Lait (1997) 77, 467-477

Original article

Effects of water addition on composition and fracture properties of Emmental cheese*

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Summary — In a number of replicated large-scale experiments, Emmental cheeses were produced from raw milk with addition of 0%, 10% and 20% water to the curd/whey-mixture subsequent to curd cutting. During ripening in standard conditions for 16 weeks, appropriate samples were cut from the cheese wheels and subjected to analysis. The results show that gross composition parameters, eg, fat, dry matter and calcium content were partially influenced by maturation but remained totally unaffected by the water addition level. The dilution of the whey, however, reduces the amount of fermentable lactose within the immature cheeses and leads to differences in pH and lactic acid content. Due to pH-induced accelerated development of propionibacteria, lactate degradation was found to be more pronounced in Emmental cheeses produced with addition of 20% water. Consequently, higher levels of propionic acid and accelerated eye formation were evident in such cheeses. On the other hand, increasing amounts of water added to the curd/whey-mixture resulted in a reduced breakdown of α_{S1}-casein and lower secondary proteolysis estimates. Additionally, stress and strain at apparent fracture were heavily affected by water addition. Emmental produced with 20% water showed significantly higher levels of fracture stress, which can be regarded as an instrumental measure of sensory firmness. As higher levels of fracture strain generally imply increased sensory elasticity of the cheese mass, the water addition technology seems to be an appropriate tool to minimise sensory defects (too short cheese body), to improve storage ability and to lower the risk of late fermentation.

Emmental cheese / water addition / composition / fracture property

Résumé — Effets de l'addition d'eau dans la composition et les propriétés à la fracture de l'emmental. Dans un grand nombre d'expérimentations faites à grande échelle, des emmentals ont été fabriqués à partir de lait cru, avec addition de 0, 10 et 20 % d'eau au mélange caillé/lactosérum après découpage du caillé. Pendant l'affinage de 16 semaines dans des conditions standards, des échantillons appropriés ont été prélevés dans les meules de fromages et soumis à des analyses. Les résultats montrent que les paramètres de composition, c'est-à-dire les teneurs en matière grasse,

* Oral communication at the IDF Symposium "Ripening and Quality of Cheeses", Besançon, France, February 26-28, 1996.
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matière sèche et calcium, étaient en partie influencés par l'affinage, mais restaient totalement inaffectés par le pourcentage d'eau ajoutée. Toutefois, la dilution du lactosérum réduisait la quantité de lactose fermentescible des fromages non affinés et entraînait des différences dans le pH et la teneur en acide lactique. Du fait de l'accélération du développement des bactéries propioniques induite par le pH, la dégradation des lactates a été trouvée plus prononcée dans les emmentals fabriqués avec une addition de 20 % d'eau. En conséquence, les taux élevés d'acide propionique et l'accélération de la formation de l'ouverture étaient évidents dans de tels fromages. D'un autre côté, la quantité croissante d'eau additionnée au mélange caillé/lactosérum entraînait une réduction de la dégradation de la caséine α_{s1} et une baisse des paramètres de protéolyse secondaire. De plus, la contrainte et la déformation à la fracture apparente étaient très affectées par l'addition d'eau. Les emmentals fabriqués avec 20 % d'eau montrent un taux significativement plus élevé de contrainte à la fracture, qui peut être perçu comme une mesure instrumentale de la fermeté sensorielle. Comme de plus grands taux de déformation à la fracture impliquent généralement une élasticité sensorielle croissante du fromage, la technologie de l'addition d'eau semble être un outil approprié pour minimiser les défectuosités sensorielles (fromage à « pâte courte » de consistance), améliorer la capacité de stockage et diminuer le risque d'une fermentation tardive.

emmental / addition d'eau / composition / propriétés à la fracture

INTRODUCTION

It is well known that, besides appearance (colour and hole formation) and aroma, texture properties play a key role in consumer acceptance of hard-type cheeses. In case of traditional Emmental cheese produced from raw milk the development of quality properties depends on, eg, raw milk quality and starter cultures, effects of the clotting enzyme as well as certain technological steps. Subsequent to effects on syneresis, milk acidification, proteolysis and propionic acid fermentation, total cheese quality will be influenced to a certain extent (Osl et al, 1991).

According to Steffen (1985), technological variations comprise treatments related to time-temperature-relations, variations in syneresis and mechanical factors as well as certain steps influencing compositional parameters. On the one hand, commonly observed textural defects such as a firm or insufficiently elastic cheese body (Rentsch, 1994; Sollberger, 1994) can be overcome by, eg, increasing the fat content of the cheeses. Alternatively, the dilution of raw milk or the curd/whey-mixture with water up to 20%, which reduces the amount of fermentable lactose in the green (immature) cheese, has been described as an appropriate tool to modify Emmental firmness as measured by semi-empirical rheological methods (Steffen, 1985). Especially the addition of water to the curd/whey-mixture represents a technique frequently used in traditional Emmental-producing countries such as Austria and Switzerland (Osl, 1991; Bachmann, personal communication). The aim of the present study was to monitor effects of the addition of water to the curd/whey-mixture during Emmental cheese-making on chemical composition and ripening and to evaluate modification of texture by analysing fracture properties of the cheese body.

MATERIALS AND METHODS

Cheese production and sampling

In large scale using 8000-L vats, a set of four Emmental cheeses was produced on two consecutive days by using a standard manufacturing schedule. On the first day, 0% and 10% water of 40°C were added to the curd/whey-mixture in vat A and B subsequent to curd cutting, respectively. On the second day, 10% water was added to the curd/whey-mixture in vat A and 20% water was added similarly to vat B. Four replicate series of these cheese making trials were performed within 1 month.

At pre-determined ages of 7, 14, 28 and 56 days blocks of 20 cm × 20 cm × cheese height were cut from the centre of one cheese wheel each. After removing the rind, the remaining cheese mass (approximately 4 kg) was used for analysis. Emmental wheels aged for 70, 91 and 112 days were cut into two halves and photographed. After organoleptic assessment with respect to appearance, texture and aroma an appropriate portion of the cheese body was sampled for analysis.

Chemical analyses

Grated cheese served as a basis for chemical analyses comprising gross composition parameters, proteolysis estimates and organic acids. All measurements were performed in duplicate. Dry matter was evaluated by the oven method according to the IDF standard 4A (Anonymous, 1982). pH was measured by probing a glass electrode into the compressed grated cheese. Total fat content was evaluated butyrometrically, and total nitrogen (N) by the Kjeldahl method according to IDF standard 20A (Anonymous, 1986). After air-drying and defatting with petroleum benzine, an appropriate portion served as substrate for alkaline urea polyacrylamide gel electrophoresis (Mayer, 1996).

From aqueous extracts prepared by 10-fold dilution of grated cheese and subsequent homogenisation, centrifugation in the cold and filtration, water-soluble nitrogen was determined by the Kjeldahl method (Steiger and Flückiger, 1979; Bütikofer et al, 1993). 12% trichloroacetic acid (TCA)-soluble nitrogen and 5% phosphotungstic acid (PTA)-soluble N was determined after 1:1-dilution of aqueous extracts with 24% TCA and 10% PTA and filtration, respectively. D(–)- and L(+)-lactic acid were determined by using an enzymatic method (Anonymous, 1989). Calcium and chloride content were evaluated potentiometrically (Anonymous, 1979; Tschager and Jager, 1986). Acetic acid, propionic acid and succinic acid were determined by HPLC using a cation-exchange column (eluent: 0.01 N H_2SO_4, flow: 0.8 mL /min) and detection at 210 nm (Jager and Tschager, 1983).

Viable propionibacteria count

10 g cheese mass were aseptically sampled from the cheese blocks with a cork borer, 10-fold diluted in 2% (w/v) sodium citrate and homogenised. After further preparation of decimal dilutions, propionibacteria were estimated on yeast lactate agar (Perberdy and Fryer, 1976).

Mechanical measurements

A 40-mm thick slice taken from the middle of each Emmental sample was wrapped in aluminium foil and thermostatted at 15°C overnight. Cylindrical specimens were prepared with a cork borer (16.5 mm internal diameter) and reduced to a height of 20 mm with a stretched wire cutting device just before measurement.

All uniaxial compression tests were performed at 15°C with an Instron 1011 universal testing machine (Instron Ltd, High Wycombe, UK) equipped with an environmental chamber. Prior to measurement the parallel plates were generously lubricated with paraffin oil. Specimens were compressed at 20 mm/min up to fracture. For each cheese sample, 3–5 replicate measurements were performed.

Raw data were transformed into stress σ (kPa) calculated from compressional force F (N) and corrected for cross-sectional area by applying:

$$\sigma = (F / r_0^2 \pi) (h_t / h_0)$$

(Casiraghi et al, 1985), where r_0 [m] represents the initial radius of the sample, and h_0 [m] and h_t [m] initial specimen height and height at any time t [s], respectively. As a relative measure of specimen deformation, Hencky strain ε [–] was calculated by:

$$\varepsilon = -\ln (h_t / h_0)$$

Statistical evaluation

The ANOVA and GLM procedures of a commercially available software package were used for statistical evaluation (SAS Institute, 1988).

RESULTS

Repeatability of Emmental production

In order to evaluate cheese-making repeatability, results of chemical analyses achieved from Emmental made with 10% water addition were subjected to analysis of variance (ANOVA) considering production day, cheese vat and maturation time as factors of influence. ANOVA results show clearly that neither production day nor cheese vat can be regarded as systematic sources of variation (table I). In all parameters evaluated, the significance of the ANOVA models can be attributed to significant changes during maturation. Regarding cheese pH, multiple mean comparisons did not show systematic effects on production day at an error probability level of $P < 0.01$.

Exemplary, figure 1 shows the lactic acid content of eight Emmental cheeses (10% water addition) and the corresponding dry matter content (arithmetic mean ± standard deviation) as affected by maturation. It can be clearly seen from the curves that significant maturation-induced changes override effects of production day and cheese vat (table I). Multiple mean comparisons ($P < 0.01$) confirmed significance of dry matter increase and lactic acid degradation. Based on these results, cheeses made with 10% water added to the curd/whey-mixture were grouped for further evaluations.

Effects of water addition on cheese composition

Analyses of variance were applied to chemical measures of Emmental cheeses manu-

Table I. Effects of various factors on chemical composition of Emmental cheese (10% water addition, $n = 8$) as estimated by analyses of variance (ANOVA).

Effets de différents facteurs sur la composition chimique de l'emmental (addition de 10 % d'eau, n *= 8) estimés par l'analyse de variance (ANOVA).*

Parameter[1]	*ANOVA results*			
	Model	*Production*	*Vat*	*Age*
FAT (g/kg)	ns[2]	–	–	–
DM (g/kg)	< 0.01	ns	ns	< 0.01
TN (g/kg)	ns	–	–	–
WS-N (g/kg)	< 0.01	ns	ns	< 0.01
TS-N (g/kg)	< 0.01	ns	ns	< 0.01
PS-N (g/kg)	< 0.01	ns	ns	< 0.01
CL (g/kg)	< 0.01	ns	ns	< 0.01
PH (–)	< 0.01	< 0.01	ns	< 0.01
PROP (g/kg)	< 0.01	ns	ns	< 0.01
LACT (g/kg)	< 0.01	ns	ns	< 0.01

[1] FAT, fat content; DM, dry matter; TN, total nitrogen (N); WS-N, water soluble N; TS-N, N soluble in 12% trichloroacetic acid; PS-N, N soluble in 5% phosphotungstic acid; CL, chloride; PH, pH-value; PROP, propionic acid; LACT, lactic acid. [2] ns, not significant; numeric values, probabilities P_{H_0} $(F > F_{obs})$.

[1] Paramètres : FAT : teneur en matière grasse ; DM : matière sèche ; TN : azote total (N) ; WS-N : azote soluble dans l'eau ; TS-N : azote soluble dans de l'acide trichloroacétique à 12 % ; PS-N : azote soluble dans de l'acide phosphotungstique à 5 % ; CL : chlorure ; PH : valeur du pH ; PROP : acide propionique ; LACT : acide lactique. [2] ns : non significatif, valeurs numériques, probabilités P_{H_0} $(F > F_{obs})$.

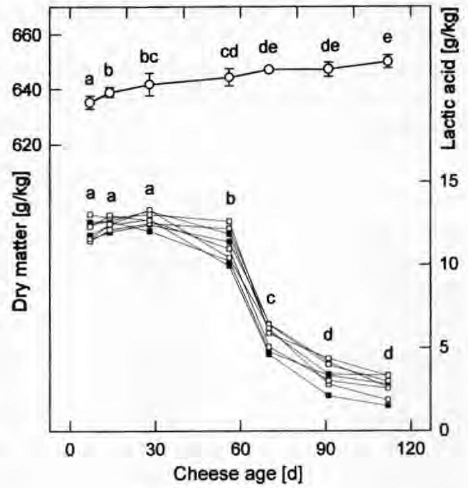

Fig 1. Effects of maturation on dry matter (○; arithmetic mean ± standard deviation; $n = 8$) and lactic acid content (□, vat A; ■, vat B) of Emmental cheeses produced with 10% water added to the curd/whey-mixture. Values marked by similar letters do not differ significantly ($P < 0.01$).

Effets de l'affinage sur la matière sèche (○, moyenne arithmétique ± écart type n = 8*) et sur la teneur en acide lactique (□ cuve A ; ■ cuve B) d'emmentals fabriqués avec 10 % d'eau ajoutée au mélange caillé/lactosérum. Les valeurs désignées par la même lettre n'ont pas de différence significative* (p < *0,01*).

factured with different amounts of water added to the curd/whey-mixture. In the model selected, maturation time and water addition served as main effects, and their interaction was considered as an additional factor of influence. In case of fat, dry matter and calcium content, only significant maturation effects, ie, increasing values with increasing cheese age attributable to water loss caused by dry ripening, were found, whereas water addition showed insignificant effects on these parameters. Fat in dry matter remained totally unaffected (table II). Additionally, a significant influence of the amount of water addition was found in chloride content and pH. As estimated by multiple mean comparison, cheese pH increased with increasing water addition, and chloride content proved to be significantly lower in cheeses produced without water addition than in Emmental manufactured with addition of 10% and 20% water.

It is evident from figure 2 that, apart from maturation effects, the development of organic acid content in Emmental cheese is heavily affected by the amount of added water. In young cheeses, differences in the lactic acid content were approximately inverse proportional to the dilution of the whey. Further degradation of lactate up to a cheese age of 16 weeks is much more pronounced in Emmental produced with 20% water. After completing maturation, lactic acid content was 6.64 g/kg, 2.69 g/kg and 1.16 g/kg for Emmental made with 0%, 10% and 20% water addition, respectively. Accordingly, the content of propionate representing the main metabolism product of the typical propionic acid fermentation in Emmental (Steffen et al, 1987) showed a direct relationship to water addition, ie, increasing values with increasing amounts of added water. ANOVAs and multiple mean comparisons confirmed the significance of water addition on organic acid content (table II). From the strong interactions it can be concluded that kinetics of lactate degradation and evolution of propionate during maturation are significantly affected by the quantity of added water.

In line with the initial decrease of the lactate content by diluting the curd/whey-mixture during Emmental production, a reduction in proteolytic activity during maturation was observed partially. Regarding relative breakdown of α_{S1}-casein and β-casein calculated from respective PAGE peak areas of casein subfractions by:

Table II. Influence of cheese age, added water and their interaction on the composition of Emmental cheese.

Influence de l'âge, de l'addition d'eau et leur interaction dans la composition de l'emmental.

Parameter[1]	*ANOVA*			*Mean comparison*[2]
	Age	*Water addition*	*Interaction*	
FAT (g/kg)	0.002[3]	ns	ns	–
DM (g/kg)	< 0.001	ns	ns	–
FDM (%)	ns	ns	ns	–
TN (g/kg)	ns	ns	ns	–
WS-N (g/kg)	< 0.001	< 0.001	< 0.001	0 > 10 > 20[4]
TS-N (g/kg)	< 0.001	< 0.001	< 0.001	0 > 10 ≥ 20
PS-N (g/kg)	< 0.001	< 0.001	ns	0 > 10 > 20
CA (g/kg)	< 0.001	ns	ns	–
CL (g/kg)	< 0.001	< 0.001	ns	0 > 10 ≥ 20
PH (–)	< 0.001	< 0.001	ns	0 < 10 < 20
ACET (g/kg)	< 0.001	< 0.001	< 0.001	0 < 10 < 20
PROP (g/kg)	< 0.001	< 0.001	< 0.001	0 < 20 < 30
LACT (g/kg)	< 0.001	< 0.001	< 0.001	0 > 10 > 20

[1] FAT, fat content; DM, dry matter; TDM, fat in dry matter; TN, total nitrogen (N); WS-N, water soluble N; TS-N, N soluble in 12% trichloroacetic acid; PS-N, N soluble in 5% phosphotungstic acid; CA, calcium; CL, chloride; PH, pH-value; ACET, acetic acid; PROP, propionic acid; LACT, lactic acid. [2] Multiple comparison of means ($P < 0.01$). [3] ns, not significant; numeric values, probabilities P_{H_0} ($F > F_{obs}$). [4] 0, 10, 20% water added to the curd/whey-mixture; >, <, significant difference.

[1] Paramètres : FAT : teneur en matière grasse ; DM : matière sèche ; TN : azote total (N) ; WS-N : azote soluble dans l'eau ; TS-N : azote soluble dans de l'acide trichloroacétique à 12 % ; PS-N : azote soluble dans de l'acide phosphotungstique à 5 % ; CA : calcium ; CL : chlorure ; PH : valeur du pH ; ACET : acide acétique ; PROP : acide propionique ; LACT : acide lactique. [2] Comparaison multiple des moyennes (p < 0,01). [3] ns : non significatif, valeurs numériques, probabilités P_{H_0} ($F > F_{obs}$). [4] 0, 10, 20 % d'eau ajoutée au mélange caillé/lactosérum ; > ; < différences significatives.

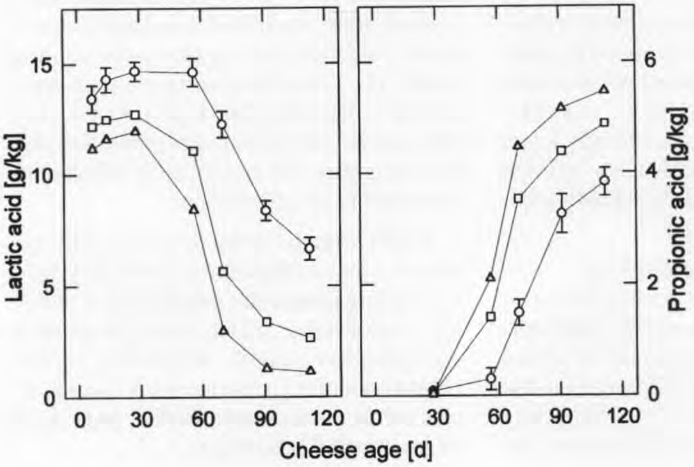

Fig 2. Mean development and selected error bars of lactic acid and propionic acid in Emmental cheeses produced without water addition (○) and with addition of 10% (□) and 20% water (△).

Évolution des teneurs moyennes et écarts types de l'acide lactique et de l'acide propionique dans de l'emmental fabriqué sans addition d'eau (○) et avec 10 % (□) ou 20 % (△) d'eau ajoutée.

$$\alpha_{S1}\text{-breakdown} = 100\,(\alpha_{S1\text{-I}} + \alpha_{S1\text{-II}}) / (\alpha_{S1} + \alpha_{S1\text{-I}} + \alpha_{S1\text{-II}})$$

$$\beta\text{-breakdown} = 100\,\gamma / (\beta + \gamma)$$

Within similar stages of ripening, mature cheeses produced with 20% added water showed significantly ($P < 0.01$) lower breakdown values of α_{S1}-casein (table III), whereas β-casein degradation remained unaffected.

Additionally, cheeses produced with water addition showed reduced secondary proteolysis as assessed by nitrogen fractionation. Figure 3 shows the influence of water addition on the development of water-soluble nitrogen (WS-N) and 12% TCA-soluble nitrogen (TS-N) which, besides maturation effects, was found to be significant after applying the ANOVA procedure as described above. Similar results were observed for 5% PTA-soluble nitrogen (PS-N), and the cheese groups produced with different levels of added water were clearly separated by multiple mean comparisons (table II). In case of WS-N and TS-N, interactions indicating effects on nitrogen degradation kinetics proved to be significant.

Table III. Influence of added water on the casein degradation in Emmental cheese during maturation.
Influence de l'addition d'eau sur la dégradation des caséines de l'emmental pendant son affinage.

Age (d)	*α_{S1}-degradation*		*β-degradation*	
	0%[1,2]	*20%*	*0%*	*20%*
56	49.3 ± 5.34[a]	41.7 ± 7.67[a]	39.7 ± 3.76[a]	43.1 ± 5.47[a]
70	65.7 ± 4.84[a]	60.3 ± 3.68[a]	47.6 ± 3.84[a]	47.2 ± 5.48[a]
91	78.4 ± 4.46[a]	63.8 ± 3.08[b]	51.9 ± 3.77[a]	52.8 ± 3.71[a]
112	82.0 ± 2.98[a]	72.1 ± 2.20[b]	53.9 ± 4.26[a]	54.6 ± 4.20[a]

[1] 0%, 20%, amount of water added to the curd/whey-mixture. [2] Mean values marked by similar superscripts do not differ significantly with respect to the amount of water added ($P < 0.01$).

[1] 0 %, 20 % : pourcentage d'eau ajoutée au mélange caillé/lactosérum. [2] Les valeurs moyennes désignées par les mêmes lettres ne sont pas significativement différentes du pourcentage d'eau ajoutée (p < 0,01).

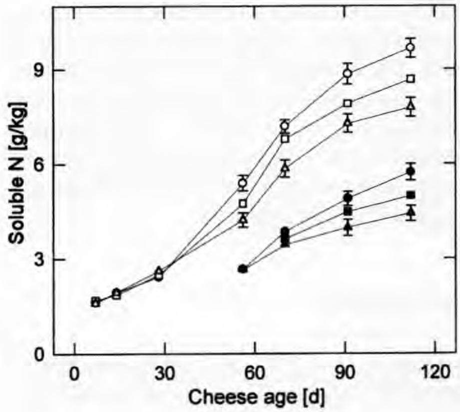

Fig 3. Mean development and selected error bars of water-soluble nitrogen (○ □ △) and 12% trichloroacetic acid soluble nitrogen (● ■ ▲) in Emmental cheeses produced without water addition (○ ●) and with addition of 10% (□ ■) and 20% water (△ ▲).

Évolution des teneurs moyennes et écarts types de l'azote soluble dans l'eau (○ □ △) et de l'azote soluble dans de l'acide trichloroacétique à 12 % (● ■ ▲) dans de l'emmental produit sans addition d'eau (○ ●) et avec 10 % (□ ■) ou 20 % d'addition d'eau (△ ▲).

Fracture properties

Selected compression curves, which were obtained by converting force and displacement into stress and strain measures, are depicted in figure 4. The shape of the stress/strain-curves generally indicated viscoelastic behaviour of the cheese mass and remained unaffected by the progress of maturation. The maximum of the curves denoted as stress at apparent fracture σ_f (kPa) correlates well with sensory perception of firmness (Rohm et al, 1991). The corresponding Hencky strain representing the deformation at apparent fracture ε_f [–] can be regarded as an instrumental measure of sensory elasticity (Luyten et al, 1987).

Figure 5 depicts average fracture properties of Emmental cheese body as affected by maturation and water addition. Generally, σ_f showed a continuous and distinct decrease with increasing ripening time. Additionally, relative differences attributable to the addition of 10% water to the curd/whey-mixture increased from approximately 10% (4-week-old cheese) to ~ 18% in case of mature Emmental. Besides maturation effects, ANOVA confirmed significance ($P < 0.01$) of the influence of water addition on σ_f. A distinct maximum of ε_f, evident at a cheese age of approximately 4 weeks, which indicates complete curd grain fusion, is followed by a further decrease. This decrease was found to be more pronounced in Emmental produced without water addition, whereas ε_f remained almost stable in cheeses produced with 20% water. Although ANOVA resulted in insignificant F-values with respect to water addition and covering the total ripening period, fracture strain proved to be significantly higher in mature cheeses (≥ 13 weeks) produced with added water.

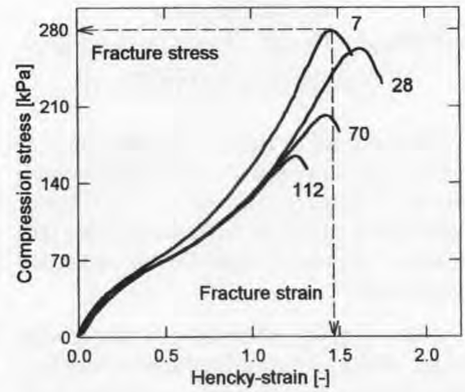

Fig 4. Stress/strain-curves of Emmental cheeses. Numbers refer to cheese age in days.

Courbes de contrainte et de déformation à la fracture de fromages emmental. Les nombres font référence à des fromages dont l'âge est exprimé en jours.

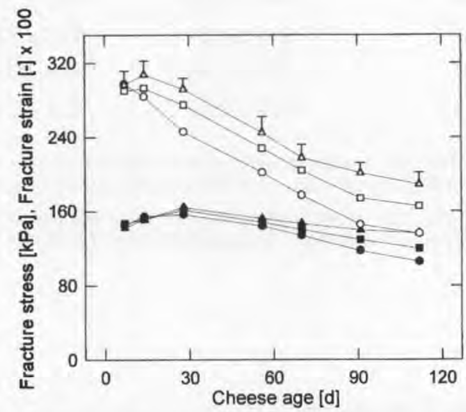

Fig 5. Mean development and selected error bars of apparent fracture stress (○ □ △) and apparent fracture strain (● ■ ▲) in Emmental cheeses produced without water addition (○ ●) and with addition of 10% (□ ■) and 20% water (△ ▲).

Évolution des teneurs moyennes et écarts types de la contrainte à la fracture apparente (○ □ △) et de la déformation à la fracture apparente (● ■ ▲) dans l'emmental, sans addition d'eau (○ ●), avec addition de 10 % (□ ■) et de 20 % (△ ▲) d'eau.

Eye formation

As can be expected from the chemical measures the proportional reduction of the amount of fermentable lactose in the cheese wheels is reflected by the pH values of the cheese mass which, in young (1 week) Emmental, were found to be 5.37 and 5.48 for cheeses produced without water and with the addition of 20% water, respectively. Between these cheese groups, pH differences remained almost constant during ripening. Corresponding values were, eg, 5.45 and 5.58 (4 weeks), 5.58 and 5.73 (10 weeks) and 5.65 and 5.75 (16 weeks). Higher cheese pH in cheeses with added water obviously enhances the development of propionibacteria showing a pH optimum of approximately 7.0 (Langsrud and Reinbold, 1973; Walstra et al, 1987). It can be seen from figure 6 that both viable count and kinetics of viable count development of propionibacteria are significantly ($P < 0.01$) affected, which leads to varying propionic acid contents of the resulting cheeses (cf fig 2). In line with the activity of propionibacteria the development of carbon dioxide and, consequently, eye formation is also forced by the addition of water. Exemplary, cross-sections of 10-week-old Emmental cheese produced with varying amounts of added water, which clearly show a different appearance, are depicted in figure 7.

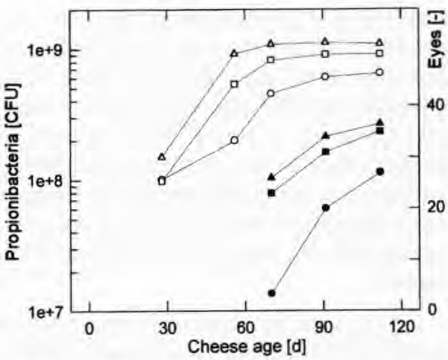

Fig 6. Mean viable count of propionibacteria (○ □ △) and eyes per cross-section (● ■ ▲) in Emmental cheeses produced without water addition (○ ●) and with addition of 10% (□ ■) and 20% water (△ ▲).

Nombre moyen de bactéries propioniques (○ □ △) et d'ouvertures (yeux) par coupe transversale (● ■ ▲) dans de l'emmental fabriqué sans addition d'eau (○ ●), avec addition de 10 % (□ ■) et de 20 % (△ ▲) d'eau.

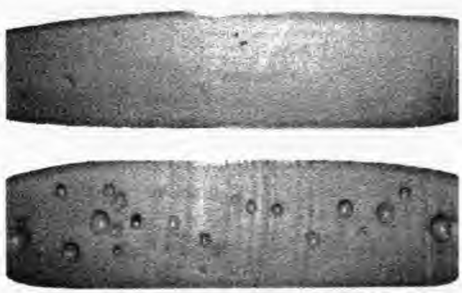

Fig 7. Cross-sections of 10-week-aged Emmental produced without water addition (upper image) and with 20% added water (lower image).

Coupe transversale d'emmental de 10 semaines fabriqué sans addition d'eau (photo du haut) et avec addition de 20 % d'eau (photo du bas).

DISCUSSION AND CONCLUSIONS

It is evident from the results outlined above that the addition of water to the curd/whey-mixture during cheese-making influences the characteristics of Emmental cheese to a certain extent. The initial dilution of the whey with the accompanied reduction of fermentable lactose and resulting differences in the lactic acid content of the young cheeses influences the kinetics of secondary fermentation and the intensity of proteolysis during ripening and, consequently, the characteristics of the mature cheese.

Regarding mechanical properties as a main feature in consumer acceptance, the addition of water after curd cutting resulted in an increase of both apparent stress and strain at fracture. It has been reported in previous studies (Rohm et al, 1995; Jaros et al, 1996) that sensory ratings performed by cheese graders using a five-point optimum scale resulted in a significant inverse relationship between sensory values and fracture stress covering a σ_f-range from 70 to approximately 250 kPa. With respect to sensory firmness, water addition therefore results in cheeses with lower acceptability as compared to Emmental produced without water addition, which may be partly compensated by increasing the fat content of the cheeses.

Figure 8 shows previously unpublished results of 93 mature Emmental cheeses, which were analysed using uniaxial compression as well as organoleptically on a five-point optimum elasticity scale by a panel of experienced cheese graders. As referred to in figure 5, the addition of water during the cheese-making process results in an increase of fracture strain which, in mature cheese, proved to be approximately 0.15 units per 10% added water. Therefore, it can be concluded that this increase may obviously correspond to improved sensory ratings, which show a distinct optimum at $\varepsilon_f \sim 1.15$–1.30.

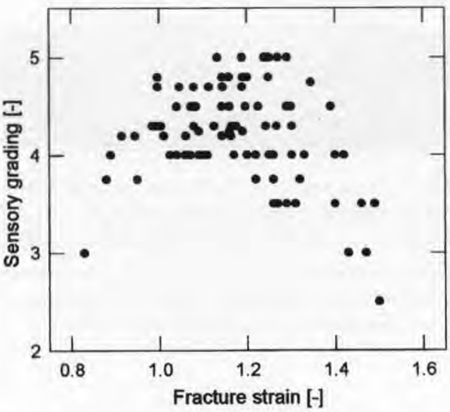

Fig 8. Relationship between apparent fracture strain and sensory grading of mature Emmental cheeses.

Relation entre la déformation apparente à la fracture et le gradage sensoriel de l'emmental affiné.

From these points of view, water addition seems to be an appropriate tool to produce Emmental cheeses with comparable gross composition but with an accelerated propionic acid fermentation and corresponding eye formation, an increased and a more stable elasticity and, consequently, with improved storage ability. Consequently, the risk of late fermentation, which is known to be higher in cheeses with inappropriate elasticity (Ginzinger et al, 1992) can be appropriately reduced.

ACKNOWLEDGMENTS

The study has been supported by part of research grants L689/91 (Department of Dairy Science and Bacteriology) and AM40/92 (Federal Research Institute of Alpine Dairying), granted both by the Austrian Ministry of Agriculture and Forestry.

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