Chapter 17

Crema—Formation, Stabilization, and Sensation

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1. INTRODUCTION

A large percentage of coffee consumed today is in the form of espresso. When comparing espresso coffee to coffee brewed using other techniques, one of its main characteristics is a dense brown layer of foam bubbles, also called crema, which covers the liquid coffee (Illy and Viani, 2005). Coffee experts use the crema to judge the quality of the extraction. For instance, crema indicates whether all parameters that influence extraction, such as degassing, grinding, tempering, and water pressure, were just right when extracting that one cup. Many consumers prefer the presence of a nice crema layer on their coffee, but it is also part of the consumption ritual. Some will spoon it off, some will stir it in, and some will swirl the cup to mix the crema into the last sip of coffee. At the same time, beautiful visuals of the crema are used to create expectations of an indulgent, smooth, and flavorful cup of espresso.

For most baristas, the formation of the crema is a craft rather than a science. A properly packed coffee bed allows a slow flow of the pressurized water. This pressure, along with the carbon dioxide (CO_2) present in the fresh roast and ground coffee and the carbonates present in the water, is the main driver for the formation of the crema. Baristas know how to adjust grinding and temping to optimize the extraction and obtain the desired color, quantity, and delicacy of the crema.

Although the crema's dark brown color or "tiger skin" and fine bubble size are signs of a good extraction, they are only secondary indications of a good extraction and tasting experience, after the flavor of the coffee. At the same time, crema has been associated with the increased "body" for which Robusta espresso coffees are well known (Navarini et al., 2004a). Studies also suggest

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that coffee foam can help distinguish Robusta from Arabic coffee (Maeztu et al., 2001a,b). However, the question is "What is the impact of color, bubble size, and crema quantity on the coffee experience?" Is there one crema that is optimal, or are crema characteristics part of the overall coffee sensory profile? We need to answer these questions before we can reflect on how to extract the perfect cup of espresso.

As a first step, it is important to understand the physico-chemical aspects of crema, and how we can fine-tune crema's properties to optimize its quality. To do this, we need to distinguish crema formation from crema stabilization. In crema formation, energy is required to create an air in liquid dispersion. With espresso coffee, we add this energy by injecting pressurized water onto the coffee bed. A typical freshly prepared crema of an espresso is shown in Fig. 17.1. We also need to stabilize the freshly formed air bubbles, which we can do via the adsorption of interfacially active compounds at the air—liquid interface.

In addition, the conditions we apply when we brew espresso coffee influence surface tension—related phenomena such as foam formation and stabilization. For instance, both the presence of carbonate in the water and the gases in the coffee have been reported as key drivers of crema formation (see Chapter 16).

Unfortunately, systematic chemical and physical studies are currently too scarce to completely understand this complex system. The most recent and comprehensive review has been published by Illy and Navarini (2011), indicating the current gap in molecular understanding in crema formation and stabilization. It is only very recently that the role of crema on the consumer experience has been investigated, with an emphasis on how crema impacts visual aspects, as well as smell and taste.

In this chapter, we will review physico-chemical processes and properties of crema formation and stabilization. We will also explain why we need to

FIGURE 17.1 Photo of an espresso crema extracted using a high pressure machine and an Arabica coffee blend (using the Nespresso extraction system).

consider the characteristics of a good crema in a wider perspective, including the full sensory experience.

2. CREMA FORMATION AND STABILITY

Foam is a complex and challenging phenomenon consisting of four key events (1) bubble formation, (2) bubble rise, (3) drainage, and (4) coalescence and disproportionation (Bamforth, 2004). In essence, foam is a coarse dispersion of gas bubbles in a liquid continuous phase. With espresso coffee, the gas phase consists primarily of the CO_2 generated during coffee roasting, which is partially entrapped within the cell structure. This continuous phase is an oil in water emulsion of microscopic oil droplets (<10 μm) in an aqueous solution of several coffee constituents (e.g., sugars, acids, proteins) as well as small solid coffee cell-wall fragments (2–5 μm) (Illy and Viani, 2005). The bubble shown in Fig. 17.2 is about 100 μm in diameter and appears to be covered by protein rich material.

The espresso crema can be classified as a metastable foam with a specific lifetime (Dickinson, 1992). In most cases, it takes up to 40 min before the crema disappears (Dalla Rosa et al., 1986). As the crema ages, its properties evolve from a liquid fine foam in freshly prepared espresso to a dry polyhedral foam upon aging. Ideally, the crema should represent at least 10% of the

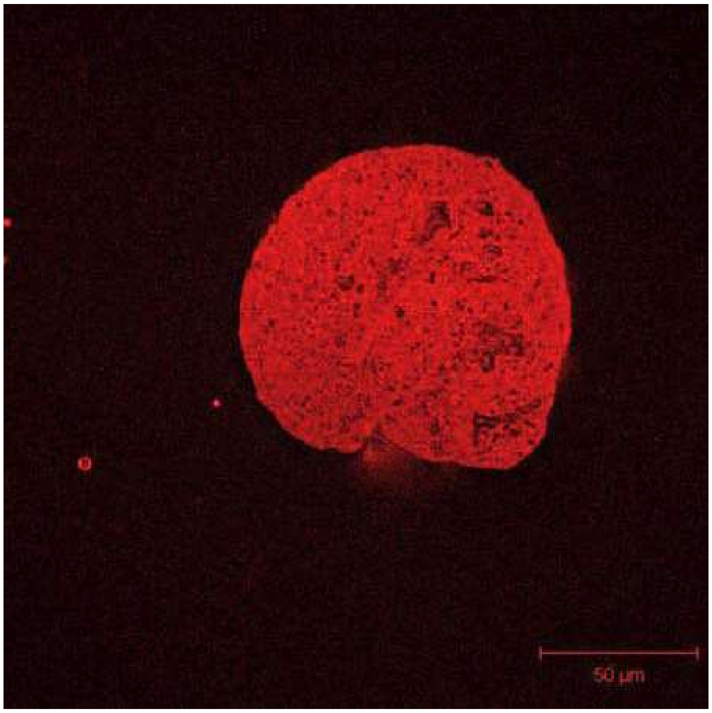

FIGURE 17.2 Confocal microscopy image of an isolated air bubble in crema prepared from a freshly extracted pure Arabica coffee using the Nespresso extraction system. Rhodamine was used for staining of proteins. *Courtesy of E. Kolodziejczyk, Nestlé Research Center, Lausanne.*

volume of an espresso (Illy and Viani, 2005) with a foam density of 0.30–0.50 g/mL (Navarini et al., 2006). The latter authors have shown a linear relationship between CO_2 content and foam weight as well as foam volume (Fig. 17.3).

There have been several attempts to describe how crema is formed in espresso coffee. As water is forced through the coffee under pressure, it emulsifies the coffee oils into the extracted liquid. In addition, roasted coffee out-gases CO_2 for a while (degassing), and the longer the coffee is exposed to ambient pressure, the more CO_2 it will release. This is why packaging materials for espresso coffee are sometimes made such to keep overpressure and CO_2 in the coffee matrix. The remaining CO_2 is then emitted during extraction.

Although CO_2 has been frequently suggested as the gas phase responsible for espresso coffee foaming, coffee experts have not investigated the bubble formation mechanism in detail. The relationship between CO_2 chemistry and foam formation has on the other hand been studied. In fact, research suggests that the bicarbonate–carbonic acid equilibrium plays a role in the dynamics of the transient phase of the espresso extraction (Fond, 1995, Chapter 16).

The transient phase of the extraction is the initial wetting stage of brewing espresso when hot water spreads into the voids in coffee particles, and, inter- and intraparticle gas is simultaneously pushed out of the coffee bed (Petracco and Liverani, 1993). This mass transfer between coffee particles and water occurs simultaneously, and the bicarbonate ions present in the extraction fluid

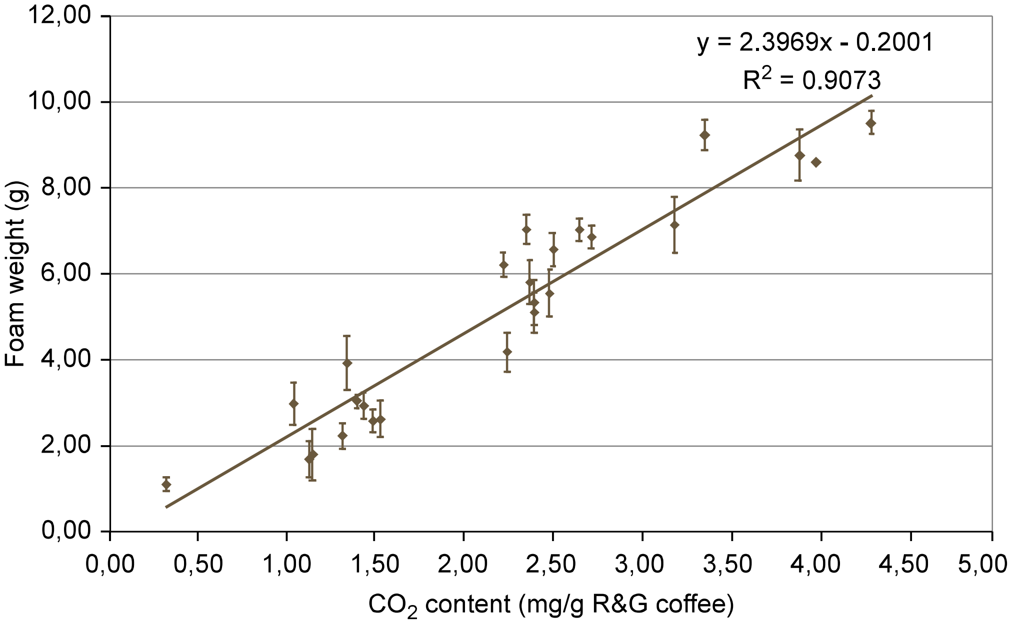

FIGURE 17.3 Espresso coffee foam volume as a function of carbon dioxide content per gram of roast and ground coffee. *From* Navarini et al. (2006).

(water), along with the displacement of its equilibrium according to the pH evolution during brewing (from 7.0 to 7.5 to 5.5−5.0) generate chemical reactions that occur at high temperatures in the coffee bed. The coffee is compacted through the water pressure, swelling of the coffee grounds, and through CO_2 degassing, which in turn generates the foam and emulsion that creates the much appreciated espresso crema.

Other research has suggested that CO_2 supersaturation conditions in coffee are a possible driving force for the formation of espresso coffee foam (Navarini et al., 2006). More specifically, the CO_2 solubilization (present in the coffee bed) in water at a high pressure and temperature may cause supersaturation conditions in the final cup, resulting in nucleation of tiny bubbles.

To explain this further, the CO_2 concentration in water might be below the CO_2 solubility during extraction at high pressure and with a water temperature of 100°C. However, it may also be above solubility at 1 bar and 70°C. These conditions are compatible with the foaming that occurs through bubble formation when there is heterogeneous nucleation and bubble rise following a phase transition (from high pressure to ambient pressure) when the high pressurized water exits the coffee bed and enters the cup. This effect, which is known as effervescence, is also observed with champagne. In this case, the effervescence may apply to the effect observed immediately after espresso preparation. With espresso, the micronic solid particles and submicronic cell-wall fragments that are present in the beverage may act as nucleation sites. In addition, the small volume of an espresso beverage offers a limited length of about 1.5−2 cm for bubble rise, and this leads to characteristically tiny bubbles in espresso foam (Illy and Navarini, 2011).

After the foam is developed, foam destabilization generally occurs through three phenomena (Prins, 1988). First there is a coalescence among the bubbles, which occurs when the film separating the bubbles collapses. Second, there is Ostwald ripening, which takes place when the foam is polydispersed in sizes. In this phase, pressure differences inside different sized bubbles diffuses the smaller bubbles into the larger ones. Third, gravity forces the liquid to separate from the air bubbles. This in turn causes the film to thin, which leads to coalescence and Ostwald ripening.

Although these phenomena are observed in any foam system, the high temperature of crema, and the way it cools from the top down will add another complexity to understanding the physical phenomena in the formation and stability of espresso crema. A previous study had suggested that the relatively high temperature of the beverage may negatively impact foam stability. The premise was that the water evaporated and caused the foam to collapse by reducing the thickness between bubbles (Navarini et al., 2006).

Another study has shown that lipid content can also affect foam stability. In a regular espresso (25 mL), the total lipids range from 45−146 mg for Arabica to 14−119 mg for Robusta (Petracco, 1989; Maetzu et al., 2001). On average, pure Arabica espresso contains a higher content of total lipids than Robusta espresso, and therefore the probability of lipid-induced foam destabilization is higher for Arabica.

Since espresso coffee is well known to contain emulsified lipids, the lipid-induced foam destabilization may also occur through oil spreading at the air-beverage interface (Schokker et al., 2002). This is consistent with the lower surface tension generally observed in pure Arabica espresso as compared to pure Robusta espresso (Petracco, 2001).

Studies suggest solid particles also affect foam stability. Such particles in a pure Arabica dry espresso foam are shown in Fig. 17.4. They are located in the plateau border, suggesting the tendency to be unattached. During drainage, unattached particles predominantly follow the net motion of the liquid, suggesting a stabilizing role of the solid particles within the crema. Hydrophobic particles may destabilize the foam by film bridging, which can cause dewetting of the surface. Although the wetting nature of the solid particles present in espresso coffee has not yet been investigated, the "tiger skin" effect observed in Arabica espresso may suggest that the solid particles have a certain foam stabilizing role (also known as pickering effect). Otherwise the antifoaming effect would be rather rapid (Kralchevsky et al., 2002).

However, the different foam adhesion phenomena observed between the two coffee species may also be due to different transition rates from liquid to dry foam. For instance, the solid-like nature of Robusta espresso foam may come from a higher drainage rate, which seems to be the prerequisite for adhesion. In contrast, the Arabica espresso foam rheology seems to be of the liquid-viscous type for a longer time.

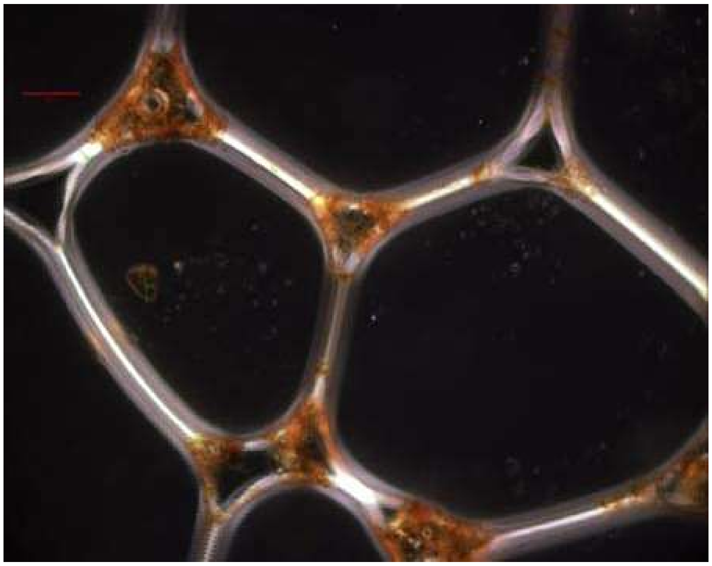

FIGURE 17.4 Optical microscopy image of a dry pure Arabica regular espresso coffee foam with the scale bars representing 50 μm. *From Illy and Navarini (2011).*

3. THE CHEMISTRY OF CREMA STABILIZATION

No detailed studies have been published so far on the chemical compounds responsible for the formation and stabilization of espresso crema. Nunes et al. (1997) found that the foamability increased linearly with the degree of roast. They also found a dependence on the amount of protein in the infusion. Foam stability of espresso coffee was found to be related to the amount of the polysaccharides galactomannan and arabinogalactan. Other dependent variables observed were total solids, pH, lipids, protein, and carbohydrate contents. A strong correlation was found between foam stability and high molecular weight compounds, suggested to consist of complexes between polysaccharide, protein, and phenolic compounds caused by the roasting process (Nunes and Coimbra, 1998).

Recent activity-guided studies on foam-active components in green and roasted coffee has given some new insight into the molecular structures of the complex molecules responsible for crema formation. Although it was found that sucrose fatty acid esters (Fig. 17.5A) are the primary foam-active agents in green coffee, low- and high-molecular weight 4-vinylcatechol oligomers (Fig. 17.5B) are the key foam-active components in the fine crema of roasted coffee (Unpublished data Kornas and Hofmann et al.).

Quantitative analysis of these foam modulators by means of liquid chromatography tandem mass spectrometry (MS/MS) demonstrated the sucrose esters to be natural products in the green coffee and to be gradualy degraded upon roasting with increasing roasting time (Fig. 17.6A). In comparison, the 4-vinylcatechol oligomers were observed to be generated with increasing roasting time (Fig. 17.6B).

As the low- and high-molecular weight 4-vinylcatechol oligomers have been found to be generated upon thermal degradation of chlorogenic acids and caffeic acid, respectively, caffeic acid was thermally treated for 20 min at 220°C and, then, added to espresso coffee beverages in concentrations of 0.007%, 0.035%, and 0.07% prior to ultraturrax-mediated crema generation. The foam volume was significantly increased with increasing levels of roasted caffeic acid, e.g., more than 60% increased foam volume was measured when the coffee beverage was spiked with 0.07% roasted caffeic acid (Fig. 17.7). For the first time, these data demonstrated low- and high-molecular weight 4-vinylcatechol oligomers, generated upon roasting from caffeic acid moieties, as key contributors to the crema of roasted coffee beverages.

To characterize the impact of the foam active components on the foam structure of the crema, the foam was collected from an espresso coffee, that was spiked with sucrose palmitate (0.05%) or roasted caffeic acid (0.007%), and from nonspiked espresso (control) and then analyzed by means of a foam scan instrument equipped with a camera. The foam pictures shown in Fig. 17.8 did not show any differences in the initial phase of roasting, but clear differences were observed in the foam structure after 300 s. The pure espresso

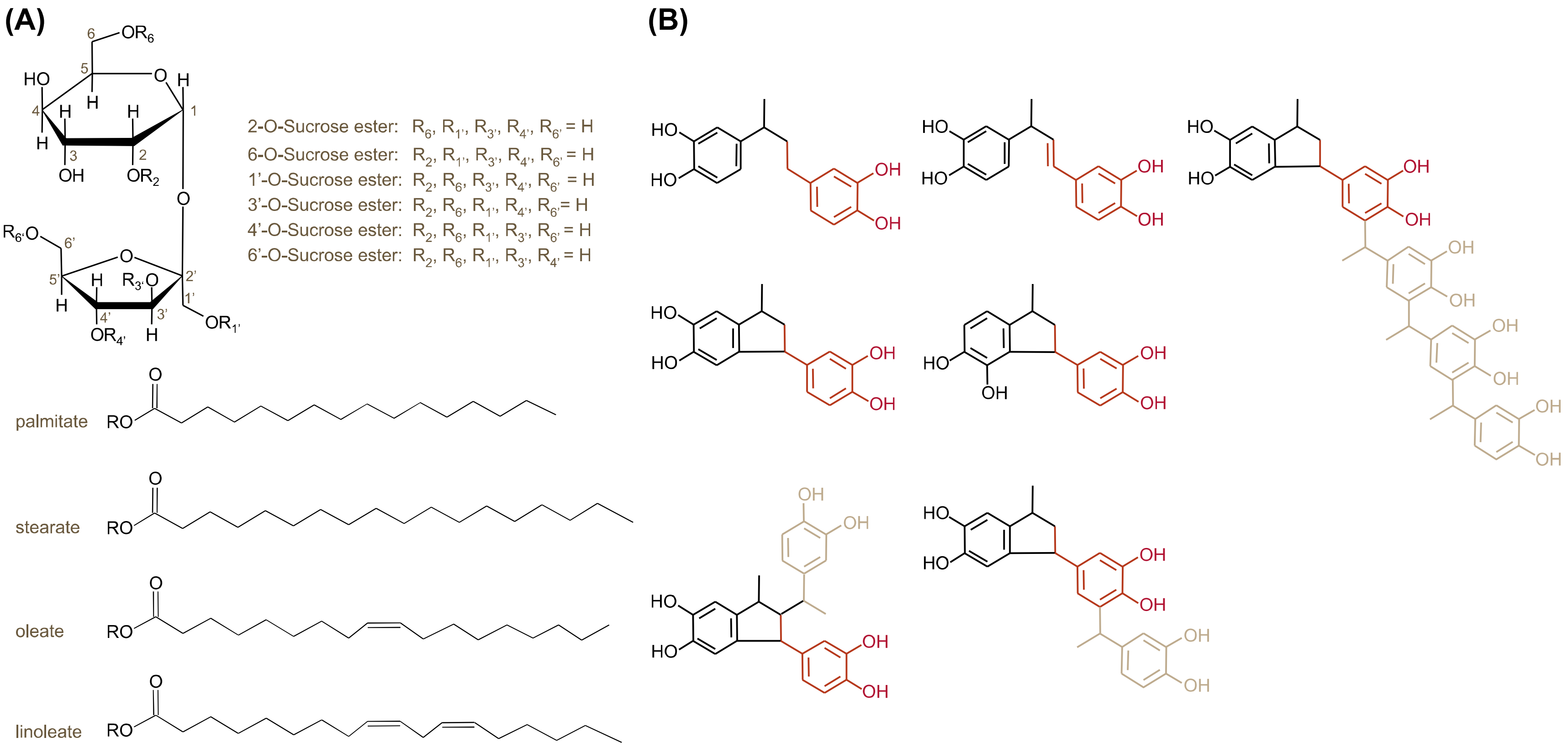

FIGURE 17.5 Chemical structures of (A) sucrose fatty acid esters identified foam from green coffee beans, and (B) 4-vinylcatechol oligomers (monomers highlighted by different color) identified in foam roasted coffee beans (Unpublished data Kornas and Hofmann et al.).

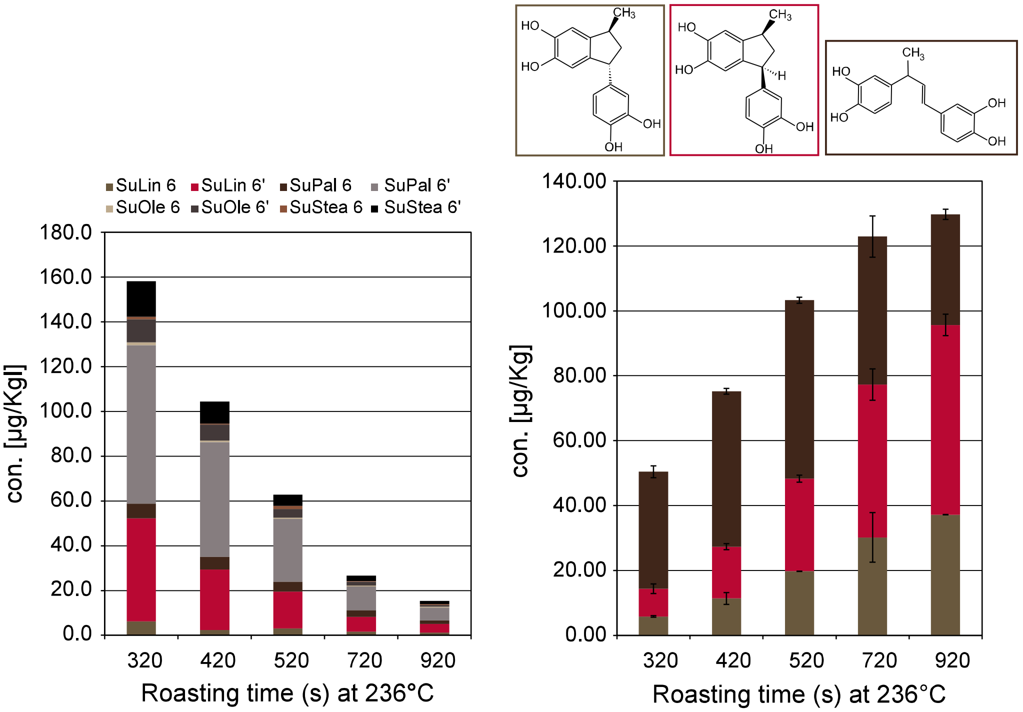

FIGURE 17.6 Influence of roasting time on the degradation of sucrose fatty acid esters (A) and the formation of a selection of 4-vinylcatechol oligomers (B) (Unpublished data Kornas and Hofmann et al.). *Su*, sucrose, *Lin*, linoleic acid; *Pal*, palmitic acid; *Ole*, oleic acid; *Stea*, stearic acid.

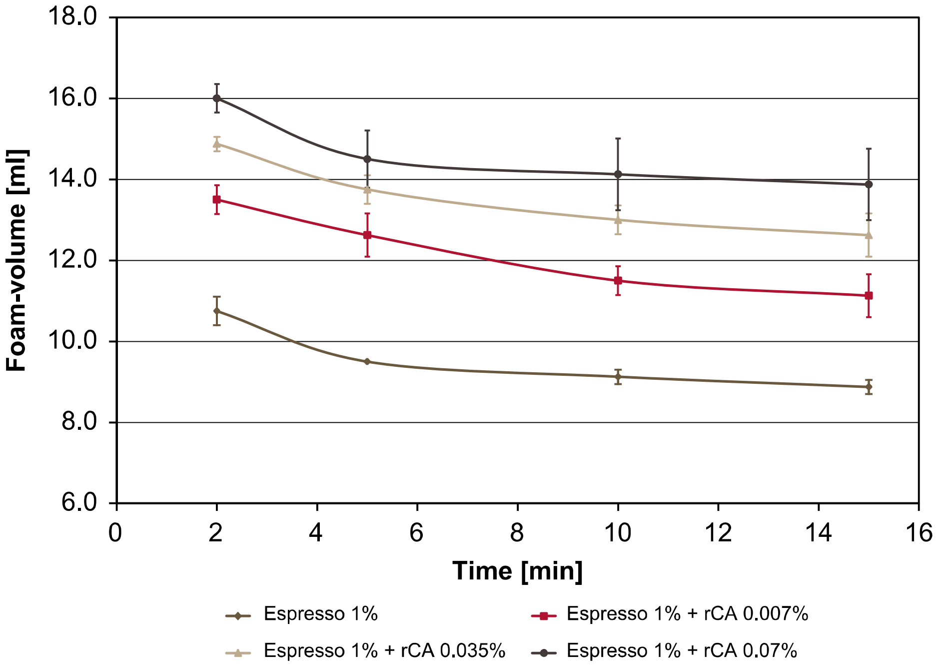

FIGURE 17.7 Influence of roasted caffeic acid on foamability and foam stability of a coffee beverage made from an instant espresso powder (1 g/100 mL) (Unpublished data Kornas and Hofmann et al.).

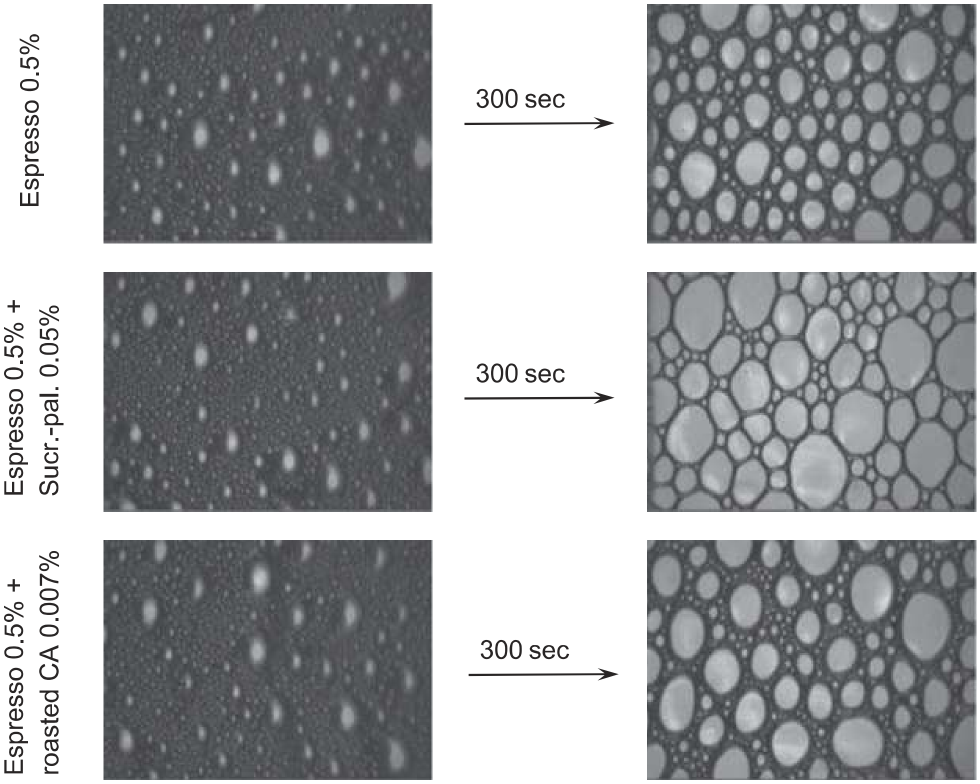

FIGURE 17.8 Foam structure of expresso spiked with sucrose palmitate (0.05%) and roasted caffeic acid (0.007%) measured after 300 s by means of a foam scan (Teclis IT-concept) (Unpublished data Kornas and Hofmann et al.).

coffee as well as the coffee spiked with roasted caffeic acid showed comparable foam structure with smaller bubbles and a higher amount of liquid between the bubbles, whereas the foam generated with coffee spiked with sucrose-palmitate shows a bigger bubble with lower amount of liquid phase between the bubbles. Therefore, the foam of the coffee spiked with roasted caffeic acid was comparable with the original espresso coffee foam in contrast to the foam of coffee spiked with fatty acid sucrose esters, which is a more coarse and dry foam. These data clearly demonstrate the 4-vinylcatechol oligomers, rather than the sucrose esters, to play a key role in determining the fine-structured crema of a premium espresso.

These results indicate that Robusta, being richer in caffeic acid and chlorogenic acid than Arabica coffee, will thus promote the formation of the high- and low-molecular weight 4-vinylcatechol-based surfactants during roasting, which in combination with the role played by the pressure and CO_2 might explain the foam promoting role of Robusta coffee in espresso blends.

4. CREMA AND THE CONSUMER

Many studies exist on how external factors influence the consumer perception or experience of a given product. For example, we know that the information consumers obtain before they consume a product influences their expectations and ultimately how they rate the quality of that product (Siegrist and Cousin, 2009; Lange et al., 2002). A consumer's level of expertise can also influence quality judgements (Sáenz-Navajas et al., 2013).

In addition, with beverages, the material of the cup or the glass that a consumer uses has a major impact on the way they experience and evaluate that beverage (Schifferstein, 2009; Wan et al., 2015). Studies also show that the way the food packaging is designed can influence various aspects of the food experience (Schifferstein et al., 2013). For all these reasons, it is not surprising that the crema has an impact on the overall espresso tasting experience.

4.1 The Impact of Crema on the Visual Perception

In a recent study by Labbe et al. (2016), researchers examined the influence of crema quantity on consumer perceptions. In this study, consumers evaluated products in three conditions, i.e., (1) visually, and researchers assessed the expectations generated by visual cues, (2) in a "blind" condition where all visual cues were suppressed and researchers assessed the in-mouth perception, and (3) by taste and sight where consumers evaluated the coffee in a standard way. Through these various conditions, researchers could separate the expectations consumers had from a product's visual appearance from their overall product perception.

The study showed that the expectations did not influence hedonic and sensory attributes in a similar manner. Although the presence of crema created high expectations on quality (a hedonic indicator), crema quantity did not impact the expected quality (Fig. 17.9). The researchers also found that the perceived quality of the product when they could see and taste it normally was higher than the blind in-mouth condition. This indicates that visual cues positively impacted the in-mouth experience.

If we look at the research in more detail, we can see that smoothness (a sensory indicator) was strongly associated with crema quantity, since coffees with crema were expected (visual condition) to be smoother than coffee without crema (Fig. 17.10). In fact, perceived in-mouth smoothness also increased with crema quantity, which was most likely due to the physical texture properties of crema. Overall smoothness was rated higher when it was seen and tasted than it was when consumers were in a blind in-mouth condition.

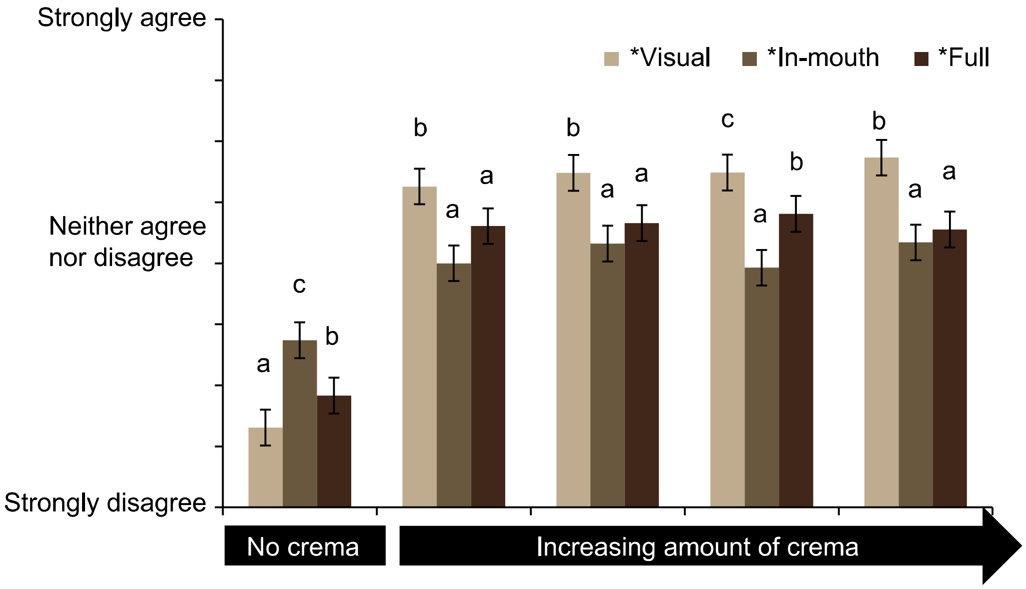

FIGURE 17.9 Average quality score for espressos with increasing crema quantity for the three evaluation conditions.

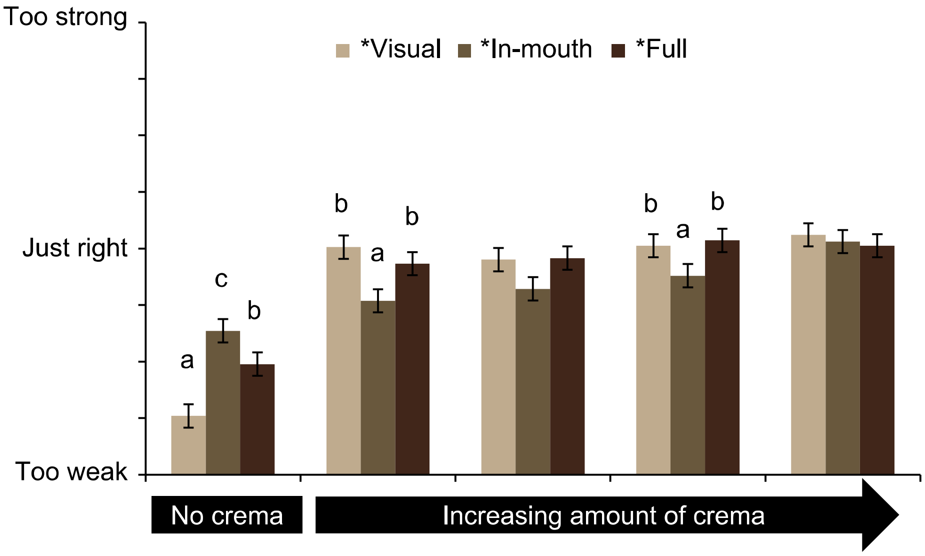

FIGURE 17.10 Average snoothness score for espressos with increasing crema quantity for the three evaluation conditions.

Overall, the study shows that crema is an important component of the espresso coffee experience. In fact, the absence of crema induced low expectations in quality, overall taste, bitterness, and smoothness which in turn reduced perceived quality and sensory attributes.

4.2 The Impact of Crema on the Aroma Release

The term aroma refers to the perception of volatiles through the olfactory system (see also Chapter 18). Volatile organic compounds can reach the olfactory epithelium in the upper part of the nose through two different pathways. Orthonasal stimulation occurs when odor-active compounds enter through the nostrils. This is the pathway that aroma molecules travel when consumers smell the coffee. However, upon tasting the coffee, retronasal stimulation occurs when odor-active compounds enter through the internal nares located inside the mouth. The following section will focus on the mechanism that impacts orthonasal aroma perception.

In one study, researchers used the Nespresso system to investigate the role of crema thickness and stability on aroma release above the cup. They compared coffees with different crema quantities (Barron et al., 2012) and stabilities (Dold et al., 2011) to coffee without crema. Although it had often been suggested that crema acts as a lid that prevents aromas from escaping (Petracco, 2005), the studies instead showed a much more complex mechanism.

Using MS methods, the study traced aroma molecules with different volatilities above the cup as a function of time. Within the first 2.5 min after the start of extraction, the presence of crema generally generated an above the cup volatile concentration that was significantly higher than that found in liquid coffee without crema (Figs. 17.11 and 17.12).

In fact, the rupture of the thin lamella located at the foam surface causes the bubbles to collapse and releases entrapped gas, containing mainly high-volatile aromas. The thinning of the films through evaporation is considered the main cause for this bubble rupture (Dold et al., 2011; Weaire and Hutzler, 1999), but other phenomena described in Section 2 may also play a role. In addition, as the liquid evaporates, the low-volatile aromas also evaporate from the liquid into the air. In contrast, when there is no crema present, all aroma release (high and low volatiles) is driven purely by evaporation from the liquid to the gas phase.

After the initial release of aromas, crema stabilization begins playing a major role in the release pattern. When there is low crema stability, the coffee releases the largest amount of aromas into the headspace. As the same time, crema volume is inversely correlated to the release of low volatiles, most likely because the crema acts as a "lid," preventing aromas from escaping.

The hypothesis that the crema layer acts as a means to liberate aromas above the cup when the crema layer is unstable was confirmed by Parenti et al. (2014) who compared different espresso preparations. This study showed an inverse relationship between crema quantity and stability when the aroma quantity was measured above the cup.

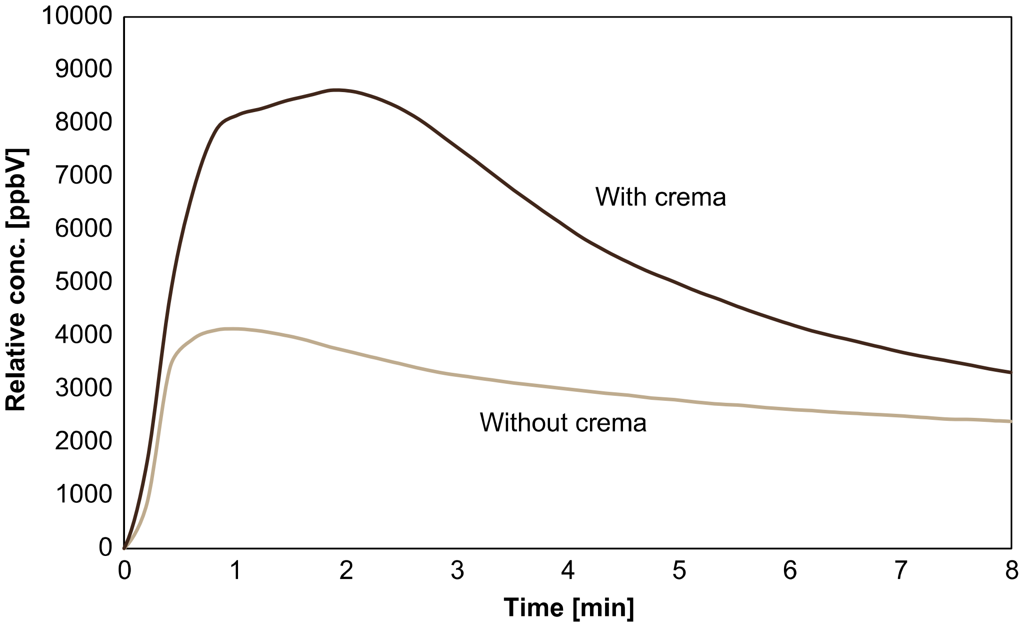

FIGURE 17.11 Volatile release profiles of the sum of selected ion mass traces as measured by proton transfer reaction mass spectrometry ion traces for samples prepared from an Arabica blend long cup coffee with crema and the same coffee without crema (removed by filtration) (t = 0 min equals 1 min after starting coffee extraction) (averages of triplicates).

FIGURE 17.12 Crema helps aromas to be released above the cup.

In conclusion, we need to consider different mechanisms when we look at the impact of crema on aroma release. This should include: (1) the way low crema stability (i.e., high bubble rupture) enhances the release of the high-volatile aromas, which are abundant in the gas phase of the foam bubbles; (2) the way high crema stability retains high volatiles because the crema acts as a barrier that entraps the aromas; and (3) how crema collapse will allow for diffusion and the subsequent release of low-volatile aromas.

For all these reasons, crema, and aroma release is often the focus when developing new espresso brewing systems. For example, the Caffè Firenze is based on pressurized air, which creates espresso coffee with a more persistent foam layer (Masella et al., 2015). This foam layer is considered responsible for a lower volatility of aroma molecules above the cup. This, in turn, confirms previous findings showing that crema stability plays a major role in aroma release (Dold et al., 2011).

With soluble coffee, researchers have also used crema creation to enhance the sensory aspects of the beverage. For instance, one study focused on aroma release above the cup for forming crema in soluble coffees with pressurized internal gas (Yu et al., 2012). However, this study cannot be linked to the mechanisms of aroma release we previously described. This is because the technology to prepare the coffee is based on gas incorporation in the soluble extract and not on the extraction technology.

Another recent technology, Centrifusion™, which Nespresso uses in its VertuoLine system, is based on using centrifugation for extraction instead of using pressure to force the water through the coffee bed. In this case, the system creates crema by combining gas expansion and mechanical formation.

The studies described above are all based on analytical methods used to quantify or reveal the mechanism of the above cup aroma release. To our knowledge, there are currently no sensory or consumer data published that illustrate the effect of crema on the perceived above cup aroma. However, various studies have examined sensory perception in-mouth.

4.3 The Impact of Crema on In-Mouth Perception

Few studies are available on the in-mouth perception of coffee (Charles et al., 2015; Barron et al., 2012; Labbe et al., 2016) and to our knowledge only Barron and Labbe have focused on crema. Researchers often use a method called temporal dominance of sensation (TDS). This methodology enables to monitor temporal evolution of the sensory perception along product tasting (Pineau et al., 2009; Le Révérend et al., 2008; Pineau et al., 2012; Pineau and Schlich, 2015).

The study by Barron et al. (2012) focuses on consumption of a dark roasted intense espresso where the amount of crema has been changed. The TDS was performed on seven sips, allowing consumption of the whole cup. For each sip, the panelists had to choose the dominant attribute of in-mouth perception among a list of 11 attributes: carbony, roasted, cereal, fruity, sweet, bitter, acidic, liquid, thick, gritty, and silky. Fig. 17.13 shows that the roasted dominance increases with increased crema quantity and remains dominant along the consumption of the cup. In contrast, a low crema amount, or no crema, triggered carbony dominance as well as bitterness.

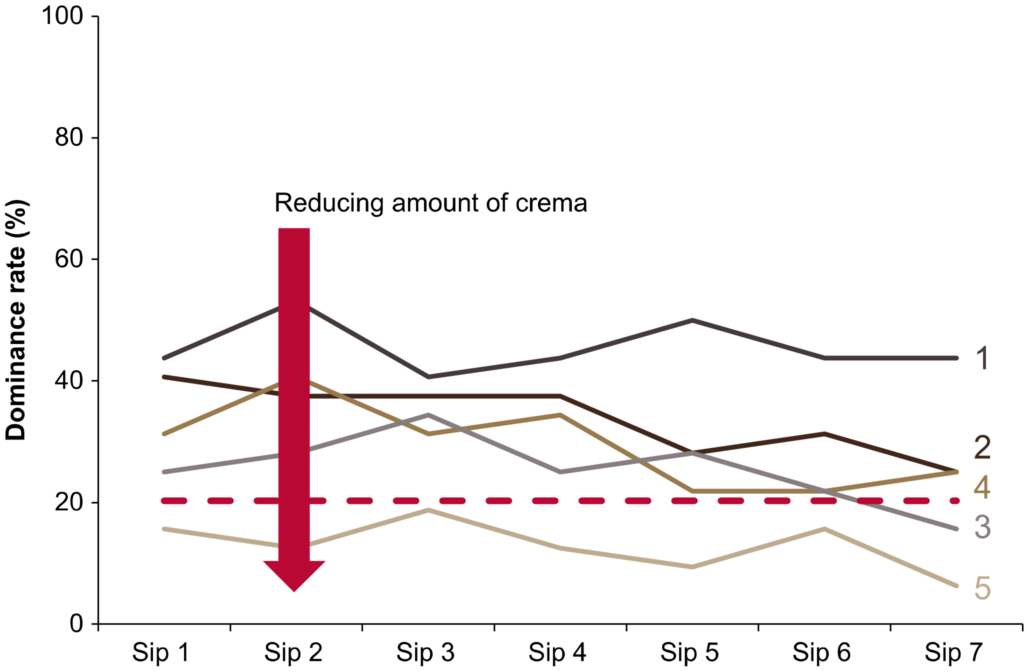

FIGURE 17.13 Comparative evolution of the roasted dominant sensation between espresso coffees with different amounts of crema consumed over seven sips. The *dotted line* indicates the level of significance. The amount of crema reduces from 1 to 5, with 5 having no crema.

The same study confirmed these results using nose-space analysis, a method where aroma release is investigated in vivo using mass spectrometry to analyze exhaled air during the consumption (Barron et al., 2012). The study showed an overall higher intensity for a larger crema amount. Combining the TDS and the nose-space data we can therefore conclude that aromas that are trapped in the crema can also be perceived in sensory perception and measured in the nose-space during consumption.

Obtaining results from nose-space analysis is, however, rather challenging as differences between panelists may be large. In the future, researchers may be able to obtain better results with advancements in analytical methods for nose space analysis. Some studies have reported analytical progress in improving discrimination between samples by coupling time of flight to MS (Romano et al., 2014).

5. OUTLOOK

There is more to crema than just the visual appearance. The statement that a good crema has to be dark brown and of a certain thickness may not be wrong, but may not be exploiting the full potential of what crema can bring to the coffee experience. Although the flavor of espresso coffee is the primary driver for product liking, textural and mouthfeel properties play a key role in the overall appreciation for consumers. Navarini et al. (2004b) already investigated this area with consumers and concluded that mouthfeel attributes can be grouped into components related to viscosity (thick), substances (rich), resistance to tongue (round), after feeling (lingering), coating of oral cavity (mouth-coating), and feeling on soft tissue (smooth). It is suggested that different coffee preparations give different concentrations and a mouthfeel vocabulary should therefore be adopted to describe these different beverages. In addition to visual appearance and texturization of the espresso coffee, crema has also been shown to enhance the aromatic aspects of the coffee, and to create expectations on the consumption of the espresso coffee.

Despite detailed knowledge on coffee composition and foam formation in beer, milk froth, and sparkling beverages, there is still little known about formation and stability of coffee crema. Results published so far are largely descriptive without proving mechanisms or their relative importance in espresso coffee. There is some knowledge on components playing a key role in crema formation and stability. However, it is well known that foams are highly complex systems to study due to its dynamics and multiple phenomena interacting on the foam in parallel. Therefore, most of the research in this field is taking place on model systems, using one or two components which allow a more systematic approach to understanding formation and stabilization. In real food systems, many different molecules are present and complexity increases significantly.

Certainly, espresso is a complex polyphasic liquid composed of (1) emulsion of oil droplets, (2) suspension of solid particles, and (3) effervescence of gas bubbles that evolve into a foam (Illy and Viani, 2005). Therefore, studying espresso crema requires a multidisciplinary approach applying most recent and highly sophisticated analytical methods to better understand this phenomenon at different length and time scales. This calls for more systematic and dedicated research on coffee foam and the parameters influencing its formation and stability. It is only when the molecular compounds, and the mechanisms of formation and destabilization are well understood, that they can become triggers to modify the crema.

Combining the consumer perception of crema with the molecular and physical approach is the prerequisite for developing strategies to improve espresso crema, which may include blending, roasting, grinding, tempering, and extraction parameters including water quality. This novel approach requires considering the espresso coffee in its integrity.

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