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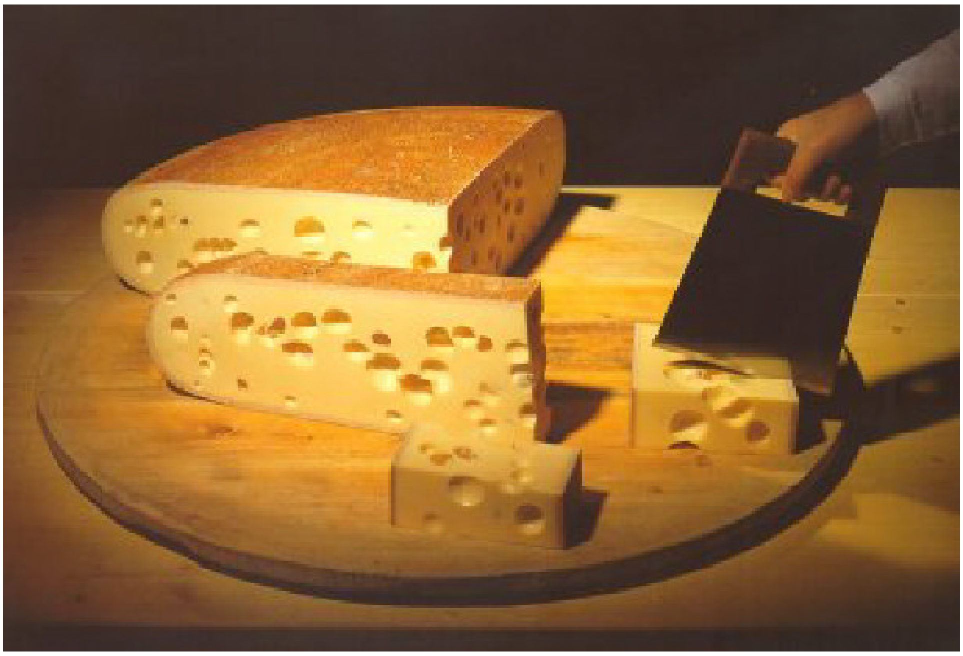

Swiss-Type Cheese

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Swiss-Type Cheese

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Introduction

Swiss-type cheeses were originally manufactured in the Emmental (Emmen valley) in Switzerland, their precursors were mountain cheeses. Emmentaler is probably the best-known Swiss-type cheese and is frequently referred to simply as „Swiss cheese“. There is no internationally recognised definition of Swiss-type cheeses that differentiates them from other varieties. Swiss-type cheeses have round regular eyes which vary in size from medium to large.

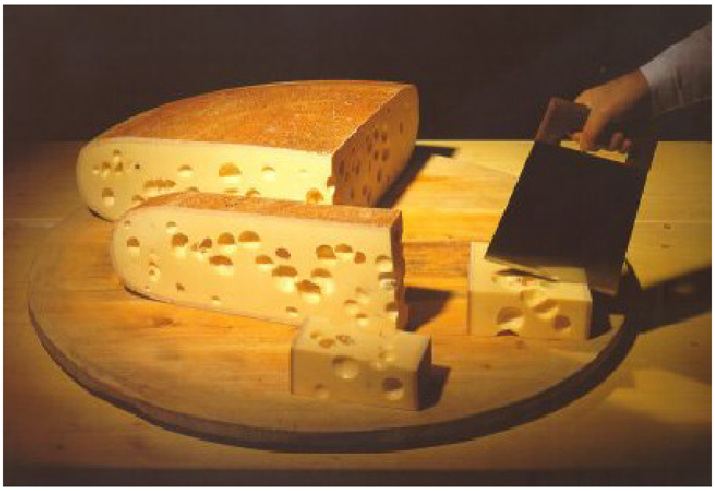
For the manufacture of Emmentaler and other Swiss-type cheeses propionibacteria are used to achieve the characteristic eyes and nutty flavour. The characteristics of Swiss-manufactured Emmentaler are:

- cylindrical shape
- firm dry rind
- weight: 60-130 kg
- 1000-2000 round eyes, diameter 1-4 cm
- flavour: mild, nutty, slightly sweet, becoming more aromatic with increasing age
- cheese body: ivory to light-yellow, slightly elastic

Today, Emmentaler cheese is produced in many countries and a great variety of other Swiss-type cheeses is also available on the market, including Svenbo, Jarlsberg, Greve, Maasdamer, Leerdamer, Comté, Beaufort and Swiss cheese. Their body and texture correspond to those of hard and semihard cheeses.

Descriptions and analytical values presented in this chapter focus on Swiss Emmentaler cheese. Besides some general information are given.

Figure 1:
Emmentaler cheese from Switzerland, - the original Swiss-type cheese



Production statistics

The annual production of Emmentaler cheese in Switzerland is around 45000 t. Swiss-type cheeses are an important part of cheese production in the European Union: France produces annually 275000 t, the Netherlands 89400 t, Germany 88300 t, Sweden 28400 t, Finland 26400 t, Austria 12800 t, Denmark 6600 t and Ireland 5000 t. The world production in 1997 was 500000 t.

Technology

In Switzerland Emmentaler cheese has to be manufactured from raw milk of silage free fed cows, therefore the bacteriological requirements are particularly stringent. Swiss Emmentaler is heated to 52-54 °C after cutting. During pressing, the temperature remains around 50 °C for many hours. At this temperature, the curd dries and undesirable micro-organisms are eliminated. That's why the cooking temperature is an important part of the hurdle technology for ensuring the hygienic safety of Swiss Emmentaler cheese produced with raw milk. The other steps of the hurdle technology are the high quality of the raw milk, the short storage of the milk prior processing, the fast and complete acidification as well as the long ripening period of at least four, but quite often even more than 8 months.

An important step in the technology of Swiss Emmentaler cheese is the addition of water (12-18 %) into the milk or into the curd. This leads to a high pH-value after the lactic fermentation (5.20 - 5.30) and consequently accelerates the propionic fermentation, leads to a soft and elastic texture and is also the explanation for the high calcium content of the cheeses.
To initiate the typical propionic acid fermentation, the ripening temperature for the cheese must be raised to approximately 20-24 °C for a certain period of time. As soon as the development of sufficient eyes is accomplished, the propionic acid fermentation is retarded by storing the cheese at a lower temperature (10-13°C).

Table 1 shows the average composition of Swiss Emmentaler cheese at different stage of ripening. The very low salt content is typical for Swiss Emmentaler cheese.

Today, Swiss-type cheeses are manufactured in many countries by technologies differing from traditional Swiss procedures. Considering the technological aspects, Swiss-type cheeses are always cooked cheeses. On the other hand, the treatment of milk, the extent of mechanisation, the weight and shape, the average composition (hard or semi-hard varieties both with different fat contents), rip-

Table 1: Average composition of Swiss Emmentaler cheese (Mean values ± standard deviation for N=30)

Parameter		Cheese age				
	Unit	1 day	20 days	3 months	6 months	1 year
water	g/kg	376.1 ± 5.8	365.8 ± 4.7	353.0 ± 6.3	347.5 ± 7.2	350.2 ± 6.1
protein	g/kg	nd	nd	283.7 ± 6.3	284.8 ± 5.9	284.2 ± 6.4
fat	g/kg	nd	nd	nd	322.2 ± 9.7	321.0 ± 9.0
salt	g/kg	nd	2.28 ± 0.50	4.19 ± 1.01	3.69 ± 0.7	nd
pH	-	5.30 ± 0.04	5.52 ± 0.04	5.65 ± 0.03	5.78 ± 0.03	5.70 ± 0.07

nd = not determined

ening time and shelf life of foreign Swiss-type cheeses are frequently very different from the original. Quite often, the process is specifically designed so that no rind forms on the cheese (maturation takes place in vacuum-packed plastic wrapping) for mass-production purposes.

Cultures

1. Lactic acid bacteria

Thermophilic lactic acid bacteria starters are usually mixed cultures of Lactobacilli (*Lactobacillus helveticus, L. delbrueckii ss. lactis*) and Streptococci (*Streptococcus salivarius ss. thermophilus*). They guarantee the homofermentative catabolism of lactose to > 90% lactate. Lactose is generally metabolised via the fructose-1,6-diphosphate (Emden-Meyerhof Parnas scheme) pathway and is fully hydrolysed within 4 to 6 hours after addition of the lactic starters. Lactic acid fermentation is completed after 24 hours. Galactose from lactose breakdown is not utilised by the streptococci, but further metabolised by the lactobacilli. For streptococci the optimum temperature for growth is between 38 and 42°C and their pH-optimum is between 6.0 and 6.5. The streptococci only produce L(+)-lactic acid, whereas *L. delbrueckii ss. lactis* converts lactose entirely to D(-) lactate. Both isomers are produced by *L. helveticus.* The lactobacilli grow best between 38 and 45°C and a pH range of 5.0 to 5.5. The lactic acid not only inhibits the development of undesired micro-organisms but also influences the syneresis and thus the texture and proteolyis in the cheese. During cheese ripening the proteinases and peptidases of lactobacilli play a major role in the breakdown of casein. Some decades ago, for the manufacture of Swiss Emmentaler, *L. helveticus* was a major component of starter cultures. Due to its intensive proteolytic activity, which promotes late fermentation, it was replaced by *L. delbrueckii ss. lactis.*
In certain areas (where the cheese milk is collected twice daily) a mesophilic culture of lactococci (*Lactococcus lactis*) is added to the evening milk for pre-ripening of the milk.

2. Propionic acid bacteria

Propionic acid fermentation is essential in all Swiss-type cheeses to obtain the characteristic eyes and the nutty taste. The fermentation is initiated by the addition of propionic acid bacteria cultures, usually containing the species *Propionibacterium freudenreichii*. These organisms are gram positive and appear under the microscope as short rods. Their pH optimum for growth is between 6.0 and 7.0 (maximum 8.5, minimum 4.6). The optimal growth temperature is 30°C, but growth also occurs at 14°C. Propionic acid bacteria are anaerobic to aerotolerant. For Swiss Emmentaler the inoculation size is very small (only a few hundred colony forming units per vat containing about 1000 liters of milk). Propionic acid fermentation begins about 30 days after the start of manufacture at about 20 - 24°C for roughly 7 weeks and then continues at a slower rate at 10 to 13°C.
In cheeses ready for consumption, about 10^8 to 10^9 cfu/g of propionic acid bacteria are present.
The lactic acid produced by the lactic starters is broken down by the classic metabolic pathway to propionate, acetate and CO_2 as follows:

$$\text{3 lactate} \downarrow \text{2 propionate} + \text{acetate} + CO_2 + \text{ATP}$$

When aspartate is present this fermentation is combined with the deamination of aspartate to succinate:

$$\text{lactate} + \text{2 aspartate} \downarrow \text{acetate} + CO_2 + \text{2 succinate} + 2\ NH_3 + \text{ATP}$$

Therefore in the presence of aspartate more lactate is converted to acetate and CO_2 than to propionate.
Strains capable of deaminating aspartate ferment higher amounts of lactate and are thus present in cheese at higher levels than strains which do not utilise

aspartate. This higher concentration of propionibacteria is responsable for increased amounts of acetate, propionate, succinate and CO_2. and therefore for more intensive flavour and larger eyes. The capability of strains to utilise aspartate is a very important factor when selecting new cultures. A very high aspartase activity will increase the amount of CO_2 and therefore the risk of late fermentation. However, moderate aspartase activity may have a positive effect on the quality of Emmentaler as regards eye formation and the flavour intensity.
Another metabolic pathway may also be used by the propionibacteria, namely the formation of succinate by CO_2 fixation which leads to a decrease in CO_2 levels. The role of this metabolic pathway may play a small role but is not yet fully understood.
The proteolytic activity of the propionic acid bacteria is of little importance. The lipolytic activity, however, may influence the development of flavour during the ripening of the cheese.

3. Facultatively heterofermentative lactobacilli

Facultatively heterofermentative lactobacilli, gram positive microaerophilic rods, ferment hexoses almost exclusively to lactic acid via the fructose-1,6-diphosphate pathway. But at low levels of glucose they also ferment hexoses to lactic acid, acetic acid, ethanol and formic acid. Pentoses are catabolised to lactic acid and acetic acid by an inducible phosphoketolase.
This group of micro-organisms contains, among others, *L. casei* and *L. rhamnosus*, which are indigenous to raw milk. During cheese ripening they grow by utilising citrate which is found in the fresh unripened cheese. Both species are able to grow at 15°C. *L rhamnosus* is the only species within the facultatively heterofermentative lactobacilli able to develop at 45°C.
By adding cultures of *L. casei* or *L. rhamnosus* the intensity of the propionic acid fermentation can be controlled and the risk of late fermentation minimised. The exact mechanism is not yet understood but it is known that bacteriocin production is not involved. It is supposed that competition between the different organisms for available substrates is involved. Cultures of facultatively heterofermentative lactobacilli are widely used by producers of Swiss Emmentaler. The cultures are added to the cheese milk together with the starter cultures.

4. Cultures used for other Swiss-type cheeses

The propionic acid fermentation is common for all Swiss-type cheeses. Usually thermophilic lactic starters such as *Lactobacillus helveticus, L. delbrueckii ss. lactis* and *Streptococcus salivarius ss. thermophilus* are also used. Some of these cheese types are semi-hard cheeses made with pasteurized milk. Therfore mesophilic lactic acid bacteria such as *L. lactis* may also be used. The propionic acid fermentation is also carried out with *P. freudenreichii*. An exception is Comté in France which is produced without the addition of propionic acid bacteria to the cheese milk.

Eye formation

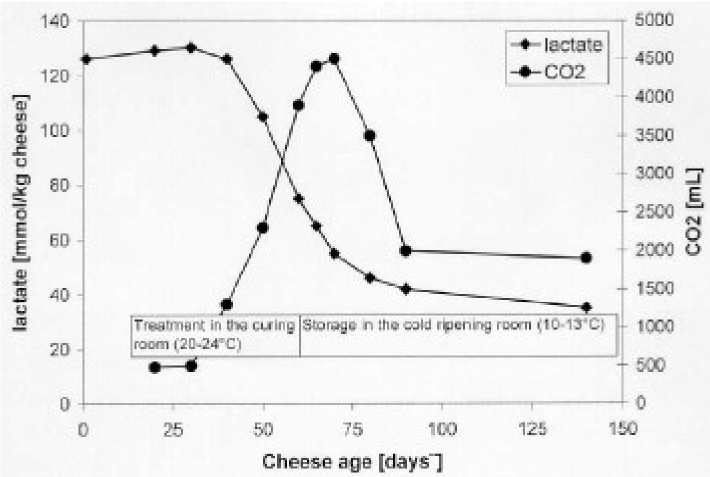
The characteristic eye formation of Emmentaler cheese is due mainly to the presence of carbon dioxide produced by propionic acid bacteria during lactate breakdown. As shown in **Figure 2**, carbon dioxide diffusion begins before propionic acid fermentation since small quantities of carbon dioxide are already produced during lactic acid fermentation. The steep rise in the production of carbon dioxide coincides with the onset of the propionic acid fermentation. After 60 to 70 days, carbon dioxide production and diffusion rates are identical. The diffusion rate drops as soon as the cheese loaves are transferred from the warm (22°C) to the cold ripening room (10-13°C).

Eye formation is a long process. At the beginning, i.e. about 30 days after manufacture, only a few eyes appear; thereaf-

ter, the number of new holes increases progressively. The maximum rate is attained after about 50 days, which is also the time of rapid eye enlargement. The appearance of new eyes declines with decreasing carbon dioxide production and the simultaneous hardening of the cheese body. Nevertheless, eye formation sometimes continues in the cold room.
The number of eyes is increased by the inhomogenity of the curd, physical openess and hydrogen forming micro-organisms. Centrifugation and thermisation of the milk or application of vacuum after filling of the curd during pressing of the cheese are performed in order to obtain a large number of eyes. In a cheese loaf of 80 kg, total carbon dioxide production is about 120 L before the cheese is sufficiently aged for consumption. About 60 L remain dissolved in the cheese body, approximately 20 L are found in the eyes and approximately 40 L diffuse out of the loaf.
Carbon dioxide pressure passes through two major phases. The first covers the period of proper eye formation in the warm ripening room. During this period, the carbon dioxide pressure remains relatively low, between 1500 and 2500 Pa, because of the low resistance of the soft cheese mass to gas compression at 22-24°C. During storage, i.e. second stage, the carbon dioxide pressure increases to 4000-8000 Pa. The differences in pressure between various loaves are higher in the second stage than in the first. The pressure increase in the second stage is explained by the higher resistance to gas compression of the cheese mass, which is due to a decrease in temperature from 22 to 12°C and by continued gas production. During the first stage there is a marked pressure increase within the eyes.

Figure 2: Lactic acid fermentation, lactate breakdown and CO_2 loss during ripening of Emmentaler cheese

(Figure adapted from Steffen C, Eberhard P, Bosset JO, Rüegg M [1993] Swiss-Type Varieties. In: Fox PF (ed.) *Cheese: Chemistry, Physics and Microbiology,* pp 83-110, Chapman & Hall, London)



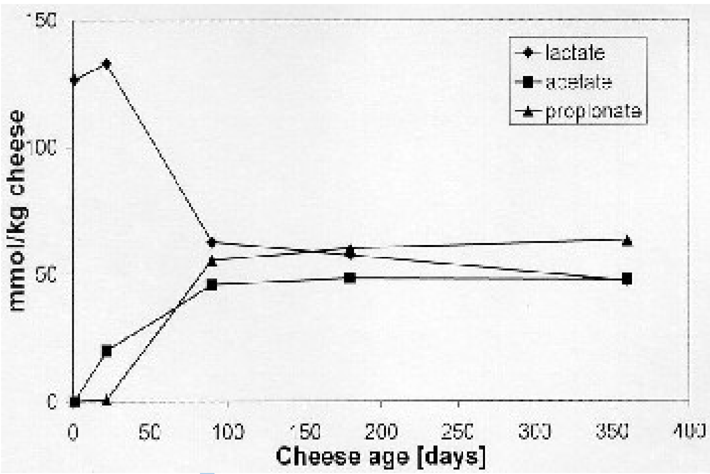
Ripening patterns

In Swiss type cheese with a dry rind, proteolysis is apart from propionic acid fermentation, the most important factor for ripening and flavour development. In Cheddar and Gouda cheese types, rennet plays an important role in proteolysis. In Swiss type cheeses, however, rennet is inactivated during the heating of the curd and does not play a significant role in proteolysis. In these cheeses, indigenous milk proteinase and the proteolytic enzymes of lactic acid bacteria are mainly responsible for protein breakdown. Generally, thermophilic lactobacilli exert a stronger proteolytic effect than mesophilic lactococci, whereas thermophilic streptococci have very little influence on protein breakdown. The proteolytic activity of propionic acid bacteria is not significant. For Emmentaler cheese, raw milk is processed and certain activity of the indigenous flora of milk may possibly be involved in proteolysis. The proteolytic enzymes of psychrotrophs from milk after prolonged cold storage sometimes influences ripening and flavour development. Proper selection of strains of lactic acid bacteria for starter cultures and the application of appropriate measures during manufacture in order to obtain the desired number of lactobacilli in the young cheese are the best means of controlling proteolysis. The activities of prote-

olytic enzymes in cheese further depend on the water content, lactic acid concentration, pH, salt concentration, water activity, copper content, storage temperature and time.
Common indices of proteolysis are the concentration of water soluble nitrogen (WSN), 12 % trichloroacetic acid soluble nitrogen (TCA-SN), sum of free amino acids, acetic and propionic acid. The amino acids are decomposed enzymatically by decarboxylation, deamination and transamination, but non-enzymatic reactions are also involved. The products arising from the catabolism of amino acids are: aldehydes, ketones, short chain acids, alcohols, aromatic acids, a-keto acids, hydrocarbons, amines, ammonia and sulfur compounds.

Table 2 shows typical ripening parameter of Swiss Emmentaler cheese at 1 day, 20 days, 3, 6, and 12 months. The lactate concentration after 20 days is typically over 130 mmol/kg and shows its maxmium at 20 days with 133 mmol/kg. Due to propionic acid fermentation, lactate is decomposed to carbon dioxide, acetic and propionic acid and the lactate concentration reduces very fast up to 3 months. After 60-70 days the cheeses are transferred to the cold ripening room and the lactate consumption is much slower, after 12 months more than 40 mmol/kg is still present (**Figure 3**).

Figure 3: Lactate breakdown and production of propionate and acetate during ripening of Emmentaler cheese.



Lactic acid fermentation produces about 20 mmol/kg acetate in the first 20 days. By propionic acid fermentation the acetate and propionate concentration increases up to 48 and 63 mmol/kg, respectively.
The concentration of n-caproic acid after 12 months is < 0.8 mmol/kg and shows that lipolysis is not significant in Swiss type cheese. By the use of milk of silage free fed, butyric acid fermentation can be suppressed without additon of lysozyme, nitrate or bactofugation and typical butyric acid concentration after 12 months is < 2 mmol/kg.

The formation of WSN and TCA-SN is increased during the storage in the warm ripening room and reaches 19.1 and 12.1% of total nitrogen (TN) after 3 months, respectively. After 12 months WSN and TCA-SN is at 28 and 21 % of TN, respectively. The accumulation of the sum of free amino acids is 5.7 after 3 months and 12.5 % of TN after 12 months. The content of arginine, a- and g-amino butyric acid after 12 months is below 200 mg/kg. The median concentration of tyramine and histamine is < 15 mg/kg (range 1 – 300 mg/kg) whereas the other biogenic amines tryptamine, putrescine, iso-pentylamine and cadaverine are only present in traces below 10 mg/kg after 12 months.
The sum of free amino acids measured after 1 day with the Cd-ninhydrin method and the TCA soluble nitrogen after 20 days allow an early prediction of flavour and texture development in Emmentaler cheese. These two parameters showed a good correlation with the index of maturity, intensity of aroma, saltiness and sourness from 3 months old cheese. The higher the content of free amino acids after 1 day, the lower the stress and strain at fracture at 3 and 6 months.
Emmentaler cheese can be found today on the market in a wide range of stage of maturation. Very young cheese (< 4 months) with TCA-SN below 12 % of TN up to extra mature cheese with TCA-SN of 23 % of TN. Other Swiss type cheeses are normally consumed very young and

Table 2: Ripening parameters of Emmentaler cheese (Mean values ± standard deviation for N=10)

Parameter		Cheese age				
	Unit	1 day	20 days	3 months	6 months	1 year
L-lactic acid	mmol/kg	62.7 ± 4.8	67.1 ± 4.1	33.2 ± 8.7	31.1 ± 9.3	25.4 ± 8.1
D-lactic acid	mmol/kg	63.9 ± 6.0	65.8 ± 6.0	29.4 ± 4.9	26.3 ± 4.3	21.6 ± 6.7
succinic acid	mmol/kg	nd	nd	3.6 ± 0.6	4.0 ± 0.6	5.1 ± 2.8
acetic acid	mmol/kg	nd	20.0 ± 1.9	45.8 ± 2.0	48.4 ± 1.3	47.6 ± 2.5
propionic acid	mmol/kg	nd	0.6 ± 1.1	55.4 ± 5.3	60.1 ± 4.4	63.2 ± 4.2
butyric acid	mmol/kg	nd	0.2 ± 0.1	0.8 ± 0.2	1.1 ± 0.2	1.7 ± 0.9
water soluble nitrogen	mmol/kg	nd	218 ± 17	610 ± 31	693 ± 33	901 ± 28
12 % trichloroacetic acid soluble nitrogen	mmol/kg	nd	90 ± 9	386 ± 39	469 ± 47	683 ± 60
sum of free amino acids	g/kg	nd	2.2 ± 0.5	16.1 ± 3.7	22.7 ± 3.2	35.6 ± 4.8
water activity		nd	nd	0.988 ± 0.005	0.973 ± 0.004	0.972 ± 0.003

nd = not determined

do not show intensive proteolysis.
In recent years a lot of research work was done in acceleration and controlling of the cheese ripening process. Starter and nonstarter micro-organisms were treated by heating, freezing, spray- or freeze-drying and were genetically modified to have a better steering of the whole cheese ripening. Despite promising results in cheese, the industrial use of attenuated or modified micro-organisms is not significant.

Textural characteristics

Cheese body and texture are very important quality aspects for both dealers and consumers. Variations from what is considered normal in body and texture within the same cheese variety are not tolerated since there is a closed relationship between the body and the texture and other qualities such as eye formation, taste and shelf-life. The structure depends to a great extent on the microstructure inside the curd particles, whereas the body consistency is characterised by the reaction of the cheese mass to compression.
The structure of the cheese body can be firm or soft and the consistency short (coarse, brittle) or long (tough, elastic).

Universal testing machines are used to determine some important body characteristics. **Table 3** shows the development of rheological parameters and penetrometry during ripening from 3 to 12 month. The texture of Emmentaler changes during ripening from elastic and relatively soft to less elastic, friable and firmer. **Figure 4** shows the typical texture profil of 6 month old Emmentaler cheese. The profile is similar to other hard cheese type varieties.

Because of the low water content, Swiss type cheese melts at relatively high temperatures. The average softening point measured with an automatic dropping point apparatus is at 74°C.
Very young (< 3 month), fat reduced or semihard Swiss type cheese are nowadays also available on the market. No or only a very thin rind is built, if the cheese loafs are ripened in plastic foil, therefore the diffusion of CO_2 is increased and eye formation is significantly reduced. Even cheese without eyes are today sold as Swiss type cheese!

Flavour characteristics

Flavour development in cheese is very much depending of the microbial compo-

sition of milk. Whilst the indigenous flora of milk is generally composed of unwanted micro-organisms, which can influence the flavour directly by their fermentative activities or indirectly by other enzymatic reactions, the desired lactic acid bacteria must be added to the cheese milk in the form of starter cultures. The additon of rennet and the different operations involved in cheesemaking and cheese ripening influences the flavour development. In Switzerland, Emmentaler cheese is made from raw milk. Certain sapid compounds in milk are in fact lost and others are produced when it is subjected to thermisation or pasteurisation before processing. The high temperatures applied during the early stages of manufacture and pressing of Emmentaler cheese are essential for flavour development. Other important factors are the fermentation and ripening processes and even their size and shape.
For analytical reasons, the flavour components are generally divided into two major groups; the volatile and the non-volatile compounds.
The volatile compounds include volatile short chain acids (**Table 2**), primary and secondary alcohols, methyl ketons, aldehydes, esters, lactones, alkanes, aromatic hydrocarbons and different sulfur and nitrogen containing compounds (**Table 4**). Methional, acetic and propionic acid are the most important volatile compounds for the typical Emmentaler flavour. Ethyl butanoate, ethyl 3-methylbutanoate and ethyl hexanoate contribute to the fruity odour note. The two furanones are responsible for the caramel-like flavour in Emmentaler cheese.
The non volatile group is composed of peptides, free amino acids, amines, organic acids (**Table 2**), salt (**Table 1**) and minerals (**Table 5**).
The peptides and free amino acids contribute to the background flavour of cheese. Free glutamic acid is mainly responsible for the umami taste. Salt (NaCl) and other minerals influence directly the saltiness and indirectly the total aroma intensity of cheese.
During ripening from 3 to 12 months the intensity of odour and aroma increase from 3.0 to 3.6 and 2.5 to 3.7, respectively (**Table 6**). Saltiness and sourness increases in the same period by about 0.5 units. Sweetness and bitterness slightly decrease during ripening. Due to the propionic acid fermentation, the sweet flavour is about 1 – 1.5 units higher than in other hard type cheese varieties without propionic acid fermentation.
Cheese off-flavour depends quite often on the properties of the cheese milk. Certain plants and feed-stuffs such as bulbous plants, leeks, vegetable wastes, herb mixtures and different mineral salt mixtures fed to dairy cows can influence the taste of milk and produce off-flavours. Certain milk enzymes can induce flavours, e.g. lipase can induce rancidity.

Swiss type cheese can be found today on the market in a wide range of maturation. Very young, elastic cheese with the typical sour lactic aroma and sweet taste up to very long ripened cheese (in humide caves) with a more intensive flavour and a nutty and spicy note.

Defects

Table 3: Results of penetrometry and uniaxial compression test of Emmentaler cheese during ripening (Mean values ± standard deviation for N=10)

Parameter	Unit	Cheese age 3 months	Cheese age 6 months	Cheese age 1 year
Penetrometry	mm	3.7 ± 1.0	2.5 ± 0.3	4.6 ± 0.6
Strain at fracture	%	68.9 ± 3.2	63.7 ± 2.5	46.5 ± 5.4
Stress at fracture	kN/m^2	614 ± 121	437 ± 58	319 ± 48
Stress at 33% deformation	kN/m^2	147 ± 16	157 ± 20	244 ± 30

Excessive proteolysis gives an overripe and sharp taste and a shorter body consistence. This defect becomes particularly evident when a large amount of casein is decomposed into low-molecular compounds (high TCA-SN level). The additional carbon dioxide released by decarboxylation clearly reduces the keeping quality of the cheese and leads to oversized and oval eye formation and taller loaves. The cheese body often cannot withstand the pressure of the gas and cracks or splits appear (see **Figure 5**). This defect is called late or secondary fermentation. As previously mentioned, excessive aspartase activity raises the risk of late fermentation.

Frequently, the course of proteolysis in a cheese loaf varies from one zone to the other, a phenomenon that is due to temperature changes in the cheese loaf during lactic acid fermentation. Since the outer zone cools faster, it often develops a bacterial flora which is proteolytically more active than the micro-organisms in the centre of the loaf. This usually leads to cheese defects such as short and firm body, sharp taste, or the development of white colour under the rind.
Butyric acid fermentation is totally undesirable, since lactate fermentation by *Clostridium tyrobutyricum* into butyric acid, acetic acid, carbon dioxide and hydrogen causes the cheese loaf to blow. Even in small amounts, butyric acid is unfavourable to flavour development.

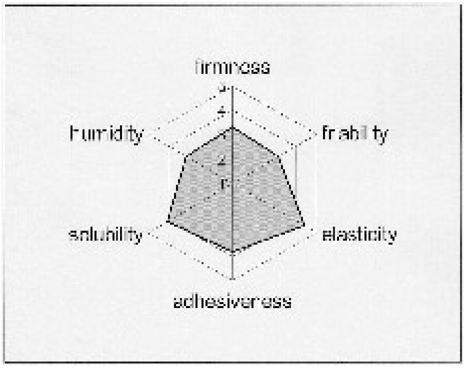


Figure 4:
Texture profile of 6 months old Emmentaler cheese.
(Figure adapted from Lavanchy P., Bütikofer U. [1999] Caractérisation sensorielle de fromages à pâte dure ou mi-dure fabrigués en Suisse. Mitteilung aus Lebensmittel-untersuchung und Hygiene 90:670-683)

Table 4:
Concentration of odorants (per kg dry matter) in Emmentaler cheese (Meanvalues ± standard deviation for N=4)

Odorant			**Cheese age**	
	Amount	**3 months**	**6 months**	**1 year**
2,3-Butandione	µg	431 ± 147	605 ± 354	531 ± 470
2-Methylbutanal	µg	181 ± 40	251 ± 43	372 ± 88
3-Methylbutanal	µg	145 ± 22	167 ± 16	152 ± 15
Ethylbutanoate	µg	27 ± 17	73 ± 23	148 ± 72
Ethyl 3-methyl butanoate	µg	0.40 ± 0.16	0.78 ± 0.21	2.48 ± 1.25
2-Heptanone	µg	522 ± 60	770 ± 57	2783 ± 1517
Dimethyltrisulfide	µg	0.11 ± 0.10	0.16 ± 0.08	0.21 ± 0.16
Methional	µg	67 ± 33	68 ± 22	50 ± 6
Ethyl hexanoate	µg	51 ± 21	164 ± 63	351 ± 156
1-Octen-3-one	µg	0.06 ± 0.02	0.05 ± 0.02	0.06 ± 0.02
4-Hydroxy-2,5-dimethyl-3(2H)-furanone	µg	1186 ± 276	658 ± 297	1002 ± 387
5-Ethyl-4-hydroxy-2-methyl-3(2H)-furanone	µg	253 ± 72	255 ± 86	547 ± 232
2-sec-Butyl-3-methoxy-pyrazine	µg	0.07 ± 0.03	0.05 ± 0.03	0.04 ± 0.01
Skatole	µg	47 ± 15	34 ± 6	37 ± 10
δ-Decalactone	µg	3751 ± 1216	1680 ± 97	1171 ± 132
3-Methylbutyric acid	mg	20 ± 10	30 ± 10	30 ± 10
Ammonia	mg	560 ± 150	720 ± 160	970 ± 190

Therefore, in Switzerland, Emmentaler cheese have to be manufactured from milk of silage free fed cows, because feeding cows with silage of low microbiological quality is the primary way of contamination of the milk with spores of these micro-organisms. In other countries, spores are either eliminated by physical treatment i. e. centrifugation or microfiltration prior to processing or germination is restricted by additives like nitrate, lysozyme or nisin which are, however, not permitted in Switzerland.

A particularly serious defect results from the eventual presence of *Clostridium sporogenes*. This sporeformer brings about non-specific very intense proteolysis, leading to putrid spots.

Taste component	Cheese age		
	3 months	6 months	1 year
Glutamic acid	5.4 ± 0.6	8.1 ± 0.3	11.6 ± 1.2
Sodium*	5.2 ± 0.6	4.5 ± 0.2	4.5 ± 0.7
Potassium*	1.3 ± 0.1	1.0 ± 0.1	1.2 ± 0.1
Magnesium*	0.7 ± 0.1	0.6 ± 0.1	1.0 ± 0.1
Calcium*	6.6 ± 0.8	6.5 ± 0.6	10.6 ± 0.7
Phosphate*	10.6 ± 1.2	13.9 ± 1.5	13.2 ± 0.6

* concentration in the aqueous extract

Table 5:
Concentration of non-volatile components (g/kg dry matter) in Emmentaler cheese (Mean values ± standard deviation for N=4)

Parameter		Cheese age		
	Scale	3 months	6 months	1 year
Odour intensity	0-7	3.0 ± 0.3	3.1 ± 0.2	3.6 ± 0.3
Aroma intensity	0-7	2.5 ± 0.3	3.1 ± 0.2	3.7 ± 0.4
Sweetness	0-7	2.5 ± 0.1	2.3 ± 0.2	2.5 ± 0.3
Saltiness	0-7	1.9 ± 0.2	1.9 ± 0.3	2.3 ± 0.2
Sourness	0-7	2.1 ± 0.3	2.0 ± 0.2	2.6 ± 0.3
Bitterness	0-7	2.0 ± 0.3	1.8 ± 0.4	1.8 ± 0.4

Table 6:
Flavour of Emmentaler cheese (Mean values ± standard deviation for N=10)

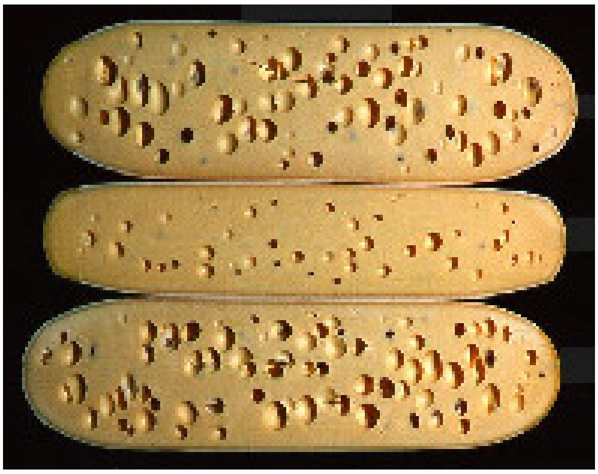


Figure 5:
Emmentaler cheese with late fermentation (upper and lower loaf)

Further Reading

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