Milk Fat Composition Affects Mechanical and Rheological Properties of Processed Cheese

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Abstract:
Laboratory-scale experiments were carried out to explore the influence of the composition of the fat phase on mechanical and rheological properties of processed model cheeses. Cheeses made from caseinates, emulsifying salts and a milk fat fraction liquid at 24°C, which was achieved by thermal separation, showed much lower moduli than processed model cheeses manufactured with a fat fraction solid at 30°C. Processed model cheeses made from caseinates, emulsifying salts and a hard butter with a low amount of unsaturated fatty acids were significantly higher in firmness than cheeses made with soft butter with a higher amount of unsaturated fatty acids. In experiments using mature Gruyère and emulsifying salts, processed cheeses made from summer Gruyère were less firm than processed winter Gruyère. The results indicate that fat composition strongly affects mechanical properties of processed cheese, and a model is provided to explain structural changes during deformation.

Zusammenfassung:
Der Einfluss der Fettphase auf mechanische und rheologische Eigenschaften von Schmelzkäse wurde mit Hilfe von Modellproduktionen im Labormaßstab ermittelt. Modellkäse aus Caseinat, Schmelzsalzen und einer bei 24°C flüssigen Milchfettfraktion, die durch thermische Fraktionierung erhalten wurde, zeichnen sich durch wesentlich niedrigere Moduln aus als Käse, die mit der bei 30°C festen Fettfraktion hergestellt wurden. Schmelzkäseprodukte aus Caseinat, Schmelzsalzen und harter Butter mit einem niedrigen Gehalt an ungesättigten Fettsäuren erwiesen sich als signifikant fester im Vergleich zu Käsen, die mit weicher Butter produziert wurden. Schmelzkäse auf der Basis von reifem, in der Sommerperiode hergestelltem Gruyère waren signifikant weicher als Schmelzkäse aus in der Winterperiode erzeugtem Gruyère. Die Tatsache, dass die Fettzusammensetzung die mechanischen Eigenschaften von Schmelzkäse stark beeinflusst, wird anhand eines Modells, das strukturelle Unterschiede während der Deformation aufzeigt, erklärt.

Résumé:
Des expériences à l'échelle du laboratoire ont été entreprises afin d'explorer l'influence de la composition en matières grasses de fromages industriels types sur les propriétés mécaniques et rhéologiques. Les fromages élaborés à partir de caséinates, de sels émulsifiants et une fraction de graisse de lait liquide à 24°C, qui ont été obtenus par séparation thermique, présentent des modules bien plus bas que les fromages industriels fabriqués avec une fraction de graisse solide à 30°C. Les fromages industriels élaborés à partir de caséinates, sels émulsifiants et beurre solide avec un léger ajoût d'acides gras insaturés, présentent, de manière significative, une fermeté plus grande que les fromages obtenus avec du beurre mou et ajoût plus important d'acides gras insaturés. Dans les expériences utilisant du Gruyère arrivé à maturité avec des sels émulsifiants, les fromages faits avec du Gruyère d'été sont moins fermes que ceux fabriqués avec du Gruyère d'hiver. Les résultats indiquent que la composition en matières grasses affecte fortement les propriétes mécaniques du fromage industriel, et un modèle est présenté afin d'expliquer les changements structuraux durant la déformation.

Key words: Processed cheese, rheology, milk fat, emulsions

1 INTRODUCTION

Rheological and texture properties of cheese are affected by its chemical composition, with the amount of fat in dry matter and the ratio of water to solids-non-fat being the most commonly used parameters to determine the type of cheese (i.e. hard, semi-hard or soft cheeses), but also by factors such as cheese-making technology or intensity of proteolysis. From a structural point of view, cheese consists of a continuous protein matrix, wherein the fat globules are dispersed [1]. Fat globule size heavily depends on cheese technology and may vary from several microns for raw milk cheeses to below 1 μm in cheese made from homogenized milk or in processed cheese.

In natural cheeses, fat globules occupy void spaces in the open protein matrix thus acting as a kind of filler in a composite [2]. At a given filler concentration, technology obviously influences the tion may prevent protein particles to interact directly with the emusified fat [9, 28]. In these cases, differences attributable to fat composition may solely represent a function of the filler itself.

However, in case of natural cheese, calcium in the Ca-paracaseinate complex is, during processing, removed by the ion-exchange capabilities of the melting salt, and insoluble paracaseinate is solubilised. Polyvalent anions from emulifying salts become attached to the protein, thus increasing hydrophilic properties [7], and the protein may interact with new membranes formed on the surface of the fat globules [8]. Therefore, filler-matrix interactions additionally influence the rheological properties of the entire system. Fig. 6 gives a presumptive model on changes, which might occur during uniaxial deformation by considering a different ratio of solid to liquid fat within the fat globules. From a deformation of a system with a soft fat fraction, i.e., a low amount of fat crystals and a higher amount of oil in the emulsified globules, some rearrangement of the matrix with lateral elongation may be expected. The fat globules themselves may easily be deformed, with the resulting ellipsoids filling the void spaces in the matrix. There is only a minor contribution to the firmness of the entire system, and the macromolecular protein system is able to store energy by elastic deformation.

If a system with fat globules containing a higher amount of solid fat crystals is subjected to a similar deformation, the globules will obviously contribute to a larger amount to the firmness of the system. As the globules themselves are stiffer, they cannot be deformed easily, and tend toward retaining their shape. This may cause some non-destructive rearrangements, elongation and flow within the protein matrix. The higher slope of G' vs ω, found experimentally for the processed model cheese with the high melting fat fraction incorporated, corresponds to shorter relaxation time through the linear viscoelastic theory [29] or, in other words, to a relatively higher amount of energy dissipated during the deformation process.

For the Gruyère raw material used for processed cheesemaking, average iodine values were 41.7 and 32.2 for raw Gruyère manufactured in the summer and in the winter period, respectively. The difference is larger than the difference between the fat fractions separated by thermal treatment. This indicates that the effects obtained by fat separation may be exceeded during normal milk production simply by natural variations in the feeding regime. Apart from the differences in texture and rheological properties of processed Gruyère from summer and winter cheeses, which can be attributed to the properties of the fat phase, we also observed a significantly lower firmness than in processed model cheese. In this context, effects of proteolysis, which lead to a partial degradation of casein into smaller peptides, have to be considered.

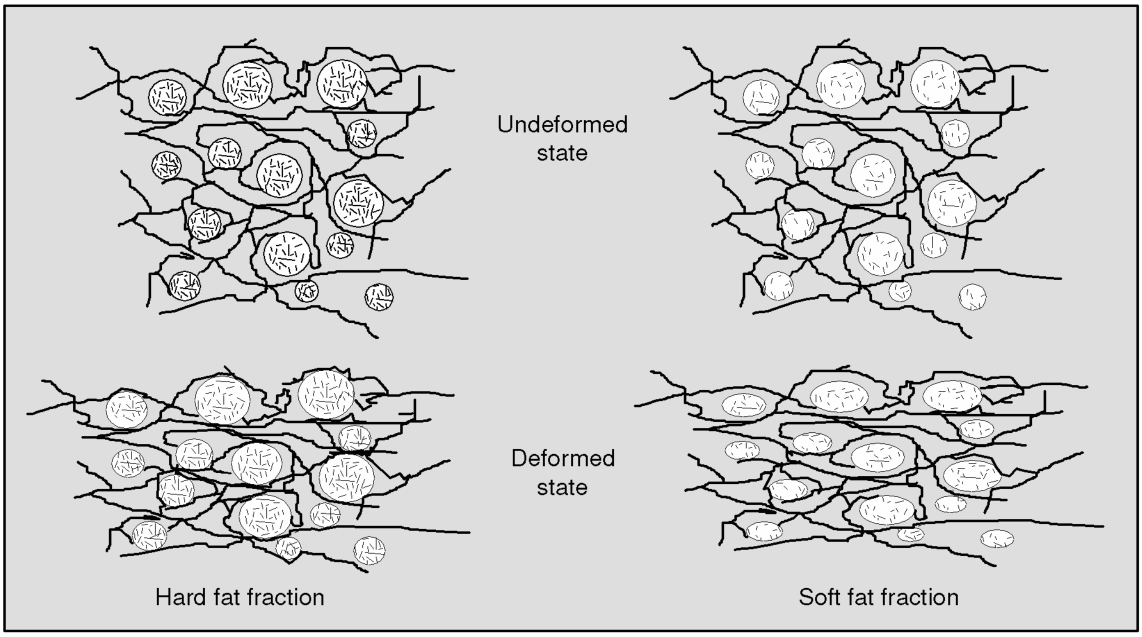

Fig. 6: Schematic presentation of processed cheese and a model for structural changes during deformation.

REFERENCES

[1] Bryant A, Ustunol Z et al.: Texture of Cheddar cheese as influenced by fat reduction, J.Food Sci. 60 (1995) 1216-1219, 1236

[2] van Vliet T: Rheological properties of filled gels. Influence of filler matrix interaction, Coll.Polym.Sci. 266 (1988) 518-524

[3] van Vliet T, Dentener-Kikkert A: Influence of the composition of the milk fat globule membrane on the rheological properties of acid skim milk gels, Neth.Milk Dairy J. 36 (1982) 261-265

[4] Gamsjäger C, Ginzinger W et al.: Characteristics and description of Vorarlberger Bergkäse. 4. Composition, Milchwiss. 53 (1998) 194-197

[5] Ginzinger W, Jaros D et al.: Raw milk flora affects composition and quality of Bergkäse. 3. Physical and sensory properties, and conclusions, Lait 79 (1999) 411-421

[6] Jaros D, Rohm H: Characteristics and description of Vorarlberger Bergkäse. 2. Appearance and texture properties, Milchwiss. 52 (1997) 625-629

[7] Caric M, Kalab M: Processed cheese products. In: Fox PF (Ed), Cheese:Chemistry, Physics, and Microbiology, Volume 2, Major Cheese Groups, Chapman & Hall, London (1993)

[8] Rayan AA, Kalab M et al.: Microstructure and rheology of process cheese, Scanning Electron Microscopy 3 (1980) 635-643

[9] Brunner A: Untersuchungen zur Struktur von Caseinatgelen und Caseinat-Lipid-Emulsionen, Dissertation, TU Munich (1991)

[10] Green ML, Marshall RJ et al.: Structure and mechanical properties of model composite foods. In: Carter RE (Ed.), Rheology of Food, Pharmaceutical and Biological Materials with General Rheology, Elsevier, London (1990)

[11] Langley KR, Green ML: The compression strength and fracture properties of model particulate food composites in relation to their microstructure and particle-matrix interaction, J.Texture Stud. 20 (1989) 191-207

[12] Lobato-Calleros C, Vernon-Carter EJ et al.: Microstructure and texture of cheese analogs containing different types of fat, J.Texture Stud. 29 (1998) 569-586

[13] Rohm H, Kneifel W et al.: Characteristics and description of Vorarlberger Bergkäse. 1. Data collection and microbiology, Milchwiss. 52 (1997) 569-573

[14] Kosikowski FV, Mistry VV: Cheese and Fermented Milk Products. Vol. II. Procedures and Analysis, AVI, Westport (1997)

[15] Peleg M: The basics of solid food rheology. In: Moskowitz HR (Ed), Food Texture. Instrumental and Sensory Measurement, Marcel Dekker, New York (1987)

[16] Casiraghi EM, Bagley EB et al.: Behaviour of Mozzarella, Cheddar and processed cheese spread in lubricated and bonded uniaxial compression, J. Texture Stud. 16 (1985) 281-301

[17] FIL/IDF: Determination of the iodine value of butter fat - Wijs method. Standard 8, FIL/IDF General Secretariat, Brussels (1964)

[18] Christopherson SW, Glass RL: Preparation of milk fat methyl esters by alcoholysis in an essentially nonalcoholic solution, J. Dairy Sci. 52 (1969) 1289-1290

[19] Pardun H: Analyse der Fette und Fettbegleitstoffe. In: Schormüller, J. (Ed), Handbuch der Lebensmittelchemie. IV. Fette und Lipoide, Springer, Berlin (1969)

[20] SAS® Institute: SAS/STAT™ Guide for Personal Computers. Version 6.12 Edition, SAS® Institute, Cary (1996)

[21] Sherman P: Emulsion Science, Academic Press, London (1968)

[22] Luyten H, van Vliet T: Influence of a filler on the rehological and fracture properties of food materials. In: Carter RE (Ed.), Rheology of Food, Pharmaceutical and Biological Materials with General Rheology, Elsevier, London (1990)

[23] Walstra P, Jenness R: Dairy Chemistry and Physics, John Wiley, New York (1988)

[24] Mulder H, Walstra P: The Milk Fat Globule, Pudoc, Wageningen (1974)

[25] Paech W: Dichte, Viskosität und Grenzflächenspannung von Milch, Rahm und Milchfett, Dt. Molkerei-Ztg. 94 (1973) 260-264

[26] Rohm H, Ulberth F: Variations in the viscosity of butter oil, Milchwiss. 51 (1996) 10-13

[27] Frede E: Der Festfettanteil - ein Klassifizierungsmaßstab für die physikalische Qualität von Milchfett, Kieler Milchwirtsch.Forschungsber. 42 (1990) 197-218

[28] Klostermeyer H, Buchheim W: Die Mikrostruktur von Schmelzkäseerzeugnissen. Kieler Milchwirtsch.Forschungsber. 40 (1988) 219-231

[29] Ferry JD: Viscoelastic Properties of Polymers, John Wiley, New York (1980)

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