups, lemonades, jams, jellies, and purees (Eckhardt et al. 2022).

Food products made from cascara not only provide an innovative and delicious way to reduce waste in the coffee industry but also offer a way to create a new revenue stream for coffee producers. As the demand for sustainable and innovative products continues to grow, cascara is poised to become a popular and sought-after ingredient in the food industry.

6.5. Other possible uses for the coffee husk and pulp

Coffee husk and pulp are residues that present great potential. Mostly it is used in coffee-producing countries, because of the great number of coffee husks, that are made while making coffee. However, research has shown that these materials have potential uses in various industries, including agriculture, energy, and manufacturing.

One of the possible uses is as cattle feed. The use of coffee husks in cattle feed is limited due to their low digestibility and reduced protein content. Besides that, the number of saccharides as is for example scratch is almost the same as it is in hay of low quality. There are also studies that focus on feeding other animals with coffee husks such as horses, pigs, fish, sheep, and chickens (Oliveira & Franca 2015). The presence of polyphenols restricts the use of this residue as a complement to animal feed. The dietary supplementation with coffee husks in the diet of cows can only be considered viable in the replacement ranging from 30% to 40% (Oliveira & Franca 2015).

A good alternative for the reuse of coffee husks is composting. This residue can be used directly as a soil cover, being a good option for soils that present a lack of potassium. Coffee husks are rich in potassium and other mineral nutrients which makes it possible to use them as an organic fertilizer with no need for any treatment. In addition, the shells used as compost favours the control of erosion and reduces temperature fluctuations, since it reduces the loss of water from the soil through evaporation (Matos 2008).

Because it has a considerable number of fermentable sugars, it has been considered an appropriate substrate for the cultivation of fungi and yeasts (Murthy & Naidu 2010). Studies evidenced the growth of *Pleostrus ostreatus* in coffee husks enriched with various concentrations of sodium selenite (Silva et al. 2012).

Coffee husk can be used as a source of biomass energy. When burned, it produces heat and steam that can be used to generate electricity. Coffee husk can also be converted into biofuels such as ethanol and biodiesel (Oliveira & Franca 2015).

It has also been verified that the application of coffee husks in the production of other materials, for example, agglomerates. While replacing wood (up to 50%) and depending on the type and amount of resins used, these new agglomerates made in the laboratory met the requirements of the European standards with the respect to the general use in dry conditions and partly in wet conditions too (Bekalo & Reinhardt 2010).

Another field where cascara can be used in cosmetics. The content of antioxidants can reduce free radicals and prevent premature aging. The products that have the potential to be developed are face masks, creams, and soaps (Hidayah Base et al. 2022).

Overall, the utilization of husk and pulp has the potential to provide economic and environmental benefits by reducing waste and creating new value-added products.

6.6. Other coffee by-products

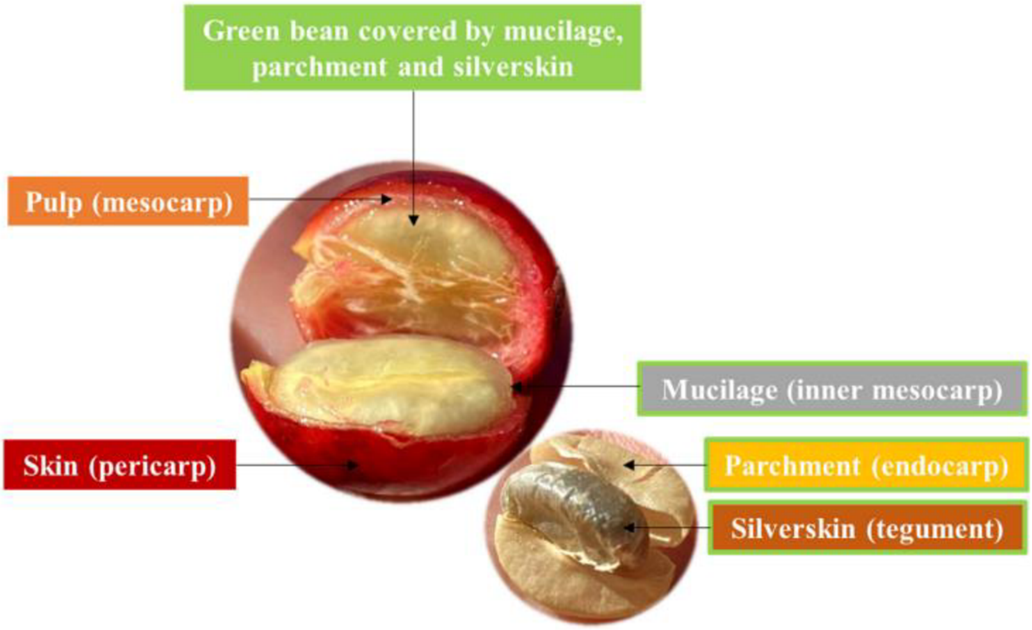

Figure 8 Identification of coffee by-products in the coffee cherry anatomy. Source: Iriondo-Dehond et al. 2020

During coffee production, other several coffee by-products are generated (see Fig 8), and they have potential use as cascara does. They can be a valuable source of raw materials for various industries, as they can be used in a wide range of applications, from food and beverages to cosmetics and agriculture. These products can range from discarded coffee grounds to leftover pulp from coffee cherries, and they have the potential to be utilized in a variety of innovative ways.

Coffee flowers (see Fig 9) are a by-product of coffee production that is often overlooked, but they have many protentional uses and benefits. The coffee plant produces fragrant, delicate white flowers that bloom for only a few days each year. While these flowers are an integral part of the coffee plant's reproductive process, they are not typically used for coffee production. However, coffee flowers have been gaining attention in recent years for their potential as a valuable by-product of coffee farming. An adult coffee tree can produce from 30 000 – 40 000 flowers - the number for *Coffea canephora* can be even higher (Nguyen et al. 2019). Their use potential is mainly in the perfumery industry, because of their aroma, which can be compared to honey, rose, or jasmine. Another potential use is as a beverage, where you can use the dried flowers as tea. The flowers have a sweet, slightly floral flavour. They can be used fresh or dried and are often used in tea blends or as a flavouring in desserts and baked goods (Lachenmeier et al. 2022). Despite their potential uses, coffee flowers are currently an underutilized by-product of coffee farming. However, as more research is conducted on their potential uses and benefits, it is possible that we will see an increase in their production and use in the future.

Figure 9 Dried coffee flowers. Source: Klingel et al. 2020

The other unavoidable and obvious by-product is the coffee leaves (see Fig 10). The leaves are regularly cut on the plantation and that is how the high amounts of them are repeatedly gained. (Lachenmeier et al. 2022). As traditional food tea leaves flavour. Coffee leaves play a role in ethnomedicine, especially in the originating countries. They contain amino acids, protein, carbohydrates, and organic acids. Also, there can be found a huge spectrum of ingredients such as alkaloids, terpenes, tannins, phytosterols, phenolic acids, etc (Chen et al. 2018). That is why the leaves have diverse potential bioactive effects such as antioxidant, antibacterial and antifungal activities (Ross 2005; Patay et al. 2016). The taste is more similar to green tea. The leaf tea has a slightly sweet and nutty flavour. Coffee leaves are also tested in several different applications. For example, animal feed, packaging material, deodorizer, and absorbance pads (Klingel et al. 2020).

Figure 10 Dried coffee leaves. Source: Klingel et al. 2020

Another by-product that has no direct food use is coffee wood. But it has the potential to be used for making food-contact materials, like coffee filters and paper cups (Furtini et al. 2021). For making furniture usually used wood from *Coffea canephora*, because it has a bigger stem than *Coffea canephora*. If we want to harvest the wood, it usually means killing the whole plant, if it is cut down too low. The little twigs and branches from coffee plants can also be used to produce paper, which can have further use as a paper coffee filter (Lachenmeier et al. 2022).

Coffee parchment (see Fig 11) is a by-product of coffee processing that is created during the removal of coffee beans from the fruit. It is the thin, papery layer that surrounds the coffee bean. Coffee parchment is an essential element in the coffee production process, as it protects the beans from moisture and other environmental factors during transport and storage. The quality of parchment can affect the quality of the coffee, as any defects or damage to the parchment can lead to damage or contamination of the coffee beans inside. It is a lignocellulosic material, that has been hardly studied and not efficiently utilized. It has been suggested as an antifungal additive with potential uses for food preservation (Mirón-Mérida et al. 2019). Because of its potential to regulate blood glucose and reduce the concentration of serum lipids, it has the potential as a low-calorie functional ingredient for dietary fiber enrichment in foods (Benitez et al. 2019).

Figure 11 Parchment from coffee beans. Source: Klingel et al. 2020

Green coffee (see Fig 12) refers to unroasted coffee beans that have not undergone any heat treatment. Green coffee beans remain after coffee fruits are cleaned of skin, pulp, mucilage, and parchment in the dry or wet method of processing coffee and are traded to the international market (Esquivel et al. 2020). Green coffee beans are still covered in their silver skin, that is removed in roasting process (Joët et al. 2010). Their main constituents are celluloses and hemicelluloses. It contains mono- and oligosaccharides, waxes and oil, minerals, amino acids, and proteins (Gonzalez et al. n.d.; Campa et al. 2005). Green coffee also contains alkaloids and the most common is caffeine, whose concentration is depending on variety and conditions while prepared tea-like beverages. Especially in Ethiopia, Jamaica, India, Java, South Sudan, and West Sumatra (Ross 2005; Chen et al. 2018). Green coffee beans are usually used as food supplements or are used for the preparation of beverages or chewing gum.

Figure 12 Ground green coffee. Source: Klingel et al. 2020

Silver skin (see Fig 13), also known as chaff, is the thin, papery layer that covers coffee beans during roasting. Unlike the previous by-products created while producing coffee, silver skin is produced at the end of the coffee-producing chain, in the roasteries as a roasting by-product in large amounts (Lachenmeier et al. 2022). In Central Europe has been traditionally used as animal feed and another non-food application is the use of parchment as a raw material for paper production (Overturf et al. 2021). There can be other uses for human consumption such as its use in any type of bakery product, extruded food product, or meat product (Beltrán Medina et al. 2020; Martuscelli et al. 2021). Also, it can be as a flavoring compound – in the mixture with salt or other spices it has a smooth smoky flavor. The advantage of adding silver skin to food spices is that it can be consumed by vegetarians and vegans too, unlike the additives from smoked ham or fish. (Lachenmeier et al. 2022). Another positive characteristic is that silver skin shows high protein and fibre in bakery products as well as in energy bars, because of its content of caffeine (Beltrán-Medina et al. 2020).

Figure 13 Silver skin. Source: Klingel et al. 2020

Spent coffee grounds (see Fig 14) are created during the preparation of coffee beverages and during the production of instant coffee (Murthy & Madhava Naidu 2012). If one kilogram of instant coffee is produced, two kilograms of wet spent coffee grounds waste is made within. That corresponds to about 6 000 000 tons of waste per year worldwide (Mussatto et al. 2011; Murthy & Madhava Naidu 2012). For food industry has spent coffee grounds use as well. They can be used as a source of dietary fibre or in bakery products as well it is used for producing alcoholic distillates (Sampaio et al. 2013; Klingel et al. 2020). There are also some experiments with coffee flour, which is high in protein, gluten-free, and highly fibrous. It could be used for bakery products, snacks, and sweet and savoury recipes. Spent coffee grounds also contain proteins, sugars, and minerals. Besides that, it also comprises fat, which has the potential to be extracted as coffee oil (Iriondo-Dehond et al. 2019).

Figure 14 Spent coffee grounds. Source: Klingel et al. 2020

7. Conclusions

In conclusion, cascara is an important by-product of the coffee industry that has historically been undervalued and underutilized. However, recent developments in the food and beverage industry have led to renewed interest in cascara, with its unique flavour profile and potential health benefits driving innovation in product development.

The history of cascara is complex and varied, shaped by cultural and economic factors that have influenced its use over time. From its use as a traditional medicine to its current role as a food ingredient, cascara has been an important part of coffee-producing cultures for centuries.

Today cascara is being used in a variety of innovative ways, from cascara tea to cascara energy bars and even cascara chocolate and beer. As the demand for sustainable and innovative food products continues to grow, cascara is poised to become a sought-after ingredient in the food industry. Its potential health benefits and flavour profile make it a versatile and valuable addition to any food or beverage product. And its use can help reduce waste and create a more sustainable coffee industry.

All in all, cascara is a valuable by-product of the coffee industry with rich history and a promising future. As more attention is given to its potential uses and benefits, cascara has the potential to become a staple ingredient in the food industry and a key player in the movement toward sustainability and innovation.

8. References

Alves RC, Rodrigues F, Nunes MA, Vinha AF, Oliveira MBP. 2017. State of the art in coffee processing by-products. In Handbook of coffee processing by-products.

Arpi N, Muzaifa M, Sulaiman MI, Andini R, Kesuma SI. 2021. Chemical Characteristics of Cascara, Coffee Cherry Tea, Made of Various Coffee Pulp Treatments. Page IOP Conference Series: Earth and Environmental Science. IOP Publishing Ltd.

Arya SS, Venkatram R, More PR, Vijayan P. 2022. The waste of coffee bean processing for utilization in food: A review.

Augustín J. 2016. U kávy o kávě a kávovinách. Jota, Brno.

Bastian F, Hutabarat OS, Dirpan A, Nainu F, Harapan H, Emran T Bin, Simal-Gandara J. 2021, November 1. From plantation to cup: Changes in bioactive compounds during coffee processing. MDPI.

Bekalo SA, Reinhardt H-W. 2010. Fibers of coffee husk and hulls for the production of particleboard.

Beltrán-Medina EA, Guatemala-Morales GM, Padilla-Camberos E, Corona-González RI, Mondragón-Cortez PM, Arriola-Guevara E. 2020. Evaluation of the use of a coffiee industry by-product in a cereal-based extruded food product. Foods **9**. MDPI Multidisciplinary Digital Publishing Institute.

Benitez V, Rebollo-Hernanz M, Hernanz S, Chantres S, Aguilera Y, Martin-Cabrejas MA. 2019. Coffee parchment as a new dietary fiber ingredient: Functional and physiological characterization. Food Research International **122**:105–113. Elsevier Ltd.

Bisht S, Sisodia S. 2010. Coffea arabica: A wonder gift to medical science. Journal of Natural Pharmaceuticals **1**:58. Medknow.

Burda A. 2013. O kávě čaji a dalších nápojích. Carter/Reproplus, Praha.

Campa C, Doulbeau S, Dussert S, Hamon S, Noirot M. 2005. Qualitative relationship between caffeine and chlorogenic acid contents among wild Coffea species. Food Chemistry **93**:135–139. Elsevier Ltd.

Campuzano-Duque LF, Herrera JC, Ged C, Blair MW. 2021, December 1. Bases for the establishment of robusta coffee (Coffea canephora) as a new crop for Colombia. MDPI.

Chen XM, Ma Z, Kitts DD. 2018. Effects of processing method and age of leaves on phytochemical profiles and bioactivity of coffee leaves. Food Chemistry **249**:143–153. Elsevier Ltd.

Davis AP, Chester M, Maurin O, Fay MF. 2007. Searching for the relatives of Coffea (Rubiaceae, Ixoroideae): The circumscription and phylogeny of Coffeeae based on plastid sequence data and morphology. American Journal of Botany **94**:313–329.

DePaula J, Cunha SC, Cruz A, Sales AL, Revi I, Fernandes J, Ferreira IMPLVO, Miguel MAL, Farah A. 2022. Volatile Fingerprinting and Sensory Profiles of Coffee Cascara Teas Produced in Latin American Countries. Foods **11**. MDPI.

Eckhardt S, Franke H, Schwarz S, Lachenmeier DW. 2022, December 1. Risk Assessment of Coffee Cherry (Cascara) Fruit Products for Flour Replacement and Other Alternative Food Uses. MDPI.

Esquivel P, Viñas M, Steingass CB, Gruschwitz M, Guevara E, Carle R, Schweiggert RM, Jiménez VM. 2020. Coffee (Coffea arabica L.) by-Products as a Source of Carotenoids and Phenolic Compounds—Evaluation of Varieties With Different Peel Color. Frontiers in Sustainable Food Systems **4**. Frontiers Media S.A.

Farah A, Dos Santos TF. 2015. The Coffee Plant and Beans: An Introduction. Pages 5–10 Coffee in Health and Disease Prevention. Elsevier Inc.

Furtini ACC, Dos Santos CA, Garcia HVS, Brito FMS, Dos Santos TP, Mendes LM, Júnior JBG. 2021. Performance of cross laminated timber panels made of pinus oocarpa and coffea arabica waste. Coffee Science **16**. Editora UFLA.

Gebremariam Woldesenbet A, Woldeyes B, Chandravanshi BS. 2014. Characteristics of Wet Coffee Processing Waste and Its Environmental Impact in Ethiopia. Page International Journal of Research in Engineering and Science (IJRES) ISSN. Available from www.ijres.org (acessed March 31, 2023)

Geremu M, Tola YB, Sualeh A. 2016. Extraction and determination of total polyphenols and antioxidant capacity of red coffee (Coffea arabica L.) pulp of wet processing plants. Chemical and Biological Technologies in Agriculture **3**. Springer International Publishing.

Ghosh P, Venkatachalapathy N. 2014. Processing and Drying of Coffee-A Review. Available from https://www.researchgate.net/publication/269986518 (acessed April 2, 2023).

Girma B, Sualeh A. 2022. A Review of Coffee Processing Methods and Their Influence on Aroma. International Journal of Food Engineering and Technology **6**:7. Science Publishing Group.

Gonzalez A G, Pablos F, Martín M J, Leon-Camacho M, Valdenebro M. 2000. Analytical, Nutritional and Clinical Methods Section HPLC analysis of tocopherols and triglycerides in coffee and their use as authentication parameters.

Gouvea BM, Torres C, Franca AS, Oliveira LS, Oliviera ES. 2009. Feasibility of ethanol production from coffee husks.

Hidayah Base N, Usman M, As I, Arief Noena RN. 2022. Indonesian Journal of Community Services Cel Potential of Coffee Fruit Waste as Main Product of Benteng Alla Utara Village, Enrekang Regency. Page Indonesian Journal of Community Services Cel.

Hoseini M, Cocco S, Casucci C, Cardelli V, Corti G. 2021, May 1. Coffee by-products derived resources. A review. Elsevier Ltd.

Hoffman J. 2014. The world atlas of coffee. Octopus Publishing Group.

Iriondo-Dehond A et al. 2019. Bioaccesibility, metabolism, and excretion of lipids composing spent coffee grounds. Nutrients **11**. MDPI AG.

Iriondo-DeHond A, Elizondo AS, Iriondo-DeHond M, Ríos MB, Mufari R, Mendiola JA, Ibañez E, del Castillo M D. 2020. Assessment of healthy and harmful Maillard reaction products in a novel coffee cascara beverage: Melanoidins and acrylamide. Foods **9**. MDPI Multidisciplinary Digital Publishing Institute.

Joët T, Laffargue A, Descroix F, Doulbeau S, Bertrand B, kochko A de, Dussert S. 2010. Influence of environmental factors, wet processing and their interactions on the biochemical composition of green Arabica coffee beans. Food Chemistry **118**:693–701.

Kleinwächter M, Bytof G, Selmar D. 2015. Coffee Beans and Processing. Pages 73–81 Coffee in Health and Disease Prevention. Elsevier Inc.

Klingel T, Kremer JI, Gottstein V, De Rezende TR, Schwarz S, Lachenmeier DW. 2020, May 1. A review of coffee by-products including leaf, flower, cherry, husk, silver skin, and spent grounds as novel foods within the European Union. MDPI Multidisciplinary Digital Publishing Institute.

Lachenmeier DW, Rajcic de Rezende T, Schwarz S. 2022. An Update on Sustainable Valorization of Coffee By-Products as Novel Foods within the European Union. Page 37. MDPI AG.

Luis C, Vegro R, Condé De Carvalho F. 1994. CONTEXTO DE MERCADO NA INDÚSTRIA DE CAFÉ E TRAJETÓRIA DOS PREÇOS NOS EUA E NO BRASIL 1. Page Informações Econômicas, SP.

Manasa V, Padmanabhan A, Anu Appaiah KA. 2021. Utilization of coffee pulp waste for rapid recovery of pectin and polyphenols for sustainable material recycle. Waste Management **120**:762–771. Elsevier Ltd.

Martuscelli M, Esposito L, Mastrocola D. 2021. The role of coffee silver skin against oxidative phenomena in newly formulated chicken meat burgers after cooking. Foods **10**. MDPI AG.

Matos AT. 2008. Tratamento de resíduos na pós-colheita do café (residues disposal in coffee post-processing). In: BORÉM, F. M. (ed.). Pós-colheita do Café (coffee post processing). Lavras, MG: Editora UFLA. p. 161-2018.

Michelman J, Carlsen Z. 2018. The New Rules of Coffee: A Modern Guide for Everyone. Ten Speed Press.

Mirón-Mérida VA, Yáñez-Fernández J, Montañez-Barragán B, Barragán Huerta BE. 2019. Valorization of coffee parchment waste (Coffea arabica) as a source of caffeine and phenolic compounds in antifungal gellan gum films. LWT **101**:167–174. Academic Press.

Murthy PS, Madhava Naidu M. 2012, September. Sustainable management of coffee industry by-products and value addition - A review.

Murthy PS, Naidu MM. 2010. Recovery of Phenolic Antioxidants and Functional Compounds from Coffee Industry By-Products.

Mussatto SI, Carneiro LM, Silva JPA, Roberto IC, Teixeira JA. 2011. A study on chemical constituents and sugars extraction from spent coffee grounds. Carbohydrate Polymers **83**:368–374.

Muzaifa M, Rahmi F, Syarifudin. 2021. Utilization of Coffee By-Products as Profitable Foods-A Mini Review. Page IOP Conference Series: Earth and Environmental Science. IOP Publishing Ltd.

Nguyen TMT, Cho EJ, Song Y, Oh CH, Funada R, Bae HJ. 2019. Use of coffee flower as a novel resource for the production of bioactive compounds, melanoidins, and bio-sugars. Food Chemistry **299**. Elsevier Ltd.

Oliveira LS, Franca AS. 2015. An Overview of the Potential Uses for Coffee Husks. Pages 283–291 Coffee in Health and Disease Prevention. Elsevier Inc.

Overturf E, Pezzutto S, Boschiero M, Ravasio N, Monegato A. 2021. The circo (Circular coffee) project: A case study on valorization of coffee silverskin in the context of circular economy in Italy. Sustainability (Switzerland) **13**. MDPI.

Patay ÉB, Bencsik T, Papp N. 2016, December 1. Phytochemical overview and medicinal importance of Coffea species from the past until now. Elsevier (Singapore) Pte Ltd.

Pendergrast M. 2010. Uncommon Grounds: The history of coffee and how it transformed our world.Basic Books.

Pleissner D, Neu AK, Mehlmann K, Schneider R, Puerta-Quintero GI, Venus J. 2016. Fermentative lactic acid production from coffee pulp hydrolysate using Bacillus coagulans at laboratory and pilot scales. Bioresource Technology **218**:167–173. Elsevier Ltd.

Poltronieri P, Rossi F. 2016. Challenges in Specialty Coffee Processing and Quality Assurance. Challenges **7**:19. MDPI AG.

Ross IA. 2005. Medicinal Plants of the World, Volume 3. Humana.

Sampaio A, Dragone G, Vilanova M, Oliveira JM, Teixeira JA, Mussatto SI. 2013. Production, chemical characterization, and sensory profile of a novel spirit elaborated from spent coffee ground. LWT **54**:557–563. Academic Press.

Silva MCS, Naozuka J, Luz JMR, ASSUNÇÃO LS, Oliviera P V., Vanetti MCD, Bazzolli DMS, Kasuya MCM. 2012. Enrichment of Pleurotus ostreatus mushrooms with selenium in coffee husks.

Teketay D. 1999. History, botany and ecological requirements of coffee. Walia

The Roasters Pack. 2022. What Is Anaeerobic Processing. Available from https://theroasterspack.com/blogs/news/what-is-anaerobic-processing (acessed March 5 2023).

Turck D et al. 2022. Safety of dried coffee husk (cascara) from Coffea arabica L. as a Novel food pursuant to Regulation (EU) 2015/2283. EFSA Journal **20**. John Wiley and Sons Inc.

Van der Vossen H. 2005. A critical analysis of the agronomic and economic sustainability of organic coffee production. Cambridge University Press.

Várady M, Tauchen J, Fraňková A, Klouček P, Popelka P. 2022. Effect of method of processing specialty coffee beans (natural, washed, honey, fermentation, maceration) on bioactive and volatile compounds. LWT **172**. Academic Press.

Veselá PD. 2018. Velká kniha o kávě. Smart press, s.r.o., Praha

Vilela FG, Perez JRO, Teixeira JC, Reis ST. 2001. Uso da casca de café melosa em diferentes níveis na alimentação de novilhos confinados.

Zeckel S, Putu Chris Susanto, Ni Made Diana Erfiani. 2019. Market potential of cascara tea from catur village .