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Review

Microstructure of cheese: Processing, technological and microbiological considerations

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Cheese is a classical dairy product, which is strongly judged by its appearance and texture; hence, a renewed interest in its microstructure has been on the rise, as sophisticated techniques of analysis become more and more informative and widely available. Processing parameters that affect microstructure play a dominant role upon the features exhibited by the final product as perceived by the consumer; rational relationships between microstructure (which includes biochemical and microbiological indicators), and quality and safety of the products are accordingly required. Subsequent to that extra fundamental knowledge, technological innovations may eventually improve current cheesemaking processes, and permit mechanistic design of novel ones. This review thus focuses on recent advances pertaining to the microstructure of cheese, and discusses them in a logical and critical manner.

Introduction

Cheese is a highly regarded food in most human cultures, and has accordingly been present throughout ages in mankind daily life. The variety of cheeses currently available is large, because a myriad of topical advances – encompassing manufacture and ripening, have cumulatively taken place over time. In addition to the somewhat intrinsic (and unpredictable) variability within each cheese type, tailor-made cheese matrices have been proposed based on specific microstructures – which have emerged side by side with introduction of alternative (or improved) methodologies in cheesemaking.

Microstructure is not a static concept; it evolves instead along the food processing chain, and eventually leads to major transformations relative to the original microstructure of the milk feedstock itself. This realization thus encompasses specific molecular compositions and spatial arrangements. On the other hand, it should be emphasized that, besides the supporting proteinaceous/fatty matrix, microorganisms are also an integral part of cheese. Microbial activity produces indeed major transformations of the cheese matrix, which will affect the final microstructure as well. Hence, it is also crucial to elucidate microorganism–matrix interactions, in attempts to understand the whole picture.

Consumer acceptance of a cheese product depends directly on its appearance, flavour and texture – which are in turn originated by a thorough combination of microbiological, biochemical and technological parameters, that affect microstructure directly or indirectly. Note that the ultimate success of any food product relies on consumers' reactions: in fact, human perception of organoleptic characteristics is closer to the consumer status at the moment of decision than data generated by any type of analytical instrumentation (Adhikari, Heymann, & Huff, 2003) – despite its constraints in repeatability and objectiveness.

Texture is intrinsically related to the arrangement of various chemical components within distinct micro- and macrostructure levels – *e.g.* proteic network or fat fraction; it is the external manifestation of such structures that eventually determines the uniqueness and distinctive character of a cheese product. However, cheeses are particularly complex systems, so full and meaningful assessment of the effects of microstructure (and texture) upon flavour and appearance is still incipient.

This paper discusses a number of fundamental aspects pertaining to microstructure of cheese – and specifically focuses on issues associated with microstructural effects arising from technological and processing approaches.

Manipulation of physical properties of milk

A huge variety of dairy products exists at present, depending on the deliberate alterations of the original

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characteristics of milk – which always start with some form of bulk concentration (Malcata, 1999). A set of downstream operations are normally applied to milk – which are intended to alter, strengthen or create structure; they are aimed at minimization (or even elimination) of potential risk factors, *e.g.* product decay *via* metabolism of contaminating microflora. Attempts to improve yield, as well as to design novel products with better organoleptic features, also lead to changes at the microstructure level.

The most important unit operations in dairy food physical manipulation, that impinge upon microstructure, are listed in Table 1, and are discussed below in further detail.

Thermal treatments

Thermal treatment is the most common operation used with milk; this is due to the tight safety that is enforced in food plants, including industrial cheese manufacture. Several distinct heat treatments have been successfully applied in industrial practice – ranging from mild to severe ones. As expected, the more severe the heat treatment, the more extensive the damages brought about thereby – as the thermal history of milk affects the properties of the coagulum, and thus the development afterwards of microstructure; heat-treated (and homogenized) milk may in fact lead to off-flavours and weak clotting features (Singh & Wauguna, 2001).

Another consequence of milk heating is whey protein denaturation, followed by aggregation; or interaction with caseins, in the first place. The fraction of whey proteins taken up may reach 50–70%, depending on their degree of denaturation. A high pre-heating temperature improves yield and stability of the final product, as well as texture – which will become smoother if short-time heating is employed, because of increased water binding to the denatured whey proteins (Hinrichs, 2001).

Pressure treatments

High pressure (HP) has been proposed as a suitable technology for milk treatment to substitute, or in addition to thermal treatment. Its relatively recent development has been associated mainly with the possibility of inactivating undesired microorganisms and/or enzymes in milk; however, one cannot disregard the effect of such a practice upon milk constituents themselves, and consequently on the final characteristics of ripened cheese – beyond improvement of microbial safety and extension of shelf-life.

So far, the most important concern in terms of HP-induced changes pertains to the physicochemical properties of casein micelles and whey proteins – as HP affects intramolecular bonds, either reinforcing or weakening them. Lopez-Fandiño, Carrascosa, and Olano (1996) reported that pressurization of cheesemaking milk at 300–400 MPa for 30 min caused an increase of 14–20% in curd weight, and a decrease of 7.5–15% in protein loss in whey. Huppertz, Fox, de Kruif, and Kelly (2006), Lopez-Fandiño (2006) and Considine, Patel, Anema, Singh, and Creamer (2007) have comprehensively reviewed the molecular changes induced by HP in milk proteins, whereas Trujillo, Capellas, Saldo, Gervilla, and Guamis (2002) highlighted the principles of HP and their implications on the final properties of dairy products. However, a thorough description of the aforementioned chemical and molecular mechanisms, and of the underlying theoretical issues is not within the scope of this review – but rather the implications of such a type of process on the structural features of cheese.

It is widely accepted that HP treatments alter milk coagulation characteristics – either by reducing or increasing the gelation time (Lopez-Fandiño, 2006), or by inducing proteolytic and lipolytic activities that promote acceleration of cheese ripening (Guerzoni et al., 1999). Exposure to HP

Table 1. Processing applications in cheesemaking milk, and effects thereof upon microstructure of cheese

Treatment parameters	Microstructural effects	References
High temperatures	No effect on structure of casein micelles	Kim and Jimenez-Flores (1995)
	Weakened clotting properties	Grappin and Beuvier (1997)
	Denaturation of serum proteins	Heinrichs (2001)
	Interactions between κ-casein and whey proteins	Schreiber (2001)
	Interactions between milk proteins and fat membrane components	Singh and Wauguna (2001)
High pressures	Effect on milk protein intramolecular bonds	Guerzoni et al. (1999)
	Change of coagulation characteristics	O'Reilly et al. (1999)
	No effect on activity of native milk enzymes	Needs et al. (2000)
	Reduction of syneresis	Wendin et al. (2000)
	Increase of cheese yield	Capellas et al. (2001)
	Closer-packed structure	Kheadr et al. (2002)
	Acceleration of cheese ripening	Huppertz et al. (2006)
		Lopez-Fandiño (2006)
Enzymes (TGase)	Modification of rheological and renneting properties	Cozzolino et al. (2003)
	Prevention of coalescence between milk fat globules	Hinz, Huppertz, Kulozik
	Incorporation of whey proteins	and Kelly (2007)
	Influence on primary and secondary stages of coagulation	Bönisch et al. (2008)
Membranes	Reduction of rennet coagulation time	Erdem (2000)
	Increase in firmness of coagulum	Mistry (2004)
	More compact structure of casein	Benfeldt (2006)
	Softer texture and altered flavour characteristics, in hard- and semi-hard cheeses	

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