Jarlsbergosten
Jarlsberg Cheese

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Jarlsberg Cheese

History and Development

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Preface

Jarlsberg cheese has become the Norwegian dairy industry's top international brand - a success on both the home and export markets.

In recent years, the demand on the international market has become so great that TINE BA has established production of Jarlsberg cheese in the USA and Ireland. Never before has a Norwegian cheese type been such a sales success.

The Jarlsberg cheese that we know today is a result of a long period of research and development which was carried out by researchers at the Dairy Institute at the Agricultural University of Norway.

The development began in 1956 and continued for about 10 years until Professor Ole Martin Ystgaard, who led the research work, decided that the research-based development was complete. It is now about 50 years since student of Dairy science, Per Sakshaug, under supervision of Professor Ystgaard, produced a cheese in his Masters' research that became the starting point of the long research project that gave us Jarlsberg cheese.

This book describes the fruitful cooperation between a research establishment and industry. It reveals how researchers were able to share their knowledge of the cheese's production technology with the dairy industry and how their professional skills actively contributed to the establishment of commercial production.

Today's Jarlsberg cheese is a result of purposeful research and has only its name in common with the cheese produced in Vestfold in the old days.

The authors consider that the research-based development of the world-famous Jarlsberg cheese is a success story that should be told. We think this book will be of interest to people all over the world who are interested in cheese and it is therefore written in both Norwegian and English.

The international dairy community will now gain insight to this story. Many people are deeply interested in cheeses and their origins, in the same way as many are interested in wine. Professor Ystgaard died in 1970, but several members of his research team, who worked with the making of Jarlsberg cheese during its development at the Dairy Institute are alive today. Authors Strand, Steinsholt and Byre actively participated in the development of the cheese and have therefore been able to make unique contributions with details on the development of the cheese. In addition, we have had the pleasure of interviewing people who were important in the development of the cheese and in the cheesemaking trials.

We therefore wish to thank Willy Authen, former manager of the Research Dairy at the Dairy Institute, for important information. Interviews with former operational manager of the Research Dairy, Einar Utne Ogre and former cheesemaker Arne Månum have provided

interesting insight in the working situations and methods used in parts of the development work.

Part of the story of the development of today's Jarlsberg cheese is clearly connected to TINE BA and support from key persons there has been of great importance. We wish to thank former Managing Director in TINE BA, Jan Ove Holmen, who enthusiastically supported the work and also gave financial support to the authors for covering expenses incurred during the writing of the book.

Rolf Heskestad, Manager of Cheese Technology in TINE, deserves a special mention for his important contribution to the book. His long experience in cheese and cheesemaking, and his considerable knowledge about cheese makes him especially qualified to write the chapter: "Some main features of the technological development of Jarlsberg cheese since 1965".

The administration at the Agricultural University of Norway (now the Norwegian University of Life Sciences) has encouraged the writing of this book. Information consultant at the University, Knut Werner Alsén, has liased with the publishers and has greatly contributed by selecting many of the illustrations and giving expert advice to the authors in matters of graphic design and other technical aspects concerning this publication.

Thanks are also due to publishing editor Henriette Seyffarth who has shown us great patience. Professor Judith A. Narvhus took on the considerable job of translating the book into English. Professor Narvhus is English and has, with her PhD in microbiology and long experience as researcher and professor in Dairy technology, the best qualifications for carrying out this demanding work with its specialist vocabulary. Our warmest thanks are conveyed to Professor Narvhus.

Introduction

Jarlsberg cheese was developed at the Dairy Institute at the Agricultural University of Norway. Under the leadership of Professor of Dairy technology Ole Martin Ystgaard, a large team of the Institute's dairy researchers and technical staff conducted the extensive research and development that culminated in the cheese.

Jarlsberg cheese has become both a national and international success. On the international market, it is considered an exclusive cheese and commands a high price. It has become a "cheese of the world", and is regarded as the prototype for a group of cheeses that are made like a Gouda cheese, but have holes, or eyes, like a Swiss cheese.

For many international cheeses, their origin is known and described. The origin and development of today's Jarlsberg cheese has not previously been documented. An authorized account of the cheese's history and origin cannot be found in any Norwegian or international scientific literature.

This book is written by dairy scientists, two of whom were involved in the actual development work: Professors Arne Henrik Strand and Kjell Steinsholt. One of the authors, former Deputy Managing Director of TINE, Odd Byre, was a student at the Dairy Institute at the time Jarlsberg cheese was developed and wrote his Masters Thesis on it. He later worked a great deal with Jarlsberg cheese, both as a research assistant at the Dairy Institute and as an employee at TINE. Roger K. Abrahamsen is Professor of Dairy Technology in the same Professorial chair previously occupied by Professors Ystgaard and Strand.

The first cheesemaking experiments to inspire researchers to initiate the work that led to the Jarlsberg cheese we know today were conducted in the Research Dairy at the Dairy Institute in the autumn of 1955. These cheesemaking experiments were a part of dairy science student Per Sakshaug's Masters Thesis. The cheeses were evaluated and analyzed in 1956, and the thesis was submitted on April 30 that year. The real research that provided the scientific foundation for the establishment of the special cheesemaking techniques for Jarlsberg also began in 1956. It is therefore logical to define 1956 as the year of the birth of Jarlsberg cheese, although several years' research was required before the original development work was deemed completed. Thus, 2006 celebrates the 50th anniversary of the birth of Jarlsberg cheese.

The history related here is almost unknown except to those who were directly involved in the work or in some other way had a special interest. Over the years, several stories have been told about Jarlsberg cheese, but they are not based on fact – yet another reason to finally write the real history of Jarlsberg cheese.

Most of this book is dedicated to the dairy science aspects of the development of Jarlsberg cheese because some of those who partook in the original research and in the practical technology development have contributed with information about the process. In this way, we have been able to show how both basic and applied research can form the foundation for commercial successes. The development of Jarlsberg cheese is a good example of how the

resources of an academic institution, such as the Agricultural University of Norway, can be an asset for the Norwegian dairy industry. This history is thereby a documentation of an innovation process that is still relevant today, where it is important that research, innovation and commercial establishment of a production process proceed hand-in-hand.

The Birthplace of Today's Jarlsberg Cheese

Air photo showing the new Dairy Institute at the campus area. The old dairy in front.

The cheese we know today as Jarlsberg is, in many ways, a cross between Gouda and Emmental (Swiss) cheeses. When Jarlsberg cheese was developed, no similar production technology was known or used anywhere else in the world. In other words, a completely new cheese had been created. It was not by chance that Jarlsberg cheese was developed at the Dairy Institute and the Research Dairy, for it was here that research-based dairy product development, in particular of cheese, was concentrated. Around this time at the Dairy Institute, the technology for making Small Swiss cheese, Norwegian Saint Paulin, Ridder cheese and the true white goat's milk cheese, Rosendal, was being studied. Considerable cheesemaking research was also carried out on Norwegian Gouda.

The Institute had a long tradition of research on milk as a raw material and with the processing of milk into various dairy products, academically based on dairy science and technology.

The National Center For Dairy Research And Dairy Education At The Agricultural University Of Norway

The Agricultural College was established at Ås in 1859. It was closed in 1897, and the Agricultural University of Norway was then established at the same location. The Act relating to The Agricultural University of Norway was passed by the Norwegian Parliament (Storting) in 1897 and sanctioned by King Oscar II on May 22 the same year. The establishment of the University paved the way for a more extensive research activity, which was very beneficial for the quality of teaching at the University.

Right from the establishment of the Agricultural University at Ås, the study of milk and milk processing was an active area. In order to improve the efficiency of butter production, the College's first Director, Frederik August Dahl, and Chemist Anton Rosing experimented with optimization of conditions during the separation of cream from milk.

The results of this work were of direct commercial application for the dairy industry since they led to the introduction of the so-called "ice method".

This method became the technology of choice until the continuous cream separator was developed by Gustaf de Laval in 1878.

As early as 1866, the process of Nøkkelost (Leydner cheese) production was studied at the Agricultural University at Ås. Various chemical aspects of milk, including different methods for determining the fat content in milk, were also studied (25, 56).

Autumn 1953 the new Institute and Research Dairy was completed. At the eighth of September the first milk delivery was made to the dairy.

The Agricultural University of Norway established its own dairy in 1900. Although small, it was a modern dairy according to the standards of that time. However, it was not particularly suitable for research on milk and milk treatment. Although the University's dairy did have cheesemaking equipment, this was totally unsuited for research on a product as complicated as cheese. An important activity at the Agricultural

University was the testing of new machines and equipment before they were taken into use by the dairy industry.

Eventually, the need for deeper and more scientific research in cheesemaking technology became apparent. In 1933, Statens Meieriforsøk was established by the Ministry of Agriculture. It was important to build up a dairy research station, and the possibility of this being located at the Agricultural University was actually considered. However, it was pointed out that neither premises nor milk were available, and that the senior teacher in Dairy science, (later Professor) Kristoffer Støren, had too heavy a teaching load to head such a research institute. Statens Meieriforsøk was therefore established without access to a suitable locality for dairy research. The main offices were in Oslo and the dairy research was conducted at various dairies around the country. Ludvig Funder was appointed to lead Statens Meieriforsøk. Funder had studied at agricultural college, at dairy school and then Dairy Science and Technology at the Agricultural University (1899-1901), where he was among the first students to qualify with a Masters Degree in Dairy Technology. Numerous comprehensive research experiments in dairy technology were conducted under his leadership, many of which are impressive studies considering that all research up until 1953 had to be conducted as part of ordinary production in commercial dairies.

Funder also made great achievements in the development and improvement of dairy products. Cheese milk ripening, development of goat's milk cheese and the production of Pultost (a Norwegian speciallity) were among the topics studied in the early days at Statens Meieriforsøk.

A New Dairy Institute At The Agricultural University Of Norway

As the research activity at Statens Meieriforsøk increased, it again became relevant to discuss a formal collaboration with the Department of Dairy Science and Technology at the Agricultural University.

The need for a research dairy with modern facilities was becoming increasingly pressing. A committee began evaluating the possibilities in April 1940 and delivered their report in June. They recommended moving all of the research activity to the Agricultural University and this eventually took place in 1942. In January 1941, the same committee proposed that Statens Meieriforsøk be totally amalgamated with the Department of Dairy Science and Technology , and recommended the establishment of a new Department, the Dairy Institute, with its own Research Dairy.

Due to failing health, Ludvig Funder gave up his job as leader of Statens Meieriforsøk when it moved to Ås. The post was first taken over by Professor Støren and later by Professor Rasmus Mork. When Professor Ystgaard was appointed in 1951, it was natural that he, as Professor of Dairy Technology, was given responsibility to further the activity earlier conducted by Statens Meieriforsøk.

The committee that had proposed the amalgamation was also instructed to develop plans for

the future organization of the new Dairy Institute, and these were delivered on December 22, 1942.

According to Mork (25), these plans proposed that:

1) A research dairy be built on the University campus;
2) The amount of milk needed annually, about 4 million kilos, would be obtained from Ås Dairy Cooperative; and
3) Plans should be drawn up for the dairy and for other buildings that were to be used for teaching laboratories, lecture rooms and offices.

After extensive debate, the plans for the organization, administration and locality were finally presented in 1946 and received unanimous acceptance.

Financing was naturally a problem. The project was eventually fully financed when the Norwegian Milk Producers' National Association (Norske Melkeprodusenters Landsforbund) supplied an interest-free loan of 1.2 million Norwegian Kroner (NOK). Planning permission for the Institute was received and construction work began in 1949. In the autumn of 1953, the new Dairy Institute and Research Dairy were opened and the first milk was delivered. The milk supply to Ås Dairy was transferred to the Research Dairy and Ås Dairy itself closed. The Manager of Ås Dairy, Willy Authen, who had been educated at the Agricultural University's Dairy Department, was then employed as the first Manager of the new Research Dairy. Starting in 1952, he also became Secretary of the Building Committee for both the Research Dairy and the Dairy Institute (3).

Construction of the new Institute and dairy provided a unique potential for dairy research in its broadest sense. Modern and spacious laboratories and lecture rooms provided stimulating conditions for researchers and students alike, and dairy graduates were often engaged as long- or short-term research assistants. The new Institute had a young and enthusiastic staff and fundamental research could now be conducted in the laboratories and Research Dairy under strictly controllable conditions (34, 51).

At that time, the Dairy Institute was divided into three sections which were led by Professor Peter Solberg (Section for Chemistry, Bacteriology and Marked Milk Technology), Professor Ole Martin Ystgaard (Section for Dairy Technology) and Professor Rasmus Mork (Section for Dairy Economy).

Dairy Engineering was then a part of the Dairy Economy section, but later became a separate section led by professor Olav Framhus.

The design of the Research Dairy made it ideally suited for cheesemaking experiments under controlled conditions (59). After the Research Dairy and the ripening and storage rooms were completed in 1956, early research was primarily on technological problems and factors associated with cheesemaking. It was possible to conduct well-designed experiments in pilot scale (400-liter cheese vats) and in vats equivalent in size to those used in commercial dairies at that time (4,000 liters). Not only was this unique capacity of the new practical research facilities important for studying traditional products, it was well suited for product development research aimed at new cheese varieties and types. The new Dairy Institute and its Research Dairy were an absolute necessity for the initiation of the work to develop the cheese that was to become known as Jarlsberg. Ystgaard wrote: "In our cheesemaking experiments, we have concentrated on the development of new cheese types. In particular, we have worked with Swiss-type cheese made from pasteurized milk.

We have succeeded in developing two types, Jarlsberg and a Small Swiss cheese (Liten Sveitserost), both of which have been well received by the consumers. We are continuing to develop the cheesemaking technology for these two cheeses in order to achieve greater production stability."

The making of cheese is dependent on a range of complicated biological changes to the components of milk and cheese and on the technology used. All of these have to be controlled in a satisfactory way in order to achieve a good end product. To understand and to be able to control all the factors that are important for cheese quality, such as time, temperature, humidity, salt concentration and acidity, knowledge of the complex interactions in cheese is necessary. It is almost impossible to describe these interactions without registering chemical, microbiological and physical conditions and sensory properties during both cheesemaking and ripening. Modern experimental design and statistical treatment of the research data are critical for understanding the effect of the various factors on the quality of the cheese.

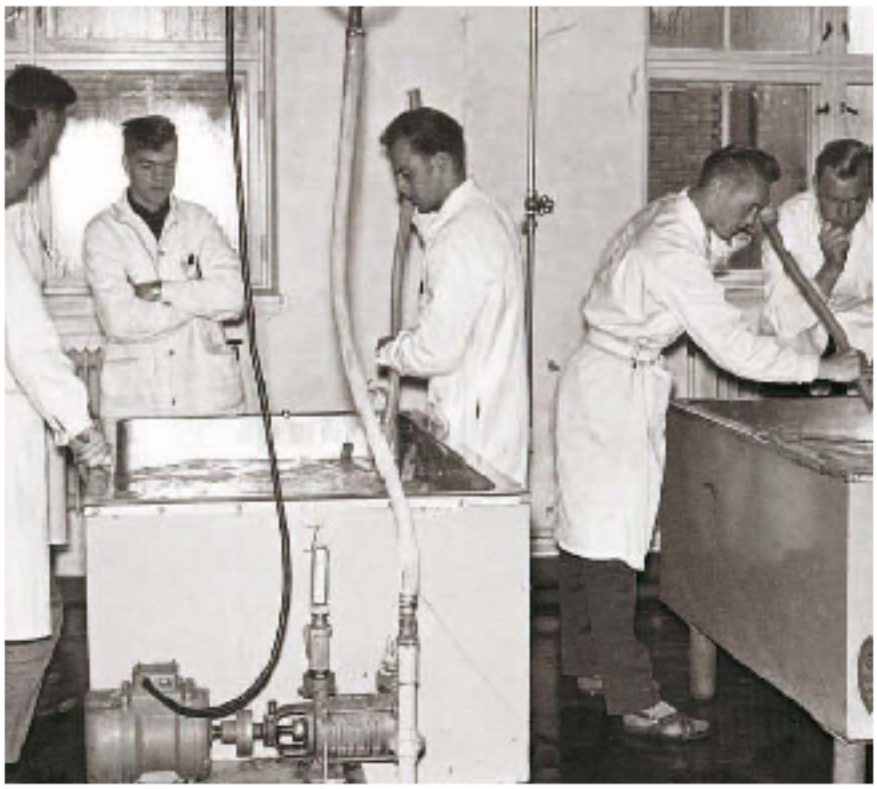
The prerequisites for this type of research were available at the Dairy Institute and Research Dairy, as was seen during the development of Jarlsberg. The scientific staff was also familiar with modern experimental design and statistics,

which was important for the design of the cheesemaking experiments and essential for the correct treatment of the large amounts of data thus obtained.

The production area in the new research dairy under construction.

When finished, the main production area was organized with churning equipment at the back, pasteurizers and separators in the middle and cheese factory in front of the hall.

The People Behind the Cheese



Students in action with cheese making. All cheese making trials, also with the Jarlsberg cheese, were conducted in semi technical scale in batches of 400 liters of milk. Six cheese vats of this capacity were available for this purpose.

Professor Ole Martin Ystgaard, the leading researcher in the developement of Jarlsberg cheese.

Led by Professor Ole Martin Ystgaard, the work of developing Jarlsberg cheese was organized as modern teamwork. Several resourceful members of staff at the Dairy Institute and Research Dairy took part in planning and conducting the cheesemaking and ripening experiments, as well as in the comprehensive analysis work that was necessary to generate the data that formed the basis for the development of the technology for the cheese.

At the time when Jarlsberg cheese was being developed, the scientific staff at the Dairy Institute was occupied particularly with studies of cheese ripening and of the microorganisms involved in the ripening process. Accociate professor Erling Brandsæter led this work, accompanied by Research Assistant Torleif Korvald and Research Technician Kjerstine Fjøsne (later Lysø).

After Jarlsberg cheese became a reality, Kjerstine Lysø was given responsibility for maintenance and production of the bacteria culture of *Propionibacterium freudenreichii* subsp. *shermanii,* which was crucial for the development of the cheese's characteristic properties. The culture was propagated in the Institute's laboratory and was sent out each week to all the dairies for cheese production. Thus, the entire commercial production was dependent on both the thoroughness of Kjerstine Lysø's work with the culture and its timely dispatch to the dairies. After 1991, this work was transferred to TINE R&D, Voll.

Towards the end of 1955, the installation of equipment for the new Research Dairy was complete. Research conducted by the Dairy Technology Section then increased its focus on cheese technology. Research Assistant (later Professor) Arne Henrik Strand became particularly engaged in all the various cheesemaking experiments.

Several other cheese types were also thoroughly studied, including the technology for Norwegian Gouda-type cheese and Small Swiss cheese (42, 43, 44, 61, 62).

All of the experiments, on both Jarlsberg cheese and the other cheese types, were conducted as factorial experiments. The design of the experiments and the statistical treatment of the data from the results were done in close collaboration with assistant professor (later Professor of Dairy Economics and Food Industrial Economics) Gudmund Syrrist, and Research Assistant (later Professor of Food Technology) Kjell Steinsholt.

The experimental design comprised four parallel cheesemakings each day. This could only be achieved with considerable work input and teamwork from qualified personnel. Many people, well-versed in practical cheesemaking and research work, took part in the research during this developmental period. Much of the practical work was carried out by research technicians Kjerstine Lysø, Hedvig Rød, Borghild Steinsland and Gerd N. Tufto. Klara Nordby, Jorid Engan Skei and Brita Nilsen also participated. From the scientific staff, Research Assistant Arne Henrik Strand, Research Fellow Kjell Steinsholt and Chemical Engineer (later Associate Professor) Alf Svensen took active part in the cheesemaking in the large research experiments for Jarlsberg cheese. Most of these people also contributed to the comprehensive chemical and

microbiological analyses that were done in connection with the cheesemaking experiments and with the cheese during maturation.

These analyses included the use of recently developed chromatographic methods to identify some chemical components that are important for the taste and aroma of Jarlsberg. In the early days, this was done by researcher Vincent Abate, but was later taken over by Alf Svensen, who systematically modernized these methods and became an expert in gas chromatographic analysis.

The Research Dairy's pilot scale cheesemaking equipment was used for all the cheesemaking experiments, but as the technology developed, the production was scaled up to full technical scale, using 4,000 liters of milk each time. The Research Dairy had several skilled personnel during the time that Jarlsberg cheese was developed. The Manager of the dairy, Willy Authen, systematically followed up the scaling up of the cheesemaking to cheese production in commercial scale. Great interest and enthusiasm was shown for the further development of the technology necessary for this scaling up, and technical managers William Bue, Einar Utne Ogre and Gunnar Petersen were active in this work. Experienced cheesemakers Roald Pedersen, Arne Månum and Gunnar Reitås were responsible for the actual cheesemaking.

Good teamwork in the dairy was imperative for the fundamental research and practical side of the cheesemaking technology. Professor Ole Martin Ystgaard led this work, and was full of both conventional and unconventional ideas.

The other dairy researchers then turned these original ideas into good research projects based on modern research principles. They were also able to make use of the latest in analysis and control methods, and had a qualified technical staff at their disposal, without whom none of this work would have been possible. The development of the practical cheesemaking technology in the Research Dairy made it possible to continue this work right up to the establishment of commercial production.

Ole Martin Ystgaard (1910–1970), born in Sparbu. Exam Artium (GCE) 1931, Dairy College 1936, Agricultural University of Norway, Dairy Science and Technology, 1939. As a teacher at Dairy College from 1940–1951, he completed a number of short- and long-term studies both at home and abroad, and finished with a Master of Science degree at Iowa State University in 1950. Professor of Dairy Science and Technology at the Agricultural University of Norway from 1951. Here, he helped plan and realise the new Dairy Institute, where he had opportunities to develop his great wealth of ideas and expert knowledge in both research and teaching. Ystgaard enjoyed lecturing, and everyone who has listened to him remembers him with gratitude. He was highly respected in his field of dairy technology and was particularly interested in cheese technology. In 1963, he received Jon Sundby's special award for his work in cheesemaking. On the basis of his great expertise in his field, Ystgaard held a number of honorary posts and was a member of various government and expert committees, such as Norway's representative in the Permanent Council at the international Cheese Convention.

Per Salshaug (1927–1992). Per Salshaug spent his childhood years at Odals Dairy at Sikarnes, where his father was Manager. After Exam Artium (GCE) and Dairy College, he studied Dairy Science and Technology at the Agricultural University of Norway, from where he graduated in 1956. Before starting his extensive career in practical dairying, he spent one year as Research Assistant at the Dairy Institute's Section for Dairy Economy. As Manager of Jæren Dairy in Bryne, he was also Headmaster at the Dairy College at the same place for five years, but had his longest association with Rogaland Dairy's Frue Dairy, where he retired as Director in 1992. Salshaug was a prominent figure with a great capacity for work. As a teacher, he was a good educationalist. He demanded a lot of his fellow workers, but most of all, of himself. Systematics and order were qualities that characterised Per Salshaug.

Erling Brandsæter (1921–1961), born in Haugsbygd. After Realartium (GCE, Natural Science curriculum) and Dairy College, he studied Dairy Science and Technology at the Agricultural University of Norway, where he graduated in 1951 with subsequent employment as Research Assistant, first at Dairy Institute's Section for Dairy Chemistry and Bacteriology, and then from 1952 at the Section for Dairy Technology. At the same time, Erling Brandsæter received a scholarship from Norwegian Agricultural Scientific Research Council to study at Iowa State University. His studies were completed there in 1955 with a Doctoral Degree based on a study of proteolytic enzyme systems in different lactic acid bacteria. He was then employed as Research Manager at Dairy Institute's Section for Dairy Technology, a position he held until his untimely death in 1961. In this position, he made great contributions both as a scientist and teacher. Brandsæter was particularly interested in cheesemaking technology. He planned the work with the selection of the propionic acid culture that is used in today's Jarlsberg cheese, and actively participated in the project for the cheese experiments that were conducted.

Torleif Korvald, born in Kongsberg 1925. Realartium (GCE, Natural Science curriculum) 1946, Dairy College 1950 with dairy practice from Kongsberg Meierier, Oppdal and Sarpsborg Dairies. Employed by Svanstad Dairy 1951. Research Assistant at Dairy Institute's Section for Dairy Technology 1954–1958. As Consultant at Norwegian Dairies' Sales Association for many years and Government Consultant 1964–1965, Korvald actively participated in the start-up and development of production of Jarlsberg cheese at Norwegian Dairies. Manager of Oppdal Dairy, 1979–1992.

Kjerstine Lysø, born in Oppdal 1925. Educated at Ørlandet Dairy College 1950. Dairymaid at Oppdal Dairy 1950–1954. Dairymaid with laboratory responsibility at Tønsberg Dairy 1954–1956. Employed at Dairy Institute's Section for Dairy Technology with responsibilities that included maintenance and timely and weekly dispatch of the culture for Jarlsberg cheese to all the dairies producing the cheese in the period 1956–1991.

Arne Henrik Strand, born in Trondheim 1927. Realartium (GCE, Natural Science Curriculum), Trondheim Cathedral School 1946, Dairy College 1951, with practice from Verdal Dairy and Gausdal Cheese Factory. Employed at Gausdal Cheese Factory 1952. Graduated in Dairy Science and Technology at the Agricultural University of Norway 1955. Research Assistant at Dairy Institute's Section for Dairy Technology 1955-1963. Research Manager at the same place 1963–1972. Professor of Dairy Technology 1972–1992.

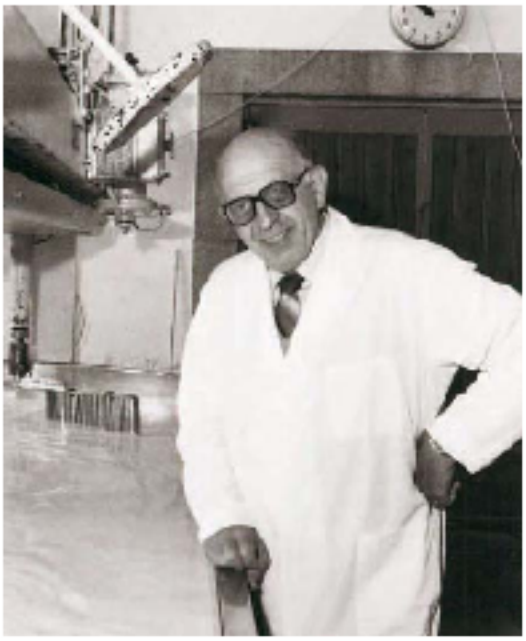
Gudmund Syrrist, born in Hedrum 1923. Examartium (GCE) 1943, Dairy College 1948, Graduated in Dairy Science and Technology at the Agricultural University of Norway 1952, cand. oecon (Master of Economy) University of Oslo 1956. Research scholarships from Norwegian Agricultural Scientific Research Council 1956–1962 with studies in the USA. Assistant Professor at Agricultural University of Norway 1963. Professor of Dairy Economics 1966–1990.

Kjell Steinsholt, born in Hedrum 1929. Realartium (GCE, Natural Science curriculum), Larvik 1948, Dairy College 1952, Dairy Science and Technology at the Agricultural University of Norway 1956, MSc at University of Wisconsin 1959 and Lic. Agric. at the Agricultural University of Norway 1960. Research Assistant at Dairy Institute's Section for Dairy Chemistry 1956–1958, University College Research Fellow 1958–1960. Employed as Consultant in Norske Isteremfabrikkers Landsforbund 1960–1961. Thereafter employed at the Dairy Institute's Section for Dairy Technology until 1966. Professor of Food Technology 1982–1996.

Alf Svensen, born in Tune, 1930. Realartium (GCE, Natural Science curriculum) 1949. Apprentice at A/S Borregård 1949–1950. Diploma Engineer in Chemistry from Technical University in Graz, Austria. Employed at the Dairy Institute's Section for Dairy Technology 1958–1982, of which nine years as Research Manager in Norwegian Dairies' Sales Association with place of employment at Dairy Institute. His tasks have been in analytical chemistry with emphasis on method development and aroma research.

Willy Authen, born in Vestby, 1915. After lower secondary school and dairy practice, he completed the Dairy Course at Dalum Dairy College in Denmark, 1935. He was thereafter employed as Dairyman at several dairies before completing his degree in Dairy Science and Technology at the Agricultural University of Norway in 1942. He then worked for one year as an assistant to Professor Støren at the Dairy Section, the Agricultural University of Norway, and employed at the Institute of Dairy Economy, same place from 1943 to 1945. Manager of Ås Aktiemeieri dairy from 1945 until it was closed in 1953, after which he took over as Manager of the new Research Dairy at the Agricultural University of Norway, 1953–1985.

Development of Jarlsberg Cheese Technology



When results from the semi technical production developed the cheese making was scaled up to 4000 l of milk.
Here the vat of 4000 l in the Research Dairy.

The starting point

In the autumn of 1955, dairy science student Per Sakshaug (later Manager of Jæren Dairy and Headmaster of Jæren Dairy College), under the supervision of Professor Ystgaard, conducted cheesemaking experiments for his Masters Thesis, "Addition of propionibacteria culture to cheese milk", at the Agricultural University of Norway (32). Interesting results were obtained, and a good-quality cheese was produced using the Research Dairy's cheese vats. Interest was awakened to further the development of a Gouda with large eyes. From that point on, the development of a Gouda with large eyes resulting from propionibacteria metabolism was led by Professor Ystgaard, and it was this work that eventually led to today's Jarlsberg cheese.

In addition to the effect on eye production, it was also expected that the addition of a pure culture of *Propionibacterium freudenreichii* subsp. *shermanii* would add an interesting taste to the cheese.

As the work progressed, Professor Ystgaard felt it was important to retain the Gouda technology. This meant, for example, that only mixed cultures of so-called mesophilic lactic acid bacteria were used in addition to the propionibacteria.

These lactic acid bacteria are called mesophilic because their optimal growth temperature is around 30 °C. It was decided that the cheese cooking temperature, that is, the highest temperature to which the cheese mass and whey is heated in the vat, was to be the same as the relatively low temperature used for Gouda. This low temperature does not inhibit the mesophilic lactic culture and its metabolism of lactose and citric acid in the milk. In other words, the necessary good growth of the starter bacteria should be guaranteed by using these conditions.

In the following description of the development of the cheese technology, we will limit ourselves to some of the research projects and Masters research work conducted at the Dairy Institute from 1956 to 1965, the year when Professor Ystgaard concluded that the cheese was fully developed as a new cheese type. Our description, therefore, builds largely on work published from the Institute during the development period or submitted as MSc theses at the Agricultural University.

Later, several Masters Theses and other research reports were also written about Jarlsberg cheese or about the propionibacteria culture, but only a few of these will be mentioned.

The First Cheesemaking Experiments That Led To A New Cheese

From about 1910, the most important cheese produced in Norway was the so-called large-eyed Gouda. Before that, a variant with very small eyes had been produced. However, for several years leading up to 1955, achieving sufficient numbers of large eyes in the cheese became an increasing problem.

In his Masters research, Sakshaug began with the hypothesis that in the original Norwegian Gouda cheese, propionibacteria were probably an important aid to achieving satisfactory eye formation. Propionibacteria are principally gut bacteria and would therefore be a part of the normal flora of the milking parlor. Sakshaug speculated that because parlor and milking hygiene had improved, the incidence of propionibacteria had been reduced. These factors, combined with pasteurization of the cheese milk, could have resulted in minimal amounts of propionibacteria in the cheese milk.

Eye formation and appearance of the cut surface of the first examples of Gouda cheese made from milk added propionibacteria in addition to usual mesophilic lactic culture (3.2).

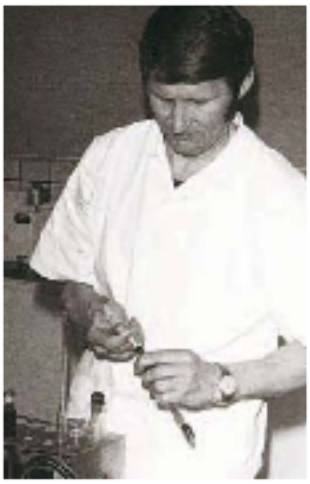
The formation of very large eyes in Emmentaltype cheese is primarily due to propionibacteria which form large amounts of carbon dioxide (CO_2) by metabolizing the lactic acid that has been formed from lactose in the milk by the lactic acid starter bacteria in the cheese.

Propionibacteria metabolize the salt of lactic acid (lactate) to propionic acid, acetic acid and CO_2. *Sakshaug's hypothesis was that the eye formation in Gouda would be improved and more like that in cheese produced earlier if a pure culture of propionibacteria was added to the cheese milk following pasteurization.* A review of the literature showed that many research groups had previously studied the effect of adding propionibacteria to Emmental cheese milk. However, no reports could be found referring to the addition of propionibacteria to pasteurized cheese milk for Gouda production using the technology that was common in Norwegian dairies. Researchers at Iowa State College (4) had reported the development of a cheese they called Iowa Swiss.

The technology used for this cheese was similar to that used for Gouda, but some of the research used a cooking temperature of 41.1˚C, which is too high for Gouda.
Sakshaug's MSc research project comprised 24 cheese vats, each with 400 liters of milk. The same cheesemaking technology was used for all vats. Sixteen round cheeses were made from each vat, each weighing 2.5 kg. To detail the cheesemaking technology used would take too long, but it is important to mention that an ordinary mixed mesophilic culture of lactic acid bacteria was used, the same as is used for butter and cheese production in Norway. The

cooking temperature was 37˚C. The experimental setup involved the addition of a strain of *Propionibacterium freudenreichii* subsp. *shermanii* at three different levels to three cheese vats containing 1% of the mesophilic lactic culture.

In a fourth vat, only the lactic culture was added. The cheeses were made on the same day and the same milk was used in each of the four vats. This experiment was repeated six times during the period September 4 to October 3, 1955. The strain of *Propionibacterium freudenreichii* subsp. *shermanii* originally came from Iowa State University. Professor Ystgaard had developed a good collaboration with Dr. F.E. Nelson following a study trip to Iowa State. Nelson gave the culture to Professor Ystgaard, and it was later found to be crucial for Jarlsberg's special properties.



Controlling the fat content of cheese milk with Gerber analyses.

After pressing, the cheeses rested in the moulds overnight. Half of the cheeses (8) were then placed in 20% brine at 8-12˚C and salted for two days. The remaining eight were left in the molds for an additional two days and were then transferred to the brine and salted for two days.

The cheeses from each of the 24 vats were divided between three warm Ripening Rooms (16°-, 19°- and 22˚C, respectively), and were continually assessed such that they could be transferred to cold storage as soon as they were ready. The number of necessary days in the Ripening Room varied from 12 to 26. After three months of cold storage, the cheeses were analyzed and organoleptically assessed. Examples of eye formation and the general appearance of the cheeses made during Sakshaug's first cheesemaking series are shown in Figure 1.

Sakshaug emphasized that his research material was too small to draw general conclusions concerning the effect of adding the propionibacteria culture on eye formation, but he pointed out some tendencies in the results:

• The control cheese showed good eye formation.
The produced Gouda was not without eyes, such as was often the problem in Norwegian dairies at that time. The results of the sensory assessment gave reason to maintain that the addition of *Propionibacterium freudenreichii* subsp. *shermanii* to the cheese milk made a slight improvement in the quality of the experimental cheese.

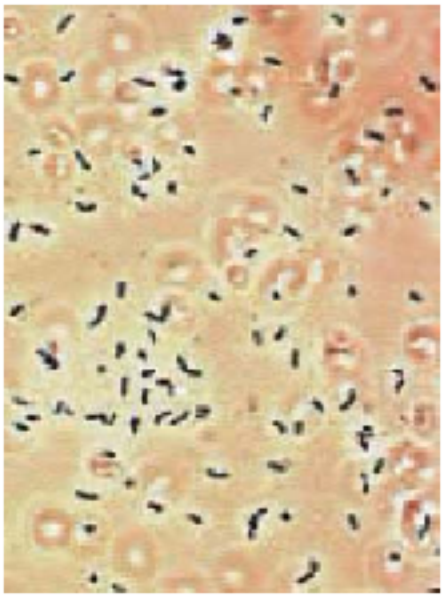
• Cheeses with the lowest and medium levels of propionibacteria generally tasted better than the control cheese. The addition of this culture had an clear effect on the concentrations of volatile organic acids in the mature cheese, but no measurable influence on the protein breakdown in the cheese. Volatile organic acids are considered important for cheese flavor.

• The variation in temperature in the Ripening Rooms within the range used in this research did not have a marked effect on the general quality of the cheese, although it was felt that the texture and taste were better in cheeses that had been stored at 19˚C.

Checking the propionic culture in the Microscope was carried out as routine work.

Work With The Propionibacterium Culture

Even though Sakshaug's research could only show tendencies, the staff at the Dairy Institute was determined to continue studying the addition of propionibacteria to Gouda cheese in greater depth. Thus, a more extensive research project was initiated, focused on developing the cheesemaking technology in order to produce a "new" cheese type.



Typical appearance of Propionic bacteria as seen in microscope at 1000 times magnification and with phase contrast.

At the same time as the technology was being developed, it was also important to look into the best conditions for maintaining the propionibacteria culture Sakshaug had used. It was assumed that this particular culture was responsible for the good eye formation and the individual taste in the experimental cheeses. Research was begun to optimize the routines for culture production in the volumes that would be necessary for both the research cheese development and also potentially in commercial production. In-depth studies of the microorganism, including growth conditions and morphology, were conducted. However, this work was not published as it was simply regarded as laboratory work aimed at achieving the necessary greatest possible stability in the full-scale cheesemaking. The laboratory data from this work is not available today, but Professor Strand, one of the authors of this book, participated actively in this work.

Left, Associate Professor Erling Brandsæter in professional communication with Chemical Engineer Vincent Abate.

The work was largely organized and led by associate professor in Dairy Technology, Erling Brandsæter. In order to select robust variants of the strain, Brandsæter cultivated the strain on various agar substrates and systematically

selected the largest colonies that developed. This work resulted in the selection of a culture that was more salt-tolerant than the original culture. The modified culture so obtained is the same as is used in today's production, and is not particularly inhibited by the salt concentrations found in cheese. This selection strategy, aimed at increasing salt tolerance, was necessary to produce a culture of propionibacteria suitable for adding to a Gouda-type cheese.

Propionibacteria are microaerophilic and therefore thrive in an atmosphere with less oxygen than in air. For cultivation of the culture, it was therefore necessary to establish an environment that was as anaerobic as possible. In addition to the usual work of plating out on ordinary Petri dishes, various methods were introduced to the Dairy Institute by visiting Researcher Dr. Georg Reinbold from Iowa State University.

The old dairy at the Agricultural University of Norway from 1900. The old dairy is now a Dairy Museum. The roof of the new Dairy Institute and Research Dairy in front. The picture is taken around 1953.

It was also important to investigate whether other strains of propionibacteria could produce cheese with the same characteristics. While visiting the Institute, Dr. Reinbold collaborated in cheesemaking experiments using another strain of propionibacteria from America. This new culture had a comparatively weak CO_2 production. However, the results were not promising as the cheese produced using this culture had an atypical taste.

A number of strains of propionibacteria had been isolated in the Dairy Institute's Section for Chemistry, Bacteriology and Market Milk Technology. Arne Henrik Strand conducted single cheesemaking experiments using ten of these isolates, but none of them resulted in a cheese with a desirable typical taste and eye formation. It was therefore decided that the development research should continue using the strain Sakshaug had used in his MSc research, but a more salt-tolerant variant was selected. This propionibacteria culture was maintained at the Institute's laboratories for many years and propagated for use in commercial cheesemaking. The Research Dairy at the Institute functioned as a "control dairy" for the culture up until the 1990s because one vat of Jarlsberg cheese (4,000 liters of milk) was produced daily in the dairy. This cheese production was closely followed, particularly regarding the propionibacteria culture's function and properties, and in this way acted as a quality assurance for Jarlsberg cheese production in the whole of Norway. The Institute continued with these "control productions" until June 1993, by which time TINE had taken over responsibility for production of the culture and the production of Jarlsberg cheese in the Research Dairy was therefore deemed no longer necessary.

Studies Of The Technological Factors Important For The Quality Of Jarlsberg Cheese

During the ten years Ystgaard considered was the period it took to develop Jarlsberg cheese as a specific cheese type, a series of cheesemaking experiments were conducted. Not all of these were recorded with publication in mind, but laboratory records are available from at least eight experiments that took place between the autumn of 1957 and June 1958. This research aimed at discovering the optimum cheesemaking technology for Jarlsberg cheese. The experiments included the addition of salt and nitrate to the cheese milk, stirring and heating (cooking) of the cheese in the vat, various storage and ripening temperatures and the use of intermediate and refrigerated storage of the cheese before waxing. In addition, this topic was studied in several MSc research theses and other research projects. Some of these will be described in later chapters.

It gradually became obvious that it would be strategically unwise to publish too much of the work on the development of this new cheese type. Too many technological details would be made available, and it would be in the interests of the Norwegian dairy industry to keep these details secret from possible competition. For this reason, only some examples of how the pure developmental research was conducted will be described here and only published reports will be cited. First, a short introduction to the planning of the various experiments that comprised the actual developmental research of Jarlsberg cheese is needed.

The Design Of The Experiments

The research experiments that were conducted to establish the optimum cheesemaking technology for Jarlsberg cheese took place at a time when experimental design, statistical data treatment and, not least, the technical equipment for doing the calculations were just developing. Of course, the statistical theories were established much earlier, and some of these theories were in fact treated as "Top Secret" by the Americans during World War II. During the 1950s, however, several good statistical textbooks were published that made statistics accessible to researchers who did not have much of a mathematical background. Books such as *Experimental design. Theory and application* by Federer (10), *Statistical Methods* by Snedecor (36) and *Experimental Design* by Cochran and Cox (9) were examples of statistical textbooks that opened up this field. These books were used as reference books for planning the research at the Dairy Institute in the 1950s and 1960s.

At the Agricultural University of Norway, two people who were particularly involved in the development of statistical mathematics and experimental design were Professors Per Ottestad and Øyvind Nissen. Ottestad was Professor of Mathematics and was particularly concerned that experimental data be treated in a way that was as mathematically correct as possible. Professor Nissen, who was Professor of Horticulture, was perhaps more practically orientated than Ottestad. His modification of certain statistical methods resulted in new statistical programs, including the internationally known FDB-pro and M-stat. Both

Ottestad and Nissen made valuable contributions to the design of the relatively large cheesemaking experiments at the Dairy Institute.

At the same time as statistical and experimental design methods were being developed, there was an enormous development in the technology for performing the necessary calculations and large amounts of data could now be analyzed relatively quickly. The advance was first mechanical, as more advanced manual calculators were developed, and later data could be analyzed electronically. During this period, a program for variance analysis was written in Fortran II at the Dairy Institute. The program was designed for the enormous card-punch machine used by Professor of Animal Husbandry, Harald Skjervold. Using this program and the available calculator equipment, it was possible to considerably shorten the length of time necessary to calculate the sum of squares for up to five variables. A number of the cheesemaking experiments that were conducted in the first half of the 1960s were designed to study the effect of several cheesemaking factors on the quality of cheese with eyes.

All of these experiments used the same design concepts and were based on the new expertise in experimental design and data analysis of multivariate experiments at the Agricultural University of Norway and the Dairy Institute. The work is published as reports from the Dairy Institute: Four of the reports concern the making of Gouda-type cheese, and one describes the technology of making Swiss-type cheese from pasteurized milk.

It quickly became obvious that the quality of Jarlsberg cheese was dependent on how well the metabolism of the propionibacteria culture was controlled during the cheese ripening. It was therefore important to gain an understanding of how this could be regulated by technological factors during cheesemaking. Propionibacteria are sensitive to both salt and acid, and thus regulation of the salt, water and acidity levels in the cheese would optimize the desired propionic acid metabolism. In a large cheesemaking experiment, the effect of the following factors on propionic acid fermentation, and thereby cheese quality, were studied: dilution of whey with water calculated as a percentage of the cheese milk volume; addition of salt to whey calculated in g/100 liters of cheese milk; addition of nitrate to the cheese milk calculated as g/100 liters of cheese milk. Four levels of each of the three experimental variables were used, resulting in 64 combinations. The cheeses were made in random order. Four cheeses weighing about 10 kg were obtained from each vat containing 400 liters of milk. These were then brine salted for different lengths of time. The number of days in brine was therefore a sub-plot factor, a terminology used in agricultural research (36).

Results from this research were published in a memorial volume for Professor Ystgaard based on some of his writings which were not published due to his untimely death. Two hundred examples of the manuscript were printed and sent to close colleagues and friends of Ystgaard. In the following paragraph, a short summary of the work described in this manuscript will be provided. It is, however, important to use this work to illustrate how the cheese was developed. A more statistically orientated publication of this work comprises a statistical analysis of 256 cheeses produced in the factorial experiment outlined above (41).

An example of the use of Analysis of Variance in this experiment is shown in Table 1. The Table shows the effect of the experimental design factors on the scores given by four judges when assessing the general quality of the cheese. The table shows that the addition of nitrate, whey dilution and brining time had a significant effect on the general quality of the cheese. It can also been seen from the Table that there is a significant interaction between brining time and whey dilution. This means that the effect that brining time had on the score for general quality given by the judges was dependent on the degree of whey dilution during cheesemaking.

In the statistical data analysis, Mean Squares of the three and four factors interactions were used as an estimate for the error variance. Further, significant effects were divided into linear, quadratic and cubic components which were then tested for significance. However, because so many F-values were calculated using the same estimate for error variance, Ottestad's method for correction of F-values was used. The statistical analysis of the data also included regression analysis where all effects significant at a 5% level were included as explanatory variables. This relatively extensive use of mathematical statistics for the analysis of experimental data made it possible to optimize the production technology of Jarlsberg cheese in a rational way. The method also made it possible to understand how the experimental factors affected the cheese quality in a way not previously possible in cheese research.

Some Results From The Cheesemaking Experiments

The cheesemaking experiments described above were conducted in 1961 and comprised 64 cheese vats and the analysis of 256 cheeses therefrom. The main experimental design factors were: the level of addition of nitrate to the whey, dilution of whey and the level of salt added to the whey. Brining time was a "sub-plot" factor. All of the factors were varied at four levels. The results that provided the basis for the statistical analyses were from the following analyses:

1. Analysis of whey and fresh cheese
- °SH in whey (titratable acidity)
- pH in fresh cheese
- Kg fresh cheese per 100 l milk

2. Analysis of mature cheese
- Cheese pH
- % salt in the cheese
- % salt in cheese moisture
- Soluble nitrogen, as % of total nitrogen
- Amino nitrogen, as % of total nitrogen
- Total concentration of volatile organic acids (ml 0.1 N/200 g cheese)
- Acetic acid content (ml 0.1 N/200 g cheese)
- Propionic acid content (ml 0.1 N/200 g cheese)
- Cheese diameter (cm)
- Sensory assessment
- General quality (scale 1-15)

- Eye formation (scale 1-15)
- Number of eyes (scale 1-5)
- Size of eyes (scale 1-5)
- Cracks (scale 1-5)
- Consistency (scale 1-15)
- Taste and aroma (scale 1-15)

The criteria assessed by sensory evaluation could be explained by the design variables and the various analyses performed. Some of the analysis results are described below to show how results from this kind of work can provide information on the quality characteristics of cheese and thereby be used to optimize the cheesemaking technology.

Titratable acidity, expressed as °SH, was measured in the whey at the end of cheesemaking and proved to be crucial for cheese properties such as consistency, eye formation, taste, aroma and general quality. However, the pH in the fresh cheese did not provide a satisfactory explanation of the variation in the quality of cheese from the different cheesemakings. These results showed that °SH was more important than pH as a parameter for predicting mature cheese quality.

Collecting the cheese mass in a pressing vat before moulding. Elnesvågen Dairy.

Experimental Design Factors

The experimental design comprised the production of cheese without the addition of nitrate and with nitrate added at three levels. Addition of nitrate is a well-known technical aid in cheesemaking to avoid butyric acid fermentation. Butyric acid fermentation in cheese is due to the growth of spore-forming bacteria in the genus *Clostridium*, so-called butyric acid bacteria, and the species *Clostridium tyrobutyricum* is the most common in cheese. Growth of such bacteria in cheese can render it totally inedible, mainly because large amounts of butyric acid are formed. In addition, so much hydrogen is produced that the cheese structure is destroyed. Unlike CO_2, hydrogen is not soluble in the cheese moisture and large holes and cracks are produced in the cheese.

The effect of adding nitrate to the cheese milk was dependent on the presence of butyric acid bacteria in the milk and the potential for them to develop in the cheese. Dilution of the whey during cheesemaking was another experimental factor. Whey dilution is used to reduce the

amount of lactose in the cheese curd at the end of cheesemaking. This is done by draining off a specific amount of whey after cutting and stirring. Water is then added, usually about the same as the amount of whey removed.

Lactose is the source of lactic acid production by lactic acid bacteria added as a starter culture. Reduction of the lactose content by dilution of the whey is thus a way to regulate cheese acidity, measured as pH. The acidity of the fresh cheese is important for the development of cheese quality parameters such as taste and consistency. The microbiological and biochemical processes that occur during cheese ripening give the cheese its flavor, consistency and eyes (in those cheeses that are meant to have eyes).

These processes are strongly affected by the pH of the fresh cheese. Dilution of the whey as a method to regulate the content of lactose and thereby lactic acid in the cheese was first used in Norway in the 1930s. Before that, the cheese was prevented from becoming too acidic by employing a higher cooking temperature in the cheese vat, thereby limiting the amounts of whey and thus lactose that were retained in the cheese curd. This process produced a hard cheese with relatively high dry matter content. Emmental cheese is a typical example of cheese that are produced using a high cooking temperature at the end of the stirring period to expel more whey from each individual cheese curd cube. The ability of the cheese curd to withhold whey or its potential to contract and expel whey is dependent on temperature. Raising the cooking temperature results in less whey in the cheese curd and this gives a harder cheese.

The addition of water to the cheese whey allows for regulation of the cheese acidity without simultaneously changing the level of moisture in the cheese. Using such technology, a cheese with lower dry matter and a softer consistency is produced without the cheese becoming too acidic. In an acidic cheese, microbiological and biochemical metabolism of lactose, fat and protein proceeds at a much slower rate and can even be totally inhibited. These metabolic processes are essential for development of the characteristic properties of the cheese. In Jarlsberg cheese, the metabolic conversion of lactic acid to Propionic acid, acetic acid and CO_2 by an added culture of propionibacteria is very important. In 1969, Ystgaard published an article from studies conducted at the Dairy Institute wherein he showed the importance of the degree of dilution of the cheese whey on the quality of Small Swiss, Norwegian Gouda and Jarlsberg cheeses (60).

The third experimental factor was the addition of salt to the cheese whey. The addition of salt in the early stages of cheesemaking affects the growth and metabolism of the lactic acid starter culture. The growth and metabolism of propionibacteria are not only sensitive to salt, but also to acid. Salt addition to the whey can therefore be expected to have an effect on the activity of these bacteria during cheesemaking, in the fresh cheese and during ripening. Butyric acid bacteria are considered to be relatively salt sensitive. In addition, although their vegetative cells are destroyed by pasteurization, the spores are not affected. It was therefore important to establish the conditions during cheesemaking and in the fresh cheese that reduce the spores' potential for germination and development into vegetative cells. Although the spores are very

salt tolerant, their germination can be prevented by low salt concentrations. The addition of salt at an early stage in cheesemaking, for example to the whey, can therefore help control the growth and activity of butyric acid bacteria in the cheese.

The addition of salt to the whey can affect the production of lactic acid by the starter culture. This will affect the pH in the cheese mass (casein) and its ability to swell and bind water. Low levels of salt both stimulate the growth of lactic acid bacteria and increase water binding in the cheese curd and swelling of casein. Conversely, greater concentrations of salt will inhibit the lactic starter and reduce water binding and swelling of casein. Brine salting is usually used for semi-hard and hard rennet cheeses such as Jarlsberg cheese. After pressing, the cheese is transferred to brine that is almost saturated with salt, usually 20%, at about 10 °C. Brining time, however, varies according to cheese type and especially to the size of cheese. Large cheeses need a longer salting time in order to achieve the necessary final concentration of salt in cheese moisture.

In the cheesemaking experiments described here, brining time is statistically considered a "sub-plot". Cheeses were removed from the brine at different times, following the same pattern for all cheese experiments.

The Effect Of Nitrate Addition To The Cheese Milk

In these cheesemaking experiments, butyric acid fermentation proved not to be a great problem. Among all the cheeses produced, only two were judged to be swollen, an indication of butyric acid fermentation. In both cases, this occurred in cheese to which nitrate had not been added.

In cheeses where nitrate had been added, a clear connection was seen between increasing nitrate concentration and a reduction in the amount of volatile organic acids formed in the cheese. The propionic acid fermentation was also clearly inhibited. The analysis of data showed a statistically significant interaction between the addition of nitrate and whey dilution. The addition of nitrate inhibited propionic acid fermentation, but when the whey was diluted, the concentration of nitrate in the whey and the cheese was also reduced. A further effect of whey dilution was an increase in cheese pH.

Whey dilution stimulated the growth of the propionibacteria to such an extent that the inhibitory effect of nitrate became less evident. Interaction between nitrate addition and whey dilution had no demonstrable effect on the production of propionic and acetic acids by propionibacteria, an important indication that this activity was proceeding normally. As a result, cheese to which nitrate was added obtained a better score for general quality and eye formation than cheese made without nitrate addition. The aroma and taste of the cheese were superior, with intermediate levels of nitrate addition and whey dilution. The conclusion was therefore that both too much and too little nitrate had a negative effect on the cheese quality.

In the production of Jarlsberg cheese it is important to note that the effect of adding nitrate

is only evident if the milk used contains relatively large numbers of spore-forming butyric acid bacteria.

The Effect Of Whey Dilution

As expected, dilution of the whey with water during cheesemaking gave a higher pH in the fresh cheese. This increase was linear with respect to the dilution level and, in fact, approximately 70% of the variation of pH in the fresh cheese could be explained by the effect of whey dilution. The pH in the mature cheese was also significantly affected by whey dilution, but this relationship was quadratic.

The difference between pH in fresh cheese and ripened cheese increased with increasing whey dilution. Analysis of protein breakdown in the cheese during ripening showed that whey dilution had a significant effect on the ripening process. In this type of study, it was usual to follow cheese ripening by measuring the amount of so-called soluble nitrogen and amino nitrogen. The amount of soluble nitrogen, expressed as a percentage of the total nitrogen in the cheese, gives an indication of how much protein has been broken down to peptides, while the amount of amino nitrogen shows how much protein has been completely broken down to amino acids.

This study showed that the soluble nitrogen content increased with whey dilution. The results also showed that the amino nitrogen levels were similarly affected, except that this relationship was linear. Propionibacteria metabolize lactic acid to propionic acid, acetic acids and CO2. This is characteristic for Jarlsberg cheese and Propionic acid was the volatile organic acid measured in greatest concentration. Certain lactic acid bacteria can also produce acetic acid from citrate naturally present in the milk. The amount of acetic acid in Jarlsberg cheese is therefore always slightly higher than would be expected from just the Propionic metabolism of lactic acid. The study showed that the concentrations of propionic acid and acetic acid increased quadratically with whey dilution.

This is to be expected, since propionibacteria are sensitive to acid and whey dilution is a useful technology to limit the acidity of the cheese. The study also showed that it was possible to achieve maximal propionic acid fermentation by combining a particular level of whey dilution with a particular brining time.

Whey dilution significantly affected all of the sensory properties of the cheese, and the consistency was best when moderate dilution was used. Too little dilution gave a hard and crumbly cheese;

too high a dilution gave a rubbery cheese. The effect of whey dilution on the score for taste and aroma in the cheese followed similar trends on the whole, and the tendency to form cracks was clearly reduced by increasing dilution levels.

The Effect Of Salt Addition To The Whey

The addition of salt to the cheese whey also had a significant effect on the results of the various

analyses that were conducted. As expected, the amount of salt in ripened cheese increased with increasing addition of salt to the whey. However, this resulted in slower ripening as the amount of soluble and amino nitrogen decreased linearly with increasing salt addition to the whey, indicating a weaker protein breakdown. The production of Propionic and acetic acids was also strongly reduced by the addition of salt to the whey, indicating that the propionic acid fermentation was strongly inhibited.

In cheeses with a low pH, high levels of salt addition to the whey negatively affected consistency and flavor, but, if the cheese was less acidic, the effect on taste was positive and consistency was not affected. As the salt levels in the whey were increased, the graders noted that the cheese more often had a short and hard consistency and sour taste, but that it was less often bitter. The score for the general cheese quality did not seem to be affected by the addition of salt to the whey.

The Effect Of Brining Time

Naturally, the concentration of salt in the cheese increased with a longer brining time. The rate of salt uptake was greatest during the first hours in the brine. As the salt concentration in the cheese increased, the increase in pH during ripening was reduced and soluble and amino nitrogen decreased.

A reduction in production of Propionic and acetic acids was also observed, giving a clear indication that salt inhibited biological activity in the cheese during ripening. These observations have a clear connection. If the propionic acid fermentation is inhibited due to increasing salt, then less lactic acid is metabolized.

Since both propionic and acetic acids this type of cheese, and it was economically very important for them that the cause be identified and eliminated. For a period in 1958, all cheese produced in the Research Dairy had this defect, including all the experimental productions of Jarlsberg cheese. The defect was noticeable only after a while, and by the time the cheese was two to three months old, it was very distinct. An odor developed that was reminiscent of cat urine and was known in the trade as "catty flavor" (cf).

When the "cf defect" was investigated, it was discovered that it had previously occurred in other countries. Several cheesemakers related that the defect cropped up from time to time and then disappeared just as abruptly as it had come. No one understood the cause of the defect or which chemical components were responsible. Professor Johns from the Department of Agriculture in Ontario, Canada visited the Institute in the autumn of 1962. He evaluated the "cf cheese" and said the taste was identical to a defect that had occurred in Canadian cheese. Later, in a letter from the same institution in Canada, Professor Irvine confirmed that the defect had often affected Export Cheddar from 1959–1960.

In addition to studying the Jarlsberg cheese produced at the Research Dairy, cheeses with the same characteristic flavor defect were submitted from other dairies. Documentation of the incidence of the defect showed that, even within one day, a single dairy could produce cheese

both with and without catty flavor. It was also registered that the taste was strongest in the outermost layer of the cheese, but that the odor varied. The texture and consistency of the cheese were normal, but they noticed that cheese with the cf defect always had a darker yellow color. In trying to understand catty flavor, there had always been a suspicion that sulfur compounds could be involved. If silver chloride was added to grated cf cheese, the odor disappeared, an indication that sulfur played a part in this taste defect. Gas chromatographic analysis of steam distillates showed that cf cheese contained higher concentrations of volatile organic acids than normal cheese. More importantly, the chromatograms from samples of cf cheese also showed a large specific peak that was barely visible in samples from normal cheese, indicating that a specific compound was responsible. The taste could also be removed by vacuum distillation of the fat from cf cheese.

A strain of *Streptococcus faecalis* subsp. *liquefaciens* and an unidentified yeast were isolated from several samples of cf cheese. Both of these microorganisms were then used in cheesemaking experiments to test whether they were responsible for the flavor defect. Although these cheeses were not of good quality, there was no hint of catty flavor.

Some of the results from these studies indicated that the cause of the defect had nothing to do with the milk, milk handling or the actual cheesemaking, and that the defect probably did not have a dairy-related cause. Studies on canned meat had showed that the compound mesityl oxide could react with sulfur and form the compound 2-mercapto-2-methyl-pentane-4-one, which gave the meat a typical catty flavor. It was shown that mesityl oxide was present in the varnish on the inside of the cans (29). Research was then initiated at the Dairy Institute whereby mesityl oxide was added to the cheese milk. Neither the milk nor the fresh cheese had a catty flavor, but after 14 days' ripening, the distinctive flavor developed in the cheese. An addition to the cheese milk of tiny amounts of mesityl oxide, as low as 0.1 ppm, resulted in cheese that was easily identified by 100 dairy personnel who were used as tasters.

At that time, one particular dairy had problems with catty flavor in Jarlsberg cheese. It was discovered that the dairy had recently re-varnished the shelves in the Ripening Rooms, and an analysis of the varnish showed it to contain mesityl oxide.

The considerable incidence of the cf defect in cheese from 1958 to the beginning of the 1960s was later explained by traces of mesityl oxide in the plastic of the rennet containers. From then on, it was recommended that there be no contact between the cheese and varnish, paint and plastic materials that contained mesityl oxide so as to avoid the catty flavor defect in hard and semihard cheeses, like the newly developed Jarlsberg cheese.

The Effect Of Copper On Jarlsberg Cheese

In Switzerland, Emmental cheese is traditionally made in copper vats while stainless steel vats are used for cheesemaking in other countries. As with Jarlsberg cheese, growth of propionibacteria is very important for the characteristic properties of Emmental. In the studies of Jarlsberg cheese technology it was therefore of interest to investigate the effect of copper on the development of propionibacteria in cheese. Knowledge was needed about the effect of

copper on the conversion of lactic acid to propionic acid, acetic acid and carbon dioxide, and whether copper in the milk would have an effect on the cheese quality. Tronstad studied this in his MSc thesis at the Dairy Institute (53).

The problems associated with catty flavor were generally known at the time Tronstad's thesis research was conducted, although the cause was not yet elucidated. It is worth noting that it was suggested in an earlier study that the addition of copper to the cheese milk could possibly block chemical transformations that could lead to off-tastes in cheese (40). German studies had shown that the addition of small amounts of copper to the cheese milk improved the quality of Emmental because it prevented a flavor defect that was reminiscent of hydrogen sulphide (21). However, it was also possible that the addition of copper would negatively affect the quality of Jarlsberg cheese.

Tronstad's MSc thesis was not comprehensive enough to draw clear conclusions. Nevertheless, the results supported what was already known about the significance of copper for the quality of cheeses produced using propionic acid fermentation. Low concentrations of copper in the cheese milk, such as 2.3 and 8 ppm, did not have a negative effect on quality. When higher concentrations were added, the cheese showed no eye formation after three months' ripening, but it was satisfactory after 4.5 months. A tinge of blue color was registered in the outer layers of the cheese. The conclusion to this work was that copper most likely retarded the microbiological and biochemical changes in the milk such that the ripening was somewhat delayed. No connection was found between the addition of copper and catty flavor.

Early Brining

The period following 1960 saw great technological advances in molding and pressing equipment for cheese. These would save both time and work, but would require adjustments to the pressing and salting technologies. Due to the need for relatively large investment in the new expensive pressing equipment, it was important to discover whether the pressing time could be shortened and the cheese quickly transferred from the press to the brine. Studies were conducted at the Dairy Institute to find out whether, and if so, how, early brining of Jarlsberg cheese would affect the lactic fermentation in the cheese and it's final quality.

In 1963, investigations were made into how variations in pressing time and in the time between pressing and transfer into the brine affected lactose metabolism in the cheese (7). Four cheeses from each of 11 cheesemakings were treated in different ways and then later studied for sensory quality and a series of chemical parameters. Two of the cheeses were pressed in a standard steel mold lined with cheesecloth and pressed at 2.5.10 5 Pa pressure for three hours.

One of these cheeses was placed in 20% brine immediately after pressing and the other was rested in the mold for 24 hours before transfer to the brine. The two remaining cheeses were pressed in the then recently developed Perfora cheese molds (molds with a strongly perforated surface) at 1.5.10 5 Pa pressure for half an hour. As with the others, one of these was brined immediately after pressing and the other one was brined after 24 hours.

The experiment showed that lactose was not present in any of the cheeses when brining was complete, even though the levels of lactose in the cheeses had varied at the time of brining. At no time during breakdown of lactose was it possible to show the presence of glucose, confirming earlier work in Sweden (35). It was therefore possible to conclude that a spontaneous metabolism of glucose also takes place in Jarlsberg cheese, following cleavage of lactose. No differences could be perceived in the quality of the cheeses that were pressed in different ways and kept for different times before brining.

In a continuation of this work at the Dairy Institute, a pressing time of three hours for cheese in steel molds with cheesecloth and 30 minutes for cheese in Perfora cheese molds was used. As before, some cheeses were brined immediately after pressing and others were brined 15-16 hours after pressing. At the Research Dairy, such a resting period following pressing in steel molds was the standard treatment for Jarlsberg cheese, and these cheeses were therefore regarded as controls in the experiment (48). The texture of cheese that was brined immediately following pressing was significantly poorer if the salting time was as long as for the control cheese. However, if the salting time was reduced, the quality of the cheese improved.
The average salt concentration in ripened cheese showed that early brining led to a greater uptake of salt compared to cheeses that had been brined later provided the same brining duration was used. Cheese pressed in Perfora molds and brined immediately after pressing attained the highest salt content brining time was held constant.

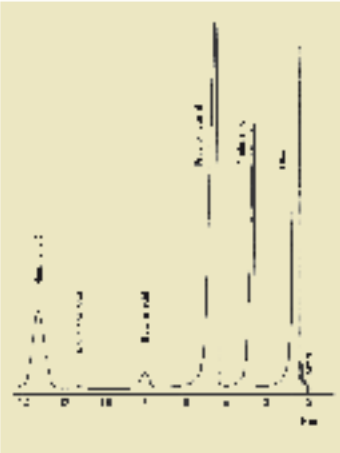
This showed that it was important to reduce the brining time if the cheese was to be brined immediately after pressing. It was suggested that for Jarlsberg cheese, a reduction of 24-hours' brining time was suitable.

Bactofugation Of Cheese Milk

As mentioned in the section "The effect of nitrate addition to the cheese milk" page 63, one of the challenges with the production of cheeses like Jarlsberg cheese is to prevent the development of periment, however, only 73˚C was used. In the preliminary experiments, bactofuged cheese milk both with and without added nitrate was used. It was found, however, that cheese from bactofuged milk with added nitrate ripened too slowly, so this combination was not used in the main experiment. The control cheese was produced according to the Jarlsberg cheese technology that was normally employed in the Research Dairy. These studies provided many interesting practical results that were of use for production of Jarlsberg cheese from bactofuged cheese milk. It was demonstrated that pasteurization and bactofugation at 73˚C reduced the number of bacteria by over 99% and that the number of anaerobic spore-formers in the bactofuged cheese milk was very low, usually under one bacterium per ml milk. The milk loss from the bactofuge varied between 1.7 and 2.4% of the amount of milk treated, which was unacceptably high. Further development of the bactofuge technique therefore included sterilization of the lost material so it could be returned to the cheese milk.

It was also discovered that bactofugation reduced the protein content in milk by about 0.2%, which resulted in a lower cheese yield. Bactofugation produced a cheese with fewer eyes. Despite this, however, sensory assessment of the general quality could not distinguish between

the experimental and the control cheese. The conclusion was therefore that it was possible to make Jarlsberg cheese without the addition of nitrate to the cheese milk, provided bactofugation was used.



Chromatogram of votatile hydro carbonic acids in Jarlsberg cheese (50).

Taste And Flavor Compounds In Jarlsberg Cheese

Various chemical analyses were important research tools at the Dairy Institute. When the work on the development of Jarlsberg cheese began, it was essential to be able to analyze the content of various compounds responsible for taste and flavor in both mature cheese and at various stages of ripening. Researcher Alf Svensen held a key position in the work with the chemical analyses. An important part of some of this work was analysis of the cheese by gas chromatography (50). The Institute owned one of the best gas chromatographs available at the time, but it soon became apparent that more advanced studies of flavor compounds in dairy products and cheese required access to mass spectrometry. It was difficult to progress quickly in the identification of all the chemical compounds that formed different peaks on the gas chromatograms unless gas chromatography was combined with mass spectrometry.

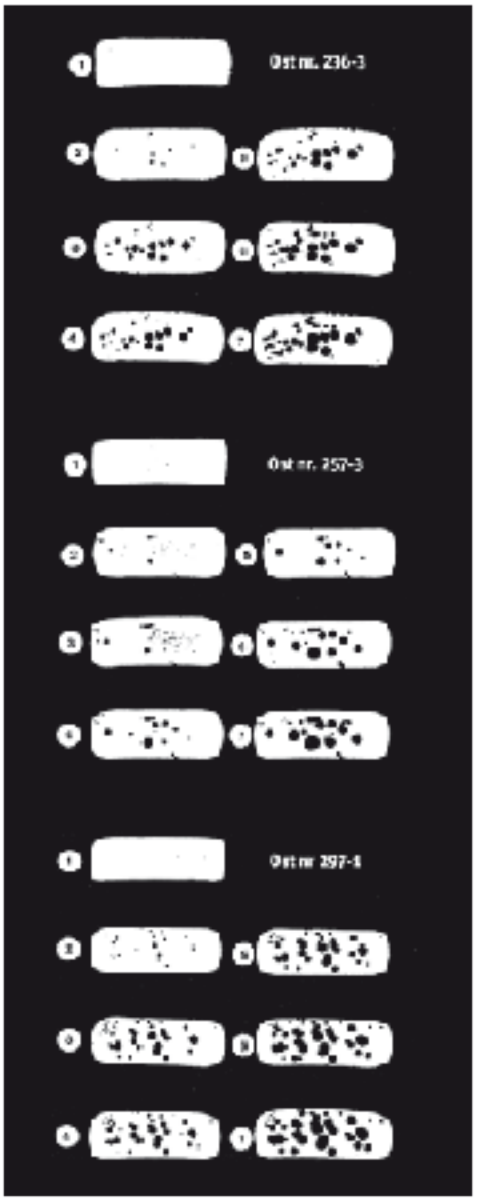
Unfortunately, this equipment was not made available for research at the Dairy Institute. Figure 2 is an example of a chromatogram from a gas chromatographic analysis of Jarlsberg cheese. The Figure shows the characteristic large peaks of propionic acid and acetic acid formed from lactic acid by propionibacteria. Lactic acid is produced by the lactic acid bacteria starter culture used to acidify the milk and to give the cheese its high content of bacteria that are so important for the cheese-ripening process.

Scanning Jarlsberg Cheese With Computer Tomography

In the years following the end of the developmental period for Jarlsberg cheese, researchers and MSc students at the Dairy Institute conducted a series of studies on Jarlsberg cheese and propionibacteria. It is not possible to go into the details of all these studies, but one particular work must be mentioned because it represents the completely novel use of a new analysis methodology for cheese research (46).

Cheese researchers have always wanted to study eye formation in cheese without damaging the cheese by cutting or puncturing. A so-called non-destructive method for

studying cheese eye formation has therefore been needed. The Departement of Animal Husbandry at the Agricultural University had a computer tomograph that they used to study the composition of animal bodies *in vivo*. The researchers at the Dairy Institute were interested to see whether this instrument could be used to study eye formation in cheese without damaging it.



Sampling a cheese during ripening, particularly cheese with rind, can have unfortunate consequences. First of all, there is a risk of mold infection at the point of cutting, and such an infection will influence the chemical conversions during the further ripening of the cheese. Second, puncturing the rind causes a change in the balance of gas pressure in the cheese and probably an increase of the redox potential. Such a cheese would therefore not behave normally during further ripening. It is possible to sample other cheeses from the same production, but there is no way to be certain whether these are identical in all respects to the cheese first sampled. Also, such an experiment is extremely expensive when so many cheeses have to be sampled. In some cases, the number of cheeses available for analysis from each production becomes a limiting factor for the size of the experiment.

Fig 3 - Photos from the scanning of three Jarlsberg cheeses by means of computer tomography. The photos shows the development of eyes in the cheese during storage in the warm room. The graph shows the temperature and time for scanning during the storage of the cheese in the warm room (46).

In 1983, 12 cheese productions on different weekdays were selected. Cheeses from four different positions in the cheese prepressing vat were scanned, and the development of eyes was followed in exactly the same place in two cheeses from each production. For each cheese, six to seven scans were made at different times following production: once in the fresh cheese after brining, three times during the Warm Room period, when the eyes are formed, once immediately after transfer of the cheese to the refrigerated Ripening Room, and one or two scans after the cheese was exposed to temperature stress after 13 weeks. Computer tomography proved to be very useful because it successfully showed eye formation as the gas was produced in cheese and could thus be used to study the factors affecting eye formation. Figure 3 shows that it was possible to demonstrate that the greatest gas production took place

in the second week in the Warm Room. In Figure 4, the development of eyes can be seen on the cut surface of five cheeses during 13 weeks following production.

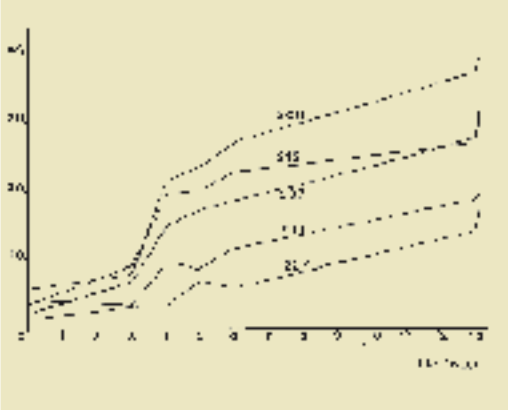


Fig 4 - The surface area of eyes calculated in % of the cheese surface area of five different Jarsberg cheeses. The three cheeses shown in figure 3 are included in the figure (46).

A Unique Cheese Type

Controlling the cheese surface, Ennesvågen 2000.

As previously explained, the research and development of Jarlsberg cheese was originally based on the production technology for Gouda cheese. This technology is largely preserved in today's Jarlsberg cheese technology. However, in our opinion, Jarlsberg cheese should be categorized as a unique cheese type and not compared to either Gouda or any of the Swiss cheeses. Jarlsberg cheese cannot be characterized as a Swiss cheese despite the fact that propionibacteria are responsible for the eye formation and the development of flavor in the cheese is reminiscent of Swiss. Nevertheless, in 1963, Professor Ystgaard wrote in a compendium that Jarlsberg cheese was a type of Swiss cheese (58). Others have also chosen to characterize it as a so-called "Swiss-type variety" (31, 37). However, this cannot be proved or disproved since there is no acknowledged international definition of a Swiss cheese variety that clearly distinguishes itself from other cheese types (37).

Jarlsberg cheese's consistency, dry matter content, lactic acid bacteria flora, ripening progression and other quality characteristics deviate from that in a Swiss cheese. In a comprehensive article written by Anders Oterholm in 2004, "Norwegian cheeses in a historical perspective", a good description is given of the sorts of considerations that were made in the USA when Jarlsberg cheese was categorized in the American cheese classification system. Here, too, the starting point was a comparison between Jarlsberg cheese and Emmental.

The conclusion of these discussions was that Jarlsberg cheese differed from Emmental in several ways (27):

- Production techniques
- The microorganisms used in the production
- Chemical composition including dry matter content and volatile organic acids
- Sensory characteristics:

-Eye formation: even eye distribution with a diameter of 10-25 mm, generally smaller than Emmental

-Consistency: hard to semi-hard, pliable and markedly softer and drier that Emmental

-Taste and aroma: mild, slightly sweet, sour and nutty, but different from the stronger, sweeter and more nutty taste of Emmental

The conclusion was that even though Jarlsberg cheese has certain similarities to Emmental, the production process, chemical composition and sensory qualities were so different that Jarlsberg

cheese should be classified as a unique cheese variant that would be better placed in another group in the American cheese classification system. The conclusion of this evaluation process was that Jarlsberg cheese was to be considered a unique and distinct cheese type in the USA. The mesophilic cultures used for the production of the cheese contain the following types of bacteria: *Lactococcus lactis* subsp. *lactis* biovar. *diacetylactis, Lactococcus lactis* subsp. *lactis, Lactococcus lactis* subsp. *cremoris* and *Leuconostoc mesenteroides* subsp. *cremoris*. A culture such as this is responsible for the acidification of the cheese milk and the cheese, and produces a certain amount of CO2 through breakdown of the citric acid in the milk and through the leuconostoc's heterofermentative breakdown of lactose in the milk and cheese. Some of the mesophilic lactic acid bacteria also produce volatile aroma components, primarily from citrate metabolism, and participate with their proteolytic enzymes in cheese ripening.

When using this type of culture, it is very important that the cheese cooking temperature does not exceed about 40˚C as this would inhibit the bacterial growth. In Gouda production, the cheese cooking temperature is usually between 36-39˚C and because Jarlsberg cheese technology is in principle like that of Gouda, similar temperatures are used (47). Both this heating and the subsequent stirring are very important for controlling the cheese moisture content, and consequently for the consistency and the ripening that then takes place.

Jarlsberg cheese and Gouda have approximately the same dry matter content: 58.5% (1, 2). Both Jarlsberg and Gouda-type cheeses in Norway are now produced in several varieties with different fat content, but originally both cheeses contained 45% fat in the cheese dry matter. Both Jarlsberg cheese and Norvegia (a Norwegian Gouda-type) with 45% fat in the dry matter will therefore have approximately the same amount of moisture in the fat-free cheese: 60-57%. Jarlsberg cheese must therefore be regarded as a semi-hard rennet cheese both with regard to the International Dairy Federation (IDF) classification and in relation to FAO/WHO cheese standard (47).

The true Swiss cheese is called Emmental and is traditionally produced from unpasteurized milk. However, if the technology for Jarlsberg cheese and Emmental are to be likened, we must compare with the production of Emmental from pasteurized milk because Jarlsberg cheese was developed with pasteurized milk as the starting point. The technology for producing Emmental is considerably different from that used for Gouda. First, a different type of lactic acid bacteria culture is used, namely a thermophilic culture. This culture contains lactic acid bacteria that grow at, and tolerate, higher temperatures than the mesophilic cultures used to produce Gouda. Pure cultures of lactic acid bacteria for Emmental usually comprise two thermophilic cultures: *Streptococcus thermophilus* and *Lactobacillus helveticus* (47).

Other sources mention the possibility of using other thermophilic cultures such as *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Lactobacillus lactis* (24, 26, 33, 37). Mesophilic species of lactic acid bacteria, such as *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris,* may be used in addition to the thermophilic cultures (33, 37). In comprehensive studies at the Dairy Institute of Swiss-type cheese produced from pasteurized milk, a mixed

mesophilic culture was used, of the type mentioned earlier, in combination with *Streptococcus thermophilus* and *Lactobacillus helveticus* (62).

The use of a thermophilic culture enables the use of a higher cooking temperature during the production of Swiss-type cheese. Swiss Emmental is produced as a very large cheese weighing between 65 and 110 kg. A cheese of this size requires a high dry matter content in the fresh cheese curd in order to retain its shape, and this is achieved by using a high cooking temperature (31). Different sources quote different cooking temperatures.

For Emmental, for example, a temperature of 52–54˚C may be used, and the temperature during pressing can remain as high as 50˚C for several hours after hooping. The cheese mass will become considerably drier than if lower temperatures are used, and many undesirable microorganisms will also be largely eliminated. American researchers have quoted the use of cooking temperatures of 50–53˚C for Emmental (24, 33). In the production of Finnish Emmental, a cooking temperature of 53–55˚C is used (22).

In studies of Small Swiss cheese at the Dairy Institute, cooking temperatures from 37 to 46˚C were used (62). Temperature was one of the experimental factors employed when developing the technology for producing a Small Swiss cheese with an average weight of 2.5 kg. With a cheese of this significantly smaller size, it is less important for their shape to have as high dry matter as Emmental.

The researchers found that a cooking temperature of 46˚C combined with a 5% whey dilution and a Warm Room temperature of 19 or 22˚C produced the best flavor in Small Swiss cheese. Good results were also obtained in relation to other cheese characteristics when a cooking temperature of 43˚C was used. However, none of the temperatures that gave good results for Small Swiss can be used for Jarlsberg cheese production.

Emmental is usually produced with about 45% fat in dry matter. Based on published figures for Finnish (22), French (33), German (23) and Swiss (31) Emmental, this type of cheese contains 51.5–53.5% moisture in fat-free cheese. This places Emmental as a typical hard cheese in the classification laid down by the IDF and FAO/WHO, whereas Jarlsberg cheese is classified as a semi-hard cheese according to this classification (47).

The propionibacteria that are used in both Jarlsberg and Swiss-type cheeses give them a characteristic taste. The distinctive eye formation and taste in both these cheese types are partially ascribed to the propionic acid fermentation that occurs, and the taste profiles of these two cheese types will therefore naturally have certain characteristics in common. It is clear, however, that the biological changes that take place in Jarlsberg cheese and in Emmental differ on several counts.

In Jarlsberg cheese, volatile aroma compounds are formed from the metabolism of citrate in the milk by mesophilic lactic acid bacteria, whereas the thermophilic bacteria used in the production of Emmental are citrate negative. Thus, in Jarlsberg cheese, a compound such as

diacetyl can contribute to the taste of the cheese. It is also generally known that lactobacilli of the type normally used for Emmental production have far greater proteolytic powers than the mesophilic bacteria used for Jarlsberg production. These cheeses will therefore have a different protein breakdown profile and will thus be expected to have different taste profiles. The products are also noticeably different with respect to ripening time. Jarlsberg cheese is normally ready for sale after about three months' ripening, whereas Emmental is usually not considered mature until about six months (31, 47).

When we sum up all these differences between Emmental and Jarlsberg cheese, it is clearly wrong to characterize Jarlsberg cheese as a Swiss cheese type despite the fact that Swiss cheese is not a clearly defined type. This has led to occasional use of the name of "Goutaler" a new class of cheese, actually a cross between Gouda and Emmental (52). This type of cheese is now produced in several European countries, but has variable quality characteristics. Cheeses such as the Dutch "Leerdamer", the German "Alpsberg" and "Felsberg" are grouped as "Goutaler" cheeses and are in the same group as Jarlsberg cheese. Jarlsberg cheese, however, is considered the prototype for cheeses in the "Goutaler family" (52).

The Jarlsberg Name

The idea which led to the development of Jarlsberg cheese was to develop a Gouda with more pronounced eye formation than Norwegian producers were achieving at that time. What such a potentially new cheese should be called was not discussed either at the start of the work or in the early development period. The researchers at the Dairy Institute were primarily concerned with studying the effect of various cheesemaking technologies on the quality of the experimental cheese. As described in detail in an earlier chapter, the work comprised many different experiments and the development of the cheese was entirely scientific. The cheese had no name until it became obvious that a new cheese type was emerging and that it had a commercial potential for Norwegian dairies. The time was ripe to find a suitable name.

After Jarlsberg cheese was launched on the market, many stories have been proposed about why the cheese was named Jarlsberg. Some have described a story relating that today's Jarlsberg cheese was an attempt to revive a type of cheese that had previously been produced at a dairy at Jarlsberg Manor, the main farm on the Jarlsberg Estate. This is not true, however, and it is therefore necessary to give a short description not only of the dairy activity at Jarlsberg Manor and in Vestfold, but also an account of what is in fact known about the choice of the name Jarlsberg cheese for the new cheese.

There is no doubt that the name Jarlsberg has a historical ring in Norway. The place now known as Jarlsberg Manor originally belonged to the Royal Farm Sæheim, and the area around Jarlsberg Manor is now called Sem. The chieftain of the Ynglinge clan resided at Sæheim. The property became an earldom in 1673, and the name Jarlsberg, from "Jarl", the Norwegian word for earl, has been used since then. From a dairy point of view, this area has special interest as it was here the country's first dairy was established in 1815. The dairy was used only in the summer – a "summer dairy" – and was established on Auli Farm, which belonged to the Earldom of Jarlsberg and was originally one of several farms that comprised the earldom (5).

Jacob Liv Borch Sverdrup was the man behind the first "summer dairy". He was a fifthgeneration descendant of Peder Michelsen Sverdrup, who had been the Danish Sheriff for the area of Kambo, Idd and Marker. Jacob Sverdrup lived from 1775 to 1841 and was educated at Copenhagen University, where he graduated in 1795 with specialization in history, languages and botany. He was employed as a teacher in Copenhagen until 1806 and then became Headmaster in Kongsberg, where he became well known for his exemplary cultivation of the fields on the land that belonged to the position.

When Earl Herman Wedel Jarlsberg visited Kongsberg in 1812, he was informed of the agricultural enterprise demonstrated by Headmaster Jacob Sverdrup. The Earl was impressed and appointed Jacob Sverdrup as Manager of Jarlsberg Manor. At that time, both the house and land suffered from lack of attention. That year was also one of great need because the harvest had failed and the English blockade during the Napoleonic Wars effectively hindered the delivery of grain from Denmark to Norway. Jacob Sverdrup proved himself a brilliant agriculturalist and in just a few years, the Estate was well managed and large harvests were achieved. Sverdrup was extremely engrossed in agriculture and is probably best known for the establishment of Norway's first agricultural college at Jarlsberg Manor in 1825. This became known throughout the country and was called "Sem Seminary" (8, 18). Under Sverdrup's leadership, the Estate changed from meat to milk production, which was then used for making Swiss cheese at Auli Dairy.

In a diary from July 1821, Consul W.M. Egeberg wrote: *"Delicious Swiss cheese is made on this farm (Auli), and we saw 374 cheeses that had been made from 37,000 quarts of milk"* (5).

Detailed economic accounts of the dairy were kept at Auli from 1826 to 1832. The livestock comprised 131 milk cows in 1826, and the dairy was in operation from May to late September. After a while, the number of cows was gradually reduced and the operative period shortened, but despite this, the amounts of milk and cheese produced increased during these years.

With the communication network of the time, distribution and sale of the cheese became a great problem. It was not unusual that consignments of cheese became spoiled during distribution and had to be returned to Jarlsberg, where it was used for own consumption. Profitability dwindled, which was undoubtedly why the Auli Dairy closed in 1832 (5).

Up until this time, it was customary in Norway to churn butter from cream and use the low- fat milk left after the cream was removed to produce low-fat cheeses such as the typical Norwegian cheeses, Pultost and Gammelost. However, the production of Swiss cheese presupposed that the fat was not removed from the milk. This type of cheese therefore became known as "fat cheese". The interest for producing Swiss cheese in Jarlsberg and Laurvig County (known as Vestfold County today) greatly increased and must doubtless be attributed to Jacob Sverdrup's initiative for making fat cheese in his area. In "Lectures in Dairy History", Professor Støren wrote (49): *"Cheese production in Jarlsberg and Larvik County was dominated by*

fat cheese. Headmaster Sverdrup awakened a particular interest for this type of production through the college at Sem."

From 1860 to 1870, several fat cheese dairies were established in Vestfold, particularly in Jarlsberg Sheriff's District. Most of the establishments were cooperatives between several milk producers, while others were purely private and started up on larger farms. These dairies were named after the farm. Anders Larsen Bakke from Østre Bakke Farm in Våle was one of the foremost men in dairying in this area and ran several private dairies (5, 54, 57). An example of such a cooperative dairy was started at Ramnes in 1860. Twenty-six farmers formed a cooperative agreement to divide the profit or loss according to shares based on the number of cows. There were 92 shares of two cows per share, 184 cows in all. Marie Olsen was in charge of cheesemaking at this dairy. She had been taught by Andreas Kundert from Switzerland, who was employed by the Royal Norwegian Society for Development as a district teacher with particular competency in cheesemaking (5). Several Swiss men were engaged in Norway at this time to assist in the development of cheese manufacturing. Some of them came to Norway under their own initiative; others were brought here under a scheme from the Royal Norwegian Society for Development. It has been estimated that there were around 100 Swiss in Norway during the period 1855 to 1870, and their attention was naturally directed to production of Emmental type cheese (57). It was logical then that these fat cheeses became known as Swiss cheeses, both because it was usually Swiss dairymen who had taught this method of production and because the cheeses resembled the sort of cheese that was traditionally produced in Switzerland.

Many of the new cheese dairies in Vestfold produced a cheese that could be described as a Small Swiss cheese. This cheese usually weighed around 25-30 kilo and was sold under the name Jarlsberg. At the zenith of production, there were over 30 so-called Jarlsberg dairies in Vestfold. Støren wrote (49): *"It was Swiss cheese that was originally imitated, but many of the dairies that were established had insufficient milk and were too primitive for this kind of production to be successful. The quality of the cheese was extremely inconsistent and much of it had to be sold off cheaply."* At that time, many were concerned with the variable and often poor quality of Jarlsberg cheeses from Vestfold (27). Master Cheesemaker Iversen actively attempted to improve the quality of the cheese. However, in *Norsk Landmansblad* in 1915 he wrote (19): *"...it would have been an advantage for Norwegian cheese production if Jarlsberg cheesemaking had never been introduced."*

In addition to the problems of quality, there is no doubt that the actual marketing of the cheese was a great problem. Each dairy had to provide its own transport to shops in the towns and were at the mercy of the different buyers. Despite all these problems, production of the Small Swiss continued for many years. One of the reasons why this was financially viable at all was that the production costs were so low that a reasonable price could be paid to the producers for the milk.

At the end of the 1800s, an enormous development in dairy technology was taking place. This led to the introduction of new methods for milk processing on an industrial scale. For example,

several factories were established for the production of condensed milk and these factories were considerable purchasers of milk. In 1904, Dale Milk Company sold its factory in Drammen and with the capital so gained, built a new condensed milk factory in Holmestrand. The new factory paid the local milk producers such a good price that many of them found it advantageous to sell their milk to the factory instead. As a result, many small cheese factories "...that were leading an extremely wretched existence" were closed down. Cheese production in Vestfold and the old Jarlsberg became history (5, 55).

Over 50 years later, when the researchers at the Dairy Institute started developing today's Jarlsberg cheese, there were probably very few ordinary consumers who knew anything about the old Jarlsberg cheese. This knowledge was probably held by only a few people with a special interest for the cheese and also by those who had studied Dairy Technology at, for example, the Agricultural University where a story such as this would have been part of the course in Dairy History.

By 1957, the development of the new cheese with large eyes that would later be called Jarlsberg had progressed so far that the Norwegian Dairies' Sales Outlet decided to start production at its dairies in Nes, Ørland, Steinkjer and Jæren, in addition to the commercial production at the Research Dairy at the Agricultural University. Now the new cheese needed a name.

It is difficult to pinpoint the exact time when agreement was reached to call the new cheese "Jarlsberg cheese". The name was suggested at an early stage by the staff at the Dairy Institute and the Research Dairy. Others were of the opinion that the cheese name should reflect the place of origin and "Ås cheese", "Follo cheese" and even "Vollebekk" were names that were considered. At that time, Vollebekk was the postal address for the Agricultural University and was originally the name of one of the farms that was purchased in connection with the establishment of the Agricultural College in 1859 (20). A competition to find a name was also suggested, but this never materialized.

The cheese from the experiments was first sold from the Research Dairy's shop as "Research cheese" and later as "Extra cheese", and was sold for the same price as Norwegian Gouda. Many customers, from as far away as Oslo, came to the shop specifically to buy the new cheese. Professor Ystgaard thought the name "Jarlsberg cheese" was an obvious choice. Following a meeting between Ystgaard and Director Petter Slagsvold of the Norwegian Dairies' Sales Association, it was announced that the name "Jarlsberg cheese" had been chosen. The actual date of the meeting is unknown, but unwritten reports from staff at the Dairy Institute and the Research Dairy, and also from Slagsvold, confirm that this meeting took place and that it was then the name was decided. The present owner of the Jarlsberg Estate, Carl Nicolaus Wedel Jarlsberg, has confirmed that an application was made to Jarlsberg Manor for permission to use the name for the new cheese. He also confirms that this permission was granted, but is only valid for the use of the name "Jarlsberg cheese" and not for general use of the name Jarlsberg. It has not been possible to find written documentation of this, either at TINE, the Dairy Institute or at Jarlsberg Manor. However, records are available showing that the Ministry

of Agriculture, in 1957, sanctioned the application for the name and definition of the new cheese (6): *"Jarlsberg: Full fat cheese of Gruyère type, cylindrical shape and weight of ca. 9 kg. Round eyes of about 2 cm diameter, evenly distributed in the cheese. Soft pliable consistency with a rich and slightly sweet taste."*

That same year, the Research Dairy obtained special labels printed with the name "Jarlsberg cheese". Today's Jarlsberg cheese is, without doubt, a totally new cheese type, and the only thing it has in common with the cheese that was produced in Vestfold in the 1800s is the name.

Protection Of The Name And Logos

Following its commercial introduction, the sale of Jarlsberg cheese increased both nationally and internationally. From 1970, a considerable increase in sales occurred and the popularity of the cheese made it natural and necessary for Norwegian Dairies' Sales Association to protect the name "Jarlsberg cheese". The Norwegian Dairies' Sales Association was renamed Norwegian Dairies (Norske Meierier) in 1984. TINE Norwegian Dairies (TINE Norske Meierier) was introduced in 1992, and after extensive reorganization in 2002, TINA BA became the official name of the company.

The first application for protection of the name was submitted to the Board for Industrial Legal Protection, Norwegian Patent Office, on February 29, 1971. The application was delivered to the Norwegian Patent Office by the company Bryn & Aarflot A/S, Patent Consultants, on behalf of the Norwegian Dairies' Sales Association. When the application was considered, it was discovered that the name Jarlsberg had been submitted for registration by Jarlsberg Mineral Water A/S on September 15, 1969. It was also pointed out that Fredrikstad Saapefabrik (Soap Factory) had applied to register the name "Jarl" back in 1922. The Norwegian Dairies' Sales Association had also applied to register this name in 1960. An application for protection of the name "Berg" was presented by other companies in 1962. Because of these other registrations, the Patent Board decided that the name Jarlsberg could only be registered for cheese under the so-called International Class 29. Correspondence shows that the Norwegian Dairies' Sales Association accepted this decision. The documents at the Patent Board also show that the individual in charge at Bryn & Aarflot A/S pushed the case in a letter dated June 20, 1971 on behalf of their client, Norwegian Dairies' Sales Association.

A short description of "the history of Jarlsberg cheese" may be found in this letter.
On the basis of the above paragraphs, it can be maintained that parts of it are historically incorrect, while certain other parts are historically interesting. Part of the letter read: *"Jarlsberg cheese was produced as early as the end of the last century. It was produced at the dairy at Jarlsberg Manor, which had been established in 1815 by Earl Herman Wedel Jarlsberg and Jacob Sverdrup. Production of Jarlsberg cheese dwindled, but was later revived by Professor O.M. Ystgaard. The owner of the Jarlsberg Estate at that time, Wedel Jarlsberg, gave Norwegian Dairies' Sales* Association *permission and monopoly to use the name JARLSBERG CHEESE."*

«It is understood that recently the name has been registered in Norway as a trade mark of the

applicant company, but there is no evidence as to the effect of such registration or what the situation would be under Norwegian law if another trader in the area formerly known as Jarlsberg, or elsewhere, started selling Jarlsberg cheese or cheese of the bland Emmental type for which Jarlsberg had an earlier reputation.»

From this text it could be understood that Jarlsberg cheese was produced continuously from 1815, but this, of course, was not the case, as has been explained. It is indisputable that the initiative for the development of today's Jarlsberg cheese was in no way a revival of the old production of Jarlsberg cheese from Jarlsberg Manor.

Professor Ystgaard's work was the development of a new unique type of cheese that was later given the name "Jarlsberg cheese". However, it is of interest to note the point made in the letter from Bryn & Aaflot A/S that the Norwegian Dairies' Sales Association were given permission and monopoly to use the name "JARLSBERG CHEESE" by the Jarlsberg Estate owner at that time. It has not been possible to find the original documents that show that such permission was actually given, but anecdotal accounts tell the same story. The present owner of the Jarlsberg Estate, Carl Nicolaus Wedel Jarlsberg, has emphasized that the permission that was given at that time was only in connection with the use of "Jarlsberg cheese", and not to a general use of the word "Jarlsberg" when not referring to cheese. At one stage in the argumentations for the protection of the name "Jarlsberg cheese", four cheese wholesalers, Norges Kolonial- og Landhandlerforbund (Norwegian Grocers Association),

Norges Kooperativ Landsforening – NKL (Norwegian Cooperative Association), Joh. Johannson and Fetevaregrossistenes Landsforening strongly recommended that the Norwegian Dairies' Sales Association be given the rights to the name "Jarlsberg cheese". Norges Kolonial- og Landhandlerforbund wrote in a letter of support dated May 21, 1971: *"In our opinion, there has been an active and extensive sales drive for JARLSBERG CHEESE for many years and the cheese now enjoys a good position in Norway as an established and well-known product. It would seem both correct and necessary that the Jarlsberg name should be protected by registration as it is obvious that cheese types of different origin and quality, but having the same name or label, can be a source of confusion for the consumer and food wholesalers."*

The original application for the protection of the name "Jarlsberg cheese" was sent from the Norwegian Dairies' Sales Association on February 29, 1971. It was made public by the Patent Office on November 15, 1971, and the final decision to register the name was made on January 7, 1972.

The registration was later renewed and is now valid until January 2012. While the application for the registration of "Jarlsberg cheese" was under consideration by the Patent Office, the Norwegian Dairies' Sales Association applied for registration of the word "Jarlsberg". The Patent Office's response to this was similar to that for "Jarlsberg cheese", although they added that similarity to the word "Carlsberg" could cause confusion. The word "Jarlsberg" was only registered for cheese in Class 29. The registration was dated April 5, 1972.

Whether registration of the word "Jarlsberg" is in agreement with the permission originally given by Wedel Jarlsberg regarding the use of "Jarlsberg cheese" is certainly a valid point for discussion. Once the word "Jarlsberg" was approved by the Patent Office for registration in other countries, registration in the United Kingdom became a problem. The Patent Office in London wrote to the Norwegian Dairies' Sales Association on July 24, 1974, via the company Elkington & Fife in London, and was clearly critical of the application for registration of the word "Jarlsberg" in the United Kingdom. They wrote: *"We understand that the name has recently been registered in Norway as a trademark of the applicant company, but there is no evidence to the effect of such registration or what the situation would be under Norwegian law if another trader in the area formerly known as Jarlsberg, or elsewhere, started selling Jarlsberg cheese or cheese of the bland Emmental type for which Jarlsberg had an earlier reputation."*

The Norwegian Dairies' Sales Association naturally wanted the opinion of the Norwegian Patent Office on the doubts and objections expressed by the London Patent Office. The Norwegian Patent Office then gave a final declaration that included the following text: *"The owner of the registration is assumed to have exclusive rights to the use of Jarlsberg for cheese that is sold in Norway. A third person's use of this trademark for cheese sold in Norway would represent an infringement of these rights, whether or not the cheese is produced in the area that was previously called Jarlsberg and Larvik County, and also whether or not the cheese is the same type that was produced in that area many years ago and sold under the name Jarlsberg cheese."*

The declaration from the Norwegian Patent Office also pointed out that the validity of the registration can be judged by court. The registration has been renewed several times and is now valid until April 5, 2012. The Norwegian Dairies' Sales Association has also registered several trademarks and logos for Jarlsberg cheese over the years, but these do not seem to have met any resistance. Several of these have also been renewed and given a new expiration date.

The Start-Up Of Commercial Production

Traditional procedure in moulding cheese, using cheese cloths and moulds of stainless steel. Here removing of cloths.

The full-scale production of Jarlsberg cheese at the Research Dairy at the Agricultural University made it possible to get a quick response from the consumers during the cheesemaking experiments. The new cheese type was well received and this made continuation of the cheese development even more interesting. The unique possibility for scaling up the production in the same scientific environment that was engaged in the research and development of the cheese provided good conditions for product development. It was also important to make use of the full-scale cheesemaking facilities at the Research Dairy so that the cheesemakers could build up their competence for working with this demanding cheese. It was also important to gain experience from continuous production of Jarlsberg cheese during an extended period. This was necessary for studying aspects such as the stability of the propionibacteria's properties and how variation in milk quality and composition could affect the production.

The results from the cheesemaking experiments in 1956 and the beginning of 1957 were so promising that it soon became of interest to start regular production at a number of dairies. However, in order for the establishment of full-scale production outside the Research Dairy to be successful, it was necessary to pass on the knowledge of Jarlsberg cheese production to the selected dairies. It was also necessary to consider which dairies should be selected to start production.

Production Starts Up

The new Jarlsberg cheese dairies were selected according to the quality of their cheese production. By statistically analyzing the data regarding the amount of bonus that the dairies had received due to the good quality of cheese they were already producing, it was possible to select the best dairies. This decision, however, presented a challenge. On the one hand, it was

obviously desirable that the best cheese factories be selected for Jarlsberg cheese production. On the other hand, these factories had a stable production of high-quality established products and therefore received a good price for their cheeses. This in turn gave the milk producers who delivered to these dairies a better price for their milk. The dairies therefore declined to give up their present production of familiar cheese in order to begin producing the new and unfamiliar Jarlsberg cheese. They also knew that the technology involved in producing Jarlsberg cheese would prove to be a greater challenge than the cheese types they were already producing. This dilemma was solved by introducing a so-called risk-bonus for Jarlsberg cheese production that was paid out per kilo of Jarlsberg cheese produced. The size of the bonus was determined by the amount of bonus each dairy was already receiving for their regular production. In this way, it was hoped that the dairies would retain their ability to pay the milk producers as well as before even though they had changed over to the new and unfamiliar cheese production.

The first dairies to be selected were Ørlandet Dairy, Steinkjer Dairy, Nes Dairy and Jæren Dairy. All of these dairies had very capable cheesemakers with good reputations for good product quality. However, it was considered a special challenge to transfer the Jarlsberg cheese production from the Research Dairy with its excellent laboratory support to a commercial factory. A course in the production of Jarlsberg cheese was therefore held at the Dairy Institute in 1957, led by Professor Ystgaard, attended by the following cheesemakers:
Schärer Uddu from Nes Dairy, Lunnan from Steinkjer Dairy, Hem from Ørlandet Dairy and Schibevaag and Kvassheim from Jæren Dairy. Pedersen from the Research Dairy also attended. These people eventually became the Jarlsberg cheese veterans.

The dairy researchers at the Dairy Institute arranged a further course for the Jarlsberg cheesemakers in 1959, and 16 cheesemakers attended. In 1962, another course was attended by 23 participants and lasted for 14 days, which was a long course for its type. In addition to courses for Jarlsberg cheesemakers, courses for dairy managers were also held at the Dairy Institute. In 1958, these courses were held in February and October. Various problems and challenges associated with the production of Jarlsberg cheese was the main theme of these courses.

Practical Problems

The staff at the Dairy Institute was engaged in other ways in the transfer of knowledge about Jarlsberg cheese production, the use of propionibacteria and of control procedures and quality assessment of both the propionibacteria culture and the cheese. The people responsible for development of Jarlsberg cheese provided consultancy help for the Jarlsberg cheese dairies. Research Assistant Arne Henrik Strand visited Ørlandet Dairy in December 1957 to advise on Jarlsberg cheese production. When occasional irregularities or quality faults arose, the scientific staff at the Institute tried to help the dairies find the causes and solutions whenever their advice was requested.

Even with the normal and natural variations in milk quality due to locality, it became obvious that cheese production did not usually present great difficulties. Sometimes, however, a faulty culture of propionibacteria could produce an atypical cheese. In fact, the advice most often

sought by the dairies concerned the use of the propionibacteria culture and the handling of the bulk starter of this culture. This kind of topic was often brought up during the cheesemaking courses at the Dairy Institute. The laboratory at the Department of Dairy Technology at the Dairy Institute supplied the Research Dairy with the bulk starter culture of propionibacteria for the full-scale production. However, when other dairies began Jarlsberg cheese production, they had to produce the necessary amount of bulk starter themselves. The starting point for the production of the bulk starter was a so-called mother culture that was sent out from the Dairy Institute each week. The selected dairies really did not have the facilities to prepare their own bulk starter. In the preparation of propionibacteria culture, sterility of growth media and the Inoculation Room was critical. The dairies were understandably reluctant to invest in the equipment necessary for optimal culture production, such as suitable autoclaves, particularly before it was certain that Jarlsberg cheese would be a success. Autoclaving in ordinary pressure cookers was attempted, but the result was not always satisfactory. However, those dairies that also produced Brown Whey cheese could use the brown cheese kettles as autoclaves after a few small adjustments, and this was generally done. Despite certain practical problems that occurred when production was established at the selected dairies, good quality cheese soon came on the market. The new cheese became popular so fast that demand began to exceed supply. More dairies began production, and by 1961, ten dairies were annually producing 2,000 tons of Jarlsberg cheese between them. Total coverage of the market was not achieved until 1962.

Exhibitions of the dairies' products are frequently arranged by and for dairy professionals. Their products are then graded for their sensory properties by an authorized panel and ranked and awarded according to their quality. Jarlsberg cheese first appeared at such an exhibition in Trondheim on November 14, 1957. The cheese had been produced by Ørlandet Dairy and was given a score of 11, indicating it was deemed "Very good".

Records show that Jæren Dairy produced 3,168 kg of Jarlsberg cheese in 1957. Production increased to 6,884 kg the following year. Nes Dairy produced 68,000 kg of Jarlsberg in 1958. At product exhibitions from 1960 to 1962, Jarlsberg cheese was displayed from an increasing number of dairies and all the cheeses were judged to be of extremely good quality. All satisfied the demands for what was known at the time as the "Clover Mark", a mark of quality in the dairy sector. Product exhibitions were held in Drammen and Trondheim in 1960. The following dairies presented Jarlsberg cheese with "Clover Mark" quality: the Research Dairy; Fredrikshald Dairy; Stokke Cheese Factory; Odal Dairy and Steinkjer Dairy. At the regional product exhibitions in 1961 and 1962, ten dairies exhibited cheeses that achieved or even surpassed the quality required for the "Clover Mark". These dairies were: Bygstad Dairy; the Research Dairy; Fredrikshald Dairy; Gjøvik Dairy; Nes Dairy; Odal Dairy; Sortland Dairy; Steinkjer Dairy; Stokke Dairy and Ørlandet Dairy. Jæren Dairy apparently did not take part in these exhibitions, although Jarlsberg cheese was also produced there.

In the first few years after 1962, no further dairies commenced Jarlsberg cheese production. However, an interesting development took place at Sortland Dairy and at Nes Dairy. Until this time, all the dairies had produced Jarlsberg cheese with rind. These two dairies began

production of rindless cheese. Sortland Dairy exhibited Jarlsberg cheese both with and without rind in 1966, and from 1968, Nes Dairy produced only top quality, rindless Jarlsberg cheese.

These glimpses of the work involved in the transfer to other commercial dairies of the production of Jarlsberg cheese from pilot scale in the Research Dairy at the Dairy Institute and fullscale production in the Research Dairy's regular production illustrate the excellent utilization of the expertise and knowledge of the researchers and cheesemakers at the Dairy Institute and the Research Dairy. The scientific personnel at the Institute felt it was necessary to participate in this knowledge transfer in order to optimize the establishment of Jarlsberg cheese production at the dairies that were selected for production.

This collaboration was an important factor in the success of Jarlsberg cheese. This kind of collaboration between researchers and industry is just as relevant and advantageous today and should be paid increased attention in order to achieve invention and innovation.

The Importance Of Jarlsberg Cheese For Tine

Jarlsberg cheese was an innovation that quickly became established as a very popular cheese both at home and abroad. It was referred to as a new type of cheese right from the start of its development period in 1956. It soon became apparent that the consumer in Norway and in many other countries greatly appreciated the taste and consistency of the new cheese. It became a valuable addition to the Norwegian cheese assortment, and rapidly became very important for TINE as it became a great commercial success.

Jarlsberg cheese first appears in Norwegian Dairies' statistics in 1961, when 1,648 tonnes were sold on the Norwegian market. Figure 5 shows annual production and exports from 1961. Production increased greatly between 1970 and 1978; after that, growth leveled out. Most Jarlsberg cheese was produced in 1997; 20,732 tonnes. The figures for 2004 and 2005 are higher than in previous years, but include production under license in the USA. A provisional record for the home market was reached in 2004, when 8,042 tonnes were sold in this market. Jarlsberg cheese soon became the second most popular cheese from TINE on the Norwegian market. Among TINE's cheeses, only Norvegia is sold in greater amounts.

Figure 5 shows that more Jarlsberg cheese is exported than is sold on the Norwegian market. However, cheese was exported from Norway long before Jarlsberg cheese was developed and introduced on the international market, mostly Norwegian Gouda (Norvegia) and Nøkkelost. In addition, certain amounts of Norwegian Edam, Norwegian Tilsiter and Normanna (Blue cheese) were exported, mostly to West Germany and the United Kingdom.

The initial export drives for Jarlsberg cheese took place as early as 1962, when a representative for Norwegian Dairies took some of the cheese to the United Kingdom and showed it to his customers there. The same year, a representative traveled to the USA and showed the product to his biggest customer for Brown Whey cheese, a product that had been exported to the USA for many years. As a result of this introduction to first-class Jarlsberg cheese , exports to the United Kingdom and the USA began the following year. The exports in 1963 totaled 224 tonnes, which gradually increased until 1972. That year, Norway voted not to join the European Union, and exports of Jarlsberg cheese to the USA greatly increased. Canada and Australia later became important markets.

The Norwegian Dairies' Sales Association 50th Anniversary Report (6) states the following regarding the export potential for cheese as various countries joined the European Union: *"Exports to the United Kingdom went well until the country became a member of the European Union. However, the Sales* Association *managed to develop an export of Gouda to Japan that more than compensated for the loss of the other markets. Exports of Normanna and Tilsiter suffered the same fate as Gouda, and it was not possible to find replacement markets.*

Production of rindless Jarlberg cheese soon started at Nes Dairy. Satisfied with eye formation?

our export trade was Jarlsberg. Despite extremely high import tariffs, a certain market has been built up in West Germany and similarly for the United Kingdom after it joined the European Union. However, it was primarily in the USA and Canada that it was eventually possible to build up an export volume for Jarlsberg cheese which the Sales Association has never before had for any cheese in any market."

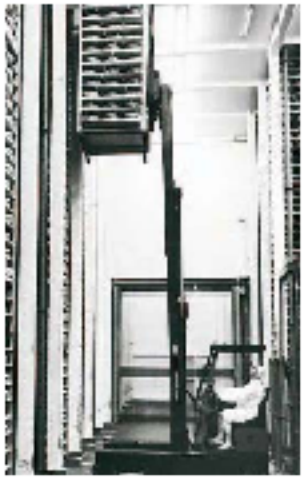
Following negotiations in what became known as "the Kennedy Round", customs duties for import of cheese to the USA were reduced and import quotas were simultaneously introduced for different cheese types, with one important exception.

Cheese that was sold for a price over a certain FOB (Free On Board) rate was exempted from the quota limitations. Norwegian dairies then decided to increase the price of Jarlsberg cheese to the USA such that it exceeded the FOB rate, thus rendering it exempt from the import quotas.

It was not easy to predict in what way the price increase would affect the volume of cheese exported to the USA. However, it turned out that Jarlsberg cheese's quality was so good, and its popularity so great, that this price increase was accepted and export actually continued to increase. This evident success of Jarlsberg cheese on the American market also aroused great interest from other cheese-exporting countries.

Several countries wanted to produce and export a cheese with similar characteristics, and there

was also considerable interest for using the same name or a name that could be associated with the successful Jarlsberg cheese. The Norwegian Dairies' Sales Association's 50th Anniversary Report (6) states the following about this situation: *"The following message from Denmark was typical for the international interest for Jarlsberg cheese, but also alarming for the Sales Association: 'The Cheese Export Committee has decided to recommend to the Government Control Agency that it be permitted to produce and export to all markets, on a dispensation basis, a quality-controlled (Lurmerket) 45+ 'Danish Jarlsberg' cheese with a moisture content of 44% on the condition that the cheese is equivalent to the Norwegian characteristics for this cheese'. Denmark now exported Jarlsberg to the USA and Canada under this declaration, far below Norwegian prices. One Danish dairy actually proffered the cheese using the name 'Jarlsberg cheese', and the Sales* Association *had to bring up the matter of protecting the name on the export markets. Nevertheless, exports of Jarlsberg to the USA increased slowly but surely despite all attempts from foreign competitors to exclude the Sales Association from this important market."*



In the USA, the "Countervailing Duty Act" gives the authorities the right to impose a duty on so-called subsidized exports to the USA that can be sufficient to compensate for the subsidies given in the exporting country. In 1974, the question was raised concerning whether this form of duty should be taken into use. Various wares were attracting the authority's attention at that time. The American National Cheese Institute pressed the authorities to introduce this law in the case of dairy products and, one by one, all countries that exported cheese to the USA were accused of subsidizing cheese to the American market. As one of the last countries of many, Norway was also accused, explicitly citing Jarlsberg cheese.

Norway refuted the accusation, arguing that the Jarlsberg cheese that was exported to the USA was not subsidized. The American authorities claimed in return that the consumer subsidies that were in use on the Norwegian home market, for example for liquid milk, acted indirectly as export subsidies. A series of discussions on these issues took place for a short while. The Norwegian Dairies' Sales Association 50th Anniversary Report (6) states: *"The American representatives had to admit that the Norwegian cooperative system within the milk sector was different from all other countries' schemes, which directly subsidized the export."*

The final decision on the question of subsidies was reached by the American Treasury Department in 1976 and did not go in Norway's favor. The consequences were that if exports of Jarlsberg cheese to the USA were to continue, the price had to be increased by 30%. Despite this large price increase, the American importers were still optimistic. However, it was deemed necessary to strengthen sales promotion of Jarlsberg cheese in the USA. The price increase made Jarlsberg cheese the most expensive large-eyed cheese type on the American market. The American importers' appraisal of the market's willingness to pay this high price proved to be correct. Exports to the USA and Canada continued to increase, and reached about 8,000 tons in 1976.

The obstacles, however, were not over, although the market seemed to accept the high price for the cheese. In 1976-1979, the USA introduced a quota restriction for imports of cheese, which included Jarlsberg cheese. Exports of this product were still relatively new in the USA, and sales were still increasing. It was thus very unfortunate that the quota restrictions were based on average imports from an earlier period, but this limited the amounts that could be exported to these markets. Exports to the American market were first managed by a subsidiary

of Nestlé. Following a reorganization of Nestlé, the Sales Association decided to start its own company in the USA. This became a fact in 1978. The company is a subsidiary, wholly owned by the Sales Association, and has since its initiation managed all Norwegian cheese sales on the American and Canadian markets.

The total exports of Jarlsberg cheese to all countries, including the license-based production in USA, reached 16,099 tonnes in 2005. Apart from the USA and Canada, these countries included many European countries and, not least of all, Australia. Concerning the Australian situation, the following was written in the Aftenposten newspaper on May 16, 1977: *"Norwegian exports to Australia have never been significant. This is partly because Australia tries to restrict the import of certain goods and partly because the long distance from Norway scares many producers off. There are therefore few export drives to this country, which has such a potential. Honorable exceptions to this are the Norwegian fish industry, which sells considerable amounts of frozen fish, the Norwegian shipping industry, which is well represented in Australia, and Norwegian cheese. There are considerable and increasing exports of Norwegian cheese to Australia, and over 1,000 tons are shipped annually the long distance to Australia. In Australia, the Norwegian exports of cheese are as great as those from Denmark. Norwegian cheese is considered a quality product here. It is more expensive than that of the competition, but known to be among the best."*

Not only have exports of Jarlsberg cheese met various trade hindrances such as customs, extra levies and quota restrictions, but also tough competition from both other countries' cheeses and from direct copies produced in other countries. Despite this, the cheese has established itself as one of the greatest and most profitable varieties in most markets where it has been introduced. It is probably correct to maintain that it is considered an exclusive cheese and is often displayed in shops alongside the more expensive wines. In addition to the cheese's special and characteristic properties of taste, flavor and eye formation, its success is not least due to the high and stable quality that has been maintained throughout the production. Well developed quality control systems and thorough quality assurance of production and the product at all the dairies in Norway have been, and still are, of vital importance for success in the export market. Capable sales and marketing by the Sales Association and later from TINE were an important prerequisite for the great success that has been experienced with Jarlsberg cheese.

Since its introduction on the market in 1961, national and international sales have developed very positively. In 2005, the total turnover had a market value of approximately 1.5 billion NOK, representing a considerable value and volume for the Norwegian dairy industry. TINE BA estimates that Jarlsberg cheese has a greater sales potential in several countries than is attainable with today's export and trade restrictions. In order to utilize this potential, TINE BA has established a licensed production in the USA and a similar agreement has been established in Irland.

Some Main Features Of The Technological Development Of Jarlsberg Cheese Since 1965

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The period for development of Jarlsberg cheese is considered to be until 1965. However, also after that time, work on optimization of production technology and development of new product varieties has been almost continuous. Some of the main aspects of this development are described below.

Rindless Jarlsberg

Rindless cheese is less wasteful for both producer and consumer. It was therefore natural that production of a rindless variety of Jarlsberg cheese became a subject for development research. The first experiments were conducted at Nes Dairy in 1965. It soon became apparent that the greatest challenge was to find a cheese film that would release the large quantities of gas produced in Jarlsberg cheese. The problem was the development of many small eyes in the outermost parts of the cheese and the formation of cracks. It was also difficult to attain the same full flavor. However, the experiments were continued, and in 1967, the quality was considered good enough for the cheese to be launched on the market.

In order to reduce the risk for small holes and cracks, it was necessary to employ a film with a very low barrier for CO2. These so-called "open" films will simultaneously have low barriers for O2. Not surprisingly, growth of mold was soon shown to be a problem, but this was solved by treating the surface of the cheese with an antifungal preparation. Several such preparations were tested and, in the end, the fungicide natamycin/pimaricin was found to be the best compromise solution. The cheese was first packaged manually and later by machine using a PVC film material. It was later discovered that this type of film contains plasticizers that may be a danger to health. These circumstances, along with a desire to further rationalize the packing process, led to the start of experiments employing vacuum packaging of the cheese. Again, a number of different films were tested. The problems of small eyes at the cheese surface and cracks immediately reappeared, usually in combination with inflated packages. In 1988, after long and comprehensive research experiments, it was determined that it was safe to start production of rindless Jarlsberg.

New Cheese Sizes

In the late 1960s, a request came from the USA asking whether it was possible to deliver a Jarlsberg cheese larger than the standard 5- or 10-kg blocks. The background for this was that the market for sliced cheese was growing, and there was a need for slices that were more suitable to the American demand. Verdal Dairy started production of large blocks of Jarlsberg cheese weighing 36 kg, which were very suitable for cutting into sizes that suited the American customer. The establishment of this production, of the cheese later called Fjordland, presented a series of technological challenges.

Authorized cheese graders at work. None of the cheese batches were presented to the market before grading had taken place.

The final pressing of the cheese was to take place in specially constructed pressing vats, after which the cheese had to be divided into pieces that would fit the cheese molds. These individual blocks therefore had some surfaces that had cut edges and others that had been in contact with the wall of the pressing vat. The cut surfaces had a more open structure, and when the cheese was then brined, a much greater uptake of salt occurred through these open surfaces. A definite improvement was achieved when equipment for sealing the opened surfaces was installed, but it was always a challenge to achieve an even distribution of salt at the level required in this type of cheese.

In 1996, the production equipment at the dairy was renewed, and it was decided at that time to change the format of the cheese blocks. The giant 36-kg block was replaced by one weighing 20 kg that had the shape of two side-by-side 10-kg blocks. This cheese was tailor made with respect to portion packaging. Compared to the large blocks, there was less waste and also more portions with a characteristic eye formation. Jarlsberg cheese in 20-kg blocks is vacuum packed in plastic bags.

Reduced-Fat Jarlsberg

In 1988, the USA requested a Jarlsberg cheese with a reduced fat content. At about the same time, there was also a dawning of interest for such a product on the home market. It was decided to establish the production of a Jarlsberg cheese with 16% fat (Jarlsberg H 30), with rind, at Steinkjer Dairy. This product was launched in 1989, but unfortunately received a cool reception in the market and therefore had a short life. Parallel to the establishment of the production of this cheese with rind, a rindless version of Jarlsberg H 30 was also being developed. Production was started at Rogaland Dairy, Høyland, with launching in 1989. This was a special product for the American market from the beginning, and was sold under the name "Jarlsberg Lite". In 1991, however, the USA demanded that the fat content be further reduced.

The US regulations stipulated that in order to permit the use of the product name "Jarlsberg Lite", the fat had to be reduced to half that of the standard Jarlsberg cheese, which contains 27% fat. The production immediately went over to Jarlsberg cheese with 13% fat. At the same time, due to yet another request from the USA, vitamin A was also added. Since then, Jarlsberg Lite has been purely an export product. Production of rindless Jarlsberg H 30, with 16% fat, continues to cover the demand from the home market. This product was later renamed "Lighter Jarlsberg".

New Taste Variety

A Jarlsberg cheese variant with smoked flavor was developed and launched in 1994. The smoked flavor is achieved by placing fully ripe Jarlsberg cheese in a liquid natural smoke aroma. To ensure a good penetration of the flavor into the cheese, it is first divided into 2.5-kg pieces. The cheese is then drained and vacuum packed in the usual way. Jarlsberg cheese with smoked flavor is produced at TINE Dairy South, Nærbø.

New Surface Treatment Of Jarlsberg Cheese With Rind

Problems with the surface of Jarlsberg cheese appeared right from the start. The cheese surface used to be waxed. The problem of loose and cracked wax was at times somewhat extensive, and the surface often then became infected with molds in those places where the wax had fallen off. At that time, the cheese label was placed on top of the wax and applied with a hot iron, a heavy and time-consuming process. If the problem of loose wax subsequently occurred, all or part of the label usually came off. On cutting such a cheese into portions, there was a chance that sections of the cheese could lose their identifying mark. A project was therefore started in 1996 with the aim of developing a method of surface treatment that would be more satisfactory. The result of this work was the replacement of waxing with a liquid plastic emulsion (Plastcoat), and the cheese label was placed in the layer of plastic instead of in the wax. This process could be done by machine directly after the cheese received its plastic coating. At the same time, a so-called "banderole", a band with décor around the cheese, was introduced. This also helped the cheese retain its shape better when in the warm Ripening Room. When the cheese was removed from the warm Ripening Room, it was vacuum packed in plastic instead of wax covered. The so-called Jarlsberg "New Look" was put into production at both of the dairy factories that were still making Jarlsberg cheese with rind, TINE Dairy South, Nærbø, and TINE Mid-Norway, Elnesvågen, in 1999.

Extra-Aged Jarlsberg

For many years, Jarlsberg cheese was not thought to be a cheese that would be improved by extending the ripening period. However, the question of launching an extra-aged Jarlsberg cheese was occasionally raised. After a period of hesitation, the decision was made in 2002 to establish the production of extra-aged Jarlsberg cheese at TINE Mid-Norway, Elnesvågen. The cheese, "Jarlsberg Special Reserve", is aged for nine months for the home market and 12 months for the export market.

Concentrated Propionibacteria Culture

Until 1991, the Jarlsberg cheese dairies were provided with propionibacteria culture from the Dairy Institute at the Agricultural University of Norway. After that time, TINE's R&D Center at Voll took over production and delivery of the mother culture to the dairies. Traditionally, the mother culture is propagated to the bulk starter culture at each factory. When the production of Jarlsberg cheese under license in the USA was established in 2000, it was considered undesirable for the dairy in the USA to propagate its own culture. From 1989 to 1995, TINE R&D pursued a research project with SINTEF and Landteknikk Fabrikk. The aim was to find a new and unique way of producing the propionibacteria culture. A prototype filter fermenter was developed and was subsequently installed at TINE R&D Voll in 1995. Many

challenges were experienced during testing and optimization of the equipment, and it was not ready for normal production until August 1, 2000, the same time as licensed production began in the USA. The filter fermenter continually produces propionibacteria culture and is 50 times the concentration of a normal mother or bulk starter culture. The culture is tapped into bottles in units equivalent to that required for one cheese vat. One hundred ml of this 50x concentrated propionibacteria culture is added to a cheese vat containing 12,000s liters of milk. The bottles of concentrated culture are frozen at -45° C and activity is retained for one year. The concentrated propionibacteria culture is thawed immediately before use and added directly to the cheese vat.

The culture production capacity for the filter fermenter at TINE R&D Voll is 750-800 liters per year. According to the production prognoses for the USA, the requirement for the concentrated culture will exceed fermenter capacity during 2006. Production of Jarlsberg cheese under license also started in Ireland in 2006. It was therefore decided in 2003 to build a new filter fermenter. One of the prerequisites for this investment was that the concentrated cultures will also be used by the Norwegian producers of Jarlsberg cheese in Norway. A centralized production of the culture will provide better quality control and quality assurance. The dairies will also save time, and seen as a whole, this centralized production will reduce production costs.The new filter fermenter is in operation from 2006. It is a modified version of the prototype, and has an annual capacity of 5,000 liters of 50x concentrated propionibacteria culture.

Around the seventies a national romantic atttitude was typical for cheese advertisement.

The Authors

Roger K. Abrahamsen is Professor of Dairy Technology at the Department of Chemistry, Biotechnology and Food Science at the Norwegian University of Life Sciences. He is employed in the same professor chair as Professor Ystgaard, who was responsible for the development of Jarlsberg cheese. Abrahamsen is a graduate in Dairy Science from the Agricultural University of Norway (1971) and has carried out research and teaching in many fields of dairy technology since 1974. He has been Professor in Dairy Technology since 1992.

Odd Byre is retired. He is a graduate in Dairy Science from the Agricultural University of Norway and in 1963 he submitted his MSc research thesis on the salting of Jarlsberg cheese. He continued as junior researcher for a period at the Dairy Institute, Agricultural University of Norway, where he continued with development of Jarlsberg cheese. Byre took further education in business administration in USA in the period 1978-79 and was employed in various positions by Norwegian Dairies (TINE BA) from 1967 to 2000. He was Financial Director and Vice Managing Director when he retired in 2000.

Kjell Steinsholt is Professor Emeritus, Steinsholt is a graduate in Dairy Science from the Agricultural University of Norway (1956) and has also studied Dairy Science at the University of Wisconsin, USA. He was employed as research assistant and PhD researcher at the Dairy Institute, Agricultural University of Norway from 1956-1960 and actively participated in the development of Jarlsberg cheese. From 1966, he was affiliated to the section for Dairy Technology at the Institute. In 1982, he became Professor in Food Technology at the Agricultural University of Norway and held this position until his retirement in 1996.

Arne Henrik Strand is Professor Emeritus. Strand is a graduate in Dairy Science from the Agricultural University of Norway (1955). Immediately following graduation he was employed as research assistant in Dairy Technology at the Dairy Institute, Agricultural University of Norway. Strand was responsible for much of the technological work in the development of Jarlsberg cheese. He was employed at the Dairy Institute as researcher and teacher for the whole of his working life and became Professor in Dairy Technology following Professor Ystgaard's death in 1972. He remained in this position until retirement in 1992.

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