Oral Processing of Dark and Milk Chocolate

by

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Abstract

The thesis reports novel scientific understanding and findings generated on the subject of chocolate oral processing. Research was carried out with a view to unravel the role of food (chocolate) - and human-related factors in governing structural and physical transformation of chocolate matrices during human oral processing. Dark and milk chocolate were studied as contrasting model matrices to investigate the influence of composition and physical properties of chocolates on microstructure and physical properties of ready-to-swallow chocolate boluses formed as a consequence of distinct eating and saliva incorporation strategies. Microstructure, and physical/material properties, in particular, particle size distribution, hardness, mechanical and rheological properties of melts, and thermal behaviour and solid fat content (SFC) of the chocolate models were characterised and compared. Differences in particle size distribution between the chocolates, and presence of milk ingredients (milkfat, milk powder, lactose) and surface-active agents (soy lecithin) in the milk chocolate, as opposed to their absence in the dark chocolate, were recognised and discussed as prominent factors contributing to underlying differences in microstructure and physical properties between the chocolate models. The dark chocolate was significantly harder as compared to milk chocolate, and in addition demonstrated greater firmness, consistency, cohesiveness, index of viscosity, yield stress and plastic viscosity of melt. Analysis of melting behaviour suggested that in comparison to milk chocolate, the dark chocolate had a slower melting-rate and greater SFC, and hence demonstrated greater energy requirement for complete liquefaction. This was reflected through the thermal parameters of solid fat index, melting onset, end and peak maximum, and enthalpy of melting assessed using differential scanning calorimetry.

A 24 subject human panel study undertaken to investigate eating (mastication and swallowing) strategies of consumers suggested that chocolate eating behaviour varied considerably across consumers. Findings highlighted that chocolate eaters adapted their overall eating strategies in response to differences in physical and related-textural properties of chocolates. In particular, total number of chews and oral processing time for the complete masticatory sequence and until the first perception to swallow, significantly differed between the two chocolates. These eating parameters were greater in the case of dark chocolate as compared to milk chocolate. Furthermore, subjects also conserved their general eating patterns and maintained similar masticatory frequencies between chocolates. Taken together, it was postulated that chocolate composition and physical properties, as well as human-related physiological and behavioural factors influenced dynamics of chocolate oral transformation, and were consequently involved in modulation of mastication and swallowing strategies. Hierarchical cluster analysis and analysis of variance were successfully implemented for segregation of population into three clusters with significant differences in eating parameters. This was followed by principal component analysis which facilitated the selection of 3 test subjects who exercised distinct overall chocolate eating strategies significantly different from each other, and moreover were from a related parent cluster.

Regardless of eating strategy, occurrence of several voluntary swallowing events before complete oral clearance of chocolates indicated that only a part of the bolus was ready-to-swallow at the first perception to swallow. Observation of expectorates confirmed that at this point, chocolate boluses constituted a pool of liquid bolus phase (molten chocolate + saliva) as well as cohesive bolus lumps (solid/partially-melted chocolate particles aggregated together by the action of saliva and molten fat). While the liquid phase was swallowed by subjects, cohesive lumps underwent further oral processing to be transformed into a swallowable consistency. Microstructure analysis of bolus liquid phase by optical microscopy and confocal laser scanning microscopy revealed a coarse oil-in-water emulsion microstructure in the case of either chocolate wherein, a relatively denser bolus structure resulting from extensive ingredient and fat globule flocculation was witnessed for dark chocolate boluses.

Results further suggested that solid fat content-related physical properties and melting behaviour were related to saliva incorporation. Greater hardness and energy requirements for liquefaction, and slower rate of melting in dark chocolate resulted in relatively longer oral processing time invested by subjects in bolus preparation. This in turn resulted in higher moisture content in ready-to-swallow boluses of dark chocolate (40.25 wt%) as compared to milk chocolate (32.20 wt%). Furthermore, these properties also resulted in cohesive-lumps of dark chocolate boluses being significantly firmer and requiring greater work for compression. In contrast, adhesiveness of milk chocolate boluses was greater in comparison with dark chocolate boluses, and was explained through the presence of milk ingredients in its chocolate matrix. Subjects processed both chocolates to similar cohesiveness of bolus lumps, interestingly indicating that this property may not be chocolate-dependent. Nevertheless, bolus saliva contents at the first point of swallow, and all mechanical properties accept adhesiveness of bolus lumps, were subject-dependent. Results indicated that this effect could be largely related to variation in physiological parameters, in particular oral processing time and salivary flow rates. Interestingly, liquid phase viscosities of milk chocolate boluses were similar to that of dark chocolate within-subjects, while this property was also subject-dependent. Adaptation of eating strategies and saliva incorporation demonstrated by subjects in response to differences in chocolate texture, and the presence of a relatively greater percentage of water-soluble solids in milk chocolate were factors which supported the fact that ready-to-swallow boluses of both chocolates had similar viscosities. Subject-dependency of chocolate bolus viscosity was explained through physiological parameters of eating behaviour and saliva flow rate which influence final moisture content in the bolus liquid phase.

Considering the importance of the continuous fat-phase in influencing oral processing and bolus formation of chocolates, effect of storage temperature (0°C, 20°C, 30°C)-induced physical changes in dark and milk chocolate on physical properties of ready-to-swallow boluses, and eating and saliva incorporation strategies of selected subjects was investigated. Thermal analysis revealed mainly SFC-related changes in the physical properties of hardness and enthalpy of melting (ΔH_{melt}). Relative to 20°C, storage at 0°C resulted in increased hardness and ΔH_{melt} for both chocolates, while an inverse effect resulted from storage at 30°C. In the case of both chocolates, all subjects adapted their oral processing time, number of chews and saliva incorporation strategies in positive relation to increase/decrease in hardness and ΔH_{melt}. Again, they conserved their general eating patterns, and maintained similar masticatory frequencies to form boluses suitable for swallowing. In the case of both chocolates, significant softening and relatively greater reduction in ΔH_{melt} of chocolate stored at 30°C resulted in significantly low firmness and work of spreading of bolus lumps obtained at the point of swallow. Once again, in the case of all subjects, adhesiveness of bolus lumps was independent of these changes in physical properties for either chocolate-type. Lastly, results suggested storage treatments resulted in each subject processing a similar chocolate-type to different endpoints in terms of bolus liquid phase viscosity. Different SFC which governed the relative extent of melting that a chocolate underwent until the point of swallow, may have influenced the degree of bolus dilution, and hence its viscosity. Throughout this study, the excellent within-subject repeatability in eating strategies, saliva incorporation, and rheological properties of ready-to-swallow bolus for a particular chocolate- and/or texture-type was noteworthy.

Aside

Tavern upon the Woodhouse hill

A Yorkshire mist and its simmering prowl within

Rosewood decks and an enfeebled liqueur creel

Amidst the tranquil night, it had an enchanted feel.

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