Ohmic-based carbonic maseration of Arabica coffee cherries : A Review

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Abstract. Coffee stands as one of the most globally significant and beloved commercial crops. Green coffee beans are typically produced from coffee cherries through one of three distinct processing techniques: wet, dry, or semi-dry process. During the wet and dry process, fermentation plays a pivotal role in the formation of distinct and desirable sensory attributes. In this comprehensive review, we delve into the intricate fermentation process, shedding light on its multifaceted impacts on flavor. Additionally, we introduce a novel approach to coffee processing, the ohmic-assisted carbonic maceration, drawing inspiration from the well-established winemaking technique. This innovative method explores the potential for using ohmic heating in carbonic maceration of coffee cherries to produce high-quality coffee beans with distinct flavor profiles; with a specific focus on crafting specialty coffee. This cutting-edge approach holds immense promise for modernizing the traditional methods that are commonly employed by coffee farmers and producers in Indonesia.

1 Introduction

Coffee is traded globally and in large volumes making it one of the most important agricultural commodities in the world. According to data from the International Coffee Organization (ICO), Total world coffee production increased by 0.9% to 10.16 million tons in [1]. Data from the ICO also shows that Indonesia with a total production of 612 thousand tons in 2020 is the 4th largest coffee producing country after Brazil, Vietnam, and Colombia. To increase the contribution of coffee commodities to the country's foreign exchange income, the economic value of coffee must be increased through quality improvement.

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Coffee in general can be classified into two species, namely Arabica coffee (Coffea Arabica L.) and robusta coffee (Coffea canephora Pierre ex Froehn). In addition, there is also the species Coffea Liberica with a total production of about 1% of the world's total coffee production The compound content of the three coffee species is relatively different so that it has different aroma profiles. Arabica coffee has a lower caffeine content and bitter taste than robusta coffee. In addition, arabica coffee also has a lower amino acid and chloric acid content than robusta coffee but contains much higher fat. The difference in the content of these compounds resulted in differences in aroma quality and cupping score [2].

Arabica coffee has a very good aroma so it is generally used as specialty coffee while robusta coffee is generally used as a mixture with arabica coffee in ground coffee and instant coffee products. In addition to the type of variety, another aspect that greatly affects the quality of coffee aroma is the level of maturity at harvest and the processing process applied which includes the fermentation process and roasting process. Therefore, to obtain coffee with high aroma quality, the processing process must be considered well [3] The taste of coffee is a direct result of the processing method applied from harvesting to storage [4].

One of the stages of processing that affects the quality of coffee beans is the fermentation stage. In the fermentation process, the mucus content that is firmly attached to coffee beans is removed microbiologically. Microorganisms in the fermentation process can come from the surface of cherries, the plantation environment, or from the processing machines used. During the fermentation process, microbial populations develop as a result of various selective pressures from intrinsic (such as coffee cultivars and regions) and extrinsic (such as processing, handling, and processing methods) variables [5, 8]. The latest development is a fermentation process that utilizes microbial starter strains and enzymes [9, 10] Inoculation with yeast and bacterial cultures is used in enzyme-based [11, 12].

There are several methods of coffee bean production based on fermentation techniques, namely the dry method (natural process), wet method (full wash), pulped natural process, honey method, and in Indonesia the wet grinding method (semi-washed) was found. This technique is used to prepare coffee beans before the drying process [10, 13-15] as well as the latest developments in the maceration carbonate process [16] which adopts wine fermentation from grapes. The maceration carbonate process in whole coffee cherries makes carbon dioxide absorbed and the fermentation process without oxygen or yeast begins by reducing sugar and making coffee cherries more acidic. Inside coffee cherries, various processes take place to give the cup its distinctive flavor. Coffee cherries can be separated from the beans in a variety of ways, including washing and natural processes.

The maceration carbonate process yields additional fruit flavors, such as those of strawberries, raspberries, cherries, bananas, and chewing gum, which will eventually be used to determine the quality of coffee. The widespread use of this method has resulted in a significant increase in the value of coffee beans on the global market. [16]. Further related to the maceration carbonate method, the process can be done by applying ohmic heating technology so that the results are more optimal. Fermentation that maintains controlled temperature through ohmic heating has been done by several studies and proven to give specialty coffee results [17-19].

2 Coffee Flavor

Aroma compounds are complex volatile compounds in coffee that determine the characteristics and sensory qualities of coffee. A factor that greatly contributes to the high acceptance of coffee by consumers is aroma, which involves more than 800 volatile compounds. The following is a summary of aroma-forming compounds that have been identified in arabica coffee beans.

Table 1. Summary of important aroma compounds identified in Arabica coffee Adaptasi [20, 21]

Key odorants identified in coffe	Concentration in Arabica coffe (ppb)	Aroma description	Sensory threshold (ppb)***
Aldehyde **2-methylbutanal** **3-Methylbutanal** **(E)-2-nonenal** **Acetaldehyde** **Propanal**	 20700 18600 19 139000 17400	 Rancid, almond-like, toasty Fruity, almond-like, toasty, ethereal, chocolaty, peachy, fatty Fatty, green, cucumber, citrus pungent, ethereal, fresh, lifting, penetrating, fruity, musty ethereal, pungent, earthy, alcohol	 1.3 0.35 0.08 0.7 `10
Acid **2-Methylbutyric acid** **3-Methylbutyric acid**	 25000 18060–32180 700	 Acidic, fruity, dirty, cheese Cheesy, dairy, acidic, sour, pungent, fruity, stinky	 10 700
Ester **ethyl-2-methylbutyrate** **ethyl-3-methylbutyrate**	 3.9 14	 Fruity, berry Fruity	 0.5 0.6
Furan **Furfural**	 5880–19370	 Sweet, brown, woody, bready, caramellic	 280
Sulfur-containing Compounds **dimethyl trisulfide** **Methional**	 28 213–240	 Sulfurous, cooked onion, savory, meaty, cabbage-like boiled potato-like, musty, tomato, earthy, vegetable, creamy	 0.001 0.2
Thiols **3-Mercapto-3-methyl butyl formate** **2-Furfurylthiol** **2-Methyl-3-furanthiol** **3-Methyl-2-butene-1-thiol** **Methanethiol**	 130 1080–5080 60–68 13 4550	 green blackcurrant, herbal, fruity, roasted, sweaty roasty (coffee-like), sulfurous Sulfury, meaty, fishy, metallic, boiled Sulfury, smoky, leeky, onion rotten eggs, meat or fish, cabbage, garlic, cheesy	 0.0035 0.01 0.007 0.00035 0.02
Furanone **dihydro-2-methyl-3(2H)-furanone** **2-ethyl-4-hydroxy-5-methyl-3(2H)-furanone (homofuraneol)**	 7580–30000 16800 1.1–11470 10930–112000	 Sweet, bread, buttery, nutty Sweet, caramel, candy extremely sweet, strong caramel, maple, burnt sugar	 0.005 20 20 10

3-hydroxy-4,5-dimethyl-2(5H)-fu- ranone (sotolone) **4-hydroxy-2,5-dimethyl-3(2H)-fu- ranone (furaneol)** **5-ethyl-3-hydroxy-4-methyl-2(5H)-furanone (abhexon)** **5-ethyl-4-hydroxy-2-methyl-3(2H)-furanone**	104-160 17300	Sweet, candy, caramel, strawberry, sugar Seasoning-like, caramel-like Sweet, caramel, bready, maple, brownsugar, burnt	7.5 1.15
Ketone **2,3-butanedione** **2,3-pentanedione** **4-(4′-hydroxyphenyl)-2-butanone**	48400–50800 3540–39600 1	buttery, creamy, fatty, oily, sweet, vanilla buttery, caramel, creamy,penetrating, sweet Sweet, fruity, berry, jam,raspberry,ripe, floral (raspberry)	0.3 20 1–10
Norisoprenoid **(E)-β-damascenone**	195–255	honey-like, fruity, apple, rose, honey, tobacco, sweet	0.00075
Phenolic compounds **guaiacol** **4-ethyl guaiacol** **4-Vinyl guaiacol** **Vanillin**	2000–17970 800–24800 8000–64800 2290–4800	phenolic, burnt, smoke, spice, vanilla, woody Spicy, smoky, bacon, phenolic, clove Spicy, dry woody, fresh amber, cedar, roasted peanut Sweet, vanilla, creamy	2.5 25 0.75 25
Pyrazine **2,3-diethyl-5-methylpyrazine (hazulnut pyrazine)** **2-ethyl-3,5-dimethylpyrazine** **2-ethyl-3,6-dimethyl-pyrazine (3,6-cocoa pyrazine)** **2-Methoxy-3,5-dimethylpyrazine (3,5-cocoa pyrazine)** **2-Methoxy-3-isopropylpyrazine**	73–95 55–330 2570-5980 1.1 2.4	nutty-roast, musty, meaty, vegetable,roasted hazelnut nutty-roast potato, cocoa roasty, nutty earthy, burnt, almonds, roasted nuts, coffee earthy, pea, beany	0.09 0.04 8,6 0,006 0.002
Pyridine **pyridine**	21280–65520	Fishy	77

The complex composition of the taste and aroma of coffee depends on the botanical variety of coffee and processing methods, including the stages of grinding, packaging, roasting, and extraction [22]. The composition of coffee beans is influenced by species, geographical origin, climate, altitude, method of harvesting, processing, and storage [23, 24].

2.1 Genetic

Coffee is a member of the genus Coffea within the family Rubiaceae. The two most significant species are Coffea arabica L. and Coffea canephora L.[5] Due to its superior sensory qualities, coffee arabica is the most widely consumed species worldwide. [25]. Here are presented the basic differences between arabica coffee and robusta coffee

Table 2. The Difference between *Coffea arabica* and *Coffea canephora* Adapted from [26, 27].

No.	Komponen	*Coffea Arabica*	*Coffea canephora*
1.	Komponen biji kopi		
2.	Ph	5.26-6.11	5.27-6.13
3.	Mineral content *	3.5-4.5	3.9-4.5
4.	Fat content *	13-17	7.2-11
5.	Caffeine content *	0.7-2.2 (average 1.4)	1.5-2.8 (average 2.2)
6.	Chlorogenic acids content *	4.80-6.14	5.34-6.41
7.	Trigonelline*	1- 1.2	0.6-1.7
8.	Oligosaccharides*	6-8	5 - 7
9.	Total polysaccharides*	50 – 55	37 - 47

* % dry matter (dm)

The anatomical picture of coffee cherries is presented in the Figure 1.

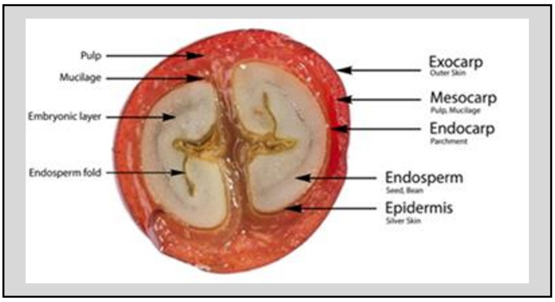

Fig. 1. Anatomy of cherry coffee [28]

According to recent research, microorganisms primarily contribute to the fermentation of coffee by breaking down the mucus on the beans and altering the sensory qualities of the final product. The following is the composition of pulp and mucilage that microorganisms use as a substrate during fermentation.

Table 3. Chemical components of mucilage and pulp before fermentation [29]

Componen (% Dry weight)	Pulp	Mucilage (Lendir)
Dry matter	29	5
Protein	10	8.9
Crude fiber	21	18
Ash	8	0.7
Nitrogen-free extract	44	35.8
Tannins	1.8-8,6	0
Pectin total substance	6.5	35. 8
Reducing sugar	12.4	30
Non reducing sugar	2	20

Caffeine	1.3	-
Ghlorogenic acid	2.6	-
Pectic total subtance	6.5	35
Cellulosa	27.7	17

2.2 Environmental

Biochemical changes in the seed determine the quality of the coffee. Scent precursors can differ depending on post-harvest methods, geographic conditions, genetic characteristics, and agricultural practices. Aside from microbial diversity, altitude parameters that impact transpiration and photosynthetic activity of plants are oxygen concentration and air temperature. These modifications cause alterations in the volatile and non-volatile compound profiles that are directly linked to the development of coffee flavor.[25, 26, 30, 31]. Studying the coffee ecosystem helps to improve our comprehension of sophisticated frameworks for additional investigation and eventual control of this intricate biotechnological process. The microbial community's structure and the final coffee beans' chemical composition can be influenced by both processing and the environment if the latter has an impact on the coffee beans' ultimate quality.[7].

2.3 Processing

Processing coffee should start as soon as possible after harvesting to avoid fruit deterioration due to fermentation or the growth of undesirable fungi. [2] One of the most crucial steps in the process is processing, which leads to the sorting stages where damaged beans are removed and the coffee bean quality is enhanced, including taste and aroma modifications. Microbial profiles and beverage sensory scores are influenced by the conditions of coffee fruit processing and fermentation.[32]. Coffee fruit's skin and pulp can be easily removed, but the beans are firmly attached to the mucilage, parchment, and silver skin. [7]. All the precursors required for the development of unique flavors and aromatic compounds in coffee beverages during roasting are present in coffee beans. Fermentation, however, has the ability to add or modify aroma notes. Coffee flavor is thought to be influenced by fermentation, either directly or indirectly. When compared to unfermented coffee, general fermented coffee is thought to have higher quality characteristics; however, an insufficient or overly fermented coffee may have an unfavorable taste. [6, 12, 33]. Therefore, an elaboration is needed for each processing technique involving the stages of fermentation in coffee. Each stage of the fermentation process has its own advantages and characteristics.

3 Fermentation in coffee

Sugar is used in fermentation, a metabolic process that can occur either in the presence (aerobic) or absence of oxygen. To get rid of mucus from the coffee parchment, it is crucial that the coffee beans ferment. Starch, cellulose, and polysaccharides like pectin make up coffee mucilage. Mucus can make it take longer for coffee beans to dry and, in certain situations, can also encourage the growth of mold, which lowers the coffee's overall quality. Enzymes found naturally in coffee fruits and microflora gathered from the surroundings aid in the fermentation process. [34]. During the fermentation process, changes in pH, sugars, organic acids, and sugar alcohols occur [35]. connected to the development of microorganisms (fungi, bacteria, and yeast) that aid in the fermentation process' reduction of mucus. During fermentation, these microorganisms release a variety of acids, alcohols, and enzymes. A variety of commercially available enzymes are available for the fermentation of coffee. Benefax is the trade name for it. Subsequent brands that contain mixtures of pectinase, hemicellulose, and cellulose are Pectozyme, Cofepec, and Ultrazym. [32].

Briefly, the natural dry process is generally applied to Robusta coffee in areas where long-term sunlight is available and rainfall is scarce such as Ethiopia, Brazil, and Paraguay [36], as done by [37] who process robusta coffee using the dry process. In Brazil and Ethiopia and for robusta coffee Generally, 'dry' or natural fermentation methods are commonly used [32]. The simplest process often used by farmers is dry processing, which is used to ferment and dry coffee on a platform and/or cement. Robusta cherries that have been sorted using floating techniques are then scattered on the ground or platform in the sun for 20-30 days until the moisture content of 60-65% (wb) reaches about 12% [5, 32]. The beans are dried in the sun or with drying air until their moisture content is between 10% and 12%. The fruits are cleaned and peeled after drying, and the pulp and dried skin are then removed. [2]. Had been observed that the use of the same starter culture, in dry processed coffee cherries produces coffee drinks with a distinctive taste. In inoculation with dry process processing produced coffee with caramel and herbal flavors, further [38] reported different results, although both studies used the same yeast in starter culture. But by using a different method, namely semi-dry fermentation, the results are different.

Coffee treated with yeast has a fruity flavor. Coffee fruits that have had the pulp removed through semi-dry fermentation yield a caramel and bitter flavor when inoculated with the same strain of yeast. The semi-dry process is a variation on the wet process in which the coffee fruit is peeled and the fermentation takes place on a platform under direct sunlight. [39]. Wet coffee processing consists of removing the pulp and skin from fresh coffee cherries. This stage involves several stages that require the use of large amounts of water in the process, especially to remove microbial mucus. In this method, cherries are inserted into a huller machine that removes the outer flesh (mesocarp and exocarp) of coffee and leaves the coffee beans covered in mucus. This mucus is fermented evenly. The coffee beans are then washed and dried. The process of wet processing involves a number of relatively intricate steps, such as the mechanical removal of the coffee pulp and skin, the microbial fermentation of the mucous layer, and the final step of sun drying to release the water. The time is shortened by this process (from 3-5 weeks to 8-10 days). The coffee fruits are mechanically ground in the semi-dry processing method, which combines dry and wet methods. Next, the coffee fruits are exposed to sunlight to begin the drying process.[2]

Wet processed coffee is generally thought to have more acidity and fragrance than dry processed coffee. [40]. Using an electric or manual pulper, the top layer of ripe cherries' pulp and skin are removed for the honey process. Coffee drying locations in Africa with consistent humidity are used to dry depulped coffee beans. The normal drying cycle lasts 10–12 days, depending on the weather. The coffee should have about 11% moisture content at this point.[41]. Animals, commercial microorganisms, enzymes, or chemicals for coffee bean incubation, or microorganisms and/or enzymes from the animal's intestines, are used in the digestion process. [42] This category includes coffee beans from cicadas, elephant dung, jacuzzi, and monkey parchment. Cherries are immediately put into a closed tank for seven days of anaerobic fermentation during the anaerobic process after harvest. The seeds are treated using two drying techniques following fermentation. [41]

3.1 Carbonic maseration

Carbonic maceration in wine fermentation was first introduced by [43]. Carbonic maceration and semi-carbonic maceration are the same process. It is a method that quickly, produces a fermentation tank with a concentrated carbon dioxide environment. Carbon dioxide gas can be produced in two different methods. When the bottom coffee cherry in the fermentation tank is crushed or pulverized, it allows nutrients to flow through. Natural coffee cherry microbes will consume the leaked nutrients and produce alcohol and carbon dioxide. In the fermentation tank, these gases will combine with extra carbon dioxide to produce a carbon dioxide-rich atmosphere, which will then trigger sophisticated biological reactions [44]. The following illustrates of carbonic maceration process

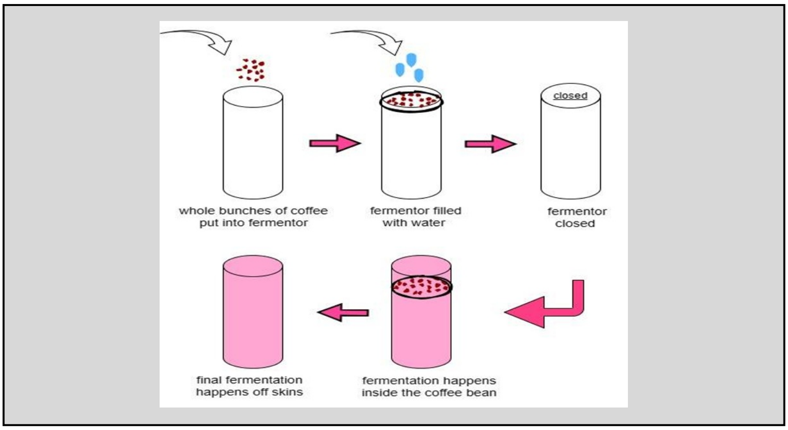

Fig. **2**. Carbonic maceration process

However, the amount of bioactive compounds and antioxidant activity in specialty coffee can be significantly impacted by innovative new processing techniques, especially anaerobic fermentation and carbonic maceration, which quickly alter the coffee fruit and produce flavors very different from those of conventional fermentation. [41]. The content of volatiles and bioactive compounds as well as antioxidant activity in specialty coffees from Peru, Ethiopia, Burundi, Nicaragua, and other countries were studied in relation to the effects of different processing methods (natural, washed, honey, anaerobic fermentation, and carbonic maceration); it was also determined whether different processing methods have an effect on these elements. Novel methods are employed by farmers to process specialty coffee in order to maintain antioxidant activity and quality. Fresh, cutting-edge methods like anaerobic fermentation and carbonic maceration have been added to the traditional full wash, semi-wash, and natural processing methods. [10, 45].

Anaerobic fermentation of coffee beans without pulp removal or what is known as carbonic maceration of whole coffee fruits under anaerobic conditions are two other methods that have been used to control the dominant microbial species in the fermentation process and their activity rates. Many practitioners are interested in these fermentation techniques, but little research has been done on them. However, a small number of people claim that this fermentation technique can produce coffee with exceptional flavor and aroma [46]. In carbonic maceration fermentation, whole coffee beans are put into the fermenter without crushing the coffee cherries.

Rich, delicate, and well-balanced aromas are common attributes of wines made using carbonic maceration. In general, carbonic maceration wines have lower density, dry extract, fixed acidity, and residual sugar content than traditionally produced wines (made from crushed grapes). The initial winemaking stage with carbonic maceration's time-temperature parameters greatly influence the color depth and tannic sensation. In this stage, traditionally made wines often have a higher phenolic component index for a given temperature than wines that underwent carbonic maceration. Nonetheless, this outcome can be undone by adjusting the amount of time stored at a specific temperature or by boosting the exchange of liquid and solid phases during the procedure [47].

In grapes, pigments are found in the skin and fruit, so one of the ways to make red wine is to extract the compounds found in the skin and pulp. So it is very important to maintain the compounds during the fermentation stage. In the fermentation stage, anthocyanins from the skin and the influence of tannin availability also affect the readiness of the wine for consumption [48].

4 Ohmic technology in coffee fermentation

Fermentation is affected by both temperature and time. By using state-of-the-art techniques like ohmic heating, high-pressure processing, ultrasound, pulsed electric fields, and medium electric fields, the industry is able to increase product yields by implementing this scientific principle in the fermentation process. [49, 50, 17] investigated the effects of ohmic heating on the acidity of fermenting fresh Arabica coffee beans. The coffee beans' overall acidity dropped from 0.53 to 0.18 after 8 hours of fermentation at a constant 30°C. Coffee beans' moisture content and acidity vary depending on the temperature and length of fermentation. It was also mentioned that ohmic heating fermentation could be used to produce Arabica coffee with the lowest acidity.

According to [51], Nowadays, the fermentation industry applies scientific ideas to boost product yield through the use of ohmic heating during the fermentation process. Meanwhile, [52] showed that using ohmic to speed up cocoa fermentation can cut down on the amount of time needed for traditional fermentation. It is also explained by [51] that the fermentation process can be sped up and the ideal temperature for fermentation can be achieved quickly with ohmic heating. [53, 54].

Research has been done on the ohmic-based fermentation of coffee cherries to enhance the flavor of the coffee beans. The results of the research indicate that this method can produce coffee with an average cup-test score of 85.713. This rating is higher than the Indonesian luwak coffee, or kopi luwak, as reported by several researchers in their cup tests. As a result, fermenting coffee using ohmic heating-based technology can significantly enhance the beans' flavor quality. [18]

5 Contributions of microorganisms to coffe fermentation and coffee quality

Microbial diversity increases quickly during the processing of coffee. Large populations of yeasts, filamentous fungi, and both Gram-positive and Gram-negative bacteria are present during the fermentation stage. [55]. Numerous species of bacteria, yeasts, and filamentous fungi have been identified, indicating a high level of microbial diversity in this process. Additionally, during this time, microbiological metabolites may permeate the grain and impact the beverage's ultimate quality. [56].

Different coffee beverage varieties have differing body, aroma, acidity, and astringency characteristics. The role of microorganisms is one of the numerous factors that affect the final quality of coffee.[57]. The species of microorganisms found during coffee fermentation with various fermentation systems and their identification methods are presented in the following Table:

Table 5. Different types of microorganisms that appear in wet and dry fermentation using arabica coffee and robusta coffee [13, 28, 37, 39, 58, 59, 60, 45].

Different types of microorganisms that appear in wet and dry fermentation using arabica coffee and robusta coffee
Bacteria:

*Enterobacteriaceae bacterium; Agrobacterium tumefaciens, Arthrobacter sulfonivoran; Acinetobacter (pittii, radioresistens,lwoffii); Acetobacter persici; Arthrobacter sp.; Bacillus (cereus, licheniformis, pumilus, shackletonii, subtilis, macerans, polymyxa, altitudinis, safensis, megaterium,dermacoccus nishinomiyaensis); Enterobacter (asburiae, hormaechei, agglomerans, Yersinia, ludwigii); Citrobacter (braakii, freundii); Enterococcus (pallens, ludwigii, cloacae); Citrobacter koseri; Cellulosimicrobium cellulans; Citrobacter freundii; Escherichia (vulneris, coli) Kosakonia cowanii; Lactobacillus (oligofermentans, oris, paracasei, coryniformis, plantarum, brevis); Leuconostoc(mesenteroides; citreum, holzapfelii, pseudomesenteroides) Micrococcus (luteus, yunnanensis); Lactococcus (hircilactis, lactis); Pantoea (agglomerans, ananatis); Staphylococcus (cohnii, epidermidis, warneri); haemolyticus, saprophyticus, xylosus); Stenotrophomonas maltophilia Pectobacterium parmentieri; Pseudomonas (putida, fluorescens, aeruginosa); Raoultella ornithinolytica; Salmonella sp.;(enterica); Streptomyces variabilis; Weissella soli; Klebsiella (pneumoniae, oxytoca); Erwinia (soli, toletana, herbicola, tasmaniensis); Serratia marcescens; Brevibacillus (parabrevis Anabaena); Asaia sp; Gluconobacter (cerinus,oxydans) Morganella morganii;Pantoea eucrina; Cellulosimicrobium cellulans, Curtobacterium flaccumfaciens, Lysinimonas soli, Microbacterium (foliorum, testaceum); Xanthomonas oryzae***.**
Yeast: *Saccharomyces (cerevisiae, bayanus, kudriavzevii, uvarum), Arxula adeninivorans; Candida (saitoana, fermentati, membranifaciens, glabrata, orthopsilosis, dubliniensis, parapsilosis, tropicalis, humilis, quercitrusa, solani, xylopsoci, railenensis, ernobii, fukuyamaensis, membranifaciens, carpophila); Debaryomyces (polymorphus, Hansenii); Pichia (guilliermondii, fermentans, guilliermondii, sydowiorum, subpelliculosa, burtonii, anomala, kluyveri, burtonii, caribbica, cecembensis); Stephanoascus smithiae; Meyerozyma (caribbica, guilliermondii); Hanseniaspora (opuntiae, vineae, uvarum);Cordyceps brongniartii; Lachancea lanzarotensis; Papiliotrema terrestris;; Starmerella bacillaris; Torulaspora delbrueckii; Wickerhamomyces anomalus; Arxula sp.; Mitchella repens; Trichosporon cavernicola; Rhodotorula mucilaginosa;*
Fungi: *Cylindrocarpon sp.; Eurotium chevalieri; Fusariella sp; Aspergillus (chevalieri, foetidius, niger, ochraceus, tubingensis, versicolor, flavus, tamarii, sydowii); Cladosporium (cladosporioides, macrocarpum);) Fusarium (chlamydosporum, lateritium, nivale, solani, sporotrichioides); Geotrichum sp.; Mucor hiemalis; Penicillium (brevicompactum, commune, decumbens, fellutanum, implicatum, roqueforti); Phoma sp.; Ulocladium sp; Penicillium (corylophilum, chrysogenum, brevicompactum, roqueforti, solitum)*

6 Conclusions and future studies

Wet, dry and semidry processing are the basic methods that coffee cherries go through in their processing stages. The latest is the carbonic maceration method, which adopts fermentation techniques in the processing of grapes into wine. This fermentation is carried out using ohmic technology so that the temperature can be maintained. Based on some literature, it is known that carbonic maceration fermentation results in coffee with better aroma, presenting fruty, nutty and caramel. A deeper study should be developed to find out the interactions in the carbonic maceration fermentation process based on ohmic technology. Several parameters should be studied including coffee aroma profile and cupping characteristics of coffee beans, roasting profile, comparative sensory evaluation as well as in-depth investigation of the growth and type of microorganisms growing in the carbonic maceration process based on ohmic technology in the future. Recent trends including the addition of some microorganism isolates that are believed to improve aroma can also be one of the studies that can be studied in the future.

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