# 3. CHOCOLATE QUALITY

Chocolate is a complex semisolid suspension of solid fine particles consisting of sugar, milk powder, milk fat, and cocoa powder in a continuous phase of cocoa butter. Chocolate quality is closely linked to the consumer experience. The quality of chocolate could be measured by physicochemical analysis and sensory properties of the end-product. Physicochemical analysis generally applied to chocolate is viscosity, texture, hardness, color, and also possibly pH, Brix, etc. Sensory analysis is usually measured by determining how the product is accepted or differentiated to the human palate by the panelists (Gunaratne et al., 2019).

Another way to measure the quality of chocolate is by testing its rheological properties. As chocolate is mainly processed in its molten state, the evaluation of quality in this stage will be very helpful in estimating the end-product quality. Glicerina et al. (2013) stated that determination of rheology in the fat continuous food products is of great importance as it affects the key quality properties such as viscosity, consistency, and mouthfeel to the end-product.

## 3.1. Rheological Properties of Chocolate

Rheology is a science that studies the deformation and flow of matter under the influence of mechanical forces. The determination of rheological properties of molten chocolate is crucial for obtaining high quality products with well-defined texture in the chocolate manufacturing process. In general, chocolate rheology is measured using two parameters, i.e. apparent/plastic viscosity and yield stress (Goncalves & Lannes, 2010).

Texture and rheological properties are directly influenced by ingredients composition, processing technique, and particle size distribution (Abbasi & Farzanmehr, 2009). Chocolate viscosity, in particular, is crucial to chocolate quality and production cost. Close monitoring to chocolate viscosity is imperative in order to obtain a good quality product and precise weight control during enrobing and moulding processes (Servais et al., 2013). Characteristics assessment of chocolate rheology in general is listed in Table 4.

Table 4. Rheology Assessment of Chocolate

| Characters | Criteria | Reference |
|---|---|---|
| Particle size distribution (PSD) | Between 1 – 50 µm; >30 µm caused gritty perception in the mouth | Do et al., (2007) |
| | <20 µm exhibits creamier texture than that of 30 µm; larger particle sizes define the grittiness/mouthfeel, while smaller particle sizes define the flow properties | Afoakwa et al., (2007) |
| | 6 – 30 µm for achieving optimal flow | Beckett et al., (2017) |
| | Ideally 15 – 30 µm ($D_{10}$ values of 1.5 µm, $D_{50}$ values of 5 – 7 µm, and $D_{90}$ values <20 µm) | McGill & Hartel, (2018) |
| Moisture | Generally, molten chocolate has 0.5–1.5% moisture content | Afoakwa et al., (2007) |
| | Extra fat of 1% is supposed to be added for every 0.3% excess moisture left at the end of conching to maintain similar flow | Saputro et al., (2016 |
| | Moisture content of >2% are normally unacceptable as it has poor keeping quality and texture | Beckett et al., (2017) |
| Viscosity | High viscosity chocolate resulted in pasty mouthfeel | Afoakwa, (2016) |
| | Low viscosity chocolate resulted in too low weight of the chocolate deposited during enrobing process; high viscosity chocolate generates "feet" and bubbles | Beckett et al., (2017) |

Particle size distribution (herein after referred as PSD) is crucial to chocolate rheology and has a direct impact on sensory. The larger particles ($D_{90}$) are critical for mouthfeel (specifically grittiness/coarseness), whilst smaller particles define the flow (Afoakwa et al., 2008[c]). Closely related to particle size distribution is specific surface area (hereinafter referred as SSA), which may help to indicate the presence of fat that influences flow properties. Both $D_{90}$ and SSA are the key parameters of assessing PSD in the chocolate manufacturing process and are inversely related to each other (Glicerina et al., 2014).

Generally, particle sizes of molten chocolate fall between 6 – 30 µm, with the majority of it falling below 20 – 30 µm for the desired mouthfeel, texture, and flow (Do et al., 2007; Afoakwa et al., 2007). However, according to Beckett et al. (2017), it was found that chocolate with higher content of fine particles sizing <10 μm fosters an overall larger surface area that needs to be enclosed by fat, thus resulting to increase in chocolate viscosity and drier mouthfell in the final product. Simultaneously, a study by Afoakwa et al. (2007) has found that introducing a small percentage of particle size of 60 – 65 μm to a molten milk-chocolate formulation increases the overall texture of the end-product. A study published by McGill & Hartel in 2018 indicated the ideal particle size distribution of 15 – 30 μm, with $D_{10}$ values of 1.5 μm; $D_{50}$ values of between 5 – 7 μm, and $D_{90}$ values below 20 μm.

Abbasi & Farzanmehr (2009) reported a direct relationship between moisture content and viscosity, in which increase of the former resulted in rise of the latter, and vice versa. In chocolate manufacture, moisture content is heavily influenced by hygroscopic characteristics of the ingredients and processing technique.

Excess water particles left in the compound might induce agglomeration due to moisture reabsorption from other ingredients or the surroundings. The presence of moisture promotes interactions among the hydrophilic particles, resulting in lump formation and increase in particle sizes consequently (Hinneh et al., 2019). The presence of particle agglomeration during the crystallization process inhibits the formation of crystalline purity and fostered the formation of amorphous ones instead. This phenomenon is directly linked to the melting behavior later on. Simultaneously, the availability of free fat responsible for the viscosity will be reduced because more fat is needed to coat the moisture also, thus the viscosity increases (Ibrahim et al., 2020).

The rheology or flow of molten chocolate as a non-Newtonian fluid is quantified as yield value and apparent (plastic) viscosity. Yield value represents the amount of energy needed to initiate flow, whilst viscosity represents the amount of energy needed to keep the fluid moving (Rosales et al., 2016). Chocolate viscosity affects mouthfeel and flavour at the same time. The human palate contains a lot of different flavour receptors that are capable of detecting numerous flavors. As the chocolate melts in the mouth, it is exposed to these receptors. The perceived taste on the palate depends on the order and rate of contact. This occurrence is related to the viscosity and the rate of melt of the chocolate. High viscosity chocolate is also associated with pasty mouthfeel, which is the impression of the product persisting in the palate even after swallowing (Beckett et al., 2017).

### 3.2. Sensory Properties of Chocolate

Chocolate has a set of complex sensory parameters to determine its quality. The quality of chocolate is determined by the combination of its taste, texture, and mouthfeel. Characteristics assessment of chocolate in general is listed in Table 5.

Table 5. Sensory Assessment of Chocolate

| Characters | Criteria | Reference |
|---|---|---|
| Appearance | Glossy, shiny, no dots/cracks/"fog", brown in color | Mayank & Kumar, (2012) |
| | Smooth surface | Shadwell et al., (2013) |
| | Glossy, no bloom | Machálková et al., (2015) |
| Taste & Flavor | Chocolaty, other flavors do not overpower the chocolate taste, good aftertaste | Mayank & Kumar, (2012) |
| | Sweet, herbal aroma, low in bitterness & astringency | Cvitanovic et al., (2015) |
| Texture | Hard at room temperature, melts at oral temperature | Abbasi & Farzanmehr, (2009) |
| | Breaks clean without any crumbles; ideally a crisp 'pop' when snapped | Mayank & Kumar, (2012) |
| | Slightly hard at first bite | Shadwell et al., (2013) |
| Mouthfeel | Melting & creamy; not dry/sticky | Thamkee et al., (2009) |
| | Cohesiveness, fatty mouthcoating | Nightingale et al., (2009) |
| | Creamy and smooth, not waxy; fast and evenly melts in mouth | Mayank & Kumar, (2012) |

The desirable appearance of a chocolate product is displayed in smooth and glossy surface, free of spots and cracks. These qualities are mostly associated with the fat crystallization and blooming phenomenon. Bloom itself is manifested in the product losing its surface gloss and the appearance of a fine whitish layer on the surface. This phenomenon is generally caused by the migration and recrystallization of sugar/fat to the surface due to inadequate storing conditions, mainly temperature. Fat recrystallization caused changes in light dispersion and light scattering effects in the matrices, thus the appearance of the product becomes 'foggy' and loses its shine and gloss (Afoakwa et al., 2009[a]; Machálková et al., 2015).

Taste is defined as the gustatory sensation that emerges on the mouth upon coming into contact with a substance. Tastewise, it is imperative that a chocolate product predominantly possesses "chocolate" flavor above any other flavors. In Indonesia, it is in fact regulated by SNI (2014) by means of limiting the addition of additives to less than 40% of the total product per weight basis. In terms of end-product quality, a chocolate product has to possess the signature "chocolate" taste and smell.

Cocoa/chocolate naturally has strong flavors due to the abundance of complex volatile and non-volatile compounds. Pure cocoa is mostly bitter and acidic, with hints of distinct flavor notes. However with the addition of sugar, milk powder, and other ingredients; combined with fair processing technique, the chocolate product that we know today is much more acceptable to the palate (Beckett et al., 2017).

Although it is difficult to completely comprehend all the taste and flavor of chocolate, a study by Thamkee et al. (2009) offered an enlightenment to help describe the flavor descriptors associated with chocolate. In the experiment, 39 respondents in Vienna (n=15) and Dresden (n=24) are to decide the sensory characteristics (particularly taste and flavor) of plain dark chocolate samples by Free Choice Profiling (FCP) technique. The result is illustrated in Table 6.

In regards to taste or flavor, descriptions such as bitter, tart, sweet, acidic, cocoa, nutty, fruity, and chocolate-like were mostly found. There are also some other minor descriptions, such as burnt, buttery, oily, metallic, caramel-like, coffee-like, salty, woody, etc. In association of the taste clusters, chocolate products were mostly associated with bitter-sweet taste. In the vicinity of bitter cluster, bitter/harsh-aftertaste, tart, cocoa, coffee, and nutty descriptors were mostly used. In the vicinity of sweet cluster, vanilla and chocolate solely appeared.

Table 6. FCP Attributes used to Describe Chocolate Taste & Flavor

| Vienna panel | | Dresden panel | |
|---|---|---|---|
| Description | Frequency of occurrence | Description | Frequency of occurrence |
| Bitter, tart | 11 | Bitter | 21 |
| Sweet | 10 | Sweet | 15 |
| Acidic | 6 | Acidic | 10 |
| Cocoa | 6 | Bitter aftertaste | 7 |
| Nutty | 4 | Fruity | 6 |
| Harsh aftertaste | 2 | Cocoa | 6 |
| Rancid | 2 | Chocolate-like | 5 |
| Chocolate-like | 2 | Musty aftertaste | 5 |
| Citrus-like | 2 | Tart | 4 |
| Burnt | 1 | Coffee-like | 3 |
| Fruity | 1 | Oily | 2 |
| Tart | 1 | Herb-like | 2 |
| Caramel-like | 1 | Nutty | 2 |
| Metallic | 1 | Alcoholic | 1 |
| Oily | 1 | Persistent | 1 |
| Plum-like | 1 | Aromatic | 1 |
| Pudding-like | 1 | Harmonic | 1 |
| Salty | 1 | Canded lemon peel | 1 |
| Cinnamon-like | 1 | Earthy | 1 |
| | | Vinegar-like | 1 |
| | | Weird note | 1 |
| | | Woody | 1 |
| | | Minty | 1 |
| | | Olive | 1 |
| | | Salty | 1 |
| | | Pungent | 1 |
| | | Vanilla | 1 |
| | | Spicy | 1 |

(Thamke et al., 2009).

Texture is defined as the integration of physical structure and surface characteristics of the product. Physical structure of chocolate could be demonstrated as hardness or the rate of ‘snap’ when the chocolate is mechanically broken by force. It could also be expressed as mouthfeel or melting properties (Nightingale et al., 2009). Assessment of chocolate texture and mouthfeel properties is carried during chewing. Hardness at first bite is assessed by the force needed to bite into the chocolate with front teeth. Mouthcoating is determined by the extent to which residue coats the mouth after swallowing (Carvalho-da-Silva et al., 2011).

In the study by Carvalho-da-Silva et al. (2011), it was found that subjects preferred chocolate which is more mouthcoating and less hard at first bite. Chocolate with low hardness characteristics can be found in bloomed or under-tempered chocolate. Svanberg et al. (2011) indicated that this occurrence could be attributed to the migration of fats that may affect the textural and physical appearance of the product. This hypothesis is backed up by the experiment of Shadwell et al. (2013). In this study, it was found that bloomed chocolate was significantly softer and more easily broken compared to regular chocolate. However, it was found that there is no significant difference concerning melting properties of bloomed chocolate compared to regular chocolate during sensory evaluation. Nevertheless, panelists still significantly preferred regular chocolate than bloomed chocolate in terms of appearance and surface smoothness.

Simultaneously, mouthfeel perception could also be attributed to the cocoa content in the formulation. Thamke et al. (2009) reported that lower cocoa content in the formulation resulted in melting and creamier mouthfeel, whereas samples with higher cocoa content were characterized as dry, mealy, and sticky.