A STUDY OF THE VISIBLE CHARACTERISTICS OF CHEESE

Amir H. Al-Dahhan, M.S. (Cornell)

The West of Scotland Agricultural College,

Department of Dairy Technology,

Auchincruive,

AYR.

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SUMMARY

These studies have shown that seaminess is a visible characteristic present in a significant proportion of Cheddar cheese made in Scotland.

Earlier work suggested that this characteristic could be eliminated by washing the curd with warm water prior to addition of the salt. This practice is not acceptable to the dairy industry in the United Kingdom. Studies were conducted to investigate the factors which may encourage the occurrence of seaminess and also to find acceptable remedies to overcome its formation.

Seaminess was found to appear as white lines in the curd particle junctions and was evenly distributed in the interior of cheese. Seams were easily recognised by sight, having a varying width and were more evident in coloured than in uncoloured Cheddar cheese. They were found in the cheese directly after pressing and became more noticeable with the time of curing up to 8 weeks.

Seams were present in both salted and unsalted cheese. Slit openness tended to form easily along the seams which form weak points in the cheese.

The seams were found to contain higher levels of calcium and phosphate than the rest of the cheese. The levels of calcium and phosphate found in experimental and commercial cheese supported the view of other workers that the seams consist of calcium orthophosphate. The seam-producing compound tended to concentrate on the surface of pressed and un-pressed salted and unsalted milled cheddared curd. The calcium levels of material from curd particle junctions increased with the curing time to reach a maximum in 8 weeks and thereafter decreased. Compared with the rest of the cheese the seams were found to contain low levels of sodium chloride, fat and protein and had a higher pH. Electrophoretic studies showed that there was no difference in the type

of protein present in the seams compared with that present in the remainder of the cheese substance.

A higher than normal level of added salt of both coarse and fine particle size increased the formation of seams but did not produce in experimental cheese a distinctive seamy condition as judged by a grading panel. Seaminess increased when the salt was added to curd of high titratable acidity.

The presence of additives in commercial grade salt, the temperature of the curd at the time of salt addition and the mellowing time did not influence the degree of seaminess present in experimental cheese but these factors affected salt retention, moisture content and other characteristics of cheese.

The type of mill used in milling the curd significantly affected the formation of seams and other characteristics of cheese. Cheddar cheese produced from curd milled with the Bell-Siro Cheese-Maker 3 equipment tended to be more seamy than that produced under experimental and commercial conditions from curd prepared with Berry, Damrow and peg mills.

The application of high pressure for pressing commercially produced cheese increased the degree of seaminess but the use of lower than normal pressure reduced but did not eliminate the condition.

Information was obtained on the rate of cooling of cheese during pressing under different ambient conditions. The temperature of cheese during pressing did not affect the development of seaminess but influenced other characteristics of cheese.

Under experimental market conditions consumers did not object to seaminess in good quality commercial Cheddar cheese.

In the course of investigations on the development of seaminess, information was obtained on a range of characteristics and composition concerning Cheddar cheese made on an experimental scale and in large mechanised factories in Scotland.

INTRODUCTION

Importance of Cheddar Cheese

In the United Kingdom in the year 1974/75, 2896.4 million gal (13167 million l) of milk were sold off farms. This placed milk as the most importance single agricultural product of farms in the United Kingdom. Of the total sales of milk off farms, 1189.0 million gal (5405.2 million l), (41.05 per cent of the total) were used for manufacturing dairy products such as cheese, butter, cream, and condensed and dried milk. Approximately 336 million gal (1527.5 million l) of milk were made into Cheddar cheese in the United Kingdom. Of all types of cheese made in the United Kingdom Cheddar is by far the most important variety, Table I.

In Scotland, mainly Cheddar cheese was made. Of the 50 million gal (227.3 million l) of milk that went into cheese manufacture, 48 million gal (218.2 million l) were made into Cheddar. Cheddar cheese is manufactured in several factories, which are distributed in Scotland as shown in Figure 1. The capacity ranges from semi-mechanised system handling daily 12,000 to 14,000 gal (54552.0 to 63644.0 l) of milk to the fully mechanised system handling from 50,000 to 100,000 gal (227300.0 to 454600.0 l) of milk per day.

Since most of this work deals with the different mechanised systems of Cheddar cheese making, a brief review of the developments which have taken place is given.

TABLE I

Sales of milk for manufacture of various varieties of cheese in The United Kingdom in 1975

(Federation of U.K. Milk Marketing Boards, 1975)

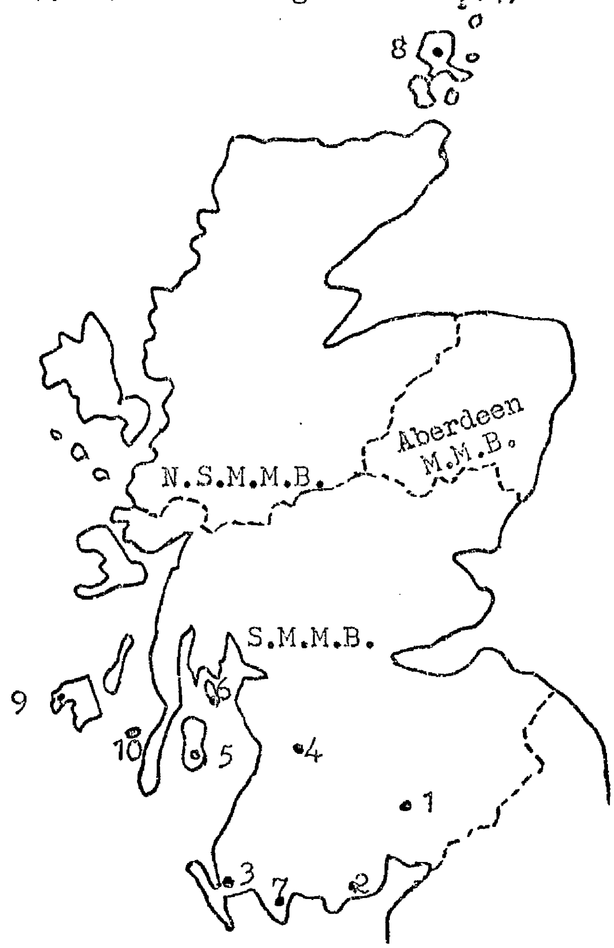
(Million gal (Million l)

Creamery production	England and Wales	Scotland	N.Ireland	United Kingdom
Caerphilly	6 (27.3)	-	.....	6 (27.3)
Cheddar	223 (1013.8)	48 (218.2)	37 (168.2)	308 (1400.2)
Cheshire	69 (313.7)	...	1 (4.5)	70 (318.2)
Double Gloucester	10 (45.5)	-	4 (18.2)	14 (63.6)
Dunlop	-	1 (4.5)	...	1 (4.5)
Lancashire	14 (63.6)	-	...	14 (63.6)
Leicester	12 (54.6)	-	5 (22.7)	17 (77.3)
Stilton	9 (40.9)	-	-	9 (40.9)
Wensleydale	9 (40.9)	-	...	9 (40.9)
Others	8 (36.4)	1 (4.5)	...	9 (40.9)
Total	360 (1636.6)	50 (227.3)	47 (213.7)	457 (2077.5)
Farm house production				
Caerphilly	1 (4.5)	-	-	1 (4.5)
Cheddar	27 (122.7)	1 (4.5)	-	28 (127.3)
Cheshire	7 (31.8)	-	-	7 (31.8)
Others	4 (18.2)	-	-	4 (18.2)
Total	39 (177.3)	1 (4.5)	-	40 (181.8)
Total	399 (1813.9)	51 (231.8)	47 (213.7)	497 (2259.4)

FIGURE 1

Distribution of Cheddar cheese factories in Scotland

(Fd. U.K Milk Marketing Boards 1974)



1. Express Food Ltd., Lockerbie Creamery, Priestdyke.
2. Scottish Milk Marketing Board, Dalbeattie Creamery, Dalbeattie.
3. Scottish Milk Marketing Board, Galloway Creamery, Stranraer.
4. Scottish Milk Marketing Board, Mauchline Creamery, Mauchline.
5. Scottish Milk Marketing Board, Torrylin Creamery, Torrylin, Arran.
6. Scottish Milk Marketing Board, Rothesay Creamery, Rothesay, Bute.
7. Sorbie Cheese Ltd., Sorbie Creamery, Sorbie.
8. North of Scotland Milk Marketing Board, Kirkwall Creamery, Orkney Islands.
9. Islay Creamery Co., Islay.
10. Gigha Creamery Co., Gigha.

Since in the dairy industry, the Imperial units are generally used, this system is used throughout the Thesis except in section 1, 2 and 4 of Chapter 1.

History of development in the Cheddar cheese technology

According to legend, cheese was made accidentally in Asia. Reference was made to cheese in the Babylonian records 2000 B.C. (Davis, 1965). Because the new product was found to possess good food characteristics more milk was converted into cheese. A description of the cheese making process used in the first century A.D. showed the fundamental processes (Cheke, 1959). As agriculture developed in different countries so distinct varieties of cheese emerged frequently named after the locality in which they were developed and found popularity. Cheddar was one of the important varieties to be developed in England. This variety was first made in the small village of Cheddar in Somerset in England in 1855 (Sheldon, 1911). Cheke (1959) reported that the production method was widely adopted in Scotland around 1875.

The equipment used was simple, made of wood or tinned metal. Raw milk was used and the microbiological quality of the milk was probably poor by today's standard. The cheese was manufactured by allowing the milk to sour naturally. Later unidentified cultures were added to the milk and were allowed to produce the required acidity. Much of the resultant Cheddar was of very poor quality. The first use in Scotland of selected strains of microorganisms was in the year 1895 (Crawford, 1958).

Until the mid 19th century all of the cheese production was in small quantities in batches e.g. 50 to 100 gal (227.3 to 454.6 l) on farms where the milk was produced. The increased need to produce larger and cheaper quantities of the product drew the attention to change the system of the making from small batches on the farms to a larger scale production in the factories. The cheese factory system was introduced and the first cheese factory was established in 1851 in Oneida County in the United States of America (Eckles, Combs, and Macy, 1951). In Britain, the first factory was commissioned in Derbyshire in 1870 (Fussell, 1955). By the year 1880 the factory system was being adopted throughout the cheesemaking world (Davis, 1965). In 1890 the Danish scientist Storch used a pure strain of bacteria in the ripening of cream for buttermaking. This was the first work on lactic acid fermentation in the dairy industry and it proved to be of great importance. The knowledge of using pure cultures was soon to be applied extensively in the cheese industry. Commercial cheese starters were placed in the market at the end of the 19th century (Jespersen, 1974). The use of quantitative acidity meansurements throughout the making procedure was introduced by Lloyd (1899). Curing of cheese was carried out by placing the cheese in ambient room temperature. Babcock and Russell (1897) and Dean (1899) drew the attention towards the use of curing rooms of lower temperature. Better quality rennet extract was made available to the cheese industry commercially and rennet preparation was introduced about 1904 (Christensen, 1972).

In the 1920's, the stainless steel was developed (Baily, 1958), and was first used in manufacturing dairy equipment in 1925 (Hall and Trout, 1968), providing excellent metal for most types of equipment and dairy processes. Later in 1939, the production of aluminium in commercial quantities provided another metal for the industry (Baily, 1958).

The production of Cheddar cheese on farms continued until the end of the second world war (1939/45). The numbers of farms making cheese thereafter decreased as dairy farmers found difficulty in obtaining labour for the manufacture. In the season 1974/75, 27 million gal (122.7 million l) of milk were made into farmhouse Cheddar cheese in England and Wales and one million gal (4.5 million l) was made in Scotland. This represents 8.33 per cent of the total Cheddar cheese production.

Many studies have been carried out on starter micro-organisms. The discovery in the thirties that bacteriophage was an important factor in the activity of cheese cultures led to many research studies and the development of better starters for the cheese industry. Whitehead and Cox (1934) introduced single strains of lactic streptococci for cheese making. Later Whitehead (1943) introduced the use of rotations of phage unrelated single-strain starters as a method of limiting phage development in the cheese factory. Improved techniques for starter preparation were developed. Towards the end of the forties starters used in the production of Cheddar cheese were either single strains of *Streptococcus lactis* and *Streptococcus cremoris* or combinations of two or more of these organisms sometimes with Leuconostocs and *Streptococcus diacetilactis*. Other studies related to starters included those on the effect of inhibitory substances in milk on starter activity. In one report soon after the introduction of antibiotic therapy for mastitis in cows, Hood and Katznelsen (1949) reported that the level of penicillin residues in milk affected the performance of cheese starters.

In 1931 and 1933 the Agricultural Marketing Acts were introduced to regulate marketing the Agricultural produce. Shortly thereafter in 1934 the Milk Marketing Boards in England and Wales, and in Scotland, were established. The formation of these Boards has greatly assisted in the development of the Dairy Industry in the United Kingdom (Davis, 1965). The ensured value which was given to milk encouraged farmers to produce more milk to meet the demand for both milk for liquid consumption and for manufacturing. In order to regulate the quality of the Cheddar cheese, a national scheme of grading was approved in 1935 for both Caerphilly and Cheddar (Scott, 1974).

In the period between 1930 - 1949 heat treatment of the milk for cheese making came into general use in Britain in the cheese manufacture. By 1949 this practice had become widely adopted (Davis, 1965). Mechanisation of the process of Cheddar cheese making began with the substitution of some manual operations with mechanical means following the same procedure of traditional cheesemaking. In this period, little progress was achieved in fundamental changes in the process (Davis, 1965). Large vats, mechanised mixing and stirring, and cutting were introduced. The use of electric pumps, wide curd knives, power mills, metal hoops, hydraulic presses and refrigeration were widely used. The HTST method of pasteurisation of the milk was adopted in the Cheddar industry. This had improved the quality of the cheese and had increased the capacity of these factories in which the batch pasteurisation had previously been used. The "Tromel", a device for separating the whey from the curd (Smith, 1946) was introduced by the Kraft Walker Cheese Company in Australia.

During this period traditional round Cheddar cheese were made, sometimes coated with wax and then cured in improved controlled curing room maintained at about 50 - 55°F (10 - 12.8°C).

Developments during 1950 - 1960. In the early 1950's attention was concentrated on attempts to shorten the time of the manufacturing process for a Cheddar cheese, and also to mechanise the different steps. The steps of Cheddar cheese making were grouped into the following distinct stages:-

Stage 1	Curd production, including addition of starter, cutting the curd, stirring the curd and cooking;
Stage 2	De-wheying of the curd and texture formation;
Stage 3	Milling, salting, and filling the hoops;
Stage 4	Pressing, packaging, curing and cutting.

The first short method of Cheddar cheese making was introduced by Walter, Sadler, Malkames and Mitchell (1953). In the original short time method special equipment was required. Normal starters at the rate of 1.5 per cent were used plus 0.75 per cent of cultures of Streptococcus durans. The time was shortened to 2 h 30 min from the addition of the rennet to the time the salted cheese curd was ready for pressing. Salting and hooping the curd was carried out in the whey. Czulak, Hammond, and Mehary (1954) modified this method so that conventional cheese equipment could be used. Two per cent of lactic acid producing starters, together with 0.75 per cent of Streptococcus durans, were used and no ripening time was given. The resultant cheese was open in texture (Downs, 1955) (Cook, 1955), and of curdy body (Morris, 1955). Crawford (1956) reported that cheese made with both methods were slow to mature and also had curdiness. Marked improvement in the flavour was reported by the author when he used a strain of *Lactobacillus bulgaricus*. Later Walter *et al* (1959) modified the method described earlier and claimed that cheese made with this new method was of good quality. Foagam, (1956) used *Streptococcus thermophilus* at the rate of 2 to 2.5 per cent and reported that resultant cheese quality was satisfactory. The total time from setting the curd to hooping was 3 h. Jones and Walker (1953) used single-strain starters at the rate of 1.5 to 2 per cent and reported that cheese made was satisfactory. In their experiments the time required from addition of starters to cheese hooped was 4 h 40 min. Whitehead and Harkness (1959) shortened the time further by using 2.5 per cent of normal starter, doubling the amount of rennet, and using higher coagulation temperature. Most of these methods were limited to experimental studies and there has been little use of the procedures in commercial practice.

Single-strain starter rotation were introduced in one Scottish Cheddar cheese factory during this period, Crawford (1958).

Large vats equipped with better mixing, agitating and cutting devices, were introduced as well as large closed cylindrical cheese tanks. The latter type of curd making unit was not however popular in the United Kingdom at that time.

The efforts on the mechanisation of the de-wheying and texture formation resulted in the introduction of the first curd fusion machine by Czulak and Hammond (1956). Fusion of the curd was achieved by pressing the curd. Czulak (1959) reported that pressing of cheese in a straight sided container did not promote the development of fibrous structure of the curd unless the curd reaches a pH of 5.8 or less. These findings lead to the introduction of another curd fusion machine in 1960 (Czulak, Freeman and Hammond 1960) in which the same principles as occurred in traditional cheese making were followed. In this new method the curd was slightly pressed and allowed to flow giving a cheddaring time of 1 h 30 min.

In the U.S.A., McCadam and Leber (1958) introduced the Ched-O-Matic system of Cheddar cheese making. In this system cheddared blocks were made with the help of pressure, the milled curd was washed with warm water at 100 to 104^{o}F (37.8 to 40^{o}C) and later sprayed with brine at the same temperature for salting the curd. The resultant cheese was described as of typical Cheddar cheese flavour by McCadam and Leber (1958). Sall (1958) claimed that the method decreased the cost of production. This system was introduced to the Express Dairies Ltd., factory at Ruyton-XI-Towns in England, but salting the curd was done in the vat instead of brine salting (Loftus Hill, 1959). This modification was used because brine salting proved to be unsatisfactory under the United Kingdom conditions. The procedure of the method was later modified by McCadam and Leber (1959) to achieve better whey drainage by using rotary screens. The Cheddar cheese made possessed cheese flavour but had some degree of seaminess (Gemmill and Leber, 1958). Kosikowski (1957) described the use of a two level arrangement of equipment for cheese making, which was later adopted in Britain (Chapman, 1966). A whey drainage and texture formation vat was described by N.V. Machinefabriek A. Bijlenga, Netherland. Greer and Zink (1957) described the use of a curd trough, in principle similar to the equipment produced by Tebel.

Efforts were also directed to the mechanisation of stage 3; that is the milling, salting and hooping steps. Stoete (1957) described the Desco mechanised salting of the curd. In Australia, an automatic machine was successfully tested in 1957 (Czulak, Freeman, and Chapman, 1958). Czulak et al, reported that this machine would perform the work of four men if used without the fusion machine. Later Czulak and Freeman (1961) described the commercial equipment "The Bell-Siro CheeseMaker 3" in which milling was followed by automatic salting and hooping. This equipment has been used in commercial cheese making in a number of countries, including the United Kingdom.

In the early fifties, a method of producing rindless Cheddar was described (Wearmouth, 1957), using special material for wrapping. This was introduced in Scotland in 1954 (Crawford, 1973). During the late fifties the world-wide trend towards the production of rindless cheese and other packaging materials increased and film replaced the conventional cotton bandage (Loftus Hill, 1959). The trend towards cutting and pre-wrapping of cheese for sale to consumers increased greatly.

Developments during 1960 - 1970. There were many areas of progress in this period. The use of the HTST pasteurisation of milk for cheese making was adopted by all cheese producers during this period. This development came as the result of the development of a code of hygienic practice for cheese making (1963). Large vats of 2,500 gal (11365.0 l) of milk capacity were adopted, equipped with better agitators, cutting devices, with better control of heating the curd, and with in-place cleaning.

New processes for continuous curd formation were described by Ubbels and Linde (1962), Berridge (1963), and Mann (1965). None of these methods are in use for the commercial production of Cheddar cheese in Britain.

The cost of labour increased and the efforts of the industry were to reduce this cost by introducing full mechanisation to most of the Cheddar cheese processes. King (1966) found that the labour cost amounts for about 50 per cent of the total cost of Cheddar cheese production. It also showed that different amounts of labour were required to carry out specific steps of the Cheddar cheesemaking process. These labour requirements are presented in Table 2, which shows that the most laborious steps are the step of draining to end of cheddaring and milling to hooping. This explains the interest of the cheese industry in the mechanisation of de-wheying and texture formation and also mechanisation of milling, salting and hooping.

During this period the Bell-Siro "CheeseMaker 3" was adopted in the Cheddar cheese industry in America, Australia, New Zealand and in the United Kingdom (Czulak, 1974). The first machine imported into the United Kingdom was commissioned in Aspatria, England in 1962 (Renwick, 1971).

The work of Czulak (1962) culminated into the development of the CheeseMaker 2. In this machine de-wheying and the texture formation of the curd was carried out continuously. The capacity of the first machine was 600 lb (272.7 kg) of curd per hour (Czulak, 1965). Czulak and Freeman (1967) reported that the quality of the curd made with this machine was of equal quality to that produced by

TABLE 2

Labour usage in the manufacture of 40 lb (18.14 kg) blocks of rindless Cheddar cheese

(King, 1966)

Operation	Man/Hours per ton (1016.05 kg)
Milk reception	0.00 - 1.50
Pasteurisation of milk to begin drain whey	0.00 - 1.23
Draining to end of cheddaring	2.18 - 2.61
Milling to hooping	2.28 - 4.01
Preparation of hoops and pressing to placing cheese in wrapping room	4.10 - 5.47
Stirring, trimming, wrapping and packaging cheese	3.96 - 5.89
Miscellaneous operations; separation of whey, boiler operation, general cleaning	1.36 - 1.61
Supervision; starter testing etc.	1.38 - 2.32
Total	17.87 - 20.49

traditional methods. The first commercial unit of this machine was commissioned in 1967. It had a capacity of 6,000 lb (2727 kg) of cheese per hour.

In New Zealand an alternative form of mechanisation was being developed. King and McGillivray (1962) described the "Cheddar-Master" system in which whey separation was carried out in special movable belt draining conveyor. Cheddaring was accomplished by placing the curd in cheddaring boxes. In 1966 the CheddarMaster system was installed in three factories in New Zealand in which the cheddaring boxes were carried and moved mechanically. Later a tower system of cheddaring was described by Bysouth, Gilles, Harkness, McGillivray and Robertson (1968) to replace the cheddaring box. In this method, after separation of the whey from the curd, the curd was stored in a tower for about 1.5 to 2 h to allow acid production and whey drainage during the travel of the curd to the bottom of the tower. During the most of this time, the curd was not allowed to flow, but during the last few minutes the curd was subjected to flow at the bottom of the tower. This process was related in part to the findings of Budd and Chapman (1960), McGillivray (1967) and Harkness, King and McGillvray (1968). The prototype of the cheddaring tower was 18 in (45.72 cm) in diameter and 6 ft (182.88 cm) tall, holding approximately 390 lb (176.9 kg) of well drained curd.

In 1969 Unigate Ltd., in the United Kingdom, developed their Tebel - Crockatt cheesemaking system (Crawford, 1976). This system comprises a combination of equipment produced by the Dutch company, N.V. Machinefabriek and W. Crockatt and Sons Ltd., of Glasgow. Whey drainage and cheddaring is carried out in special Tebel whey drainage cooler. In the U.S.A., Pickney, (1964) described his improvement in the whey drainage equipment. In the year 1967 Stoelting Bros. Company introduced their cheddaring device. Wallace (1968) introduced his method "Lactomatic" in Australia as a new method of Cheddar cheese making.

Work continued in all aspects of the industry. The use of vacuum was introduced during pressing the curd to achieve close texture cheese. Different methods were described by Wearmouth (1961), Czulak, Freeman and Hammond (1962), Irvine and Burnet (1962), Robertson (1963), and Robertson and King (1965).

King (1966) has shown that draining to hooping requires 25 to 30 per cent of the labour requirement in the rindless cheese factory, whereas the operation of the hoops to packing of the wrapped cheese requires 44 to 55 per cent of the total labour used. To achieve reduction in labour requirement, the large hoop system method of pressing large quantities of curd was developed in New Zealand (Robertson, 1963), the commercial version of the machine was introduced in 1967 (Robertson, 1967).

Developments during 1970's. More single-strain starter rotations were introduced and were widely used in several Cheddar cheese factories. Lawrence (1971) reported that their use in Scotland was satisfactory. By pairing the single-strain starters in proper rotation, good flavoured cheese can be produced (Lawrence and Pearce, 1972). Because of the introduction of different types of starters by different organisations, who used different coding systems to describe them, great confusion was created. Crawford (1972) called for the proper coding of starters and suggested that information giving all important characteristics of cultures was essential to the cheesemaker.

In the 1970's the research work carried out in the previous years resulted in the introduction of complete mechanised Cheddar cheesemaking systems. Different models of cheese vats are in use. These vats have capacities from 2,000 to 3,000 gal (9092.0 to 13638.0 l) and are equipped with mixing, agitating, and cutting device. Heating of the curd is effectively achieved by automatic means. The vats are also equipped with in-place cleaning systems. New Cheddar cheese factories in the United Kingdom are at the present time using one of the following types of vats (Crawford, 1976):-

1. The "OST" Tank made by Alfa Laval;
2. The Double "O" Tank - Damrow Ltd;
3. The "W" cheese tank - Golden Vale Engineering;
4. The Tebel Matic.

The commercial version of the CheeseMaker 2 (Mark II) was described in 1972 (Czulak, Freeman and O'Connell, 1972). The first commercial machine was operated in New Zealand in 1973 (Harris, 1973). In the United Kingdom this type is at the present time in operation at the Scottish Milk Marketing Board, Galloway Creamery, Stranraer. This unit was commissioned in 1974.

Most of the development of the New Zealand system of the mechanised Cheddar system was completed by 1970. Since that time details have been modified, the development of the Tower system of cheddaring (Robertson and Bysouth, 1971) and a continuous press have been completed. In the United Kingdom at the present time 7 units of the Cheddaring Tower are in operation. In Scotland this system is in use at the Scottish Milk Marketing Board, Mauchline Creamery and at Express Foods Ltd., Priestdykes Lockerbie Creamery. The use of the 'large hoop' method of pressing was adopted in Australia, Canada, Denmark, England, Netherlands, Northern Ireland and Scotland (Robertson, 1974). Large hoops are in use in the Sorbie Cheese Company Ltd., at Sorbie, Scotland.

The Tebel-Crockatt Cooler for Cheddar is represented in Scotland in the unit operated in Sorbie Creamery. The cheeseMaker 3 unit for milling, salting and hooping is in operation at Scottish Milk Marketing Board's, Dalbeattie and Galloway Creameries. The installation of these new systems in operation in the United Kingdom was recently reviewed by Crawford (1976).

In Scotland, a multi pre-press and mellowing table, automatic stacking and destacking press for 40 lb (18.14 kg) moulds were developed jointly by the Scottish Milk Marketing Board and W. Crockatt and Sons Ltd., Glasgow. The same group are working on developing a demoulding machine (Crawford, 1976).

Visible characteristics of Cheddar cheese

Cheddar cheese manufactured in different parts of the world and sold in domestic or international dairy produce markets is normally subjected to a 'grading' process by an official trade or governmental agency so as to maintain and regulate standards of quality as an aid to marketing and also to ensure that product quality is of an established and recognisable level.

Grading and selection processess for dairy products are particularly developed in export-oriented countries such as Denmark, the Netherlands and New Zealand which have supplied high quality graded products to the United Kingdom for many years. The reputation of the dairy produce of these countries has been established on the basis of uniformity of quality of their produce in the view both of the marketing organisation and also of the consumer.

The 'grading' or 'inspection' of the produce also assists in determining the most suitable market for the produce. In the case of cheese, which has a variable shelf life, the grading can indicate not only the comparison between the produce being examined in relation to standards of quality but also whether or not the cheese is suitable for normal or for shorter or longer storage before sale. The actual system of grading varies from country to country but attention is paid to accepted characteristics for a particular variety of cheese.

In cheese grading the official judges the produce by sensory means. The judgement is based on an assessment of flavour and aroma, texture, body (firmness), colour and finish in relation to established characteristics for a particular variety.

In Scotland the grading of cheese is conducted by officials of the Company of Scottish Cheesemakers Ltd., about eight weeks after the cheese has been made. The Grader examines the cheese and allocates one of the following standards of quality:- "1st Grade", "Graded" or "No Stamp". Cheese allocated to "1st Grade" conform closely to the accepted features of the variety. "Graded" cheese are deficient in some respect and require to be sold soon after grading. "No Stamp" cheese are of very poor quality and are normally used in the manufacture of processed cheese.

The visible characteristics of the cheese are the first to be given attention by the Grader and also by the consumer as they relate such characteristics to the quality of the cheese. Thus the visible characteristics of Cheddar cheese are commercially important.

The main visible characteristics of cheese can be divided into two sections:-

1. Characteristics related to the body and texture of the cheese;
2. Characteristics related to the colour and apprearance of the cheese.

Characteristics related to the body and texture. The cheesemaker and dairy technologist always use the term 'body' to refer to the physical properties of consistency which include firmness, elasticity and plasticity. Good bodied cheese should show smooth, and uniform surface and feel solid and firm. A smooth bodied cheese is free from rough particles of curd and feels smooth when a portion of the cheese is worked between the thumb and fingers. The plug of good bodied cheese bends before breaking.

The term texture is used to refer to the compactness of the particles of cheese and to the manner of union of the curd particles. A good textured cheese is one which has very good fusion between the curd particles and is free from openings.

The cheese samples lose points in grading when the body and texture are not as described above, due to the occurrence of some undesirable characteristics which cause certain defects in cheese. There are many defects in body and texture of Cheddar cheese which can be easily observed by the consumer.

Crumbly body, which is easily broken when cheese is plugged, sliced or kneaded in the fingers. This lack of fusion is evident throughout the cheese.

Open texture in cheese is evident by openings in the body of the cheese. Their presence can be easily recognised by the consumer from the appearance. Good quality Cheddar cheese always has a compact body free from such openings. These openings can be of two different types.

(i) so-called mechanical openness which is related to the mechanical fault of the pressing and other handling of the cheese which cause inadequate cohesion between curd particles;

(ii) slit openness in cheese which is related to gas formation in the cheese.

The term seamy cheese refers to cheese in which the fusion of the curd particles along the curd junctions is not complete and the cheese is easily broken along these junctions which appear as distinct lines.

Characteristics related to the colour and appearance. The first impression of the cheese quality is determined by the visible appearance of such product.

Colour of the cheese is the first characteristic which attracts the attention and interest of the consumer and is used by him as an indication or guide to the quality of the cheese he wishes to buy.

A good quality Cheddar cheese must have a uniform colour throughout the interior of the cheese whether it be coloured by the addition of the dye annatto or uncoloured.

The official cheese grader would reduce the points score for colour if one of the following defects appeared in the cheese:-

1. Bleached colour in cheese which is characterised by less intensity of coloured cheese or whiter than normal uncoloured cheese.

2. Bleached discolourisation which appears in coloured cheese near cracks in the interior of the cheese.

3. Mottled cheese. The colour of the cheese appears uneven. This defect can be found in both white and coloured cheese.

4. Seamy colour. When the degree of seaminess in cheese is evident, white lines are found along the curd particle junctions so forming a network effect of lines on the cut face of the Cheddar cheese. Seamy colour can be easily recognised by the appearance in both white and coloured Cheddar cheese. This defect is shown in Figure 11.

5. White specks. These appear as small pin size white spots throughout the cheese body and cause an uneven colour of the cheese.

Seaminess in Cheddar cheese

The occurrence of the defect seaminess in Cheddar cheese is well known to the cheese industry. The condition is characterised by the formation of light coloured lines and is described as seamy coloured cheese (Van Slyke and Price, 1932). In Cheddar cheese seaminess is considered as a defect of both colour and texture (Wilster, 1951; Van Slyke and Price, 1952; Davis, 1965; Trainer, 1966).

A number of theories have been offered for the formation and composition of the seams. Van Slyke and Price (1952) believed that the seams were formed by the accumulation of fat globules exuded from the surface of the curd particles at the junction of the curd particles. This explanation was accepted by Czulak (1961). In 1965 however a new explanation of seam formation was put forward by Conochie and Sutherland (1965). According to these workers the seams in both white and coloured Cheddar cheese were due to the formation of calcium orthophosphate (Ca $HPO_4.2H_2O$) in the vicinity of the curd particle junctions. The accumulated crystals were lighter in colour than the rest of the cheese interior.

In seeking an explanation of the cause of seaminess the manufacturing stages were examined. Hanson and Shepardson (1940) considered excessive agitation of milk as a cause. The interval between milling and salting and the period from salt addition to hooping were extensively examined in relation to the development of seaminess. Van Slyke and Price (1952) considered that any treatment of the curd during this interval that encouraged exudation of fat from the surface of the curd would lead to the increased incidence of white lines in the cheese. According to these workers the accumulation of fat globules prevented the curd particles from fusing together for some time after pressing. These workers advocated the washing of the curd prior to salt addition as a means of eliminating the fat layer and so the defect. But Hanson and Shepardson (1940) reported that washing the milled curd with warm water did not prevent seaminess.

In the preliminary trials of the Bell-Siro "CheeseMaker 3" equipment for curd milling, salting and hooping Czulak (1961) observed a reduction of up to 75 per cent in fat losses in the whey after salting and from the press. The same author reported that the machine treated curd was much less damaged in the milling and subsequent operations than the curd in traditional milling and salting procedures. He also reported that in all these operations, the mechanical impact of the usual blunt blades of the mill and of violent agitators in traditional operation causing exudation of fat and often lead to seaminess. In 1963 seaminess was reported in the United States of America in factories which had introduced the Bell-Siro "CheeseMaker 3" equipment (Czulak, 1963). The presence of seaminess was related to the application of dry salt to the unwashed curd. By comparison, no seaminess was noticed in the same factory when the traditional American method of Cheddar cheese manufacturing, in which the salt was added to the washed curd, was used.

Czulak, (1963) reported that seaminess could be eliminated by spraying the Cheddar curd directly after milling with warm water at between 115 to 120°F (43.3 to 51.7°C) at a rate of 0.5 to 0.75 gal (2.3 to 3.38 l) of water to 100 lb (45.36 kg) of the curd using the same procedure of curd washing used by the American cheese factories. The success of this practice was related to the removal of milk fat which had exuded from the surface of the curd. No fat was left to accumulate between the particles and so cause the formation of seams. Czulak, Conochie and Hammond (1964) reported that they had been able to obtain the most complete elimination of the defect when the amount of the wash water was increased to 0.75 gal (2.38 l) per 100 lb (45.36 kg) of curd. Czulak et al (1964) related the occurrence of seaminess to the amount of added salt. When more than 3.5 per cent (w/w) of salt was added the milled curd tended to be more seamy in spite of spraying the curd with water. These observations lead him to conclude that seaminess was more likely caused by some alteration in the curd particles possibly as a result of severe dehydration on contact with dry salt, and is due to the accumulation of fat in the curd particle junctions. Accordingly he suggested that spraying the curd with warm water would probably cause some changes in the structure of the organisation of the casein in the surface layer.

The method described above of eliminating seaminess was not satisfactory in practice because it led in some cases to reduced salt content in cheese and to increased levels of moisture (Czulak, 1963). Besides when the curd was sprayed with water the curd pieces tended to stick together forming lumps of curd which interfered with even salt application and even weighing and mould filling. Spraying the curd with water caused a decrease in salt retention in the final cheese, because more salt was carried away with the whey. To obtain the required salt level, about 0.3 per cent (w/w) more salt had to be added compared to the amount used in dry salting. The added salt requirement would be of commercial cost significance.

McDowall and Dolby (1936) found that the salt added to cheese curd penetrated 0.05 in (0.13 cm) in 15 min and 0.15 in (0.36 cm) in 1.5 h. The salt penetrated well throughout the curd particle within less than one day. Tuckey and Ruehe (1940) reported that the average salt content of cheese 20 min after salt addition was 1.33 per cent (w/w), after 40 min it was 1.60 per cent (w/w), and after 60 min it had increased to 1.7 per cent (w/w). The amount of salt retained in the final cheese is affected by the amount of added salt. O'Connor (1968) reported that with a salting rate of 0.5 per cent (w/w), about 100 per cent of the added salt was retained, while with salting rate of 3 and 6 per cent (w/w) about 66 and 42 per cent respectively of the salt added was retained in the final product. When some of the salt is dissolved in the aqueous phase (whey), the uptake of the salt into the inside of the curd depends on the temperature of the brine and its concentration. Higher salt uptake was obtained at higher temperatures and at higher salt concentration in the brine (Breene, Olson and Price, 1965). Addition of more than 3 per cent (w/w) of salt caused undesirable effects on the body of the cheese (Whitehead and Harkness, 1954). Shorter texture cheese resulted when the time from milling to the addition of salt was shortened to 30 min (Hood and Gibson, 1948).

In an important contribution of knowledge on the subject of seaminess, Conochie and Sutherland (1965) reported that the seams were formed due to the formation and accumulation of crystals of calcium orthophosphate ($Ca\ HPO_4.2H_2O$) in the area of the particle junctions. These workers discounted the earlier explanation of the accumulation of fat as the cause of the defect. The formation of calcium orthophosphate is related to the amount of both Ca and P ions that exude from inside the curd particle which was encouraged by the addition of sodium chloride to the cheddared milled curd and to higher acidities of the curd. According to Conochie and Sutherland (1965) an initial high concentration of sodium chloride on the surface of the curd causes the curd to shrink in volume, and so release more whey resulting in further solution of salt and bring Ca and P ions to the surface of the particle. Most of these ions remain on the surface layer, although some are carried away with the whey. After pressing, a film of water is formed between the unfused particles, containing high concentration of both Ca and P ions and sodium chloride.

Because of the strong influence of this sodium chloride concentration on the calcium orthophosphate, it is possible to attribute the crystallisation of this chemical to the diffusion of sodium chloride away from the seam into the cheese. According to Breene et al, (1965) the amount of whey released from the inside of the curd depends on the moisture content of the curd, the amount of salt and the salt particle size.

Conochie and Sutherland (1965) explained the previously observed elimination of seaminess by washing the curd directly after milling and before salting as proposed by Czulak (1963) and Czulak, Conochie and Hammond (1964) as being due to the removal of the phosphate and calcium ions from the surface layer. Additionally spraying with water tends to lessen the dehydration and contracting effect on the surface layer due to the application of salt and also would increase the salt diffusion (Conochie and Sutherland, 1965).

The presence of calcium othophosphate in many varieties of cheese; Roguefort, Swiss, Tilist and Trapist was first reported by Swiatek and Jawroski (1959). In Cheddar cheese, Conochie and Sutherland (1965) and Brooker, Hobbs and Turvey (1975) reported its presence in both seams and in the rest of the cheese.

In 1964 a further occurrence of seaminess in Cheddar cheese produced in the United States of America was reported by Czulak, Conochie and Hammond (1964). These workers suggested that seaminess could be eliminated by increasing the amount of water used for spraying to about 2.5 gal (11.4 l) per 100 lb (45.36 kg) of curd. The cheese obtained after this treatment was found to have a moisture content of 36 to 37 per cent compared to 34 to 35 per cent when no washing was used. The salt content in the final product was lower, 1.4 per cent compared to 1.8 per cent in unwashed curd.

McDowall and Dolby (1935) reported that the concentration of both Ca and P were increased in the whey from 0.060 per cent CaO, and 0.131 per cent P_2O_5 measured at 85 min after cutting the curd at an acidity of 0.165 per cent lactic acid to 0.325 per cent CaO and 0.267 per cent P_2O_5, at 225 min after cutting at an acidity of 0.61 per cent lactic acid. The level of both were increased after 335 min from the cutting of the curd at an acidity of 0.91 per cent lactic acid to 0.525 per cent CaO and 0.381 per cent P_2O_5. Conochie and Sutherland (1965) reported an increase in the amount of both calcium and phosphate ions with the increase of the whey acidity. These findings were in agreement with the earlier results obtained by McDowall and Dolby (1935). According to Conochie and Sutherland (1965) more phosphate was released in the whey of salted curd compared to that released in the whey of unsalted curd. They also reported that, the lower the pH of the curd, the greater is the amount of phosphate released, and suggested that seaminess can be reduced by applying the salt (sodium chloride) at as low a pH as possible.

In 1966 a team of workers of the United States Department of Agriculture (Holsinger and Pallansch, 1966) reported that seams were mainly composed of a chemical of calcium phosphate nature, together with fat, whey protein and slightly elevated levels of chloride. The light colour of the seams was related to the possible shift in the dye due to the change in the solubility of the chemical compared with the pH shift. They related the occurrence of the seams in the Cheddar cheese to insufficient washing of the curd.

In a recent study into the nature of the occurrence of the microscopic inclusions in Cheddar cheese, Brooker, Hobbs and Turvey (1975) reported the presence of small inclusions of a calcium phosphate nature throughout the entire cheese body. From the location of these inclusions, in the space between the fat and casein phases of the cheese, they concluded that these crystallised from pockets of residual whey.

In Scotland mechanised systems have been introduced and are at present in operation in different factories. An increased incidence of the occurrence of seaminess in the Scottish cheese was noticed by Crawford (1973). He has drawn the attention of the Cheddar cheese industry towards the occurrence of this visible defect in Scottish Cheddar cheese.

SCOPE OF WORK

For many years the attention of a number of research workers in the dairy industry has been focussed on the development of new methods and equipment for the manufacture of Cheddar cheese by shorter semi-continuous mechanised methods. New machines have been developed, produced commercially, and installed in a number of cheese factories in different parts of the world. At present time most of the Cheddar cheeses sold in the world markets is made by using shortened methods and new mechanised procedures by means of different machines and equipment. The introduction of mechanised equipment in the United Kingdom has been particularly noticeable in the period 1973 - 1975 (Crawford, 1976). Commercial experience showed that in some parts of the world good quality cheese can be made by these machines, but some is of poorer quality. The defect known as 'seaminess' has been associated with the use of mechanised equipment and methods. In the U.S.A. a high incidence of seaminess was reported in Cheddar cheese made by the Bell-Siro "CheeseMaker 3" (Czulak, 1963). It was also noted that such defect were reported in some of the cheese made in Australia (Czulak, 1963), and Scotland (Crawford, 1973).

Cheddar cheese is the most extensively made variety of full fat hard cheese in the United Kingdom (Federation of U.K. Milk Marketing Boards, 1975) and is valued for its smooth close texture, firm body, well developed flavour and long keeping quality. Seaminess can be commercially significant defect in Cheddar cheese in certain markets. Seamy cheese tends to break easily along the particle junctions, and in severe cases of seaminess, the cheese may fall apart. In practice such cheese is difficult to cut and this may cause a decrease in the market value.

Seaminess was described by Conochie (1966) as "the condition in which the outline of the milled curd particles is still evident in the cheese some weeks after manufacture. In severe cases the cheese may fall apart on cutting, due to the poor fusion between the curd particles".

In recent years few workers have studied the nature of this defect in Cheddar cheese, to find proper remedies for such a defect. Many explanations have been given by different research workers to explain how the defect occurrs, and also the factors that cause seaminess. Remedies were also introduced to overcome the defect in Cheddar cheese made by continuous mechanised methods. One such remedy was to wash the curd prior to salting. These remedies were not completely acceptable in commercial practice in Scotland. Effective remedies which can be easily used during the mechanised system of cheese manufacture are required to overcome seaminess in Cheddar cheese. This work is intended to study the factors that cause seaminess and to find commercially acceptable remedies.

Chapter 1 of this work describes the material and methods used for the chemical analysis of seams, cheese, whey, milk, starters and rheological measurement of cheese. Included is a description of the different methods of cheesemaking used in the production of Cheddar cheese throughout the study, together with a description of the procedures used by a scoring panel.

Chapter 2 is concerned with the study of different characteristics of seams e.g. appearance, size, distribution, formation, and chemical composition. Included is an investigation into the effect of the curing time of Cheddar on the formation of seaminess.

Chapter III reports on investigations carried out into the effect of different factors relating to the salting process on the development of seaminess:- amount of added salt, salt particle size, the acidity of curd at the time of salt addition, acidity of curd produced by different strains of starters at the time of salt addition, presence of additives in commercial salt, the effect of temperature of the curd at the time of salt addition, and mellowing time. Some of these studies were extended to commercial application.

Chapter IV describes the effect of the factors related to the process of milling the curd during the production of Cheddar cheese on the development of seaminess in particular the size of the milled curd, the type of mill, the condition of the cutting edge, the moisture content of the curd, and the time between milling and salt addition. Most of these investigations were extended to commercial application.

Chapter V of this thesis describes the investigation carried out to study the effect of factors related to the hoop filling and pressing stage on the seaminess in Cheddar cheese i.e. the time from hoop filling to final pressing, the use of different pressure in pressing, and the temperature of the curd during pressing. It also includes a study of heat loss from cheese curd during the time of pressing.

Chapter VI describes the work carried out to study the effect of the level of both calcium and phosphate present in the milk which is used for production of Cheddar cheese on the seaminess in the final cheese. Also reported is the work on the effect of the presence of calcium orthophosphate in curd particle junctions on the degree of seaminess induced.

Chapter 7 describes the procedure and the findings of a study which was carried out to assess the occurrence of seaminess in commercial Cheddar cheese produced by five main factories during a period of 6 months in 1975.

Chapter 8 describes a study of consumer reaction to the presence of seaminess in commercial Cheddar cheese sold in the shop of the Department of Dairy Technology, at the West of Scotland Agricultural College, Ayr.

CHAPTER 1

MATERIALS AND METHODS

SECTION 1. THE DETERMINATION OF THE CHEMICAL COMPOSITION OF SEAMS

1. Determination of sodium chloride

In the year 1878, Volhard introduced his method for salt determination in cheese, and the first cheese analysis was reported by Sartori in 1890 (Sartori, 1890). This method has been subjected to very extensive studies, resulting in many modified methods. In 1932 Davies (Davies, 1932) introduced a modified method which depends on the digestion of cheese sample with silver nitrate, water, and nitric acid. Later Wilster, Price, Morris, Goss and Sanders (1937) introduced another modification of the Volhard method. This modification was adopted by the American Dairy Science Association. In this method, the sample was digested in 0.171 N silver nitrate, water, nitric acid, and potassium permanganate, using feric ammonium sulphate as an indicator. The excess of silver nitrate was measured by titration with 0.171 N potassium or ammonium sulphocyanate. It was suggested for the determination of salt in new and old cheese such as Cheddar, Blue Vein, Camembert, Limburger, and Cottage cheese, and later was extended for use with Brick, Bel Paese, Neufchatel, Cream and other varieties. Marquardt (1938) reported obtaining reliable results when using this method for determining the salt content of cheese.

Work has been further directed towards the finding of easy and quick methods of salt determination. Arbuckle (1946) indicated that by using mercuric nitrate a titration method could be successfully adopted for the determination in young cheese. Breene and Price (1960) showed that the direct titration of Cl ion with $AgNO_3$, using K_2CrO_4 as indicator, could be used satisfactorily on cheese ranging in age from 1 day to 17 months by substituting dichlorofluorescein (DCF) for the potassium dichromate.

In 1960, Herrington and Klyen (1960) used a silver electrode to measure chloride in milk directly using a potentiometer. Fox (1963) used this method to determine the salt content of cheese. Dixon (1965) reported that satisfactory agreement between the Volhard method and the measurement by the potentiometer had been achieved.

The International Dairy Federation produced a standard method for the determination of sodium chloride in all cheese varieties (FIL - IDF 17, 1961). The method depended on the measurement of sodium chloride liberated after the destruction of the organic matter by means of potassium permanganate and nitric acid. The quantity of sodium chloride present in the sample was determined by indirect measurement of the amount of 0.1N silver nitrate required to react with sodium chloride, using ammonium thiocyanate.

In 1952, the British Standard Institution published a method which has been used extensively in Britain for the salt determination in cheese (BS 770, 1952). Later in 1963 this method was revised and another standard method was published (British Standard Institution, 1963). This method required addition of nitrobenzene. Davies (1973) indicated that omitting the addition of this hazardous chemical did not effect the results obtained.

Method used. After reviewing the alternative procedures the author chose the British Standard Method (1963), with the modification that the use of nitrobenzene was omitted and the amounts of other chemicals used were proportional to the size of the sample used in the determination. The following procedure was used for the determination of sodium chloride in the seams:-

Since the amount of material available from seams was limited 130 - 150 mg of samples from the seams and from parts away from seams were weighed in 50 ml conical flasks, before the addition of 1 ml of distilled water, 3 ml 0.05 N silver nitrate, and 1 ml concentrated nitric acid. The flasks were placed on a hot plate, and when the contents had boiled until a clear lemon colour was reached, about 0.03 g urea was added, the flasks were shaken and left to cool. Thereafter 0.5 ml of distilled water and 0.2 ml of alum indicator was added. Finally the samples were titrated with KCNS solution of known strength until the end point was reached. The salt content of samples was then calculated.

2. Fat determination in seams

The modified Gerber method (British Standard Institution 696, 1938) is frequently used for the determination of fat in hard cheeses. The method requires the use of 3 g of sample. Another simplified modification of the method was recommended by Davies and Macdonald (1952) and proposes the use of 5 g of the cheese sample. In both methods, sulphuric acid is used as oxidising agent, and the fat is dissolved in amyl alcohol, forming a distinctive column, which can be read directly as fat percentage in special Gerber tubes. The Rose - Gottlieb method (British Standard Institution 1741; 1963) employs ammonia to dissolve the sample, using a special extraction cylinder.

The fat is extracted from the sample by using ethanol, ether and petroleum spirit. The weight of the extracted fat is determined and the fat percentage in the sample can be calculated. Elsdon and Walker (1942) indicated that the method of Rose - Gottlieb is preferred because the fat is not submitted to any drastic treatment with acid or by heating.

In 1959 the International Dairy Federation produced their method (FIL - IDF 5, 1959) based on Schmid - Bondzynski - Ratzlaff method in which hydrochloric acid is used. In 1963 the British Standard Institution (BS 770, 1963) produced their method which was in general agreement with the above method. In 1968, the British Standard Institution (BS 1743, 1968) described a method for the determination of fat in dried milk in which ammonia solution is used. The method is based on the extraction of the fat present by means of ethanol, diethyl ether and petroleum spirit. Since the samples used for analysis were in the form of dried cheese, the following procedure was carried out:-

Into a dried Mojonnier extraction flask of known weight, 100 to 200 mg of the sample were added, and the weight of the sample determined. To the flask was added 10 ml of distilled water, and 2 ml of 880 ammonia. The sample was dissolved by keeping the flask under hot water, then allowed to cool. Fat extraction was carried out by the addition of 10 ml of ethanol, followed by shaking of the open flask. 15 ml of diethyl ether were added, the apparatus was stoppered, shaken for 30 s. The stopper was removed, 15 ml of petroleum spirit was added with rinsing of the neck, closing, shaking for about 30 s. The extraction flask was then left to stand until separation of the layers had taken place (at least 30 min). The supernatent layer was carefully transferred by decantation to a 100 ml flask.

Two further extractions were carried out as described above. In each extraction, the supernatent layer was added to the same flask.

The flask was then placed in the vacuum oven maintained at 80°C to evaporate the solvent, then placed in an oven at 100°C for one hour, then left to cool in a desicator and was weighed. The flask was then washed three times with 5 to 10 ml of petroleum ether and was again placed in the oven at 100°C for another 30 min. The flask was placed again in the desicator to cool, and finally was re-weighed.

A blank determination was carried out on 10 ml of distilled water following the same procedure.

The fat percentage in the sample was then calculated applying the following formula:-

$$\text{Fat percentage in the sample} = \frac{\text{Difference in weight of the flask (mg)} - \text{Difference in weight of blank (mg)}}{\text{Weight of the cheese sample (mg)}} \times 100$$

3. The determination of protein in the seam

Protein in cheese is generally determined by the Kjeldahl method (Ling, 1956). In this study a modified procedure of the micro Kjeldahl method (A.O.A.C., 1965) was used.

The determination was carried out as follows:-

About 60 to 80 mg of sample was placed in a 50 ml Kjeldahl flask of known weight, and the weight of the sample was determined. A blank was taken and was treated in a similar way to the sample. To each flask, 3 ml concentrated sulphuric acid and two tablets of a catalyst (containing 1 g sodium sulphate and 0.1 g of copper sulphate) were added. The flasks were heated on a gas flame for about one hour until the contents were completely digested and had become clear. The flasks were left to cool for 10 min. The neck of the flasks were then washed with distilled water, placed again on the flame for another 30 min until the digestion was completed. The kjeldahl flask was connected to the distillation apparatus. A receiving flask (100 ml) containing 25 ml of N/50 HCl and two drops of indicator (methyl red - methylene blue) was placed at the end of the distillation apparatus. To the digest 10 ml of sodium hydroxide/sodium thiosulphate solution was added. A stream of air was passed through the apparatus during the distillation. The flask was heated for about 8 min. The distillate sample was then titrated with N/50 solution of sodium hydroxide until a light green colour was reached.

The total protein present in each of the samples was then calculated using the formula:-

$$\text{Total protein (percentage)} = \frac{(\text{ml NaOH for blank} - \text{ml NaOH for sample}) \times 14.007 \times 6.38 \times 100}{\text{Weight of sample (mg)} \times 50}$$

4. Measurement of pH in seams

The measurement of hydrogen ion concentration (pH) has been used as a method of determining acidity in cheese, and its importance has been well recognised by the dairy industry. Samiss and Santschi (1924) used a electrometric method to measure the pH in cheese.

Later in 1927, Watson (1927) used quinhydrone electrodes for such measurement.

Sufficient distilled water was added to the cheese sample to form a paste in order to achieve better contact with the electrodes. The amount of water added had great effect on the reading obtained (Brown and Price, 1934). The same researcher found that, the application of pH measurement in the cheese making was useful for controlling the manufacturing operation. In 1963 the British Standard Institution issued a standard method with no reference to the amount of distilled water to be used (BS 770, 1963). The temperature of the sample causes a difference in the reading obtained (Dixon, 1965). O'Connor (1968), reported that the most reliable pH reading could be obtained when equal weights of water and sample were used. The above principle was used in this determination.

The measurement of the pH of all samples of material from seams and other parts of the cheese follows:-

100 mg of the samples were placed in a special small beaker and 0.1 ml of distilled water was added. The cheese and the water were mixed together to form a paste. pH readings were obtained using PYE 290 pH Meter fitted with a units combination glass electrode (Activion Glass Ltd., Scotland). Before measurement, the equipment was adjusted using buffers of known pH taking into consideration the temperature of the sample. Readings were made in duplicate.

5. Determination of Lactic acid/Lactates in seams

The International Dairy Federation (FIL - IDF 69, 1972) describes a method for the determination of lactic acid/lactate in dried milk. In this method, fat, protein, and lactose are simultaneously removed from the sample by the addition of copper sulphate and calcium hydroxide followed by filtration. The lactic acid is converted to acetaldehyde by concentrated sulphuric acid in the presence of copper sulphate. The acetaldehyde is then measured colorimetrically using p - hydroxydiphenyl.

The IDF method referred to above was selected and carried out as follows:-

Between 30 and 40 mg of the samples were placed in a tared 50 ml volumetric flask which was reweighed to determine the actual weight of the sample. To the flask, 35 ml of distilled water was added, and 3 h were allowed for the lactate to dissolve. 5 ml of copper sulphate were then added, whilst mixing and then the flask was left to stand for 10 min. While shaking, 5 ml of calcium hydroxide suspension were added slowly and left for 10 min. The content of the flask was made up to 50 ml with distilled water, mixed well and filtered, discarding the first few ml of the filtrate. From the filtrate, 1 ml was pipetted into a test tube. 6 ml of the sulphuric acid - copper sulphate solution were added and mixed. After the tube and contents had been heated in boiling water for 5 min, and cooled to ambient temperature in running water, two drops of p - hydroxydiphenyl reagent were added, and the tube was shaken vigorously. The tube was placed in a water bath at 30^{o}C for 15 min, shaken from time to time, and then placed in a boiling water bath for 19 s. The tube was then cooled to ambient temperature by running water. The optical density was measured against a blank which had been treated in the same way as the sample, at a wave length of 520 nm using a Pye-Unicam Sp 1800 spectrophotometer.

A standard curve was prepared by taking different amounts of lithium lactate in 50 ml of distilled water. These samples were treated in the same way as the cheese samples. The optical density was measured in the same spectrophotometer and the readings obtained plotted to prepare a standard curve which is present in Figure 2.

6. Determination of ash

The British Standard method (BS 1743, 1968) described a method of ash determination of dried milk. This method was used to determine the ash in the dried cheese sample, and carried out as follows:-

To a dried crucible, of known weight, 100 mg to 110 mg sample were placed and all was reweighed, and the actual weight of the sample was then determined. The crucible was then placed in the muffle furnace at a temperature of 540°C to 550°C for 1 h. After cooling in a desicator the crucible was reweighed and then the ash content in the samples was calculated, according to the following:-

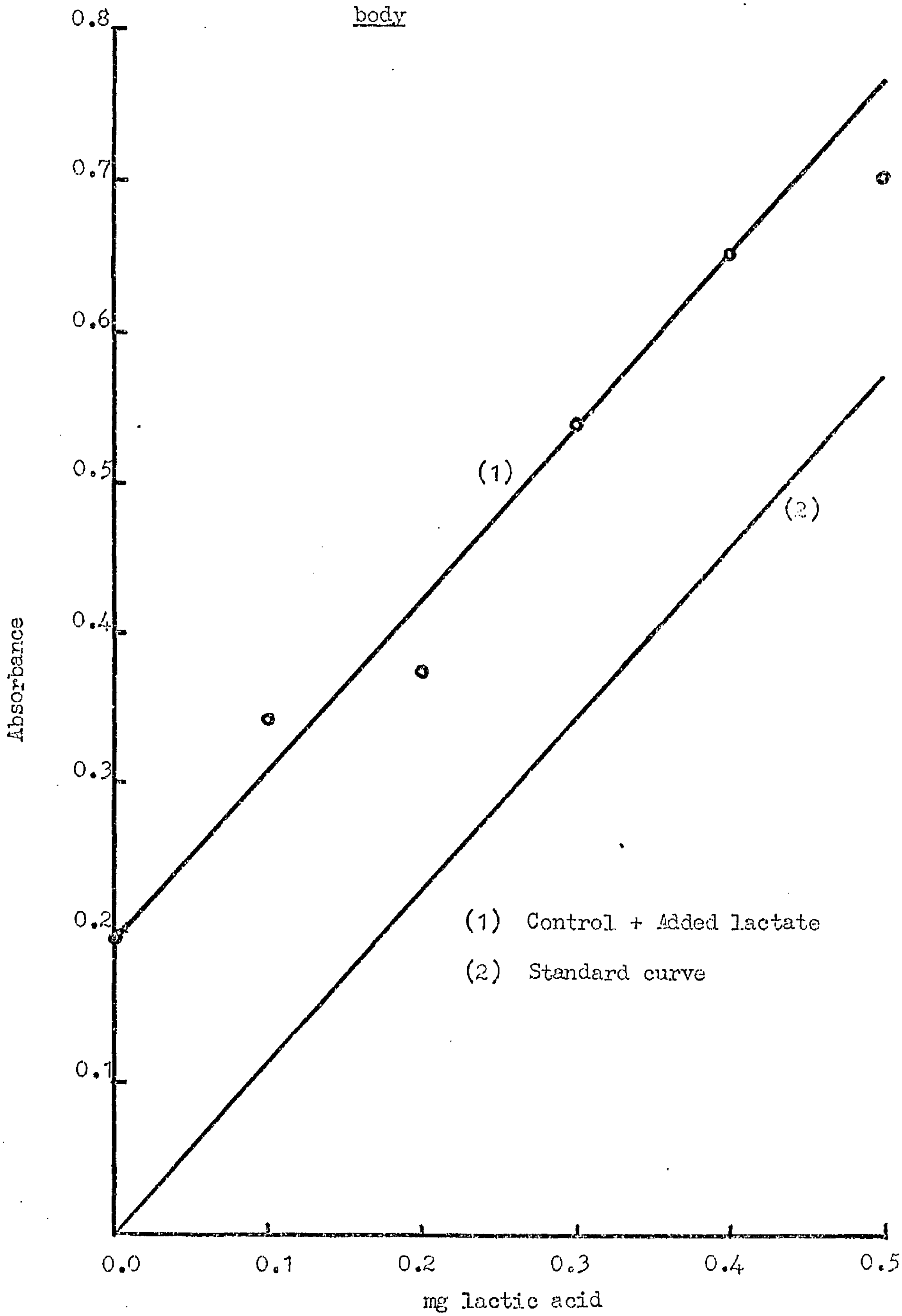
$$\text{Percentage ash} = \frac{\text{weight of ash (mg)}}{\text{original weight of sample (mg)}} \times 100$$

7. Determination of phosphate in seams

Various methods are in use for the determination of

FIGURE 2

Standard curve for lactic acid/lactate determination in samples taken from seams and the rest of the Cheddar cheese body



phosphorus in food. Phosphorus is measured volumetrically by precipitation and then titration of the excess standard alkali solution with standard acid (Pearson, 1962). Wilson (1951) used the principle of precipitation of the phosphate as quinoline phosphomolybdate, followed by addition of excess alkali and then back titration.

Colorimetric method for the determination is also used. In many of these methods ammonium molybdate is added to the solution and by means of the addition of a reducing agent, a colour is formed and measured. The results are then compared to specific standards, to determine the phosphorus present.

Allen (1940) described a method based on the conversion of all phosphate present in the sample to inorganic orthophosphate. This is carried out by digesting the sample with sulphuric acid, and hydrogen peroxide. The addition of ammonium molybdate forms a phosphomolybdate complex. When amidol is added, a blue pigment is formed and is then measured. The results are compared to measurements made with specific standards and the amount of phosphate are established.

The International Dairy Federation introduced their methods (FIL - IDF 33, 1966 and FIL - IDF 33 A, 1971) for the measurement of the phosphorus content in cheese. In these methods the same principle of sample digestion with sulphuric acid and hydrogen peroxide is used. Sodium molybdate and hydrozin sulphate are then added.

The phosphate in the samples was determined according to the method described by Allen (1940). The determination was conducted as the following:-

Into a Kjeldahl flask of known weight, 100 mg of the cheese sample was placed and the exact weight of the sample determined. To the flask was added 1.2 ml of concentrated sulphuric acid and two glass beads before being warmed until the contents became dark brown. Two drops of hydrogen peroxide were then added and the digestion continued until the contents became clear and fuming. The neck of the flask was washed with a small volume of distilled water, and was heated to fuming. When the flask was cooled, 21.65 ml of distilled water, 1 ml of 8.3 per cent (w/v) ammonium molybdate and 2 ml of 1 per cent amidol (w/v) in 20 per cent potassium metabisulphite were added. The mixture was allowed to stand for 10 min. The optical density was then measured using Pye-Unicam, Unicam Sp 1800 spectrophotometer at 720 nm against a blank sample which was treated in the same way as the samples.

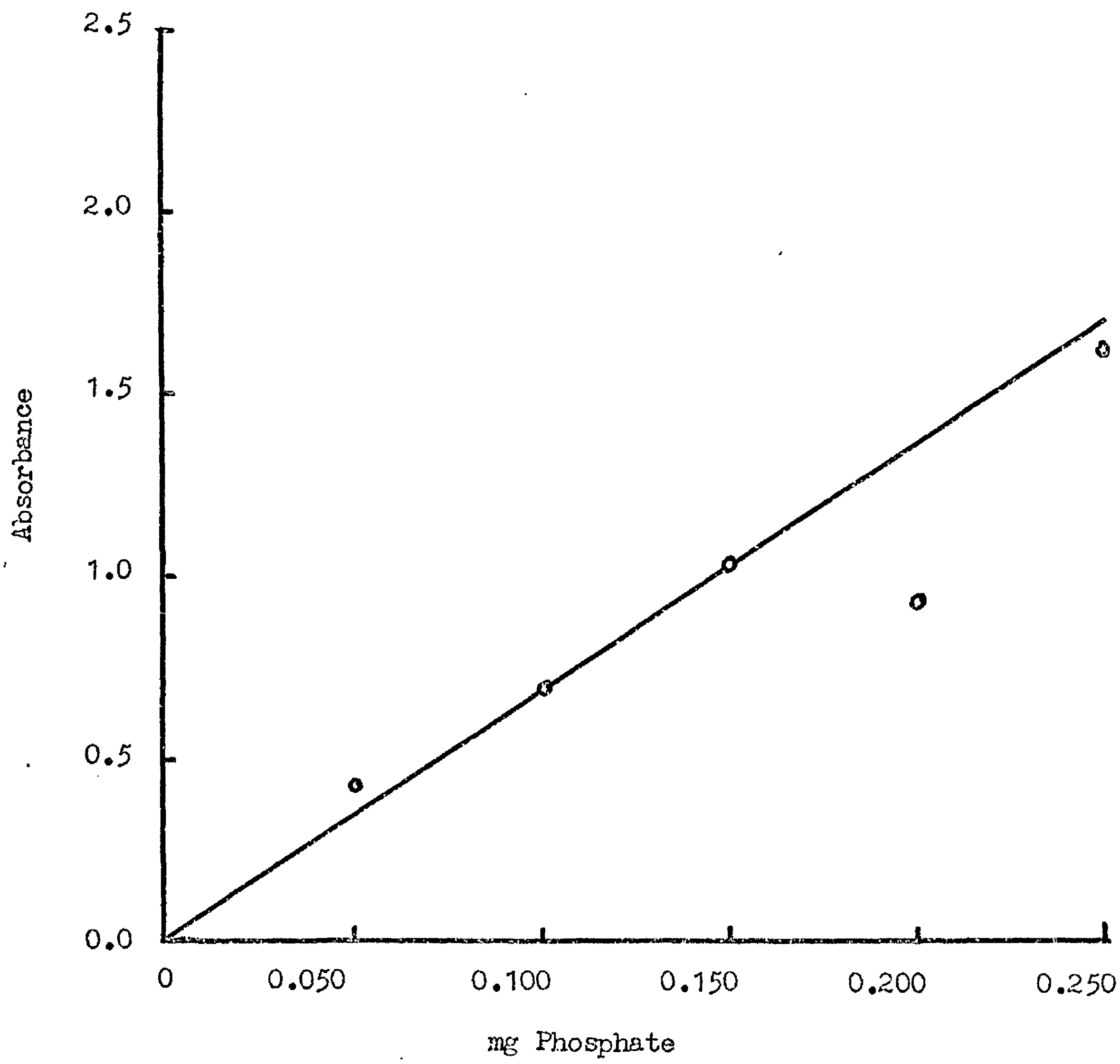
Standard solutions of the following concentration: 0.100 mg, 0.150 mg, 0.200 mg, 0.250 mg phosphate were prepared using $KH_2\ PO_4$ solution containing a known phosphate concentration. All these were treated in the same way as the test samples. The optical density was measured. The standard curve was prepared and is presented in Figure 3.

8. Determination of calcium in seams

The brief survey of literature indicates that calcium can be determined by precipitation as calcium oxalate followed by titration with permanganate solution (Ling, 1956). The use of the method is limited because of the long time required, and the interference that

FIGURE 3

Standard curve for phosphate determination in seams and the rest of the cheese body



results from the presence of phosphate in the samples. In order to prevent this interference Pearson (1970) advised the use of acetic acid prior to the addition of ammonium oxalate. This principle was adopted by the British Standards Institution (1966) in its method (BS 2472) for the determination of calcium in ice cream, and was also adopted by the International Dairy Federation (FIL - IDF 36, 1966) for the determination of calcium in milk.

Another method used to determine calcium in cheese involves the use of Ethylenediamine tetra acetic acid (EDTA) as a titrant in the presence of an indicator sensitive to calcium ions.

Hilderbrand and Reilly (1957) reported the use of 'Calcon' as an indicator in the determination. Kamal (1960) reported that 'Calcein' gave satisfactory results. Yalman, Bruegmann, Baker and Garn (1959) attributed the difficulties in achieving satisfactory results to the properties of calcium orthophosphate. Sawyer and Hayes (1961) reported that the addition of excess EDTA and back titration with standard calcium solution using 'Calcon' as an indicator gave satisfactory results, and the presence of phosphorus did not appear to have an effect on the end point of the titration.

These classical methods have been used for samples which contain large quantities of calcium. In order to determine small quantities and in a shorter time, two methods are commonly used e.g. flame photometry (flame emission) and atomic absorption (Aurand and Woods, 1973). Have and Mulder (1956) reported that when flame photometry was used, good agreement was obtained with standard chemical techniques in determining the calcium content in both milk and cheese.

A flame emission spectrophotometric technique was chosen by the author for use in the determination of calcium in cheese samples and was carried out as follows:-

A portion of 100 to 150 mg was taken from the dried cheese samples and were ashed following the procedure described on page 40. From 3.8 to 8.7 mg amounts of the ash were dissolved in 2.5 ml of 6 M HC1 in a flask. The contents of the flask were heated on a steam bath then evaporated to dryness, redissolved in 5 ml of 6 M HC1 and was heated for 30 min. Then 5 ml of buffer solution (containing 6000 ppm lanthanum as spectroscopic buffer) were added. The volume was made up with distilled water to 50 ml.

Standard solutions containing 0 to 50 ppm calcium were prepared containing 600 ppm lanthanum.

The calcium content was determined using flame emission spectrophotometry on a Pye-Unicam Sp 900 instrument.

9. Electrophoresis

Electrophoresis is a method that utilizes charge differences for the separation and purification of protein (Haschemyer and Haschemyer, 1973). One of the earliest support media for zone electrophoresis was filter paper (Block, Durrum and Zweig, 1958). Aschaffenburg and Drewry (1955) used paper electrophoresis of whey protein fractions. Smithies (1955) described a method of zone electrophoresis on starch gel. Bell (1962) introduced a procedure for the detection of whey proteins. Pederson (1963) applied the method of acrylamide gel electrophoresis to the separation of whey protein using the same buffer employed by Bell (1962). Raymonds (1964) described a simple technique for employing a continuous buffer system in polyacrylamide gels. Both methods, starch gel and ployacrylamide gel were used in the study of whey proteins and good results were obtained (McKenzie, 1971) but the starch gel has been superseded by a great extent by polyacrylamide gel zone electrophoresis of protein.

Polyacrylamide gel electrophoresis is used successfully in the identification of whey protein. This method was used in the identification and the comparison of the type of the protein present in different samples. The following procedure was used:-

Two samples from the seams, and another two samples of non seam areas of cheese, and one of skim milk were taken. 100 mg of each sample was taken and each was placed in separate flasks, 0.1 ml distilled water, and 3 ml gel buffer were added and were mixed well, centrifuged for 10 min at 2500 rpm. The samples prepared in this way were used in the test.

Cyanogum 41 (12 g) was dissolved in 150 ml tris-citrate buffer. Ammonium persulphate (0.15 g) was added and the flask shaken until the crystals dissolved. β dimethyl-amino-propionitrate (0.15 ml) was added, the solution was mixed and dearated and then poured in to a Perspex mould (180 mm x 110 mm x 5 mm), covered with a Perspex lid carrying five slot formers, and left until polymerisation was completed. The prepared samples were then placed in the slots and covered with wax.

The mould, with the slots nearest to cathode, was placed in the electrophoresis tank which contained buffer solution made of boric acid (18.5 g/l) and sodium hydroxide (2.0 g/l). Absorbent lint was placed at the end to make contact between the buffer and the gel. Polythene film was used to cover the mould. The electrophoresis was carried out at $4^{o}C$ by applying constant voltage of 100 volts.

When the fraction of the samples travelled almost to the end of the mould, it was removed and was immersed overnight in a solution of 0.1 per cent (w/v) amido black 10 B (B.D.H.) in 10 per cent, acetic acid. Destaining the dye was carried out by extensive washing in 5 per cent acetic acid.

The gel was then examined and vacuum sealed in a cellulose/ polythene laminate pouch, and photographed.

SECTION 2 CHEMICAL ANALYSIS OF MILK, STARTER, WHEY, AND CHEESE AND RHEOLOGICAL MEASUREMENTS

1. Salt determination

The salt content of cheese was determined using the following procedure:- 2 g of grated cheese was added to a conical flask, together with 10 ml of distilled water and 25 ml of 0.05 N silver nitrate. 10 ml of concentrated nitric acid was added, and the contents were gently boiled until the curd was digested and the colour became clear lemon. 0.3 g of urea was added to the hot solution and allowed to cool. Then 2 ml indicator solution and 50 ml distilled water were added. The excess of the silver nitrate was then determined by titration with 0.05 N KCNS solution to an orange tint end point that persisted for 15 s. In the same manner the ml KCNS needed for a blank in which no cheese sample was added, was determined. The percentage of the salt in the sample was determined by finding the difference between the titrations of the blank and sample (B - S), multiplying with the equivalent of 1 ml of KCNS in terms of NaC1. The percentage of salt in the cheese sample was then calculated. The average of two readings were taken and recorded. All the chemicals and indicators used were in accordance with the British Standard Method (1963). Salt concentration in the aqueous phase is calculated according to the following:-

$$\text{percentage salt in aqueous phase in cheese} = \frac{\text{percentage salt}}{\text{percentage moisture}} \times 100$$

2. Moisture

Approximately 3 g of the grated cheese sample was weighed accurately in an aluminium foil container (Foilpak 10335, supplied by R. R. Brodie Ltd., Glasgow) with a diameter of 3.25 in (8.26 cm) and a depth of 0.75 in (1.91 cm). The container and the sample were placed in a fan ventilated hot air oven at 102°C. Final weight readings were taken, the weight of container and the sample were constant. The amount of moisture in the sample was then calculated and the percentage of moisture in the cheese was determined (BS 770, 1963). The average of two readings was taken.

3. pH

Ten grams of the grated cheese sample were weighed and placed in small plastic container along with 10 ml of distilled water. The cheese and water were mixed thoroughly by means of a Silverson mixer until a paste was obtained. The pH value were then determined by means of a PYE 290 pH meter - using combination glass electrode (Activion Glass Ltd., Scotland). The average of two readings was recorded.

4. Content of carbon dioxide

Carbon dioxide losses from Cheddar cheese have been measured by Van Slyke and Hart (1903). A method for the determination of the carbon dioxide present in a cheese sample was described by Clark

(1912), and later modified. More recently, Hiscox, Harrison and Wolf (1941) in their study of the volatile acids in cheese, used the technique of aerating the sample with CO_2, free air to eliminate the carbon dioxide that may be present in the distillate for 20 min, and the carbon dioxide was obtained as the difference of two readings obtained with and without aerating the sample.

A method for the determination of carbon dioxide in cheese described by Kolthoff and Sandell (1943), was later modified by Swartling and Willart (1953). The modified method was based on the use of a solution of sodium hydroxide to dissolve the cheese sample in special container, followed by acidification by sulphuric acid. The carbon dioxide driven away from the sample with CO_2 - free air, was absorbed in a barium hydroxide solution held in a special absorption column (Pettenkoffer tube). Titration of the barium hydroxide solution with 0.1 N HC1 solution was then undertaken to determine the carbon dioxide extracted from the cheese sample.

Robertson (1957) used freshly boiled distilled water (with no added sodium hydroxide) to the cheese sample, and reported that better homogenisation of the sample was obtained. This was later confirmed by Man (1959). A special blender was introduced by Man, who also used five drops of propanol in order to improve the absorption of carbon dioxide by a 0.3 N solution of sodium hydroxide. Robertson (1962) replaced the Pettenkoffer type tube containing barium hydroxide for CO_2 absorption with a sintered bubbler containing 0.25 N sodium hydroxide.

The method described by Robertson (1962) was selected for use in the study for the determination of carbon dioxide of cheese.

The arrangement of equipment for the determination is presented in Figure 4, and the procedure was as follows:-

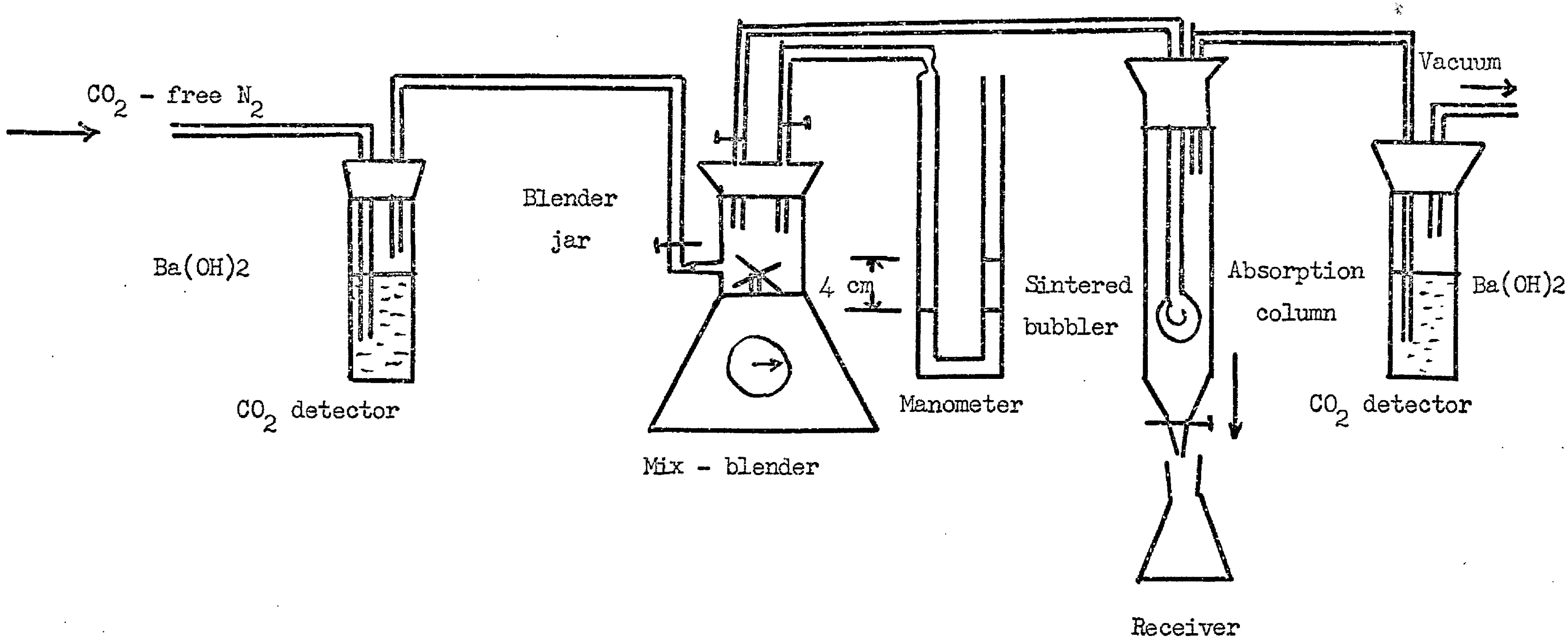
With a long butter trier, a sample of cheese was taken from a 40 lb block. About 25 to 35 g of the cheese was taken from the middle of the core sample and were placed directly in a tared blending jar containing 100 ml of distilled water. The container, with the pipe connections all closed was reweighed, and the exact weight of the cheese sample determined. The jar was placed on special blender pipe, the connections were all connected to the apparatus, and the blender was operated at high speed for 35 s. To the absorption column was added, 20 ml of 0.25 N sodium hydroxide and 5 drops of propanol. The tubes were all opened and CO_2 - free nitrogen at 100 ml per min was passed through the cheese emulsion for 30 min maintaining the pressure in the blending jar by means of vacuum at the other end at an atmospheric pressure of $\pm$ 4 cm of water, measured by a manometer. The sodium hydroxide solution was then drained in 150 ml receiving flask, washing the column with distilled water. To the flask, 4 ml of 1.5 N solution of barium chloride and 1 ml of 0.5 per cent (w/v) indicator were added. The remaining hydroxide was then titrated to a phenolphthalin end point with 0.1 N HC1 solution. The content of carbon dioxide (ml/g cheese) was then calculated according to the following:-

$$CO_2 \text{ (ml/g cheese)} = \frac{(\text{ml 0.1 N HC1 blank} - \text{ml 0.1 N HC1 sample}) \times 1.12}{\text{weight of the cheese sample (g)}}$$

5. Measurement of cheese firmness

FIGURE 4

The arrangement of equipment used in the determination of carbon dioxide content in commercial Cheddar cheese



Rheology can be defined as the study of the assessed deformation and flow of matter (Davis, 1965). Cheddar cheese possesses many rheological characteristics, such as elasticity, plasticity and springiness. The firmness of cheese is assessed by the cheese grader kneading the sample in the hand. Subjective assessment of these characteristics is dependant on the grader's experience. Since around the mid twenties, many workers had tried to assess many operations of the cheese making process by objective methods using special instruments. The measurement of the curd firmness before cutting the curd has been a subject for study. Most of these devices were based on the principle of compressing the curd to cause deformation and to measure the recovery over a certain interval of time.

The Isodyne - rheometer (Scott Blair and Coppen, 1941) was used to test the finished cheese, but the sample required for the test was large, and limited its use in the industry (Coppen, 1943). Since then an improved instrument has been developed. A ball compressor to measure the firmness of the cheese was described by Caffyn (1945). This equipment was used with different types of cheese including Gruyère. It had the advantage of being simple, did not cause damage to the cheese surface or the interior when the test was carried out (Mocquot , Scott Blair and Baron, 1947).

The ball in the ball compressor acts in a similar way to the grader's thumb (Caffyn, 1945), and by using the test, the quality of the cheese can be determined (Baron, 1949). The firmness of cheese is greatly affected by the amount of moisture in the cheese.

When measuring the firmness, the cheese tested should always be at the same temperature, a change of one degree Fahrenheit will cause a change of 1.5 B.C.T. units (Wearmouth, 1952). Variations in firmness are due to the sensitivity of many mechanical properties of cheese to temperature (Wearmouth, 1953).

The ball compressor can assess the firmness of cheese accurately provided that the measurement is based on two readings on the top and another two on the base (Baron, 1949). Wearmouth (1955) reported that the accuracy could be increased if more readings were taken.

The ball compressor of Caffyn and Baron (1947) which is used in the determination of firmness, works on the same principle as of the Brinell test used in steel industry. It operates on the basis of a sphere of steel being pressed under constant load into the cheese surface for 30 s. Its penetration is measured by a special gauge and is expressed as ball compressor total "B.C.T.". On the removal of the load, the deformation caused during pressing is removed. The extent of the recovery of the depressed area during 30 s is recorded as the elasticity and is measured by the difference between the two readings and expressed as percentage of the total deformation (Baron and Harper, 1950). These reports on the Ball Compressor related to use of the instrument with traditional bandaged cheese rather than rindless cheese.

In the measurements undertaken in this study, the test cheese was placed on the table, the ball compressor was then placed on the first side of 10 lb (4.54 kg) block of rindless cheese. The dial of the gauge was set to zero. The load was put on and a reading was taken after 30 s. The load was then removed for another 30 s and another reading was obtained. Following the same procedure, three readings on the top and another three readings on the base of the cheese were obtained. All the readings obtained were corrected to a temperature of 60°F (15.6°C) adding one B.C.T. unit per degree fahrenheit (1.8 B.T.C. per degree centigrade) when the temperature of the tested cheese was below 60°F (15.6°C), substracting the same when the temperature of the cheese was more than 60°F (15.6°C).

6. Determination of fat in milk

Throughout the study, the fat content of the milk used in the cheese making experiments, was determined according to B.S. 696, part 2: 1969 (British Standards Institution, 1969).

7. Determination of solids-not-fat in milk

The solids-not-fat content of the milk used in cheesemaking experiments was determined using the formula given in B.S. 734: 1959 (British Standards Institution, 1959).

8. Measurement of titratable acidity of milk, starter and whey

The titratable acidity of milk, starter and the whey sampled during the process of cheese making was measured according to B.S. 1741 (British Standards Institution, 1963), using 1 ml of a 0.5 per cent (w/v) solution of phenolphthalein as indicator to obtain an accurate measurement (O'Connor, 1968).

SECTION 3 SYSTEMS OF CHEESE MANUFACTURE, SALT ADDITION, SCORING THE CHEESE AND STATISTICAL ANALYSIS

A. Water heated vat - experimental, small scale

Fifty gallons of milk were pasteurised in a small HTST pasteuriser at 161.5°F (72°C) for 15 s and cooled to 88°F (31°C) before being pumped to a water-heated vat. Single-strain starters of Str. cremoris were added at the rate of 2 per cent in the proportion of $\frac{1}{3}$ fast strain, and $\frac{2}{3}$ slow strain. The starter was mixed thoroughly into the milk (where necessary cheese annatto colouring was added) and a 10 to 15 min ripening time was allowed. Rennet was added at the rate of 4 oz per 100 gal (113.7 ml per 454.6 l) of milk and coagulation took place at 88°C (31°C). When the coagulation was completed and the curd reached the required firmness, the curd was then manually cut with cheese knife blades, 0.5 in (1.27 cm) size. Scalding was followed by using hot water in the jacket of the vat, heated by injection of steam. A temperature of 102°F (38.9°C) was reached after 1 h, while the curd was continuously stirred until 30 to 35 min before the removal of the whey, when the curd was allowed to settle.

When the titratable acidity of the whey reached 0.17 to 0.19 per cent lactic acid, the whey was removed, and the curd was piled on the side of the vat and was cut into slabs. The curd was cheddared by the traditional method of piling blocks of curd, until the required acidity was reached.

The curd was then fed to a electrically operated Damrow milling machine. Forty-four lb (19.96 kg) of milled curd pieces were placed in small plastic bin 16 in (40.6 cm) wide, 24 in (70 cm) long, and 10 in (25.4 cm) deep . Dry vacuum salt was added at the rate of 3 per cent (w/w) according to the method described on page 59. The salt was thoroughly mixed with the curd and the salted curd was then placed in a conventional rectangular 40 lb (18.14 kg) mould. Pressing took place in 10 in (25.40 cm) Crockatt horizontal cheese press at an air line pressure of 80 psi (5.63 kgf/cm^2) for 18 h. Thereafter the block of cheese was wrapped in a double ply waxed cellulose laminate (Pukkafilm) and sealed in a Crockatt heat sealing press before being placed in a fibreboard case and stored at 50°F (10°C). The system is presented in Figure 5.

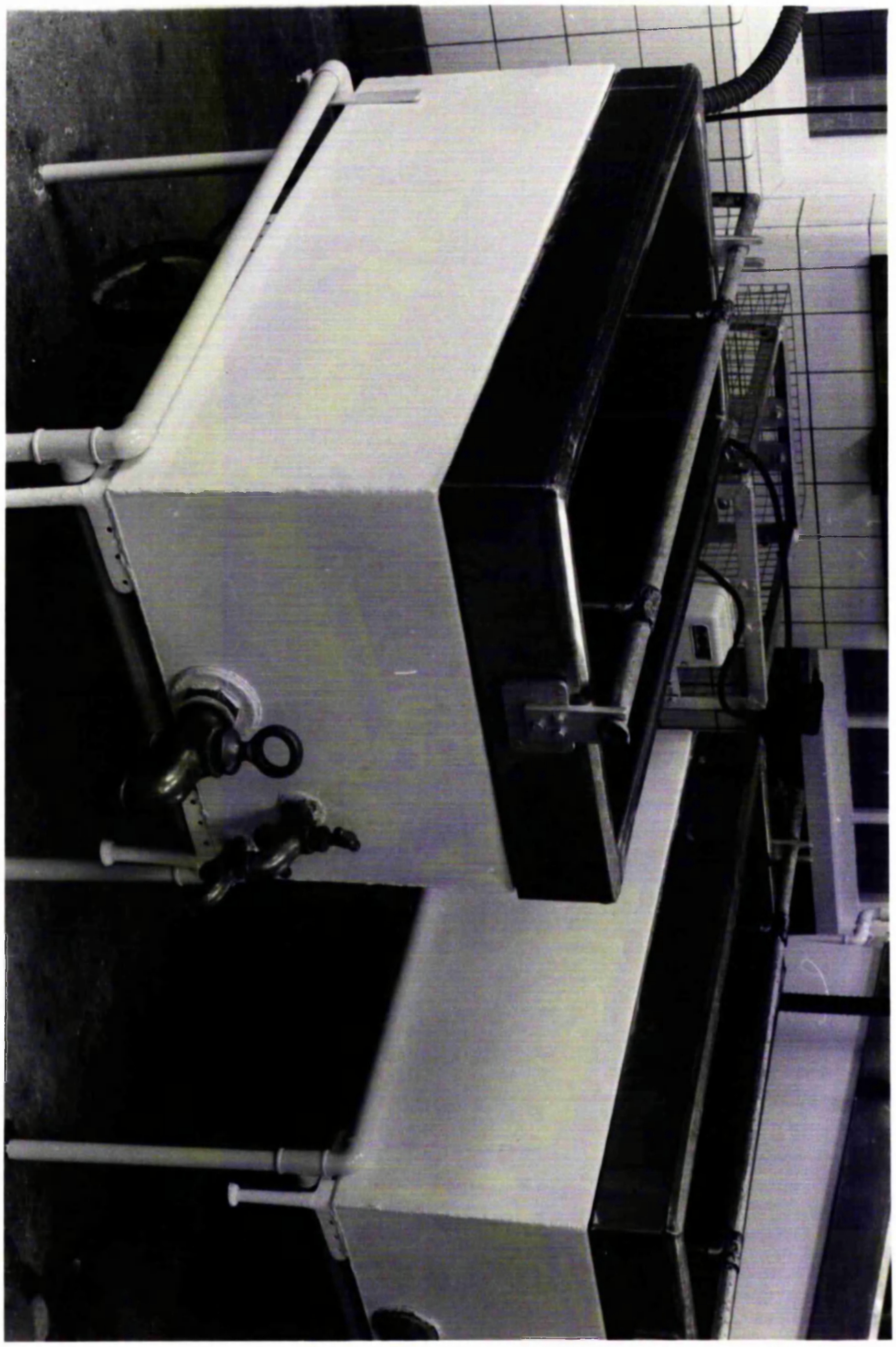
B. Cheddaring box system - experimental - large scale

The milk was heated at 161.5°F (72°C) for 15 s, in a HTST pasteuriser. The milk was cooled in the heat exchanger to 88°F (31.1°C) and added to a 500 gal (2273 l) steam heated vat. Single-strain, or mixed-strain starters were then added to the milk, at the rate of 2 per cent. After starter addition a ripening time of around 12 min was allowed. When coloured Cheddar cheese was required, cheese colour "Annatto" was added at the rate of 4 oz (113.65 ml) per 100 gal (454.6 l) of milk, and thoroughly mixed with the milk. Rennet was added to the vat at the rate of 4 oz (113.65 ml) per 100 gal (454.6 l) of milk, mixed well with the mechanical agitator for about 5 min and then the contents of the vat were left undisturbed for coagulation to take place.

FIGURE 5

The arrangement of equipment used for cheese manufacturing system

Small water heated vat



When the coagulum reached the required firmness, the curd was cut by operating the mechanical knives until the required size of curd particle was obtained. Scalding the curd was carried out by injecting steam into the jacket of the vat while the stirring of the curd was continued, to reach a temperature of 101°F to 102°F (38.3 to 38.9°C) in one hour. Stirring the curd was continued until the removal of the whey from the vat.

When the required acidity level was reached, the curds and the whey were pumped by means of an Alfa Laval LM1 cheese curd pump to fall on a vibrating screen, where separation of the whey from the curd was accomplished. The curd was then allowed to fall into a standard New Zealand cheddaring box measuring 4 ft (121.9 cm) long, 5 ft (152.4 cm) deep, and 1 ft (30.48 cm) wide and made of stainless steel (King and McGillivray, 1962).

Cheddaring was carried out in the cheddaring box, by turning the box through 90° at intervals of 15 min. When the acidity reached the required level, the single large curd block was taken out of the box and was cut by hand into small slabs, thereafter milled in a Damrow type milling machine and divided into 44 lb (19.96 kg) lots of curd as required in each experiment. The curd was then treated as required by the particular experiment.

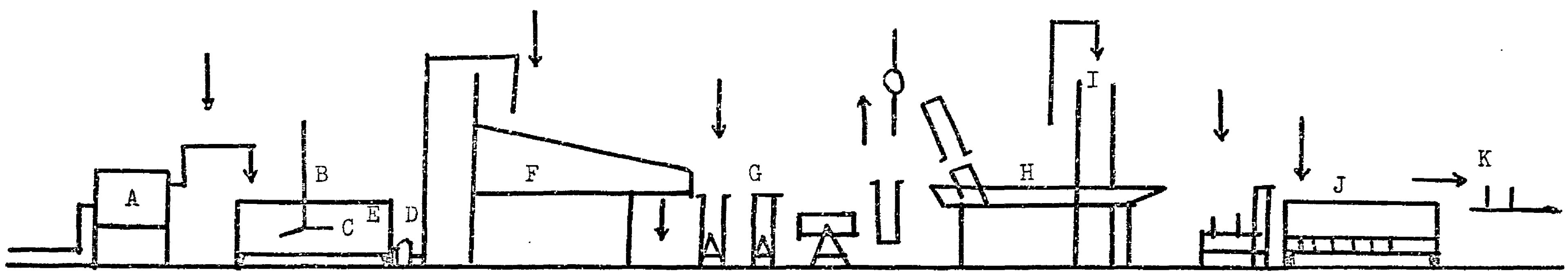
The flow diagram of the system is presented in Figure 6.

C Cheddaring 'tower' system - commercial

In a commercial Cheddar cheese factory handling a 50,000 gal (227,300.0 l) of milk per day, employing the 'CheddarMaster Tower'

FIGURE 6

Flow diagram of cheddaring box system - (experimental) used in the production of Cheddar cheese



A	H.T.S.T. pasteuriser	F	Separating screen	K	Rectangular hoop (40 lb capacity)
B	Vat	G	Cheddaring box		
C	Agitator	H	Cooler		
D	Centrifugal pump	I	Damrow power mill		
E	Valve	J	Salting box for segregation of lots of curd for individual treatments		

system for cheese manufacture (Bysouth <u>et al</u>, 1968), milk was pasteurised at 161.5°F (72°C) for 15 s and pumped to 10 Alfa Laval OST vats each of 2600 gal (11,819.6 l) capacity. Mixed-strain starters were metered and pumped with the milk to the vats, at the rate of 2 per cent (w/v). Annatto was added to each vat at the rate of 4 oz (113.65 ml) per 100 gal (454.6 l) of milk. The completion of pumping the milk and the starter to the vat required about 15 to 20 min. This time was regarded as the ripening time. Rennet was added at the rate of 4 oz (113.65 ml) per 100 gal (454.6 l) of milk and was left to set at a temperature of 88°F (31.1°C). When the coagulum was sufficiently firm, the curd was cut to the required size by operating the mechanical knives. The curd was then scalded in one hour to 102°F (38.9°C).

The whey and curd were pumped to fall on the inclined dewheying conveyor on which the curd was moved upwards while stirring was provided by peg stirrers, to achieve proper whey separation. At the end of this conveyor, the curd was fed to an air blower unit, which conveyed the curd to the top of the cheddaring tower.

The curd was held in the tower for 1.5 h, to reach the required acidity and develop the required texture and fusion. Cheddared curd was then delivered from the bottom of the tower in large blocks into a Berry mill from the tower and milling was automatic and continuous once begun.

The milled curd was then carried on a conveyor to the CheeseMaker 3 unit where the curd was salted, mixed and automatically placed in rectangular mould. After pre-pressing, the filled moulds of curd were allowed to rest without pressure for between 25 to 30 min.

The moulds were then placed in an air operated (10 in (25.4 cm cylinder) horizontal cheese press with an air supply of 80 psi (5.63 kgf/cm^2), and pressed overnight (18 h). The cheese blocks were then vacuum sealed in a nylon cellulose laminate and placed in curing room at 50^{o}F (10^{o}C).

Figure 7, shows the flow diagram of the cheese manufacturing steps in this system.

D. Traditional cheddaring and CheeseMaker 3 system - commercial

In a partially mechanised commercial Cheddar cheese factory in Scotland, the milk was heat treated at 161.5^{o}F (72^{o}C) for 15 s in an HTST pasteuriser and pumped to six open vats, each of 2600 gal (11,819.6 l) capacity. Single-strain starters were metered and pumped to the vats at the rate of 2 per cent (v/v), with proportions of 2/5 fast strain, and 3/5 slow strain. When coloured Cheddar was manufactured, annatto was added at the rate of 3 oz (85.24 ml) per 100 gal (454.6 l) of milk. A ripening time of 15 to 20 min was allowed; the time required for completion of metering starter to the vat. Rennet was added at the rate of 3 oz (85.24 ml) per 100 gal (454.6 l) of milk and after mixing, the contents of the vat were left undisturbed at 88^{o}F (31.1^{o}C) until coagulation was completed.

When the coagulum was of the required firmness, the curd was cut by means of a special knife consisting of blades at 7/8 in intervals to the required size. Scalding to 102^{o}F (38.9^{o}C) in one hour was achieved by injection of steam to the vat jacket while the curd was continuously stirred. Before the removal of the whey, the

FIGURE 7

Flow diagram of the 'Cheddarmaster Tower' system - used for commercial Cheddar cheese manufacture

at S.M.M.B., Mauchline, Scotland

A Milk line

B Starter line

C Mixing point

D OST vat

E Whey separation conveyor

F Blower

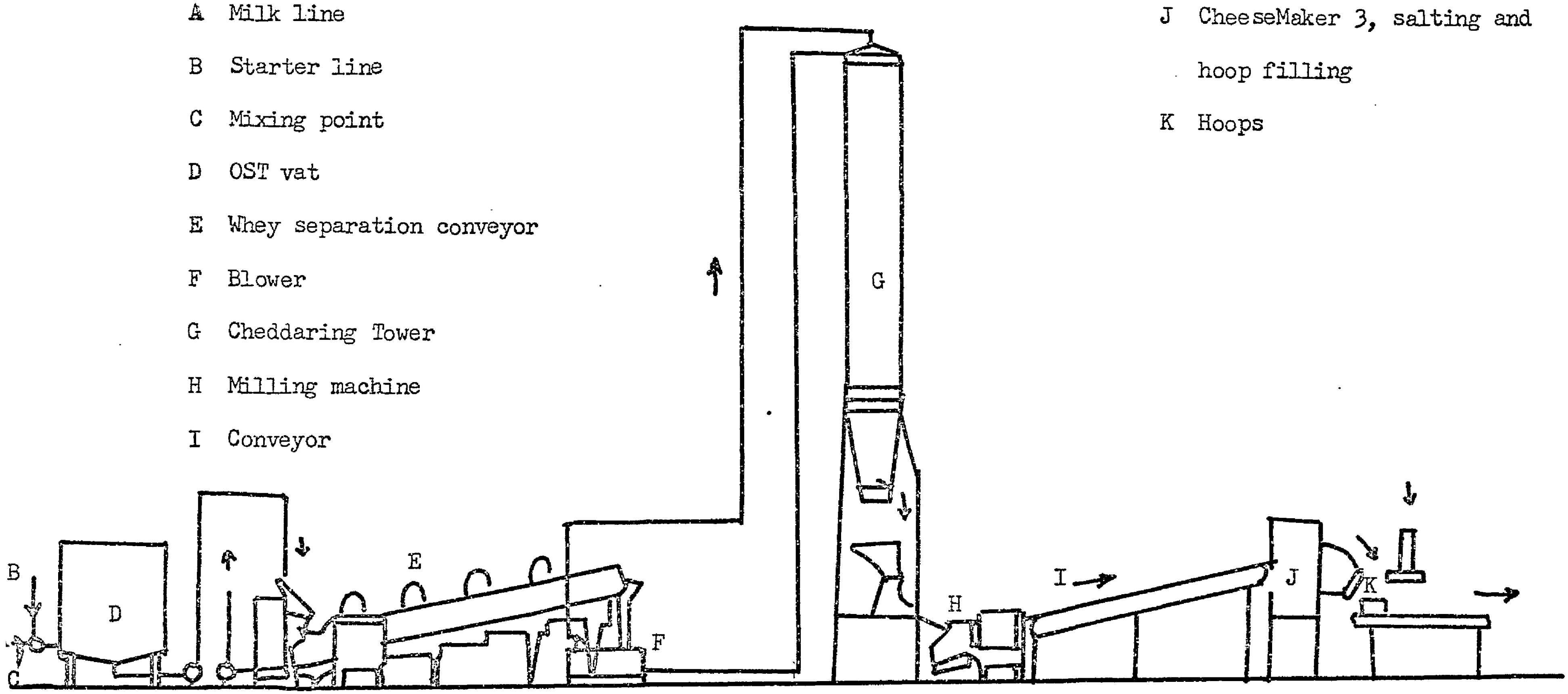
G Cheddaring Tower

H Milling machine

I Conveyor

J CheeseMaker 3, salting and hoop filling

K Hoops



curd was allowed to settle for 30 to 35 min. The whey was drained away from the vat and the curd was piled on the sides of the vat, and cut into slabs of about 10 in (25.4 cm) wide.

Cheddaring was carried out in the vat following the traditional procedure. The slabs were turned each 15 min and were piled until the titratable acidity of the curd reached about 0.7 per cent lactic acid and the texture of the curd was as required.

The slabs were placed on a conveyor, carried to the milling section of the CheeseMaker 3, where it was milled, fed to the salting section, and automatically salted, with about 3 per cent (w/w) dry vacuum salt. Mixing was done automatically in the rotating drum of the machine and the salted curd was mechanically placed in 40 lb (18.14 kg) hoops. The filled moulds were then pre-pressed and were left unpressed for about 10 to 35 min. They were placed in air operated (10 in (25.4 cm) cylinder) Crockatt cheese presses with compressed air supply of 80 psi (5.63 kgf/cm^2) and pressed for 18 h. The blocks were then hand wrapped in waxed cellulose laminate, machine sealed, boxed, labelled and placed in the curing room at a temperature of 50°F (10°C).

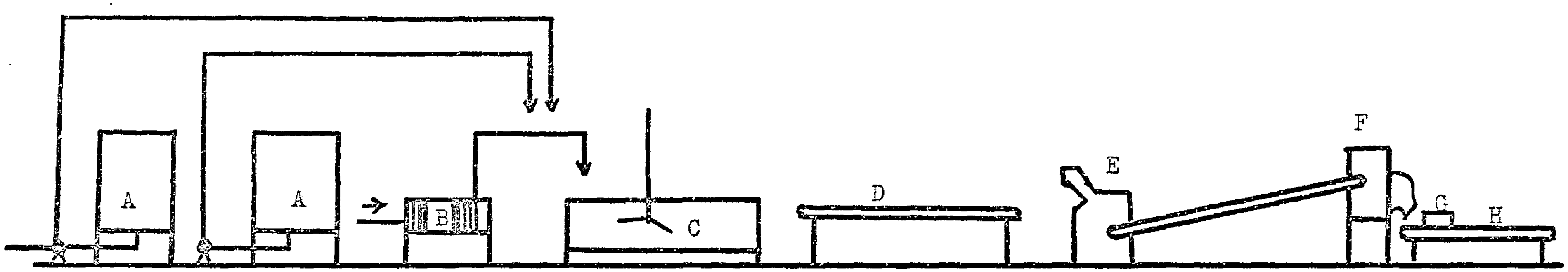
The flow diagram of this system of cheese manufacturing is presented in Figure 8.

E. Addition of the salt to the milled curd and the treatment of the curd afterward

The milled curd was divided into six or nine lots (the number depended on each experiment) each of 44 lb (19.96 kg) and each

FIGURE 8

Flow diagram of the traditional and CheeseMaker 3 system - Commercial - of Cheddar cheese manufacture



A	Starter tanks
B	H.T.S.T. pasteuriser
C	Vat
D	Conveyor
E	CheeseMaker 3 milling section
F	Salting section and mould filling
G	40 lb rectangular mould
H	Conveyor to press area

was placed in an aluminium box (Figure 9), so that identical treatment could be given to the separate lots of salted curd. Care was taken to avoid contamination between high and low level salt treatments.

A predetermined amount of salt was added to each lot of the curd in the boxes in two applications to each box. After the addition of salt the curd and the salt were mixed by hand for about 30 s. Salting of the curd was completed in a time of one minute.

By adopting this procedure it may be claimed that each batch of curd received similar treatment and that the level of salt added to the curd was the variable factor.

Each lot was then placed directly into a designated pre-pared hoop, pre-pressed for 15 to 20 s, dressed and placed in the air operated cheese press fitted with a 10 in cylinder. The air line pressure was normally adjusted to 80 psi (5.63 kgf/cm^2). The cheeses were left in the press overnight (18 h).

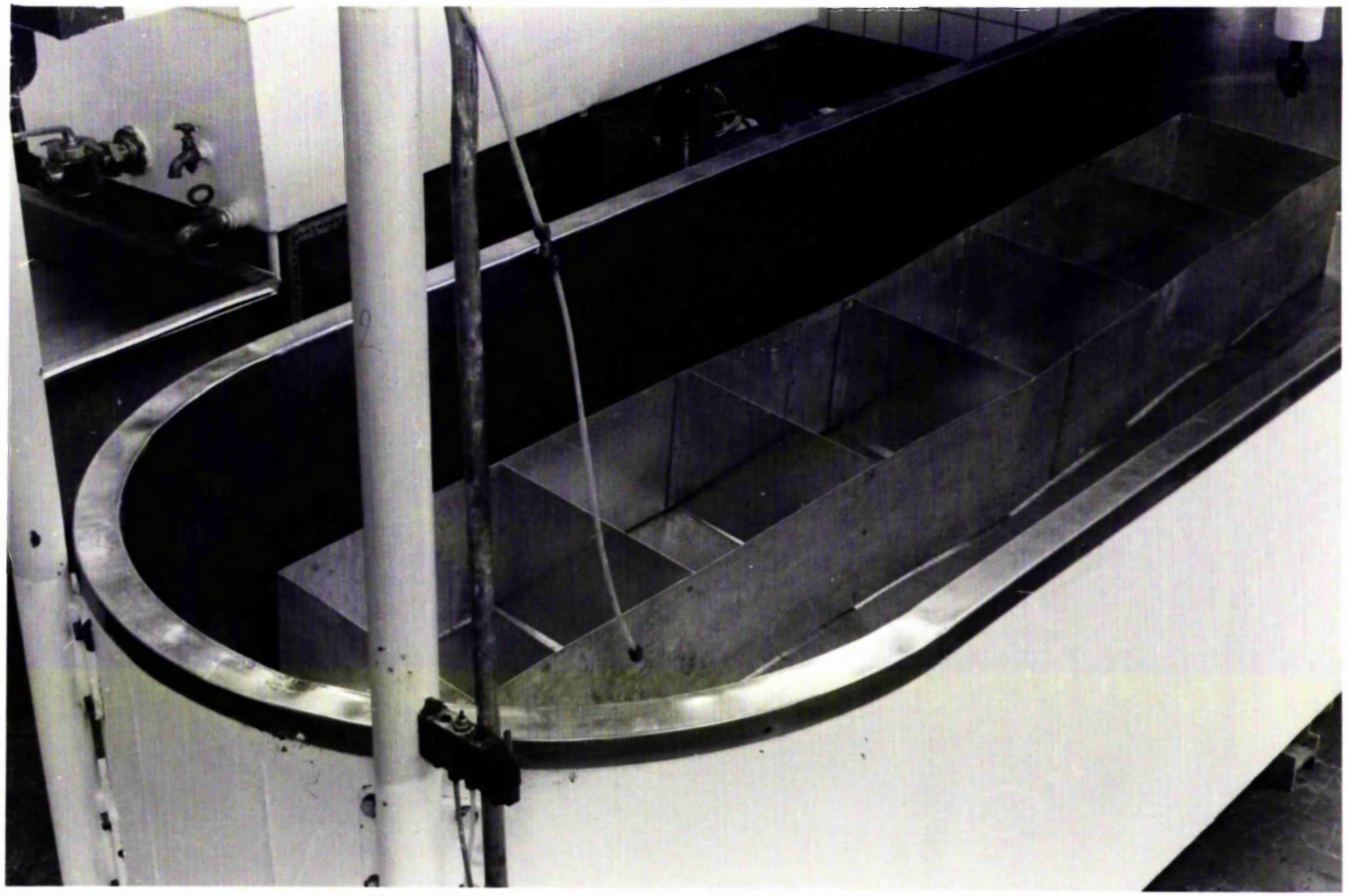
The cheese was wrapped in waxed cellulose laminate, heat sealed, boxed and placed in the curing room at 50^{o}F (10^{o}C). All cheeses were scored and judged at the required time.

F. Presentation and scoring the cheese

Subjective assessments are widely used in judging the quality of cheese but the judges that carry out such assessment should be self-consistent in their rating (Sheppard, 1954). Dawson (1961) reported the use of photographs as an aid in the examination of texture.

FIGURE 9

The arrangement of aluminium boxes used in salting the curd



The cheeses made in the experiment in this study were graded by a panel consisting of the author and seven members of staff of the Department of Dairy Technology of the West of Scotland Agricultural College, Ayr, Scotland. Training sessions were undertaken to standardise as far as possible the expertise and basis of scoring of members of the grading team.

A slice of about 0.5 in (1.27 cm) thick was cut from the surface of each cheese tested. The cheese and the slice were then placed on a table at random, in a well lighted room, and were given a code number as shown in Figure 10.

Photographic standards of pieces of cheese with different degrees of seaminess; 0, 3, 5, 8, and 10 were made available to the panel for consultation during the time of grading. Photographic standards of 0 and 10 degree seaminess are presented in Figure 11.

The cheeses were awarded points according to their characteristics, measured within a predetermined scale. The scales were as follows:-

<u>Seaminess</u>	0	no seaminess	10 very seamy
<u>Fusion</u>	0	not fused	10 completely fused
<u>Openness</u>	0	not open	10 very open
<u>Body</u>	0	very weak	10 very firm
<u>Flavour</u>	0	severe off flavour	10 no off flavour
<u>Colour</u>	0	severe mottling	10 uniform colour

After the first scoring, the cheese was cut into four 10 lb (4.53 kg) blocks which were vacuum sealed in laminate pouches, placed in their boxes and returned to the curing room at $50^{o}F$ ($10^{o}C$).

FIGURE 10

<u>The presentation of the Cheddar cheese for scoring by the grading panel</u>

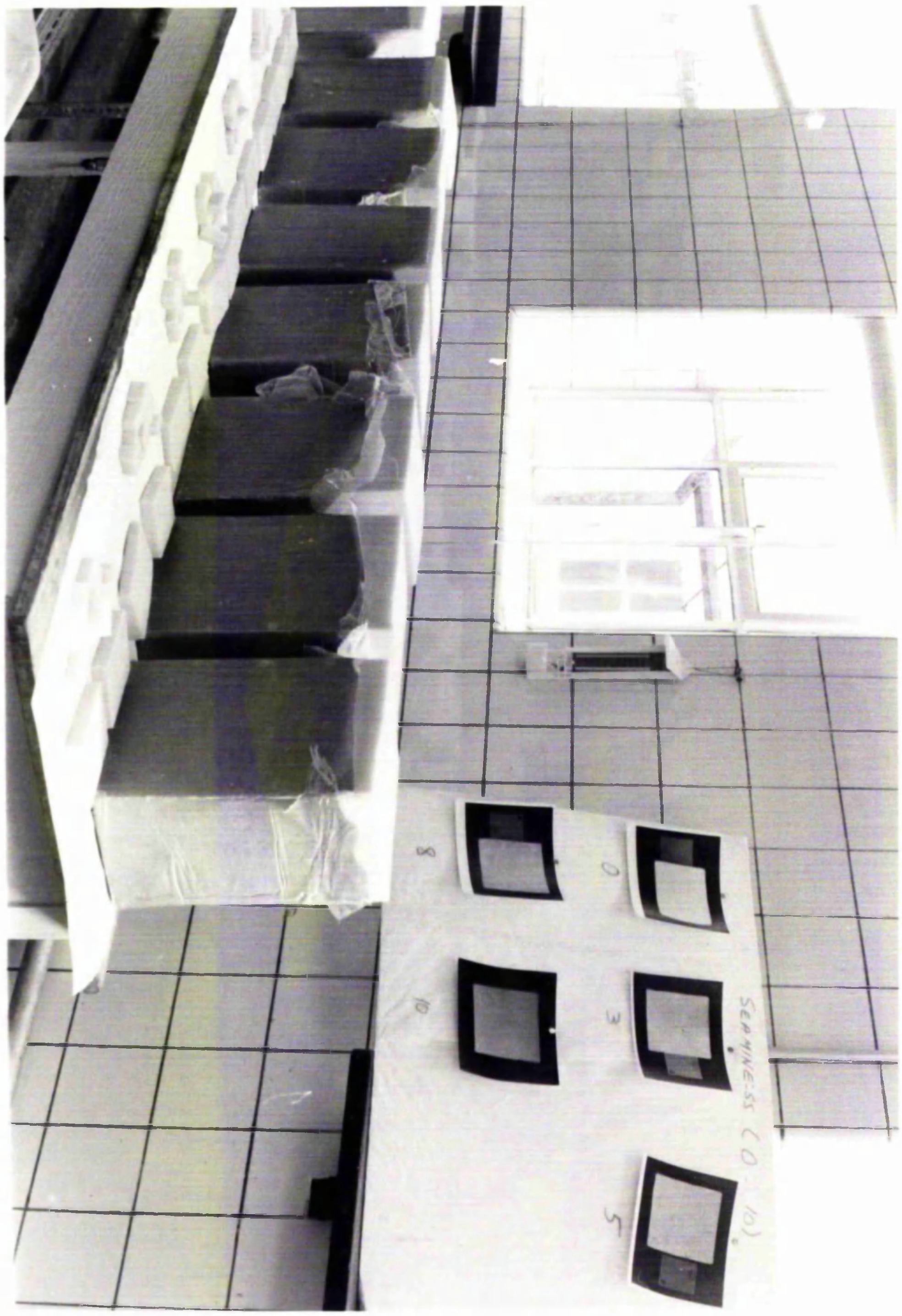
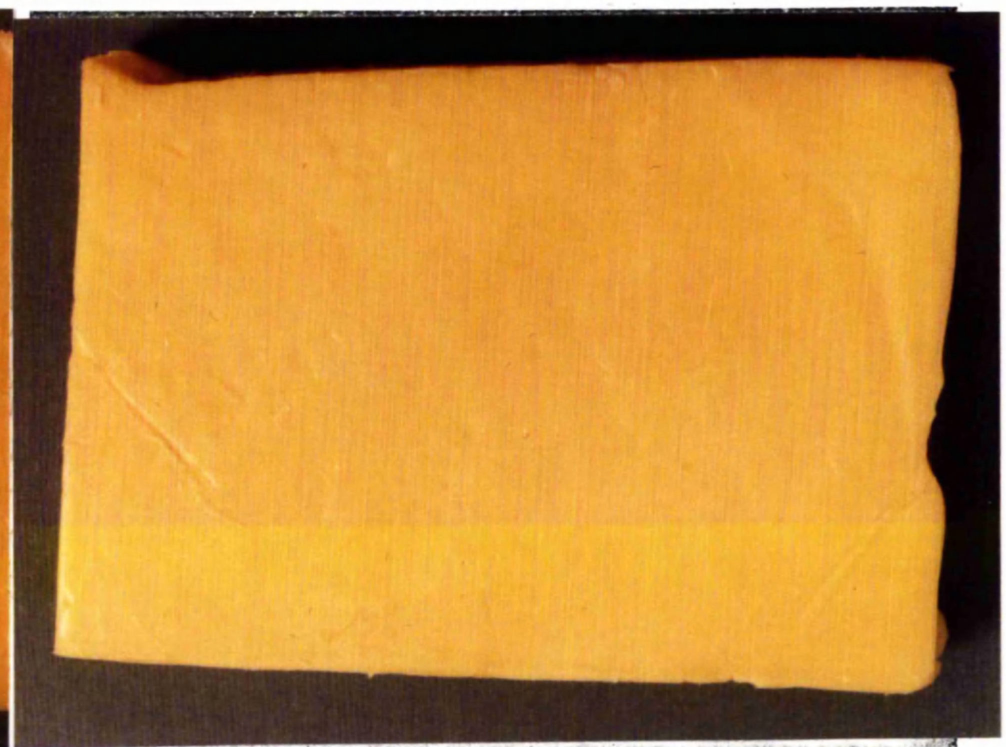


FIGURE 11

Standard photographs of seaminess 0 and 10 points made available to the scoring panel during the time of scoring Cheddar cheese

Seamy (10 points)

Non -- seamy (0 points)



G. Statistical methods

Statistical analysis of the data (individual and total scores) obtained in this study was carried out according to the methods described by Snedecor and Cochran (1976) (analysis of variance).

Note

The terms 'hoop' and 'mould' are used synonomously in the commercial cheese industry in the United Kingdom for the containers in which salted curd is pressed. The terms do not describe the shape of the container or whether it is for conventional round or rectangular block cheese. The related filling operation may be referred to as either 'hooping' or 'moulding'.

SECTION 4 PREPARATION OF EXPERIMENTAL SALT (SODIUM CHLORIDE)

1. Determination of the particle size of dry vacuum salt

In the mechanised system of Cheddar cheese manufacture, dry vacuum salt is used. The salt weighed out according to the weight of the curd, or is dispensed automatically according to the depth of the curd, on a conveyor. Depending on the particular system, mixing of the salt and curd is accomplished in a special rotating drum or by moving the curd by special rotating peg stirrers. The salt used in these machines is coarse and must be free flowing.

Since the objective of the experiment was to investigate the effect of salt particle size, it was necessary to determine the particle size of the dry vacuum salt which was normally used in the industry.

In order to achieve this, a bulk laboratory sample of about one kilogram was prepared by taking small amounts of salt by means of small scoop from different parts of a 50 kg bag of commercial salt. The sample was placed in an oven maintained at 100°C for 16 h. The density of the salt was determined by placing a 150 g sample of the dried bulk sample in 250 ml capacity cylinder of the J. Engelsmann AG Jolting Volumeter JEL ST 2. The density was measured by running the volumeter for 1250 jolting strokes. The volume of the sample was then determined, and the bulk density of the sample was calculated by dividing the weight of the sample by the final volume. The average of five readings was taken and are given in Table 3.

According to the data given by Endecotts (Test sieves,

TABLE 3

The determination of the bulk density of the commercial grade dry vacuum salt

Test	Weight of salt (g)	Volume after test (ml)	Density of the salt (g/ml)
1	150	110	1.363
2	150	109	1.370
3	150	110	1.363
4	150	110	1.363
5	150	109.5	1.367
Average			1.366

Endecotts, 1970), 25 g of the sample should be used in the separation test. The screening test was carried out by taking 25 g of well dried salt sample, weighed in a balance of 0.01 g precision, and placed in the top sieve. The shaker (Endecotts test sieve shaker Model EFL 2) was operated for 5 min. This time was found to be satisfactory for the sample used in the test. All the test sieves used were 8 in Endecott Test Sieves (1970). The salt which was retained in each of the eleven sieves was then weighed, and the weight of the salt was recorded.

The surface mean of the different particles of the salt were then calculated according to the following formula:-

$$D\,S = \frac{W}{(W/D)}$$

Where DSis the surface mean, W is the per cent salt retained in the sieve, and D is the aperture mean. This equation was used because after milling the salt, the particles possess irregular shape, and by this formula the best estimation can be achieved under these conditions.

The results of these measurements are presented in Table 4.

2. Salt milling

From the data presented in Table 4, approximately 58 per cent of dry vacuum salt particles are of the size of more than 350 μm and

TABLE 4

Particle size determination of commercial grade dry vacuum cheese salt in 5 samples

Sieve mesh No	Aperture (μm)	Aperture mean (μm)	Per cent retained of sample (W)				
			Sample I	II	III	IV	V
16	1000	-	-	-	-	-	-
22	710	855	0.17	0.24	0.32	0.16	0.16
25	600	655	1.54	1.53	1.77	1.73	0.81
30	500	550	7.64	8.25	8.20	8.16	8.32
44	355	427.5	44.83	44.55	48.25	46.43	47.09
52	300	327.5	20.41	19.84	19.86	19.63	20.01
60	250	275	13.46	13.68	12.39	12.74	12.86
85	180	215	8.61	8.61	6.96	8.51	7.35
100	150	165	1.42	1.37	0.85	0.97	0.88
120	125	137.5	1.10	1.09	0.72	0.81	0.72
170	90	109.5	0.65	0.68	0.44	0.53	0.40
collector	-	45.0	0.12	0.16	0.24	0.31	0.32
W/D			0.2977	0.3007	0.3070	0.2957	0.2929
Surface mean			333.54	333.54	325.76	338.22	342.64

and 33 per cent of less than 350 µm and greater than 250 µm. It also showed that the surface mean of the dry vacuum salt was 333 µm.

In order to investigate the effect of dry vacuum salt of smaller particle size on the development of seaminess in Cheddar cheese, it was required to reduce the particle size of the salt normally used. This was accomplished by milling the dry vacuum salt using a Minkek Mill manufactured by KEK Limited, Cheshire, U.K., using a vibratory feeder (Model DRIS) of Glen Greston, Stanmore, Middlesex, England, U.K.

Dry vacuum salt was placed in the oven at 100°C for 16 h. Milling was carried out at different settings of the vibratory feeder which regulated the salt supply to the mill, ensuring that the level of the salt in the mill hopper was kept constant. The mill was run for 10 min at each of the settings. The density of the milled salt was determined according to the procedure described on page 63, and found to be 0.75 g/ml suggesting the use of 25 g sample for the distribution test (Test Sieves, Endecotts, London, 1970). The different fractions of the milled salt obtained are presented in Table 5.

3. Cheese salt

It was decided to use milled salt of particle size of 50, 73, and 107 µm. Salt separation of the milled salt into these fractions was carried out by placing 25 g of well dried salt in the top sieve of the stack of sieves used in this separation. The stack of sieves consisted of a sieve of 355 µm followed with 180, 125, 95,

TABLE 5

Particle size distribution of milled dry vacuum salt at different feed speed to the KEK Mill

Sieve from top	Aperature (μm)	Weight of salt retained in each sieve (g) Setting of the vibratory feed 85	88	89	90
1	350	0.0	0.7	0.9	1.2
2	250	0.7	0.5	0.9	1.2
3	180	0.4	0.6	1.0	0.6
4	90	1.5	2.2	4.5	4.8
5	45	14.6	16.1	13.2	13.4
6	collector	7.4	4.7	4.3	3.5
Total		24.6	24.8	24.8	24.7

56, 45 and collectors. The shaker was operated for 5 min, and the fractions retained in sieves No. 4, and 6. This procedure was repeated until the required amount was collected, stored until required in the experiments.

CHAPTER II

STUDY OF THE CHARACTERISTICS AND CHEMICAL COMPOSITION OF SEAMS

CHAPTER II

STUDY OF THE CHARACTERISTICS AND CHEMICAL COMPOSITION OF SEAMS

SECTION 1 CHARACTERISTICS OF SEAMS

1. Appearance of seams

The seams appear along the junction lines between the curd particles, and they are seen on the cut surface and the interior of the cheese as dense white lines. The seams present in severe cases of seaminess, form a network of lines on the face, and can be easily recognised by the eye. Figure 12 shows seams in both white and coloured Cheddar.

It was found that seams in coloured Cheddar cheese are more evident than uncoloured cheese. This may be due to darker colour of the rest of the cheese which supplied a good contrast to the white lines.

When a thin slice of cheese was placed in front of a light source, the lines appear to be denser than the rest of the cheese and do not allow the light to pass through, showing the exact boundaries of the curd particle, as a wall made of bricks. Figure 13 shows this pattern described above.

2. Size of seams

Sections from the seams were taken and were placed under the microscope and the width of the seams was measured by means of an eye-piece micrometer.

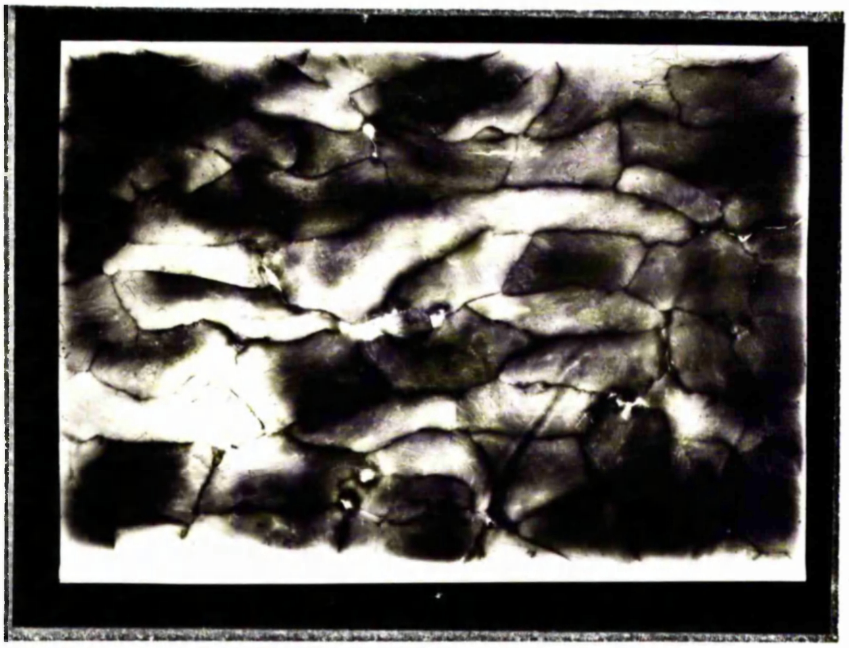
FIGURE 12

Seamy and non - seamy White and Coloured commercial Cheddar cheese

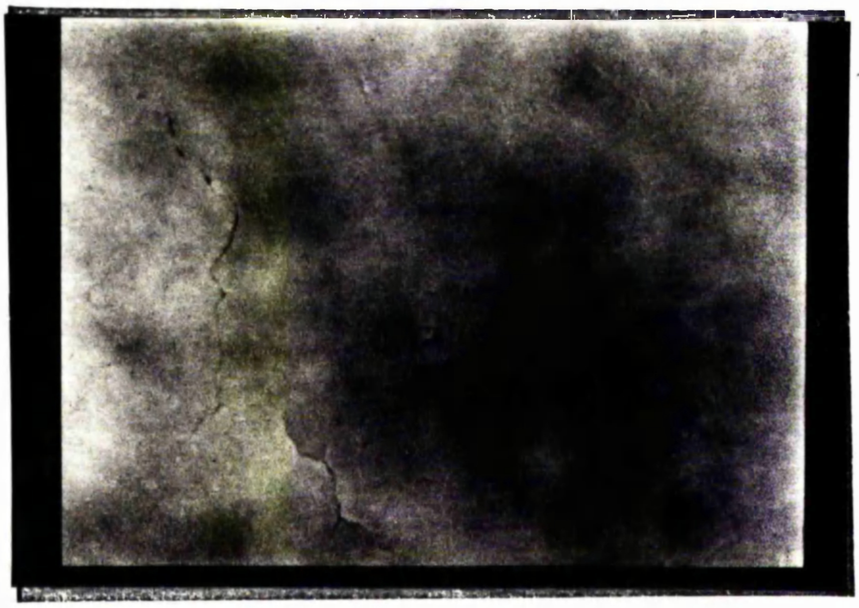
1. Non - seamy White Cheddar
2. Non - seamy Coloured Cheddar
3. Seamy White Cheddar
4. Seamy Coloured Cheddar

FIGURE 13

Appearance of seams under the light compared to non - seamy cheese



a. Seamy Cheddar



b. Non - seamy Cheddar

These measurements which are presented in Table 6 shows that the width of the seams may range from 65 to 1030 μm.

3. Distribution of seams

To determine the distribution of seams in rindless Cheddar cheese, two 40 lb (18.14 kg) blocks of very seamy cheese and another block of non-seamy Cheddar were taken. All cheeses were cut by special wire cutters into four, 10 lb (4.536 kg) blocks. Each was cut into 0.5 lb (0.227 kg) pieces by another wire cutter. Samples were taken such that, four pieces were taken representing one face of the cut surface, from the surface, first third, and the middle of the block. Sampling was carried out as shown in Figure 14. To ensure uniform conditions for grading the samples were vacuum sealed in polyethylene laminate, and were presented to the scoring panel and scored for seaminess according to that described on page 60. The results of the scoring are present in Table 7.

The results appeared in Table 7 indicates that in the severe cases of seaminess, the seams are distributed throughout the cheese block.

4. Formation of the seams

The scoring of the Cheddar cheese in many experiments throughout this study, showed that seams in the cheese can be seen directly after taking the cheese out of the press (one day old). The degree of seaminess increased with the age of the cheese. The highest scores for seaminess in some cheese were reached after 8 weeks of curing but in others a longer time was required. This is shown in the graphs presented in Figure 16, following page 79.

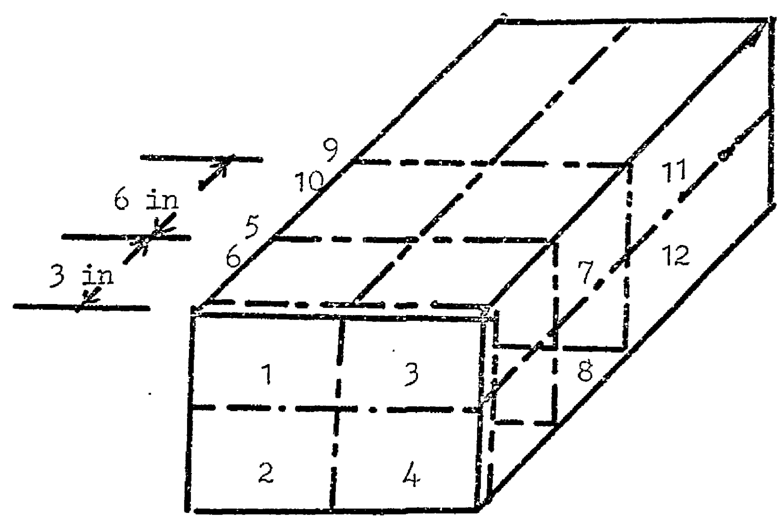
TABLE 6

Measurements of the width of the seams

Reading in the eyepiece	Width of the seams (μm)	Reading in the eyepiece	Width of seams (μm)
5.0	650	1.9	247
7.5	975	1.0	130
3.1	403	0.5	65
2.6	338	1.8	234
1.4	182	1.2	156
1.5	195	2.0	260
1.1	143	5.0	650
0.5	65	0.9	117
0.6	78	1.0	130
1.8	234	0.5	65
8.0	1040	2.0	260
1.8	243	3.0	339
4.5	585	2.0	260
5.0	650	2.0	260
2.0	260	2.3	299
3.0	390	2.0	260
3.4	442	3.0	339
3.2	416	1.2	156
0.6	78	1.4	182
0.9	117	0.8	104
0.5	65	7	91
1.5	195	4.3	559
1.0	130	1.5	195
1.6	208	1.3	169
3.2	416	1.0	130
1.8	234	1.2	156
2.0	260	0.5	65
2.3	299	3.0	390
3.8	494	5.0	650
5.0	650	0.5	65

FIGURE 14

Points of sampling of 0.5 lb cut pieces from a 44 lb (19.96kg) block commercial cheese used in the determination of the seam distribution in the Cheddar cheese



Surface	Samples 1, 2, 3, 4
3 in	Samples 5, 6, 7, 8
Centre	Samples, 9, 10, 11, 12

TABLE 7

Seams distribution in white and coloured Cheddar: scores of seaminess given by scoring panel (5 judges) to cut pieces taken from different depths of a 44 lb (19.96 kg) cheese block

Type of Cheddar	Judge	Samples of first surface				Samples of second surface				Samples of middle surface				Mean
		1	2	3	4	5	6	7	8	9	10	11	12	
White seamy	1	10	10	10	10	10	10	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10	10	10	10	10	10	10
	3	10	9	10	9	10	9	10	9	10	10	10	10	9.7
	4	10	10	10	10	10	10	10	10	10	10	10	10	10
	5	10	10	10	10	10	10	10	10	10	10	10	10	10
Coloured seamy	1	10	10	10	10	10	10	10	10	10	10	10	10	10
	2	10	10	10	10	10	10	10	10	10	10	10	9	9.9
	3	10	8	8	8	8	10	10	10	10	10	10	8	9.2
	4	10	10	10	10	10	10	10	10	10	10	10	8	9.9
	5	10	8	9	8	10	10	10	9	10	10	9	7	9.2
Coloured non-seamy	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0

SECTION 2 THE CHEMICAL COMPOSITION OF SEAMS

Introduction

Cheese in which the particles of the curd are outlined in light coloured lines is described as seamy in colour (Van Slyke and Price, 1952). The cause for this colour is not well known to the industry. Many workers suggested that certain materials accumulate between the two particle junctions, and form a distinctive white line on the surface of the cheese (Eckles, Combs, and Macy, 1955). This is always described by the cheese grader as seamy colour. Seams can be found in both white and coloured Cheddar, but as found in Section 1 to be more evident in coloured Cheddar.

The occurrence of the defect in Cheddar cheese lead to intensive studies aimed at providing an understanding of its nature and of the conditions that encourage its occurrence. The knowledge of the chemical composition of the seams is necessary to identify the materials that accumulate in this area and cause the formation of seams.

The accumulated matter was thought to be mainly composed of milk fat, exuded from the two adjacent curd particles to the line of their junction (Van Slyke and Price, 1952), (Eckles, Combs, and Macy 1955), and (Czulak, 1961). Later Conochie and Sutherland (1965) suggested that the material making up the seams is the chemical compound calcium orthophosphate; $Ca\ HPO_4.2H_2O$, which forms crystals in the junction line and results in a dense layer which appears as a distinctive white line. This chemical compound (calcium orthophosphate) is also found to be present in the body of the Roquefort and Swiss cheese (Swiatek and Jaworski, 1959). Brooker, Hobbs, and Turvey (1975), reported the presence of small calcium orthophosphate crystals in the body of Cheddar cheese, and were also present in higher concentration on the surface of the curd particles (line of particle junctions). They found that the crystals are located in spaces between the fat and casein phase of the cheese, indicating that they were crystallised from pockets of residual whey. Conochie and Sutherland (1965) related their formation to the release of both phosphate and calcium ions from the curd particles to the surface of the curd and their accumulation in the area of their junctions due to the effect of salt added to the curd during salting. Holsinger and Pallansch (1966) reported that the seams contained primarily whey proteins, slightly elevated level of chloride, calcium and phosphate.

In order to understand the causes and the factors that may encourage the occurrence of seaminess, it is essential to determine the identity of the materials present in the seams, and the mechanism of their formation. This study was intended to achieve that.

Experimental

To determine the difference between the chemical composition of the seams and the rest of the cheese body, a 10 lb (4.536 kg) block of a very seamy white Cheddar cheese, of 5 months old was selected from a commercial source.

To achieve good comparison between the seams and the body of the cheese, three samples from the seams, and another three from the comparable parts of the rest of the cheese were taken for the analyses. Since there were many differences reported in the composition of seams, it was decided to investigate the difference between the samples in the content of fat, protein, salt (sodium chloride), lactate, ash, phosphate, calcium, pH and the determination of the electrophoretic pattern of the protein present.

In order to provide a reasonable comparison in the calcium content in both seamy and non seamy cheese, samples were taken from both the surface and the centre of the salted, unsalted, pressed and unpressed one day old cheddared curd. The curd was produced according to the data appeared in Table 94. The curd was salted with dry vacuum salt at the rate of 3 per cent (w/w). Salting and treatment of the curd afterward was carried as described on page 59.

Sampling

A. Sampling from seams and the rest of the cheese body

The cheese selected for sampling was cut into slices of 0.5 in (1.27 cm) thickness with a wire cutter. By means of a needle, microsamples were picked from the white lines sited under the magnifying lense, to insure accurate sampling from the lines. Samples from the seams were collected in special sampling bottles. In the same manner, samples from the same surfaces were taken from the rest of the cheese body and were collected in another special sampling bottle. Sampling was continued by cutting the cheese again and more material was collected until three samples from the seamy areas and another three from the cheese away from the seams were obtained of sufficient amount for the analyses referred to above.

B. Sampling from salted, unsalted, pressed and unpressed curd

Samples from salted, unsalted, pressed and unpressed curd were taken from the surface of the curd particles by scraping on the surface gently with a small needle when they were one day old. At the same time, the curd particles were cut, and samples from the centre were taken in another sampling bottle. Sampling was carried out until the required amount was collected.

From the same curd, a lot of 44 lb (19.96 kg) was taken and placed in a plastics container 16 in (40.6 cm) wide, 24 in (70 cm) long and 10 in (25.4 cm) deep. The curd was salted at the rate of 3 per cent (w/w) and treated afterwards as described on page 59.

The block was given 18 h pressing and then a 0.5 in (1.27 cm) thick slice was cut off and scored for seaminess by members of the panel. The curd particles were carefully broken apart. Samples were picked from the surface and the centre of the curd particles as described above.

Since the process of taking the sample required a long time, in which the slices of the cheese were exposed to the atmosphere during sampling, the seams appeared to dry out more quickly than the rest of the cheese. This variation in the moisture loss may cause variation in the concentration of these materials being determined, and cause inaccurate comparison. It was essential to eliminate this source of variation by freeze drying the samples to provide good storage conditions of the samples until they were analysed.

All the samples were placed in the hood of a freeze dryer Model EFO 3 (Edwards High Vacuum Ltd.), and were left for three days at a temperature of - 58°F to - 76°F (-50°C to -60°C), until the samples were completely dry. The samples were then stored at - 4°F (-20°C) until they were used for the analyses.

Chemical analyses. The freeze dried samples from the seams and the rest of the cheese body were analysed for salt (sodium chloride), fat, protein, pH, lactate, ash, phosphate and calcium according to the methods described on pages 33, 35, 36, 38, 39, 40, 42 and 44 respectively.

The ash content and calcium content of the samples taken from salted and unsalted curd both pressed and unpressed were determined according to the methods described on pages 40 and 44.

Gel electrophoresis. Two samples from the seams and another two taken from comparable parts of the rest of the cheese body were taken and their electrophoretic pattern was determined according to the method described on page 45.

Results

The results obtained for the chemical analyses of each sample are recorded in Table 8. These results show that the seam contains higher levels of phosphate and calcium than the rest of the body of the cheese. Calcium content of the seams is three times higher than the rest of the cheese.

TABLE 8

A comparison of the chemical composition of seams and the rest of the body of Cheddar cheese

Sample	Type of sample	Salt (%)	Fat (%)	Protein (%)	Lactate (%)	Ash (%)	Phosphate (%)	Calcium (%)	Magnesium (%)	pH
1	Seam	2.37	49.50	32.6	4.57	9.47	0.351			5.190
	Non seam	2.58	51.9	38.1	4.25	5.22	0.102			5.135
2	Seam	2.40	48.7	34.3	3.84	9.40	1.081			5.170
	Non seam	2.49	51.5	36.6	4.09	3.77	0.376			5.115
3	Seam	2.25	47.9	34.6	4.22	9.63	1.149			5.150
	Non seam	2.52	53.6	37.7	3.94	6.52	0.322			5.105
	Seams							*2.40	*0.04	
	Non seam							*0.80	*0.05	

*Calcium and magnesium contents determined on the ash of the combined samples 1, 2 and 3 of each type of material.

The seam contained lower levels of salt, fat and protein than the rest of the cheese body, but these differences were not too large. There was no difference in the lactate content present in both types of samples.

The seams were of slightly higher pH than the samples from the body of the cheese.

The results of the calcium determination of samples taken from the surface and the centre of the curd particle taken from salted, unsalted, both pressed and unpressed curd of non-seamy Cheddar are presented in Table 9.

Electrophoresis. The electrophoretic pattern of the samples used is shown in Figure 15. This indicates that there is no difference between the protein pattern of samples of seams and the rest of the cheese.

Discussion

The results recorded in Table 8 show that, the samples taken from the seams contain higher level of calcium, phosphate, and ash than those taken from the rest of the cheese. Calcium content in the seams is three times higher than in the rest of the body. The same is true for the content of phosphate. According to Conochie and Sutherland (1965), and Hollisinger and Pallansch (1966), both calcium and phosphate were present in the form of calcium orthophosphate in the seams and the rest of the cheese body. Brooker et al (1975) also reported the presence of the same compound in both locations in Cheddar cheese. The same researcher also reported that this compound

TABLE 9

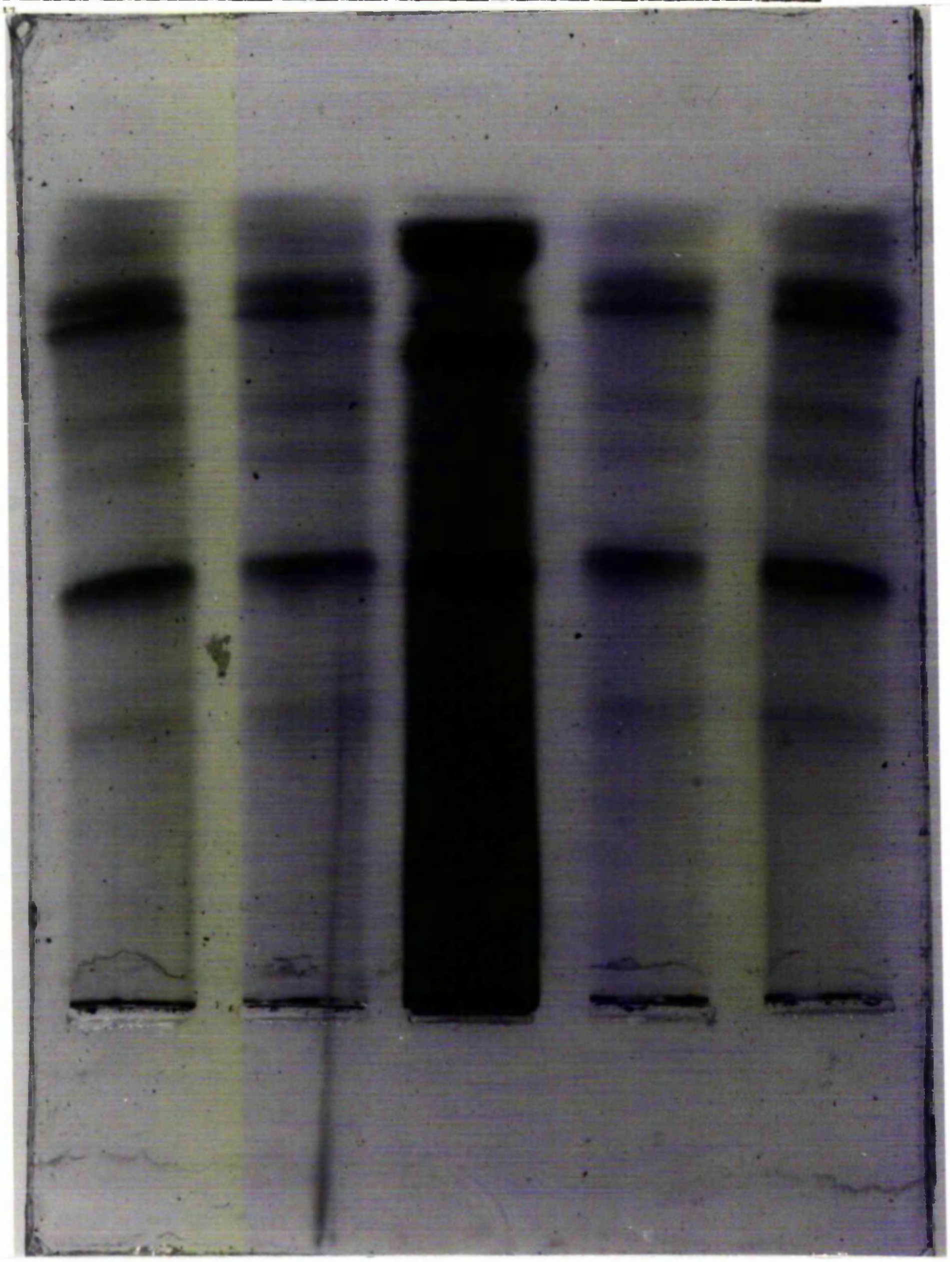
Calcium and magnesium content in samples taken from the surface and the centre of the curd particles of un-salted and salted both pressed and un-pressed cheddared curd

Type of sample		% in Ash Ca	% in Ash Mg	% in Dry Matter Ca
Unsalted, Unpressed				
Surface	A	28.2	1.28	1.3
	B	27.6	1.13	1.1
Centre	A	31.6	1.20	1.1
	B	26.7	1.11	0.9
Salted, Unpressed				
Surface	A	15.1	0.62	1.3
	B	14.8	0.60	1.3
Centre	A	18.7	0.71	1.1
	B	17.2	0.63	1.0
Salted, Pressed				
Surface	A	17.8	0.69	1.2
	B	18.9	0.72	1.3
Centre	A	19.7	0.73	1.1
	B	19.8	0.72	1.1

A and B are duplicates

FIGURE 15

<u>Electrophoretic pattern of the proteins present in samples from the seams and the rest of the Cheddar cheese body</u>



1.A.	Seams	2.A.	Seams	3.	Skim milk
1.B.	Non-seams	2.B.	Non-seams		

Note that A and B represent samples of the same cheese tends to concentrate on the surface of the curd particle, and they reported that the amount increased with time. The high level of the calcium and phosphate present in the samples taken from the seams indicates that these chemicals may be present in a form of a compound and possibly calcium orthophosphate.

The fat content of the seams was 3.6 per cent (w/w) less than the rest of the cheese. This indicated that the seams are not mainly composed of the accumulated fat as was suggested by Van Slyke and Price (1952), Eckles et al (1955) and Czulak (1961).

The results of the analyses also showed that the seams contain less sodium chloride than the rest of the cheese body tested.

The protein content was lower in the seams than the rest of the cheese, and the electrophoretic pattern of these proteins showed no difference in the type of proteins present in both the seams and the samples from the rest of the cheese. Holsinger and Pallansch (1966) reported that the seams were composed primarily of whey protein.

The measurement of the pH in both types of samples showed that higher pH readings were obtained in the seams. This finding is in agreement with those of

Holsinger and Pallansch (1966) who reported higher pH readings in the seams compared to the rest of the cheese.

It was then decided to measure the calcium content in the seams in the same block of cheese at different intervals during the curing period.

The results indicated that there was small differences in the calcium content in the samples taken from the surface of the curd and from the area away from the seams. This agreed with the results obtained by Brooker et al (1975). The results also show that the amount of calcium present in both salted unpressed and salted pressed curd is same as that present in the samples taken from the unsalted unpressed curd.

Conclusion

The seams contained more calcium and phosphate than other parts of the body of the cheese, they are possibly present in the form of calcium orthophosphate.

Seams contained lower fat, protein and sodium chloride than the rest of the body of cheese. Their pH is slightly higher than the rest.

No difference was found in the type of proteins present in samples from the seams and the rest of the body of the cheese.

SECTION 3 THE EFFECT OF CURING TIME ON SEAMINESS

Introduction

Czulak, (1963) described seaminess as a defect in appearance which is usually transient. Cheddar cheese is cured for different period of time before sale. This time may range from three months to one year or even longer. Seaminess present in such cheese may undergo some changes during this time which may lead to other defects in cheese. Seaminess was noticed in both mild and mature Cheddar at different levels in commercial cheese. This study was set to investigate the effect of the curing time on the degree of the seaminess present in Cheddar cheese and the changes that may take place in cheese quality because of its presence.

Experimental

Cheese tested. All cheeses included in the study of the effect of salt addition and of salt particle size (Section 1 and 2, Chapter III) both experimental and commercial Cheddar were included in this test. The production data of their making appears on Tables 96 and 97.

Scoring the cheese. All the cheeses included in the test were presented to the scoring panel for scoring when the cheese were 1, 4, 8, 24 and 52 weeks. The presentation of the cheese and its scoring by the panel were conducted as described on page 61.

Chemical analysis. The determination of the salt content, moisture content, and pH of the cheese were performed according to the methods described on pages 47, 48 and 48 respectively. These analyses were carried out when the cheese were 8, 24 and 52 weeks old.

Determination of calcium during curing time. Samples from the seams and from the rest of the body of the cheese were taken from 40 lb (18.14 kg) commercial Cheddar cheese and freeze dried following the procedure described on page 71. Sampling was carried out when the cheese was of one day, 4 weeks, 8 weeks and 24 weeks of age. Calcium was determined according to the method described on page 44.

Measurement of carbon dioxide content. The carbon dioxide content of commercial Cheddar of different ages was determined by the method described on page 50 of this thesis.

Results

The mean scores given to the experimental Cheddar cheese (of Section A, Chapter III) when the cheese was 1, 4, 8, 24 and 52 weeks old, are presented in Table 113.

The mean scores (seaminess) for the commercial Cheddar cheese made with mixed-strain starters (of Section B, Chapter III) when they were 1, 4, 8, and 24 weeks old are presented in Table 114 and the results of the scoring of the commercial Cheddar cheese made with single-strain starters (Section B, Chapter III) are presented in Table 115 when the cheese were 4, 8, 24, 36 and 52 weeks old.

The results of the determination of calcium in the samples is presented in Table 10.

The results of the measurement of carbon dioxide content of

TABLE 10

The level of calcium present in samples taken from the seams and the rest of the body of Cheddar cheese at different ages during curing

Age of the cheese	Material sampled	Sample	Calcium (%) in Ash	Calcium (%) in sample (dry matter)
1 day	Seams	A	15.61	1.001
		B	17.69	1.194
	Non-seams	A	14.34	0.849
		B	17.12	0.877
4 weeks	Seams	A	20.48	1.560
		B	20.37	1.448
	Non-seams	A	17.06	0.855
		B	16.86	0.792
8 weeks	Seams	A	17.65	1.493
		B	18.00	1.471
	Non-seams	A	17.49	0.787
		B	18.22	0.820
24 weeks	Seams	A	20.60	1.360
		B	20.74	1.520
	Non-seams	A	14.49	0.697
		B	16.89	0.755

* Samples A and B are duplicates

the cheese are presented in Table 11.

Statistical analysis. The results obtained in the scoring of the Cheddar cheese were analysed for the degree of the significance according to the method described on page 62. The results (seaminess) of the analysis of variance in the difference of treatment are presented in Table 12, 13 and 14.

Discussion

Experimental Cheddar cheese (single-strain starters)

In the experimental Cheddar cheese, it was found from the means of scores given to the cheese at different ages, that seaminess increased to reach the highest level 8 to 24 weeks after manufacture and thereafter started to decrease (Figure 16).

Fusion of the resultant cheese was significantly affected. It tended to increase from 6.07 when the cheese was 1 week old to 7.40 points when the cheese was 24 weeks old. The fusion scores when the cheese was 52 weeks old (4.61 points) showed a significant decrease ($p < 0.001$).

The mean scores of openness given to the cheese when the cheese was 4 weeks of age decreased with the time of curing. This unexpected result may be attributed to the effect of the vacuum sealing of the cheese after each grading.

The mean scores indicated that the body of the cheese improved significantly ($p < 0.001$) from 6.38 points when they were scored one week after manufacture to 7.62 points at 24 weeks of age.

TABLE 11

Carbon dioxide present in commercial Cheddar cheese made with mixed-strain starters

Cheese	Age (days)	Mean CO_2* (ml/g)	Seaminess 0 - 10	Fusion 0 - 10	Openness 0 - 10	Body 0 - 10	Flavour 0 - 10	Colour 0 - 10
1	137	0.153	4	6	4	7	7	5
2	137	0.161	7	6	4	7	7	5
3	140	0.312	3	6	10	6	8	5
4	140	0.243	6	7	7	7	8	7
5	142	0.249	6	6	5	7	8	5
6	142	0.164	7	6	4	6	6	6
7	142	0.166	7	6	2	5	7	7
8	142	0.238	9	5	5	5	7	7
9	142	0.286	5	6	6	7	6	7
10	144	0.234	7	6	6	7	8	5
11	189	0.218	6	7	6	7	7	8
12	189	0.278	5	7	8	7	7	6
13	189	0.283	5	7	6	6	7	7

* Mean of three readings.

TABLE 12

Analysis of variance; total scores of seaminess given by scoring panel (5 judges) to experimental Cheddar cheese at different ages

Source of variation	D.F.	Mean square	F
Salt addition	1	547.60	8.78 *
Particle size	2	97.82	-
Salt addition x size	2	19.01	-
Replicates	2	322.50	5.17 *
Experimental error	10	62.38	
Age	4	148.75	6.23 ***
Age x treatments	20	10.97	-
Sampling error	48	23.88	
Total	89		

Age means (total scores)	
1 week	10.4
4 weeks	6.2
8 weeks	8.4
24 weeks	13.7
52 weeks	7.8
S.E. of difference	± 1.63

- Not Significant ($p > 0.05$)

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

TABLE 13

Analysis of variance; total scores of seaminess given by scoring panel (5 judges) to commercial Cheddar cheese made with mixed-strain starters at different ages

Source of variation	D.F.	Mean square	F
Machine salted x rest	1	102.01	-
Salt addition	1	328.05	7.11 *
Salt particle size	1	1.80	-
Salt addition x size	1	45.00	-
Experimental error	20	46.12	
Age	3	978.81	42.76 ***
Age x treatment	12	18.90	-
Sampling error	60	22.89	
Total	99		

Age means (total scores)	
1 week	7.44
4 weeks	19.08
8 weeks	19.32
24 weeks	9.48
S.E. of difference	± 1.35

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

TABLE 14

Analysis of variance; seaminess in commercial Cheddar cheese (single-strain starters) made with different amounts of added salt and of different particle size at different ages during curing

Source of variation	D.F.	Mean square	F
Machine salted x rest	1	0.30	-
2% x 3%	1	122.51	6.86 *
In 2%	1	4.22	-
In 3%	1	6.40	-
Experimental error	15	17.86	
Age	4	122.78	12.99 ***
Age x treatment	16	16.90	-
Sampling error	60	9.45	
Total	99		

S.E. of difference:	Treatment	=	± 1.34
	Age	=	± 0.97
	T in A	=	± 2.36
	A in T	=	± 2.17

Means:

4 weeks	9.27
12 weeks	9.43
24 weeks	9.42
36 weeks	9.03
52 weeks	8.24

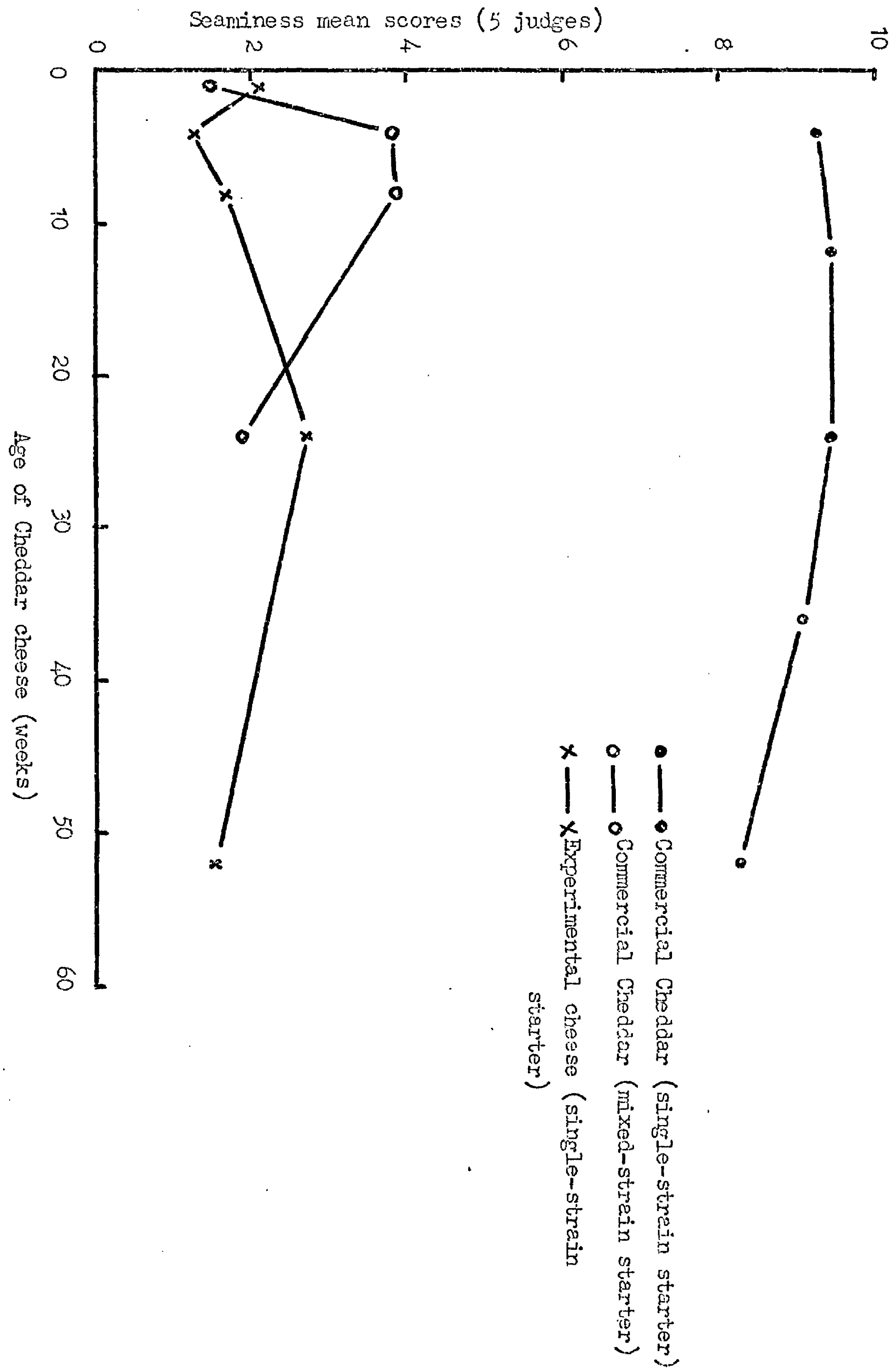
- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

FIGURE 16

The effect of curing time on seaminess in experimental (single-strain starter), commercial (mixed-strain starter) and commercial (single-strain starter) Cheddar cheese



But the body tended to be weaker, and was given a mean score of 5.29 points when the same cheese was scored at 52 weeks after manufacture. This decrease was significant ($p < 0.001$). The mean score given to cheese salted at 4 and 2 per cent (w/w) indicated that the resultant cheese when the higher rate was used were firmer than those in which a lower amount of salt was used, and this difference was significant ($p < 0.05$)

The time of curing affected the flavour of all the cheese significantly ($p < 0.001$). The mean scores (2.77 points) given when the cheese was scored at 52 weeks of age were lower than the scores given to the same cheese when scored at 8 weeks of age. No significant ($p > 0.05$) difference between the cheese that received 4 and 2 per cent (w/w) of added salt.

The colour of the cheese was significantly ($p \angle 0.001$) affected by the time of curing. The mean scores given decreased significantly ($p < 0.001$) with the increased time of 52 weeks after manufacture.

<u>Commercial Cheddar cheese (mixed-strain starters)</u>. In these cheese, the mean scores given to the seaminess present were significantly ($p < 0.001$) affected with the time of curing. The seams became progressively more distinct with age during the first 8 weeks of curing and thereafter became less noticeable.

The mean scores given for fusion indicated that the scores increased from 4.7 points when the cheese was one week of age to 7.14 points when scored at 8 weeks after manufacture, and then decreased to 5.58 points when scored at 24 weeks of age. Time of curing affected the fusion of the cheese significantly ($p < 0.001$).

The mean scores of openness indicated that the cheese was very open in texture one week after manufacture, but tended to be less open with the time of curing. This result may be due to the effect of sealing under vacuum each time after the cheese was scored. Yet when the cheese was kept for another 16 weeks, the mean scores of openness increased from 1.62 to 4.51 points. The result indicated that in this type of cheese there was a high level of gas formation during the curing time. While no measurement for CO_2 were made in the experimental cheese, previous results (Table 11) had indicated the presence of high levels of carbon dioxide in cheese made at the same factory.

Robertson (1957) reported that the level of carbon dioxide in cheese made with mixed-strain starters is higher than in cheese made with single-strain starters. He also reported that the carbon dioxide content increased rapidly in the 10 to 20 days after manufacture. The carbon dioxide concentration then ceased to rise, giving little further change in the next period of the rest of curing time. When the gas is formed in the cheese, it tended to accumulate in the openings, and exert a pressure. This pressure cause the curd particles to break apart on the seams, since these represent a weak points of fusion. Non-starter organisms may also contribute to gas formation and be associated with the development of openness (Dowson and Feagan, 1960). Czulak, (1953), Crawford (1962) and Gilles and Curtis (1963) observed that commercial cultures containing hetero-fermentative starters produced open-textured cheese.

The mean score given to the body of the cheese showed that the cheese tended to become weaker with the increase of curing time.

The mean score decreased significantly ($p < 0.001$) from 8.27 points given when the cheese was 8 weeks of age to 6.00 points when scored at 52 weeks after manufacture. The cheese that received 2 per cent (w/w) added salt tended to be weaker than that which received 3 per cent (w/w). This difference was significant ($p < 0.001$).

The scores given to the flavour showed a significant ($p < 0.001$) decrease with the increased time of curing. The mean scores given to the cheese when scored at 1 week of age was 8.67 points in comparison to 7.06 points given at 24 weeks of age.

During the curing there was a significant increase in the scores given to the colour of the cheese. There was a significant ($p < 0.05$) difference in the scores given to the cheese resulting from machine salting by comparison with those where the process had included hand salting. There was a significant ($p < 0.05$) difference between the cheese which received 3 than those which received 2 per cent (w/w) added salt.

Commercial Cheddar (single-strain starters). Commercial cheese made with single-strain starters, and from curd milled with the Bell-Siro CheeseMaker 3 showed more distinct seaminess as during time increased. Seaminess increased from 9.27 points at 4 weeks to 9.43 points at 12 weeks and then tended to decrease to 8.24 points when the cheese was scored at 52 weeks of age. The difference between the highest and lowest scores was significant ($p < 0.001$). Also the mean score of cheese that received 2 and 3 per cent (w/w) added salt showed a significant ($p < 0.05$) difference, with a mean of 8.83 points and 9.32 points respectively.

The mean score given to the fusion decreased significantly ($p < 0.001$) with the increase in the curing time. The fusion in the cheese which were machine salted was found to be significantly ($p < 0.05$) more than that found in the hand salted cheese. This may be due to the higher amount of salt added in the machine salting.

There was no significant difference in the scores given to the openness of the cheese during all the curing time. But there was a significant increase in the scores given to the cheese which received 2 per cent added salt. Addition of a low level of salt tended to result in more open cheese.

The body of the cheese in the treatments decreased significantly with the time of curing. The cheese that received 2 per cent salt tended to be weaker than those which received higher amounts of added salt. The machine salted cheese were firmer in body than the rest of the cheese and this may be attributed to the greater amount of salt added during the machine salting.

Curing time affected the flavour of the cheese significantly ($p < 0.001$). The cheese that received lower level of salt tended to produce more off flavour than those which received greater amounts of salt.

The mean score given to the colour of the cheese decreased significantly during the curing time ($p < 0.001$), and there was no significant difference between the different treatments.

The results of the analysis of samples taken from the seams and non-seam material which are presented in Table 10 indicated that the seams contained higher levels of calcium than the rest of the body. This result is in agreement with that found in Section 2 of this Chapter. The amount of calcium present increased with the time of curing from

1.098 per cent when the cheese was 1 day old to 1.484 when the cheese was 8 weeks of age.

Conclusion

Seaminess may be seen in the cheese directly after it is taken out of the press. The seams increased in intensity with the time of curing to reach the highest level between 8 to 24 weeks after manufacture. Thereafter the seams became less distinct depending on the type of the cheese.

Slit openness tended to form along the seams because they form a weak point of fusion. This change is encouraged by the formation of increased amount of carbon dioxide.

Curing the cheese for six months or more caused a significant decrease in the quality of the cheese and tended to result in weak bodied, poorly fused cheese of inferior flavour. These changes take place rapidly in curd that received a low level of added salt (2 per cent).

The amount of calcium present in the seams increased to a maximum in 4 to 8 weeks of curing. Addition of 3 and 4% (w/w) salt increased seaminess significantly ($p < 0.05$).

CHAPTER III

A STUDY OF THE EFFECT OF FACTORS RELATED TO THE PROCESS OF SALT ADDITION ON SEAMINESS IN CHEDDAR CHEESE

CHAPTER III

A STUDY OF THE EFFECT OF FACTORS RELATED TO THE PROCESS OF SALT ADDITION ON SEAMINESS IN CHEDDAR CHEESE

INTRODUCTION

In the manufacture of Cheddar cheese, salt is added to the curd to achieve a final salt content in the final cheese of 1.6 to 1.8 per cent (w/w). The effect of salt level in cheese quality has been the subject of many investigations. In this section, the factors that relate to the process of salting the curd, and which may induce seaminess in Cheddar cheese were investigated.

A. Amount of added salt

In the process of Cheddar chesemaking, the milled cheddared curd is salted by the addition of an amount of salt proportional to the amount of curd. In the mechanised systems now in use in Scotland, the amount of salt is determined on the basis of the weight of curd passing the salting point or on the depth of curd on a belt conveyor after the mill. The salt is sprinkled on the curd, mixed by one of several methods, and finally placed automatically in special moulds. Dry vacuum salt (BS 998, 1957) is normally used and is added at rates from 2 to 4 per cent (w/w) of the curd in order to achieve a salt content in the final cheese of 1.6 to 1.8 per cent.

Many types of equipment have been used in mechanised salting. Some use the dry salting procedure outlined above whereas others use brine of different concentrations (Park, 1970). The Bell-Siro Cheese-

Maker 3, automatic milling, salting, and hoop filling unit developed in Australia, is one of the most common types of equipment that has been used in the Cheddar cheese industry.

Salt distribution by the mechanised system of salting was found to be uneven, cause variation in the amount of salt applied, and consequently result in variation in the final salt content of the cheese, not only between vats, but also between cheese from the same vat (Morris, 1961), (O'Connor, 1968). Czulak, Freeman and Hammond (1961) reported however that these variations were smaller than the overall variation found in non-mechanised systems of salting.

Uneven distribution of the salt means that some of the curd receives more salt than is intended by the cheesemaker while other parts receive less.

Many workers reported that salt in the cheese affects the quality of the final cheese. Marquardt (1939) suggested that consideration must be given to the salt content of cheese because of its effect on flavour, texture, and ripening of Cheddar cheese. He considered a salt content of 1.58 to 1.7 per cent to be most satisfactory. Whitehead and Harkness (1954) reported that the addition of salt at a rate of more than 3 per cent (w/w) to the milled curd adversely affected the body and the texture of the final cheese. Irvine (1955) reported that cheese with 4.33 to 5.33 per cent salt in moisture scored better than those containing less or more. O'Connor (1968) reported that addition of salt at high rate may decrease the cheese quality. Van Slyke and Price (1952) reported that high amounts of salt caused the cheese to ripen slowly. The level of sodium chloride affected the cheese hardness (Wiek, 1965).

High salt content had an effect on the pH and the moisture content of the cheese (Reynolds, 1948).

Czulak (1963) reported that curd to which salt was added at a rate of more than 3.5 per cent (w/w) showed a greater tendency to produce seaminess in cheese even when the curd was sprayed with warm water. The same author reported that seaminess was more marked in cheese of low moisture content with high levels of salt and where the salt used was of a coarse nature (Czulak, 1963). Conochie and Sutherland (1965) related the formation of seams in cheese to the effect of sodium chloride applied to the curd. Conochie (1966) reported that the addition of salt in high concentration to the surface of the curd accentuated the condition of seaminess in Cheddar cheese. McCadam and Leber (1958) reported that brine salting resulted in the production of cheese of uniform salt distribution and of good quality of texture and colour. Geurts (1973) reported that the movement of the salt in the cheese in brine salting was regular and could be described as a diffusion process.

It is clear, from this review that certain workers have linked the defect seaminess with high salt levels.

Since it is known that under commercial conditions, the addition of high levels of salt takes place (O'Connor, 1968), the following study was made to investigate further the effect of large amounts of salt on the development of the seaminess.

B. Salt particle size

In the mechanised salting system, a coarse dry vacuum salt which runs easily, does not cake and can therefore be spread on the cheddared milled curd is used. Czulak (1963) reported that seaminess was associated with the addition of coarse salt, and when fine salt was used, the level of seaminess was reduced and in most cases avoided.

C. Sodium chloride

In the previous part, it was shown that a very seamy condition was obtained even when a low level (e.g. 2 per cent (w/w) of added salt was used. The objective of this test was to investigate the effect of salt application to the cheddared curd.

D. Additives in commercial salt

Since the introduction of the mechanised system of salting the curd, special salt has been introduced which moves freely in the machine and does not cake under working conditions. In order to provide these conditions, chemicals such as propylene glycol are used in the manufacture of salt to give these final characteristics (Page, 1954). According to the British Standard Institution (BS 998, 1969), salt produced in the United Kingdom is generally treated with an anti-caking agent such as potassium ferro cyanide or amonium ferric citrate at the rate of approximately 18 ppm. Conochie and Sutherland (1965) reported that impurities in the salt may induce seaminess in the final cheese.

This study was made to measure the degree of seaminess that may be induced due to the presence of additives in the salt. A comparison of commercial grade salt and Analar grade sodium chloride was undertaken.

E. Acidity of the curd at the time of salt addition

In the manufacture of Cheddar cheese, the curd is milled by special machines when the titratable acidity of the whey exuding from the curd reaches a pre-determined level. This is followed by the addition of a pre-determined amount of salt. In general practice, the cheesemaker always aim to mill the curd when the acidity reaches about 0.7 per cent lactic acid in about 4.5 h to 5 h from the time of rennet addition to the milk.

In the continous mechanised system of Cheddar cheese manufacture, many vats are made into cheese daily and handled at different stages of the process according to pre-determined time of manufacture. The time given for each vat to be handled from the time the whey run to milling and salt addition is limited. During this time the starters are expected to produce the required level of acid production. The performance of individual starters used varies in the vats, and this affects the rate of acid production. In certain instances the starters organisms fail to grow at a satisfactory rate and fail to produce the required level of acidity and either the curd has to be put through the mill and salt added to the curd when the titratable acidity of the whey is lower than normal or else the process time has to be increased. Dolby (1941) reported that salting at a low pH resulted in a harsh meaty body and less flavour. On the other hand the acidity produced in a particular vat may increase very quickly and reach the aimed level of titratable acidity in shorter time than that programmed for. In some mechanised systems this vat would be held for the normal time, causing an increase in the acidity and so the curd at the end of the process may be milled at higher level of titratable acidity than that aimed for. The Cheddar cheese proteins are possibly modified by pH and frequently show alignment of the small protein globules (Hall and Creamer, 1972).

From a survey carried out by the author using the production data of five major cheese factories in Scotland, it was shown that the titratable acidity of the curd when the salt was added varied from the low level of 0.5 per cent lactic acid to around 0.85 per cent lactic acid.

About 20 min are required to mill the curd made from one vat of 2400 gal (10,910.4 l) of milk. Acidity development is rapid at this stage of the process and so where milling of the vat started at an acidity of 0.70 per cent lactic acid, the last of the cheddared curd would be milled at higher levels. The comparison might be 0.70 per cent lactic acid at the begining and 0.85 per cent lactic acid at the end.

McDowall and Dolby (1935) reported that the level of calcium and phosphate present in the whey was increased with the increase of acidity of the whey leaving the curd. This suggested that the whey which may be trapped between the curd particles contains more of these ions. An increase of the level of both ions may lead to an increase in the amount of calcium orthophosphate that may form between the lines of junctions. In the second Chapter of this study it was found that the amount of calcium orthophosphate present in the seams is greater than that present in the rest of the body of the cheese. This formation then may lead to more seam formation in Cheddar cheese salted at higher acidity.

The objective of this study was to investigate such conditions and their relationship to the seam formation in the Cheddar cheese.

F. The effect of the acidity of the curd produced by different strains of starters at the time of salt addition

In the Cheddar cheese industry, different strains of micro-organisms are used as starters to produce the required level of acidity during the subsequent curing. Two types of starters are in use in Cheddar factories namely mixed-strain and single-strain (Reiter and Moller-Madsen, 1963). Many factors effect the lactic acid-producing streptococci used as starters in the manufacture of cheese. Crawford (1959) studied the effect of the conditions of propagation of the cultures and their effect on the acid producing ability during the process of cheesemaking. The most serious problem that faces the production of acid in the cheese process is the presence of bacteriophage at a contamination level able to stop the growth of starter bacteria or to decrease their growth and acid production. Whitehead and Hunter (1945) considered the air-borne bacteriophage as the most important source of infection. The importance of bacteriophage was still as great after 30 years of intensive work on the problem (Lawrence, Thomas and Terzaghi, 1975). Much research work has been undertaken to overcome this difficulty by developing starters that can resist the 'phage' attack or are phage un-related. One of the main procedures used to achieve this, is to use the starters in rotation depending on their un-related characteristics (Lawrence and Pearce, 1972).

Lawrence (1971) suggested the use of the following rotation of eight strains of starter bacteria on four consecutive days. He reported that their performance in a small number of Cheddar cheese factories was very satisfactory:

First day	ML8	AM1
Second day	WM1	AM2
Third day	H2	E8
Fourth day	P2	SK11

Since these strains were used in industry, it was decided to investigate the effect of the acidity of the curd produced by these different bacteria on the development of seaminess.

G. Curd temperature at time of salt addition

In the process of Cheddar cheesemaking, the salt is added to the milled curd which is usually carried to the salting units by means of conveyors. During this time of passage there is normally a decrease in the temperature of the curd. The amount of heat loss from the curd depends on the time between milling and salting and also on the difference in temperature of the curd and the room temperature. In addition the initial temperature of the curd also depends on the method of production and the system that has been used. It is expected that curd made by following the traditional cheddaring method in the vat or similarly in the Tebel-Crockatt system would be of low initial temperature i.e. prior to milling. On the other hand in a system such as the 'Cheddarmaster' with the cheddaring tower in which the curd is not exposed to cooling effect the ambient temperature, the curd temperature prior to milling would be high.

This suggests that the temperature of the curd at the time of salt addition varies from one system to another. This variation would effect the solubility of the salt and also would affect the rate of salt penetration into the curd. Geurts, Walstra and Mulder (1974) reported that the pseudo diffusion cofficient of sodium chloride in the moisture in the cheese as 0.2 cm^2/ day. While the true diffusion coefficient in pure water is about 1 cm^2/day. He also reported that more salt was absorbed with an increase of temperature.

The objective of this study was to investigate such effects if present and their relation to the development of seaminess in Cheddar cheese since it is known from the previous part that salt addition plays a role in its development.

H. Mellowing time

After the addition of salt to the curd in the traditional method of Cheddar cheese manufacture, the curd is left for a period of time before being placed in the mould and thereafter subjected to pressing. The objective of this practice is to allow more time for the salt to dissolve and penetrate into the curd, and also to allow the curd to mellow. Tuckey (1941) reported that cheese made from curd which had been mellowed for 40 to 60 min had a higher salt content and better flavour than that made with a mellowing time of

20 min. In modern mechanised systems, the curd is placed in the moulds directly after salting. This change in procedure may have some effect on the physical conditions of the curd at this point. Morris (1966) reported that placing the curd in the hoops immediately after salting caused a slightly lower score for body.

This test was set to study the difference in the procedures mentioned above.

EXPERIMENTAL

Cheesemaking and treatment of the curd

A. Amount of added salt

<u>A.1. Preliminary experiment</u>. In the Cheddar cheese industry, salt is added at a rate varying from 2 to 4 per cent (w/w). For the preliminary experiment it was decided to add salt to the milled curd at the rates of 3 and 4 per cent (w/w).

One vat of 400 gal (1818.4 l) of pasteurised milk 161.5°F for 15 s (72°C for 15 s) was made into uncoloured (white) and another into coloured Cheddar cheese according to the processing procedure given on page 55. The production data are given in Table 95 (Appendix A).

From each vat a 44 lb (19.96 kg) lot was taken, and the salt was added to the curd as described on page 59. The dry vacuum grade of industrial salt was added to the white cheddared curd at the rate of 3 per cent (w/w), and to the coloured curd at 4 per cent (w/w). The cheese were treated thereafter as described on page 59.

A.2. Large scale experiment. It was found from the preliminary experiment that the addition of 3 to 4 per cent dry vacuum salt to the white and coloured milled curd caused considerable seaminess in the final cheese. This experiment was designed to compare the degree of seaminess caused by low and high levels of added salt, i.e. (2 per cent (w/w) and 4 per cent (w/w).

It was decided to investigate the effect of salt particle size on the development on seaminess.

Three separate vats of 350 gal (1591.1 l.) of pasteurised milk were made into white Cheddar cheese using the system described on page 55 of this thesis. The details of the manufacturing procedure are given in Table 96 (Appendix A).

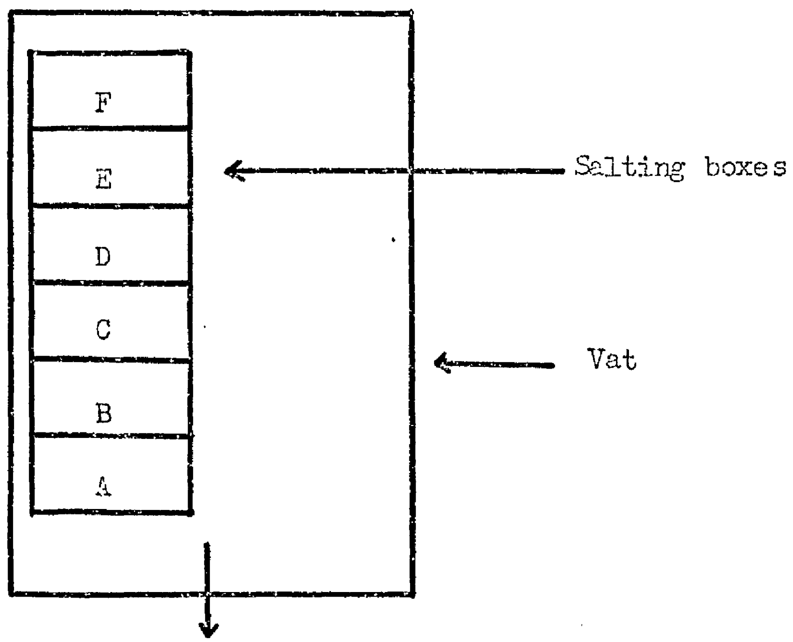
Three types of salt were used in the salting of the milled curd:- (1) commercial grade dry vacuum salt (333 μm), (2) and (3) milled dry vacuum salt with a mean particle size of 107 and 50 μm. Six separate lots of curd each of 44 lb (19.96 kg) were weighed and placed in the aluminium salting boxes. Salting and curd treatment were carried out according to the procedure described on page 59, and indicated in the plan given in Figure 17.

B. Salt particle size

B.1. Experimental curd. From the results of the preliminary trials where curd was treated with salt of different particle size, it was found that there was a difference in the seaminess scores, but this was not significant ($p > 0.05$). Another two vats of 400 gal (1818.4 l) each of pasteurised milk were made into

FIGURE 17

Plan of the treatments of the curd with different amount of salt and of different particle size



Treatment	Amount of salt added (%)	Salt particle size (μm)	Replicate	Vat
A	4	50	1	A
			2	B
			3	C
B	4	107	1	A
			2	B
			3	C
C	4	333	1	A
			2	B
			3	C
D	2	50	1	A
			2	B
			3	C
E	2	107	1	A
			2	B
			3	C
F	2	333	1	A
			2	B
			3	C

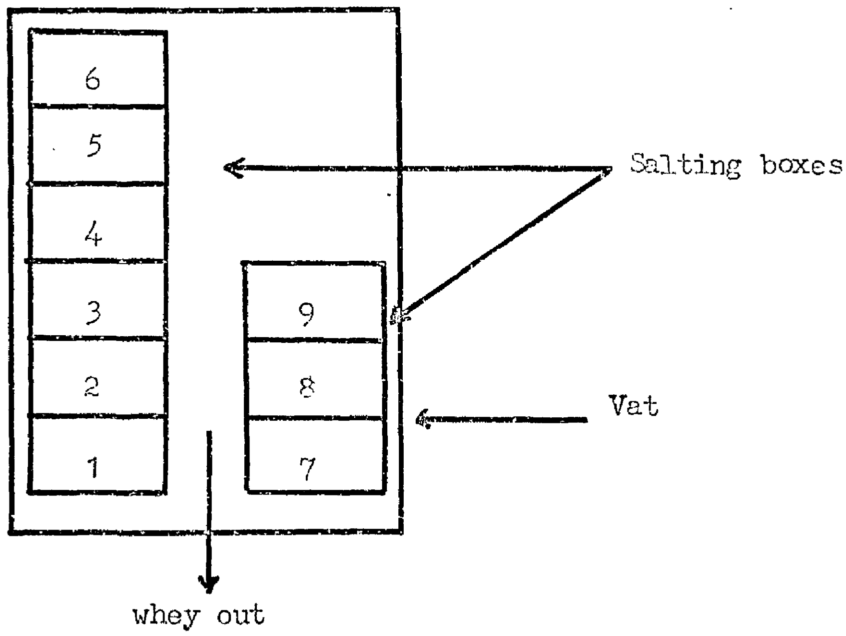
white Cheddar. The curd was treated with the same type of salt used in previous experiments at the rate of 2 and 3 per cent (w/w). Two cheese were treated with 3 per cent added salt of each type of salt plus one cheese treated at the rate of 2 per cent added salt of the different types of salt. The treatments were carried out according to the plan presented in Figure 18. The production data of the cheese-making are presented in Table 96 (Appendix A).

B.2. Commercial curd (mixed-strains). The cheese was made in the New Zealand 'Cheddarmaster' tower system in Mauchline Creamery of the Scottish Milk Marketing Board, Scotland. The Cheddar cheese was produced according to the method described on page 56 of this thesis. The cheese production records are presented in Table 97

The milled curd used in this test was taken from the belt conveyor that takes it to the automatic salting unit of the Bell-Siro 'CheeseMaker 3'. Four lots of curd, each of 44 lb (19.96 kg) were taken and placed in plastics containers (10 in (25.4 cm) deep x 16 in (40.6 cm) wide x 24 in (70 cm) long). Salt was added to each of the portions of curd at the same time according to the method described on page 59. At around the same time i.e. using curd from the same vat one block was picked from the commercial production line. This block had been prepared from similar curd which was mechanically salted. All the cheese were pre-pressed in the machine attachment and were left aside for about 20 to 25 min before being placed in the same Crockatt press which had a 10 in (25.4 cm) cylinder and an air supply of 80 psi (5.63 kgf/cm^2). This procedure was repeated at the same factory on curd from the same vat four times giving five replicates for each treatment.

FIGURE 18

Plan of the arrangements for study of the effect of salt particle size on the development of seaminess in Cheddar cheese



Treatment	Amount of salt added (%)	Salt particle size (μm)	Treatment Vat D	Treatment Vat E
G	3	50	G1	G3
H		107	H1	H3
I		333	I1	I3
D	2	50	D4	D5
E		107	E4	E5
F		333	F4	F5
G	3	50	G2	G4
H		107	H2	H4
I		333	I2	I4

Commercial grade dry vacuum salt and milled dry vacuum salt with a particle size of 73 µm were used. These salts were added to the curd at the rate of 2 and 3 per cent (w/w).

The cheese were left in the press at the factory for 18 h, before being vacuum packed in a laminate, boxed, labelled and placed in the curing room maintained at 50°F (10°C) at the College.

B.2. Commercial curd (single-strain starters). Since the previous experiment was carried out with curd made with mixed-strain starters, a further trial using curd produced in the Dalbeattie Creamery of the Scottish Milk Marketing Board, was made in which single-strain starters were used.

Cheese was made at the factory in six open vats each of a capacity of 2600 gal (11819.6 l) of milk. One vat was selected at random for the experiment.

The curd was manufactured according to the system described on page 58. The processing data are presented in Table 97 (Appendix A).

Four 44 lb (19.96 kg) lots of milled cheddared curd were taken from the conveyor after milling with a 0.5 in (1.27 cm) knife in the Bell-Siro 'CheeseMaker 3' unit. Each lot was placed in a plastic box as in the previous experiment. Salt was added to all four lots at the same time following the procedure described on page 59. The curd was then placed in separate rectangular moulds, pre-pressed in the same unit attachment to the machine, left aside for 20 min on a conveyor before placing the moulds in the final press. At around the same time i.e. with curd from the same vat, one block of machine salted curd was picked at random from the line. All the cheeses were left aside for 20 to 25 min, and were placed in a horizontal air operated press (10 in (25.4 cm) cylinder supplied with air at 80 psi (5.63 kgf/cm^2). This procedure was repeated another three times giving four blocks for each treatment. The plan of salting is present in Table 15. All cheese were left in the press for 18 h.

All the cheeses were wrapped in waxed cellulose laminate, machine heat sealed, boxed, labelled and stored in the factory curing room at 49°F (9.4°C) until they were transported to the curing room at the College and were presented to the panel for scoring.

C. The effect of sodium chloride. In the same commercial factory in which the previous experiment was conducted, one vat of 2600 gal (11819.6 l) of pasteurised milk was manufactured into uncoloured Cheddar cheese. The processing details are presented in Table 103 (A) (Appendix A).

The curd was milled with a CheeseMaker 3 milling unit equipped with a 0.5 in (1.27 cm) knife. One lot of 44 lb (19.96 kg) of curd was taken before salting, placed in the hoop, pre-pressed, and then left aside. Another block which had been machine salted was picked from the line. After 20 min the hoops were placed in a horizontal press fitted with 10 in (25.4 cm) cylinder Crockatt cheese press and supplied with air at 80 psi (5.63 kgf/cm^2).

The knife was then replaced with 0.75 in (1.91 cm) knife and two blocks were taken and treated as described above.

All the cheeses were left in the press for 18 h, and were then wrapped in a waxed cellulose laminate before being machine heat sealed, boxed and placed in the curing room at 50°F (10°C) until they were presented to the scoring panel.

D. Presence of additives in commercial salt. One vat of

TABLE 15

Statistical layout of the addition of salt of different particle size to commercial Cheddared curd made with mixed-strain starters

	Replicates (code number) of each treatment				
Batch	2% added salt (73 µm)	2% added salt (333 µm)	3% added salt (73 µm)	3% added salt (333 µm)	machine salted (333 µm)
1	A 1	B 1	C 1	D 1	E 1
2	A 2	B 2	C 2	D 2	E 2
3	A 3	B 3	C 3	D 3	E 3
4	A 4	B 4	C 4	D 4	E 4

400 gal (1818.4 l) of milk pasteurised at 161.5°F for 15 s (72°C for 15 s) was manufactured into coloured Cheddar cheese according to the cheesemaking system described on page 55. The production data are presented in Table 98 (Appendix A).

Three types of salt were used (1) commercial dry vacuum salt, I.C.A. A code (2) commercial dry vacuum salt B, I.C.I. and (3) pure Analar grade sodium chloride.

The curd was weighed into 9, 44 lb (19.96 kg) lots, placed in separate aluminium salting boxes. The salt was added as described on page 59 of this thesis.

E. Acidity of the curd at the time of salt addition

E.1. Preliminary experiment. One vat of 400 gal (1818.4 l) of pasteurised milk was made into uncoloured Cheddar according to the system of cheesemaking described on page 55. The production data is given in Table 99 (Appendix A).

When the titratable acidity of the curd reached 0.5 per cent lactic acid, a slice of the curd was cut from the curd in the cheddaring box, milled by an electrically operated Damrow mill, divided into two lots each of 14 lb (6.35 kg). Dry vacuum salt was added at the rate of 3 per cent (w/w) according to the methods described on page 59. The curd was then placed in two New Zealand type round moulds, left for 20 to 25 min and then placed in a hand operated press under a pressure of about two tons.

The same procedure was repeated when the titratable curd acidity reached 0.70 per cent and 0.90 per cent lactic acid, giving two replicates for each treatment. All the cheeses were left overnight in the press, scalded with hot water to promote rind formation and were left another night. They were taken out, dressed, and left in the curing room at 50°F (10°C) for a week, turned every day. The cheeses were labelled, waxed and were kept in the curing room at 50°F (10°C) until scored by the panel.

E.2. Full scale experiment. Two vats each of 400 gal (1818.4 l) of milk were made into coloured Cheddar using single-strain starters in one vat and mixed-strain starters in the other. The cheese was manufactured according to the system described on page 55. The details of the manufacturing steps are given in Table 99.

When titratable acidity of the curd reached 0.5 per cent lactic acid, a piece of the curd was taken from the cheddaring box and was milled with an electrically operated Damrow milling machine. Three lots of 44 lb (19.96 kg) were weighed out and were placed in three boxes. The salt was added at the rate of 3 per cent (w/w) as described on page 59. The cheeses were pre-pressed, and then were placed in horizontal cheese press supplied with an air supply of 80 psi (5.63 kgf/cm^2) and fitted with 10 in (25.4 cm) cylinder.

The same procedure was repeated when the acidity of the curd reached 0.7 per cent and 0.9 per cent lactic acid giving 3 replicates in each treatment.

All cheeses were left at the final pressing for about 18 h before being hand wrapped, machine sealed, boxed and kept in the curing room at 50°F (10°C) until the cheese were presented for grading by the panel.

F. Acidity of the curd, produced by different strains of starters, at the time of salt addition

Four vats each of 400 gal (1818.4 l) of milk were made into Cheddar cheese on four consecutive days (one each day) according to the system described on page 55. In each vat two pairs of single-strain starters mentioned above were used, the production data are presented in Table 100 (Appendix A).

By the procedure described above (page 100) three 44 lb (19.96 kg) lots of curd were milled when their whey titratable acidities:- 0.5 per cent, 0.7 per cent and 0.9 per cent and subsequently salted at the rates of 3 per cent (w/w).

G. Temperature of the curd at the time of salt addition

Two vats each of 400 gal (1818.4 l) of milk were made into coloured Cheddar cheese according to the procedure described on page 58. The production data of cheesemaking are given in Table 101.

When the titratable acidity of the whey draining from the cheddaring curd slabs in the vats reached 0.5 per cent lactic acid, two lots of 140 lb (63.5 kg) were removed from the vat, leaving the third lot to continue cheddaring in the vat. One of these two lots was placed in a 50 gal (227.3 l) water-jacketed vat, and the curd was cooled by means of running cold water in the jacket of the vat until the temperature of the curd reached 72°F (23.3°C). During the same time the second portion of the curd was placed in another small vat and the curd was heated while cheddaring to about 100°F (37.8°C) by means of running hot water in the jacket of the vat.

When the acidity of the curd reached about 0.60 per cent lactic acid, the cooled portion was milled using an electrically operated Damrow milling machine. Three 44 lb (19.96 kg) lots of curd were weighed out and placed in the aluminium salting boxes in the vat (Figure 9). The other lots of curd were treated in the same manner.

All of the milled curd was then salted and the curd and salt mixed by nine persons at the same time. All lots of salted curd were then placed in the prepared moulds. The moulds and the curd were treated in the manner described in the previous experiment.

H. Mellowing time

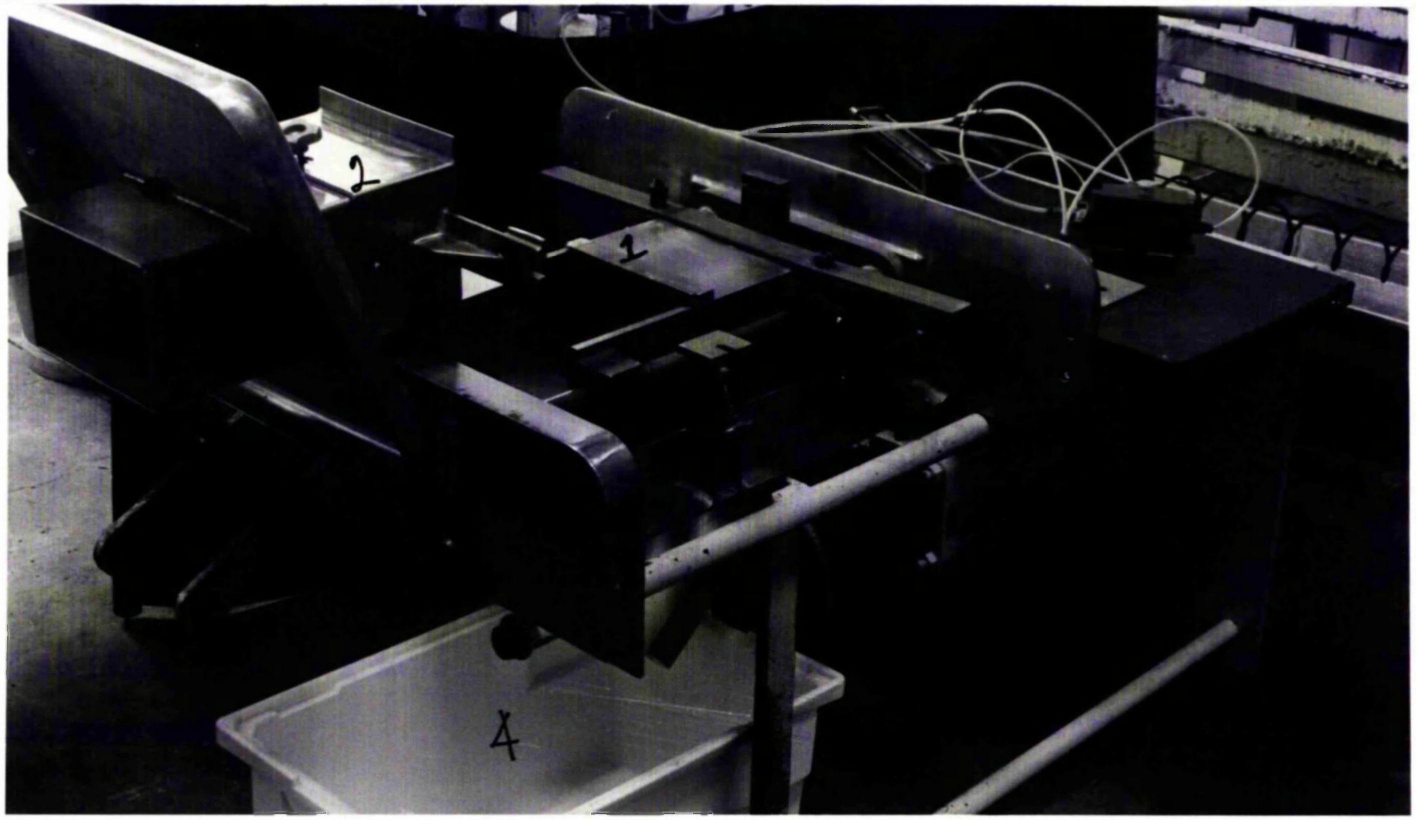
One vat of 400 gal (1818.4 l) of pasteurised milk (161.5°F (72°C) for 15 s) was manufactured into coloured Cheddar cheese following the system described on page 58 until the curd was completely cheddared. The processing data are presented in Table 102 (Appendix A).

When the titratable acidity of the curd reached 0.6 per cent lactic acid, the curd was milled with 0.5 x 0.5 in (1.27 x 1.27 cm) knife of the CheeseMaker 3, assembled as shown in Figure 19.

Two 44 lb (19.96 kg) lots of milled curd were placed in plastic containers as described on page 54. Dry vacuum salt was added simultaneously to each portion of curd at the rate of 3 per cent (w/w) and mixed in accordance with the procedure described on page 59. One lot was then placed directly after salting and mixing in a prepared conventional 40 lb (19.96 kg) mould set aside for 25 min,

FIGURE 19

The assembly of the CheeseMaker 3 milling section in the lab operated by means of pressed air



1. 0.5 in (1.27 cm) knife grid
2. Curd compartment
3. 6 in (15.24 cm) air operated cylinder
4. Box for collecting milled curd

and was then placed in the cheese press. The other lot was left in the box for 50 min, during which the curd was stirred three times to prevent the curd from matting together. The curd was then placed in a mould treated in the same way as the first lot.

This procedure was repeated another 3 times giving 4 replicates for each treatment.

The pressing and subsequent treatment of the cheese was in accordance with the description given on page 59.

Scoring the cheese

The cheese were examined and scored by the grading panel according to the procedure described on page 60 at various ages up to a maxiumum of one year.

Chemical analyses

Samples were taken from the pieces presented to the panel, for salt and moisture determinations. The salt in aqueous phase and pH values were determined according to the methods described on pages 47, 48, 48, and 48 respectively.

Rheological measurements

The firmness and the elasticity of the cheese were measured by the method described on page 52.

RESULTS

A. Amount of added salt

<u>A.1. Preliminary experiment</u>. The results of the scoring and corresponding analyses at different ages are given in Table 116 (Appendix B).

The mean score of seaminess given to the cheese increased from 0.5 when the cheese was one week of age to a maximum of 4 points when scored at 7 and 8 weeks of age. The cheeses were of good quality.

<u>A.2. Large scale experiment</u>. The mean scores given by the panel for seaminess, fusion, body, flavour and colour of the cheese at one, four, and eight weeks after manufacture with the results of the chemical analyses carried out when the cheese was 8 weeks of age were analysed statistically according to the method referred to on page 62.

The results obtained suggest that the addition of more salt induced some degree of seaminess in the final cheese. The score for seaminess in the cheese prepared with fine salt was less than that of cheese prepared with the same level of coarse salt.

The analysis of variance of the results obtained in the cheese at different ages is presented in Tables 16 to 23.

These results indicate that seaminess was significantly affected ($p < 0.01$) with the amount of added salt (increased).

The size of the salt particle had no significant ($p < 0.05$) effect on the seaminess.

TABLE 16

Analysis of variance; seaminess scores for experimental Cheddar cheese made with different amounts of added salt and of different particle size examined at various times during curing

At one week

Treatment	D.F.	Mean square	F
Salt addition	1	0.89932	6.67 *
Particle size	2	0.04962	-
Particle size x addition	2	0.01554	-
Replicates	2	1.19677	8.87 *
Experimental error	10	0.13490	
Sampling error	72	0.05252	
Total	89		

At 4 weeks

Treatment	D.F.	Mean square	F
Salt addition	1	0.97702	9.57 *
Salt particle size	2	0.05079	-
Particle size x addition	2	0.17388	-
Replicates	2	1.41468	13.86 *
Experimental error	10	0.13490	
Sampling error	72	0.05252	
Total	89		

At 8 weeks

Treatment	D.F.	Mean square	F
Salt addition	1	1.02968	13.83 **
Salt particle size	2	0.05925	-
Particle size x addition	2	0.06281	-
Replicates	2	0.45380	6.1 *
Experimental error	10	0.07445	
Sampling error	72	0.05766	

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

TABLE 17

Means of seaminess scores given by scoring panel (5 judges) to experimental Cheddar cheese one, four and eight weeks old made with different amount of added salt of different particle size

Salt particle size (μm)	4% added salt	2% added salt	Mean
	At one week		
50	2.19	0.84	1.43
107	1.86	0.76	1.24
333	2.21	1.27	1.70
Mean	2.08	0.95	
	At 4 weeks		
50	1.88	0.33	0.96
107	1.37	0.33	0.77
333	1.24	1.05	1.14
Mean	1.48	0.54	
	At 8 weeks		
50	1.75	0.32	0.91
107	1.74	0.84	1.28
333	1.74	0.89	1.28
Mean	1.75	0.68	

TABLE 18

Analysis of variance of fusion, openness, and body scores of experimental Cheddar cheeses (aged 8 weeks) made with different amounts of added salt of different particle size

		Fusion		Openness		Body	
Source of variance	D.F.	Mean square	F	Mean square	F (pooled E)	Mean square	F (pooled E)
Addition	1	3.60	-	8.10	-	13.61	13.61 ***
Salt particle size	2	4.48	-	3.90	-	0.28	-
Addition x particle size	2	0.70	-	3.70	-	0.54	-
Replicates	2	12.54	6.27*	61.03	14.06 ***	5.21	5.21 **
Experimental error	10	2.00		2.87		0.46	
Judges	4	14.13	9.55 ***	2.60	-	4.88	4.88 **
Judges x addition	4	6.13	4.14 **	2.15	-	2.22	-
Judges x particle size	8	1.60	-	0.44	-	1.11	-
Judges x addition x particle size	8	1.35	-	1.38	-	0.99	-
Sampling error	48	1.48		4.68		1.12	
Total	89						
Pooled E	58			4.34		1.00	

- not significant ($p > 0.05$), * significant ($p < 0.05$), ** significant ($p < 0.01$), *** significant ($p < 0.001$)

TABLE 19

Analysis of variance of flavour and colour scores of experimental Cheddar cheeses (aged 8 weeks) made with different amounts of added salt and of different particle size

Source of variance	D.F.	Flavour Mean square	Flavour F (pooled E)	Colour Mean square	Colour F
Addition	1	0.10	-	0.68	9.37 *
Salt particle size	2	0.41	-	1.88	-
Addition x particle size	2	0.30	-	0.08	-
Replicates	2	1.34	-	5.22	4.58 *
Experimental error	10	1.22		1.44	
Judges	4	27.45	20.18 ***	4.85	7.24 ***
Judges x addition	4	0.21	-	0.68	-
Judges x particle size	8	0.27	-	0.42	-
Judges x addition x particle size	8	1.50	-	0.20	-
Sampling error	48	1.38		0.67	
Total	89				
Pooled E	58	1.36			

- not significant ($p > 0.05$), * significant ($p < 0.05$), *** significant ($p < 0.001$).

TABLE 20

Analyses of variance of salt content, salt in aqueous phase, moisture content and pH values of experimental Cheddar cheese (aged 8 weeks) made with different amounts of salt and of different particle size

Source of variation	D.F.	Salt		Salt in aqueous phase		Moisture		pH	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F
Addition	1	0.8407	60.35***	9.6800	63.18***	10.3664	50.70***	0.0014	-
Salt particle size	2	0.0040	-	0.0172	-	0.0448	-	0.0014	-
Addition x salt particle size	2	0.0046	-	0.0117	-	0.0828	-	0.0014	-
Replicates	2	0.0200	-	0.1539	-	2.1012	10.25**	0.0058	-
Error	10	0.0139		0.1532		0.2049		0.0015	
Total	17								

- not significant ($p > 0.05$), ** significant ($p < 0.01$), *** significant ($p < 0.001$)

TABLE 21

Means of fusion, openness and body scores of experimental Cheddar cheese (aged 8 weeks) made with 2 and 4% added salt of different particle size

Added salt	Salt particle size (μm)			Mean	Standard error of difference ±		
% (w/w)	50	107	333 (dry vacuum salt)		Addition	Size	Addition x size
			Fusion				
4	7.07	7.33	6.73	7.04			
2	7.80	7.66	6.87	7.44			
Mean	7.43	7.50	6.80		0.30	0.36	0.52
			Openness				
4	3.80	3.60	3.60	3.67			
2	4.33	3.53	4.93	4.27			
Mean	4.07	3.57	4.27		0.44	0.54	0.76
			Body				
4	7.73	7.73	7.47	7.64			
2	6.67	7.00	6.93	6.87			
Mean	7.20	7.37	7.20		0.21	0.26	0.36

TABLE 22

Means of flavour and colour scores of experimental Cheddar cheese (aged 8 weeks) made with different amounts of added salt and of different particle size

Added salt	Salt particle size (μm)			Mean	Standard error of difference ±		
% (w/w)	50	107	333 (dry vacuum salt)		Addition	Size	Addition x size
			Flavour				
4	7.87	7.73	7.93	7.84			
2	8.13	7.80	7.80	7.91			
Mean	8.00	7.77	7.87		0.24	0.30	0.42
			Colour				
4	7.87	7.93	7.53	7.78			
2	8.67	8.60	8.13	8.47			
Mean	8.27	8.27	7.83		0.22	0.28	0.39

TABLE 23

Means of salt, salt in aqueous phase, moisture content (%) and pH values of experimental Cheddar cheese (aged 8 weeks) made with different amounts of added salt and of different particle size

Added salt	Salt particle size (µm)			Mean	Standard error of difference ±		
% (w/w)	50	107	333 (dry vacuum salt)		Addition	Size	Addition x size
			Salt content				
4	1.66	1.62	1.72	1.67			
2	1.22	1.25	1.24	1.24			
Mean	1.44	1.44	1.48		0.06	0.07	0.10
			Salt in aqueous phase (%)				
4	4.63	4.70	4.80	4.71			
2	3.20	3.30	3.23	3.24			
Mean	3.92	4.00	4.02		0.18	0.22	0.32
			Moisture (%)				
4	36.13	36.22	35.94	36.13			
2	37.56	37.66	37.72	37.65			
Mean	36.85	36.99	36.83		0.21	0.26	0.37
			pH				
4	5.14	5.19	5.18	5.17			
2	5.15	5.14	5.17	5.15			
Mean	5.14	5.17	5.18		0.02	0.02	0.03

B. Salt particle size

B.1. Experimental curd. The grading results obtained when the cheese was 8 weeks old were statistically analysed by the method referred to on page 62.

The results of the analyses of variance at 8 weeks after manufacture are presented in Table 24 and 25. The data used include that obtained in the last experiment (the amount of added salt) for the different treatments of different particle size salt.

These results indicate that the size of salt particle had no significant effect ($p > 0.05$) on the development of seaminess in Cheddar cheese.

B.2. Commercial curd (mixed-strain starters). The mean score for seaminess and other characteristics awarded by the grading panel and the results of chemical analyses of these cheese at the time of scoring were statistically analysed by the method described on page 62. The statistical analyses of variance of seaminess, body, colour, salt, salt in aqueous phase, moisture and firmness at the age of 8 weeks are presented in Tables 26 to 28.

These results indicate that under the commercial conditions encountered the size of salt particle had no significant ($p > 0.05$) effect on the level of seaminess found in the resultant cheese.

The analysis of variance also indicates that there is no significant ($p > 0.05$) difference in the fusion, openness, flavour and pH of the cheese made with salt of different particle size.

B.2. Commercial curd (single-strain starters). The grading scores given to the cheese by the panel when they were 4 and 8 weeks

TABLE 24

Analysis of variance; of seaminess scores for experimental Cheddar cheese made with 2%, 3% and 4% levels of added salt of different particle size examined 8 weeks after manufacture

Treatment	D.F.	Mean square	F
	2% Added salt		
Particle size	2	3.44	-
Replicates	4	8.33	-
Experimental error	8	3.91	
Judges	4	3.48	-
Particle size x judges	8	0.78	-
Sampling error	48	1.42	
Total		1.42	
	3% Added salt		
Particle size	2	0.20	-
Replicates	3	2.73	4.96 **
Experimental error	6	0.38	
Judges	4	2.96	5.34 **
Particle size x judges	8	0.18	-
Sampling error	36	0.58	
Total	59		
Pooled E	42	0.55	
	4% Added salt		
Particle size	2	0.22	-
Replicates	2	3.26	-
Experimental error	4	1.88	
Judges	4	10.16	3.17 *
Particle size x judges	8	1.91	-
Sampling error	24	3.41	
Total	44	3.46	
Pooled E	28	3.20	

- Not significant ($p > 0.05$), * Significant ($p < 0.05$), ** Significant ($p < 0.01$)

TABLE 25

Means of seaminess scores of Cheddar cheese (aged 8 weeks) made with salt of various particle size applied to curd at 2%, 3% and 4% (w/w) levels

Salt particle size (μm)	2% (w/w) added salt	3% (w/w) added salt	4% (w/w) added salt
50	0.40	0.55	2.17
107	0.72	0.45	2.40
333	1.14	0.35	2.23
S.E. of difference	±0.56	±0.23	±0.65

TABLE 26

Analysis of variance; the effect of salt particle size on seaminess in commercial Cheddar (mixed-strain) aged 8 weeks made with 2 and 3% (w/w) added salt of different particle size

Treatment	D.F.	Mean square	F
Treatments	4	11.88	-
Machine salting x rest	1	4.05	-
2% x 3%	1	28.09	-
Within 2%	1	12.50	-
Within 3%	1	2.88	-
Experimental error	20	9.80	
Judges	4	115.36	16.04***
Judges x treatment	16	76.24	10.60***
Sampling error	80	7.19	
Total	124		

Means

Added salt (%)	Salt particle size (µm)	Mean of seaminess
2	72	4.04
2	333	3.04
3	72	4.36
3	333	4.84
Machine salting	333	4.52

Standard error of difference ± 0.88

- Not Significant ($p > 0.05$)
* Significant ($p < 0.05$)
** Significant ($p < 0.01$)
*** Significant ($p < 0.001$)

TABLE 27

Analysis of variance; body and colour scores of commercial Cheddar cheese (aged 8 weeks) made with mixed-strain starters with 2 and 3% (w/w) added salt of different particle size

		Body		Colour	
Source of variation	D.F.	Mean square	F	Mean square	F
Machine salted x rest	1	0.34	-	0.20	-
2% x 3%	1	24.01	13.80 **	7.84	4.45 *
In 2%	1	0.08	-	0.50	-
In 3%	1	2.47	-	3.38	-
Experimental error	20	1.74			
Judges	4	33.07	23.79 ***	37.34	21.22 ***
Judges x treatments	16	0.94	-	0.62	-
Sampling error	80	1.39			
Total	124				
Pooled E	100			1.76	

- not significant ($p > 0.05$)
* significant ($p < 0.05$)
** significant ($p < 0.01$)
*** significant ($p < 0.001$)

TABLE 28

Analysis of variance; salt, salt in aqueous phase, moisture and firmness of commercial Cheddar cheese (aged 8 weeks) made with mixed-strain starters with 2 and 3% (w/w) added salt of different particle size

		Salt (%)		Salt in aqueous phase (%)		Moisture (%)		Firmness (B.C.T.)	
Source of variation	D.F.	Mean square	F	Mean square	F	Mean square	F	Mean square	F
Machine salt x rest	1	0.0529	-	0.4489	-	0.6194	4.49*	8.53	-
2% x 3%	1	0.2645	16.33***	2.6645	18.84***	1.3572	9.85**	133.13	9.79**
In 2%	1	0.0144	-	0.1210	-	0.0136	-	0.06	-
In 3%	1	0.0068	-	0.0360	-	0.0336	-	17.96	-
Error	20	0.0162		0.1414		0.1378		13.60	
Total	24								

Means

	Salt (%)	Salt in aqueous phase (%)	Moisture (%)	Firmness (B.C.T.)
2% fine salt (73 µm)	1.58	4.30	36.43	62.2
2% commercial grade dry vacuum salt (333 µm)	1.65	4.52	36.36	62.0
3% fine salt (73 µm)	1.87	5.20	35.82	58.3
3% commercial grade dry vacuum salt (333 µm)	1.85	5.08	35.93	55.6

Cont. TABLE 28

Machine salted (commercial grade dry vacuum salt	1.61	4.44	36.53	61.0
Standard error of difference ±	0.08	0.04	0.23	2.33

\- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

*** Significant ($p < 0.01$)

old are presented in Table 117 (Appendix B). The chemical composition of cheese resulting from each treatment is presented in Table 118 (Appendix B).

The analyses of variance of seaminess scores when the cheese were 8 weeks old are presented in Tables 29 . . These indicate that there was no significant ($p > 0.05$) difference in the level of seaminess with different amounts of salt of different particle size. Seaminess was present in all cheese at a high level.

C. Sodium chloride

The results of the scoring and composition of the cheese are presented in Table 36.

The results show that seaminess was present in the unsalted cheese.

D. Additives in commercial salt

The mean scores of the grading the cheese by the panel were analysed for seaminess according to the method referred to on page 62. The analysis of variance of seaminess of 8 weeks-old cheese is given in Table 37.

The results of the analysis of variance indicate that there was no significant difference in the level of seaminess in cheese made with the different types of salt used. The mean score of seaminess ranged from 1.07 to 1.87 with a standard error of difference of $\pm$ 0.62. The cheese were described by the panel as non-seamy.

TABLE 29

Analysis of variance; seaminess scores of 8 weeks-old commercial Cheddar cheese made with single-strain starters and salt of different particle size added at levels of 2% (w/w) and 3% (w/w) to the curd

Source of vaiiation	D.F.	Mean square	F
Machine salted x rest	1	0.64	-
2% x 3% (w/w) added salt	1	0.20	-
In 2% (w/w) added salt	1	0.90	5.29 *
In 3% (w/w) added salt	1	0.10	-
Experimental error	15	0.17	
Judges	4	26.56	221.33 ***
Judges x treatments	16	0.42	3.50 ***
Sampling error	60	0.12	
Total	99		

- not significant ($p > 0.05$)

* significant ($p < 0.05$)

*** significant ($p < 0.01$)

TABLE 30

Analysis of variance; fusion, openness and body scores of 8 weeks-old commercial Cheddar made with single-strain starters and salt of different particle size added at levels of 2% (w/w) and 3% (w/w) to the curd

Source of variation	D.F.	Fusion: Mean square	Fusion: F	Openness: Mean square	Openness: F	body: Mean square	body: F
Machine salted x rest	1	0.02	-	20.70	8.88***	3.80	8.26*
2% x 3% (w/w) added salt	1	0.01	-	0.61	-	2.81	6.11*
In 2% (w/w) added salt	1	0.23	-	0.63	-	0.23	-
In 3% (w/w) added salt	1	0.00	-	0.40	-	0.10	-
Experimental error	15	0.79		2.33		0.46	
Judges	4	6.84	14.55***	6.98	30.35***	7.48	18.24***
Judges x treatments	16	0.76	-	2.79	12.13***	0.81	2.00*
Sampling error	60	0.47		0.23		0.41	
Total	90						

- not significant ($p > 0.05$)

* significant ($p < 0.05$)

*** significant ($0 < 0.001$)

TABLE 31

Analysis of variance; flavour and colour scores of 8 weeks-old commercial Cheddar cheese made with single-strain starters and salt of different particle size added at levels of 2% (w/w) and 3% (w/w) to the curd

		Flavour		Colour	
Source of variation	D.F.	Means square	F	Means square	F
Machine salted x rest	1	2.72	6.04*	0.01	-
2% x 3% (w/w) added salt	1	0.31	-	0.20	-
In 2% (w/w) added salt	1	0.63	-	0.63	-
In 3% (w/w) added salt	1	3.60	8.00**	2.03	7.00*
Experimental error	15	0.31		0.29	
Judges	4	3.52	7.82***	6.11	22.63***
Judges x treatments	16	0.37	-	0.29	-
Sampling error	60	0.48		0.27	
Total	99				
Pooled E	75	0.45			

- not significant ($p > 0.05$)

* significant ($p < 0.05$)

** significant ($p < 0.01$)

*** significant ($p < 0.001$)

TABLE 32

Means of seaminess, fusion and openness scores of 8 weeks-old commercial Cheddar cheese made with single-strain starters and salt of different particle size added at levels of 2% (w/w) and 3% (w/w) to the curd

Treatment	Fine salt (73 um)	Commercial grade dry vacuum salt (333 µm)	Standard error of difference ±
Seaminess			
2% (w/w) added salt	9.30	9.60	
3% (w/w) added salt	9.50	9.60	
Machine salted		9.30	0.13
Fusion			
2% (w/w) added salt	7.40	7.25	
3% (w/w) added salt	7.35	7.35	
Machine salted		7.30	0.28
Openness			
2% (w/w) added salt	2.70	2.45	
3% (w/w) added salt	2.30	2.50	
Machine salted		1.35	0.48

TABLE 33

Means of body, flavour and colour scores of 8 weeks-old commercial Cheddar cheese made with single-strain starters and salt of different particle size added at levels of 2% (w/w) and 3% (w/w) to the curd

Treatment	Fine salt (73 µm)	Commercial grade dry vacuum salt (333 µm)	Standard error of difference ±
Body			
2% (w/w) added salt	7.65	7.80	
3% (w/w) added salt	8.05	8.15	
Machine salted		8.40	0.21
Flavour			
2% (w/w) added salt	8.45	8.20	
3% (w/w) added salt	7.90	8.50	
Machine salted		7.85	0.21
Colour			
2% (w/w) added salt	8.15	7.90	
3% (w/w) added salt	7.70	8.15	
Machine salted		8.00	0.17

TABLE 34

Analysis of variance: salt content, salt in aqueous phase, moisture, pH, firmness and elasticity of 8 weeks-old commercial Cheddar cheese made with single-strain starters

Source of variation	D.F.	Mean square	F	Mean square	F	Mean square	F
		Salt (%)		Salt in aqueous phase (%)		Moisture (%)	
Machine salted x rest	1	0.00	-	0.21	-	1.12	4.87*
2% x 3% (w/w) added salt	1	0.84	40.98***	9.15	43.57***	6.52	28.35***
In 2% (w/w) added salt	1	0.05	-	0.66	-	0.39	-
In 3% (w/w) added salt	1	0.01	-	0.12	-	0.03	-
Error	15	0.02		0.21		0.23	
Total	19						
		pH		Firmness (B.C.T.)		Elasticity	
Machine salted x rest	1	0.00	-	0.00	-	1.06	-
2% x 3% (w/w) added salt	1	0.03	-	40.32	-	4.41	-
In 2% (w/w) added salt	1	0.00	-	12.50	-	0.30	-
In 3% (w/w) added salt	1	0.00	-	0.40	-	0.32	-
Error	15	0.01		20.69		6.61	
Total	19						

- not significant ($p > 0.05$), * significant ($p < 0.05$), ** significant ($p < 0.01$), *** significant ($p < 0.001$)

TABLE 35

Means of salt content, salt in aqueous phase, moisture, pH, firmness and elasticity of 8 weeks-old Cheddar cheese made with single-strain starters and salt of different particle size added at levels of 2% (w/w) and 3% (w/w) to the curd

Treatment	Fine salt (73 µm)	Commercial dry vacuum salt (333 µm)	
	Salt content		
2% (w/w) added salt	1.37	1.54	
3% (w/w) added salt	1.95	1.88	
Machine salted		1.75	
Standard error of difference			± 0.10
	Salt in aqueous phase		
2% (w/w) added salt	3.90	4.48	
3% (w/w) added salt	5.82	5.58	
Machine salted		5.20	
Standard error of difference			± 0.32
	Moisture		
2% (w/w) added salt	35.08	34.64	
3% (w/w) added salt	33.52	33.64	
Machine salted		33.62	
Standard error of difference			± 0.34
	pH		
2% (w/w) added salt	5.09	5.11	
3% (w/w) added salt	5.20	5.16	
Machine salted		5.14	
Standard error of difference			± 0.06
	Firmness		
2% (w/w) added salt	57.0	59.5	
3% (w/w) added salt	61.6	61.2	
Machine salted		59.9	
Standard error of difference			± 3.22
	Elasticity		
2% (w/w) added salt	41.4	41.0	
3% (w/w) added salt	42.1	42.5	
Machine salted		42.3	
Standard error of difference			± 1.82

TABLE 36

Mean seaminess scores and chemical composition of salted and unsalted commercial Cheddar cheese aged 4 and 8 weeks

Added salt (%)	Size of the milled curd (in) (cm)	At 4 weeks seaminess scale (0 - 10)	At 8 weeks seaminess scale (0 - 10)	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
3	0.5 (1.27)	9.75	9.75	5.28	34.08	1.99	5.8
Unsalted	0.5 (1.27)	5.25	1.75	5.44	39.00	-	-
3	0.75 (1.91)	10.00	10.00	5.15	34.16	1.74	5.1
Unsalted	0.75 (1.91)	6.75	4.25	5.42	40.34	-	-

TABLE 37

Analysis of variance of seaminess; the effect of additives in commercial salt

Treatment	D.F.	Mean square	F
Treatment	2	2.76	-
Experimental error	6	2.84	
Judges	4	5.59	11.64**
Judges x treatment	8	0.84	-
Sampling error	24	0.70	
Total	44		

Means of seaminess scores

Analar grade sodium chloride	1.07
Commercial grade dry vacuum salt A (I.C.I.)	1.87
Commercial grade dry vacuum salt B (I.C.I.)	1.20
Standard error of difference	± 0.62

- Not significant ($p > 0.05$)

** Significant ($p < 0.01$)

E. Acidity of the curd at the time of salt addition

E.1. Preliminary experiment. The grading panel's mean scores were analysed for the degree of significance using the method described on page 62.

The results of the statistical analysis of variance of seaminess is presented in Tables 38 and 39. Seaminess was significantly affected by the acidity of the curd at the time of salt addition.

E.2. Full scale experiment. The results of the statistical analysis of cheese scoring results are shown in Tables 40 and 41.

The analysis of variance of seaminess scores of Cheddar cheese aged 8 weeks indicates that the extent of seaminess was significantly increased ($p < 0.05$) by the acidity of the curd at the time of salt addition. This was true for cheese made with single-strain or mixed-strain starters.

F. Acidity of the curd produced by different strains of starters at the time of salt addition

The results of scoring the cheese and their chemical analysis are presented in Tables 119 to 126 (Appendix B).

The analysis of variance of seaminess are presented in Tables 42 to 44.

G. Temperature of curd at the time of salt addition

The results of the scoring of cheese salted at different temperature and the results of the chemical analyses of samples when

TABLE 38

Analysis of variance; seaminess scores of 8 weeks-old Cheddar cheese salted at different acidities (preliminary experiment)

Treatment	D.F.	Mean square	F
Acidity	2	55.60	45.95 ***
Replicates	1	7.50	6.20 *
Experimental error	2	0.40	
Judges	4	18.05	14.92 ***
Judges x acidity	8	1.35	-
Sampling error	12	1.35	
Total	29		
Pooled E	14	1.21	

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

TABLE 39

Means of seaminess scores of Cheddar cheese (aged 8 weeks) salted at different acidities (preliminary experiment)

Treatment Titratable acidity at milling (%)	Mean of seaminess at 8 weeks
0.5	2.3
0.7	5.5
0.9	6.9

Standard error of difference ± 0.49

TABLE 40

Analysis of variance; seaminess scores of 8 weeks-old Cheddar cheese salted at different acidities

	Vat 1 (Single-strain starter)			Vat 2 (Mixed-strain starter)		
Treatment	D.F.	Mean square	F	D.F.	Mean square	F
Acidity	2	22.86	14.84*	2	50.06	8.02*
Replicates	2	2.86	-	2	0.26	-
Experimental error	4	1.54		4	6.24	
Judges	4	6.56	5.01**	4	11.28	7.67***
Judges x acidity	8	3.09	2.36*	8	2.51	-
Sampling error	24	1.31		24	1.47	
Total	44			44		

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

*** Significant ($p < 0.001$)

TABLE 41

Mean seaminess scores of 8 weeks-old Cheddar cheese salted at different acidities

Titratable acidity at salting (% lactic acid)	Mean score of seaminess Vat 1/single-strain starter	Mean score of seaminess Vat 2/mixed-strain starter
0.5	0.1	2.3
0.7	0.5	3.0
0.9	2.4	5.7
Standard error of difference ±	0.45	0.91

TABLE 42

Analysis of variance; seaminess in 8 weeks-old Cheddar cheese salted at different acidity and made with different strains of starter bacteria

Treatment	D.F.	Mean square	F
Vats	3	19.88	14.51 ***
Acidity	2	64.77	47.28 ***
Vat x acidity	6	5.70	4.16 **
Experimental error	24	1.37	
Judges	3	41.29	117.97 ***
Judges x vats	9	1.62	4.63 ***
Judges x acidity	6	2.58	7.37 ***
Judges x vats x acidity	18	0.54	-
Sampling error	72	0.35	
Total	143		

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

*** Significant ($p < 0.001$)

TABLE 43

Means of seaminess scores of Cheddar cheese salted at different acidities and made with different strains of starter bacteria

	Titratable acidity (% lactic acid)			
Vat	0.5	0.7	0.9	Vat mean
1	1.08	1.83	3.67	2.19
2	0.83	0.50	1.33	0.89
3	1.42	2.00	3.42	2.28
4	1.00	1.92	4.75	2.56
Mean scores	1.08	1.56	3.29	

Standard error of difference: ±

Between vats means	± 0.28
Between acidity	± 0.24
Between vats x acidity	± 0.48

TABLE 44

Comparison of significance of means of seaminess scores of Cheddar cheese made when salt was added to the curd at different acidities

Different strains of starters were used

Treatment/Acidity	Vat 1	Vat 2	Vat 3	Vat 4	Mean
0.5 x 0.7	-	-	-	-	-
0.5 x 0.9	***	-	***	***	***
0.7 x 0.9	***	-	**	***	***

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

*** Significant ($p < 0.001$)

the cheese was 8 weeks old were analysed statistically. The analysis of variance of scores for seaminess, fusion, openness, body, flavour and colour are presented in Tables 45 to 47.

H. Mellowing time

The results of the statistical analysis of the scores and the chemical analysis are presented in Tables 48 and 49 respectively.

DISCUSSION

A. Amount of added salt

a. Preliminary experiement. The addition of medium or coarse grained salt at the rate of more than 3 per cent (w/w) caused the condition of seaminess in the cured cheese. The results obtained in this trial showed that an average of 4 points degree of seaminess was present in the samples tested. This result confirmed that the addition of salt to the cheddared curd may cause a condition of seaminess in Cheddar cheese(Table 116).

The results showed that the degree of seaminess present was increased with the increase of the age of the cheese. It was noticed also that the seams were more marked in coloured Cheddar.

To measure more fully the relationship between salt addition and seaminess it was essential to use a large scale experiment and a scoring panel.

b. Large scale experiment. The analysis of variance of

TABLE 45

Analysis of variance: seaminess in 8 weeks-old Cheddar cheese salted at different temperatures

Source of variation	D.F.	Mean square	F
Treatments	2	20.58	-
Experimental error	12	16.53	
Judges	4	13.23	13.10 ***
Judges x treatments	8	0.72	-
Error	48	1.01	
Total	74		

Means A (100°F) 2.00

B (86°F) 3.36

C (74°F) 1.64

Standard error of difference ± 1.15

\- Not significant ($p > 0.05$)

*** Significant ($p < 0.001$)

TABLE 46

Analysis of variance; body, flavour, and colour of Cheddar cheese (aged 8 weeks) salted at different temperatures

			Body		Flavour		Colour	
Source of variation		D.F.	Mean square	F	Mean square	F	Mean square	F
Treatments		2	0.36	-	1.78	-	0.52	-
Experimental error		12	0.97		1.22		0.55	
Judges		4	2.40	5.33**	2.35	-	1.33	4.92**
Judges x treatments		8	0.06	-	0.21	-	0.25	-
Sampling error		48	0.45		1.03		0.27	
Total		74						
Means	A (100°F)		8.20		8.44		8.36	
	B (86°F)		8.32		8.28		8.08	
	C (74°F)		8.08		7.92		8.16	
Standard error of difference ±			0.28		0.31		0.21	

- Not significant ($p > 0.05$)

** Significant ($p < 0.01$)

TABLE 47

Analysis of variance; fusion and openness of Cheddar cheese (aged 8 weeks) salted at different temperatures

Source of variation	D.F.	Fusion Mean square	Fusion F	Openness Mean square	Openness F
Treatments	2	0.98	-	0.12	-
Experimental error	12	0.43		13.05	
Judges	4	14.06	24.67***	24.95	41.58***
Judges x treatments	8	0.32	-	0.70	-
Sampling error	48	0.61		0.60	
Total	74				
Pooled E	60	0.57			
Means A (100°F)		7.20		3.04	
B (86°F)		7.24		2.92	
C (74°F)		6.88		2.92	
Standard error of difference ±		0.21		1.02	

\- Not Significant ($p > 0.05$)

*** Significant ($p < 0.001$)

TABLE 48

Analysis of variance: seaminess scores given to mellowed Cheddar cheese aged 8 weeks, mellowed for 50 minutes before pressing

Source of variation	D.F.	Mean square	F
Treatment	1	4.50	-
Experimental error	6	2.98	
Judges	3	3.71	3.50 *
Judges x treatment	3	0.75	-
Sampling error	18	1.06	
Total	31		

Treatment means

Unmellowed	3.81
Mellowed	4.56
Standard error of difference ±	0.61

\- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

TABLE 49

Analysis of variance: pH, moisture, salt and salt in aqueous phase of mellowed (50 min) and unmellowed Cheddar cheese, 8 weeks of age

		pH		Moisture (%)		Salt (%)		Salt in aqueous phase (%)	
Source of variation	D.F.	Mean square	F	Mean square	F	Mean square	F	Mean square	F
Treatment	1	0.0001125	-	0.2850	-	0.027612	9.12*	0.32000	8.93*
Error	6	0.0003292		0.1762		0.003029		0.03583	

Means	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
Unmellowed	5.14	34.66	1.82	5.22
Mellowed	5.14	34.29	1.94	5.62
Standard error of difference ±	0.13	0.30	0.039	0.13

\- Not significant ($p > 0.05$), * Significant ($p < 0.05$)

seaminess in cheese made with both 2 and 4 per cent (w/w) added salt showed that seaminess was significantly ($p < 0.01$) affected by the amount of added salt. Seaminess increased significantly ($p < 0.01$) with the increase of the salt added to the cheddared curd (Table 16).

In this experiment the level of seaminess remained very low (1.7 points) in all the resultant cheese, and none of them was described as seamy cheese.

The amount of salt retained in the cheese ranged from 1.72 per cent to 2.0 per cent for the cheese that received 4 per cent (w/w) salt. Six blocks were of moisture content below 36.00 per cent, and were comparable to those produced by Czulak (1963).

The mean scores also showed that the body of the cheese varies significantly ($p < 0.001$) with the amount of the added salt. The cheese produced when a rate of 4 per cent (w/w) added salt was used were firm bodied cheese (7.64 points). Using 2 per cent (w/w) added salt, the resultant cheese was less firm (6.87 points) (Table 18).

Curd that received 4 per cent (w/w) salt produced cheeses which were described as mottled coloured cheese. The mean scores for colour given to these cheese were lower than those given to cheese made with 2 per cent (w/w) added salt. The scores were 7.78 and 8.40 points respectively and colour is significantly affected ($p < 0.05$) with the amount of added salt (Table 19,22).

Fusion of the curd particles showed slight difference in the mean scores, 7.04 points when 4 per cent (w/w) added salt was used and 7.44 points when 2 per cent (w/w) added salt was used. The difference which was not significant ($p > 0.05$) may be due to the effect of salt addition and to the occurence of seaminess in these cheeses (Table 18).

'Openness' scores of the cheeses which were tested showed that the cheese containing the higher levels of added salt had less openness than those containing less salt, but this difference is not significant ($p > 0.05$) (Table 18).

There was a very slight difference (not significant $p > 0.05$) in the mean scores for flavour of the cheese at the age of 8 weeks 7.84 points to the high salt cheese, and 7.91 to the low salt cheese. The differences increased however as the cheese became older, when more off-flavours were found in the cheese produced with a lower level of added salt (Table 19).

When 4 per cent (w/w) added salt was used in salting the curd, the resulting cheese retained more salt than when the curd received 2 per cent (w/w) of salt. This difference was significant ($p < 0.001$). There was no significant difference ($p > 0.05$) between the amounts of salt retained in the final cheese made with different particle sizes. This was also true in the concentration of salt in the aqueous phase in these cheeses which was however significantly affected ($p < 0.001$) by the amount of added salt of both types (Table 20).

The cheese that received 4 per cent (w/w) added salt contained lower moisture than those which received 2 per cent (w/w) salt. This difference was significant ($p < 0.001$). There was no significant ($p > 0.05$) effect of different particle size on the amount of salt retained in the final cheese. The mean moisture content of cheese resulting from both treatments was 36.13 per cent for those cheeses that received 4 per cent (w/w) salt and 37.65 per cent for those where 2 per cent (w/w) salt had been added (Table 23)

The mean pH reading of the cheeses indicated that, the cheeses of lower salt content tended to be slightly more acid than those in which higher salt was retained. The mean pH of the cheese of lower salt content was 5.15 compared to 5.17 that of high salt content cheese (Table 23).

B. Salt particle size

B.1. Experimental curd. Seaminess levels of cheese made with 4 per cent (w/w) added salt of different particle size; 50, 107 and 333 µm were 1.754, 1.742, and 1.745 points seaminess respectively. This indicated that all types of salt used induced the same degree of seaminess in the final cheese. There was no significant ($p > 0.05$) effect of the particle size on the development of seaminess (Table 16). This result indicates that the same degree of seaminess can be induced by fine salt (50, and 107 µm particle size) and the ordinary commercial grade dry vacuum salt (333 µm particle size). The level of seaminess present in all cheeses was low and no cheese were classified as seamy. These results are contrary to those reported by Czulak (1963), who reported that seaminess was more marked and more frequent with cheese made with coarse salt and practically absent with cheese made with fine salt. Yet the same author did not define the particle size of the fine salt he used.

The analyses of variance of seaminess given to the resultant cheese at 8 weeks of age showed that also there was no significant difference ($p > 0.05$) when 2 and 3 per cent (w/w) added salt was used (Table 24).

The salt content of the final cheese were within the normally accepted level of 1.6 to 1.8 per cent, when 3 and 4 per cent (w/w) of the three types of salt were used. But when 2 per cent added salt was used of the same types, the final salt content of the cheese was below the level required.

B.2. Commercial curd (mixed-strain starters). The level of seaminess present in the matured commercial cheese was higher than that present in the cheese made in experiment B.1. The scores for seaminess given to the cheese made with salt of a particle size of 73 μm were slightly lower than those given to the other cheese. However these differences were not significant ($p > 0.05$), indicating that there is no significant effect of salt particle size on seaminess induced in these cheese (Table 26). The level of seaminess present was below that necessary to result in a cheese which could be classified as seamy. These results confirm the information obtained in the previous experiment with experimental curd.

The analyses showed no significant ($p > 0.05$) difference between the scores given to the fusion, openness, and flavour, but the scores given to the body of cheese which received 2 per cent added salt were significantly ($p < 0.01$) lower than that given to cheese which received 3 per cent added salt. There was no significant difference within the cheeses that received 2 per cent added salt and 3 per cent (w/w) of the two types of salt used. The body of the cheese tended to be weaker when less salt was added (Table 27).

The cheese that received less salt, had significantly ($p < 0.05$) higher scores than the others. Addition of higher salt tended to cause uneven colour in the final cheese. The mean scores for colour which are presented in Table 27 shows that all the cheese were of low scores compared to other commercial Cheddar cheese.

The addition of higher amounts of salt to the cheddared curd caused a significant ($p < 0.01$) increase in the final salt content and the salt concentration in the aqueous phase of cheese. There was no significant ($p > 0.05$) difference with the cheese to which received 2 per cent or 3 per cent (w/w) added salt of both particle size. The mean of final salt retained showed that addition of 2 per cent (w/w) salt to the curd resulted in cheese of low salt content (Table 28).

The moisture content of the final cheese was significantly ($p < 0.01$) affected by the addition of the two different levels of salt of 2 and 3 per cent (w/w) but this difference was not significant ($p > 0.05$) when the cheese received salt of different particle size at both levels of the addition (Table 28).

These variation in the resultant cheese were reflected in significant ($p < 0.01$) differences in the firmness of the cheese as determined by B.C.T. readings. The ball compressor values indicates that the cheese which received 3 per cent (w/w) added salt of the salt of both particle size, were more firm bodied than those which received 2 per cent (w/w) added salt. The elasticity characteristics of the cheese were significantly ($p < 0.05$) lower when the cheese received 3 per cent (w/w) added salt. But there was significant ($p < 0.05$) difference because of the salt particle size in both rates of addition.

There was no significant ($p > 0.05$) difference in the pH of the resultant cheese.

B.2. Commercial curd (single-strain starter). The results of the scoring showed that the degree of seaminess obtained in this experiment was much higher than that found in the previous parts (B1, B2). The mean score for seaminess in cheeses made with 2 per cent (w/w) added salt, both fine (73 μm) and coarse (333 μm) was 9.30 and 9.60 points respectively. This difference is significant ($p < 0.05$). All of the cheese were considered to be very seamy. The final salt content in these cheeses ranged from 1.37 to 1.54 per cent which is considered below the optimum level for salt in commercial Cheddar.

When fine and coarse salts were added at the rate of 3 per cent (w/w), the mean score for seaminess in the resulting cheese at 8 weeks was 9.5 and 9.6 respectively. This difference is not significant ($p > 0.05$). The salt content in the cheese ranged between 1.81 and 2.02 per cent which was within the range of salt in commercial Cheddar. The cheese produced in this experiment were described as very seamy (Table 32).

The mean score for seaminess in the samples taken from the line where machine salting took place was 9.3 and the cheese were considered to be very seamy. There was no significant ($p > 0.05$) difference in the seaminess between the cheese resulting from hand and machine salting (Table 29).

The fusion characteristics of all cheeses were not significantly ($p > 0.05$) affected either by the addition of different amounts of salt or by the use of salt of different particle size. Scores for fusion given to the cheese ranged from 7.25 to 7.40 for all treatments (Table 30).

The results of analysis of variance indicate that there was no significant ($p > 0.05$) difference in the scores for openness in the cheese which was hand salted with either 2 per cent (w/w) or 3 per cent (w/w) of added salt. There was a significant difference ($p < 0.001$) between the openness scores for machine salted and manually salted cheese in this experiment. Openness in machine salted cheese was less than that in hand salted cheese. However the openness condition of all cheeses was very low and the texture was good in all cases. The score for openness ranged between 1.35 and 2.70 points.

The mean scores for body given to the cheeses indicated that weak-bodied cheese resulted when 2 per cent (w/w) added salt was used of either commercial grade dry vacuum salt or milled salt of 73 µm particle size. The analysis of variance showed that there was a significant difference ($p < 0.05$) in the scores given to the body of the cheese treated with 2 per cent (w/w) and 3 per cent (w/w) added salt. There was a significant ($p < 0.05$) difference between the body of machine salted cheese and those which were manually salted. The body of the machine salted cheese was firmer than the others (Table 30).

The scores awarded by the panel indicate that the resultant matured cheese were of different flavour. There was no significant difference ($p > 0.05$) between the scores given to the cheese produced with 2 per cent (w/w) or 3 per cent (w/w) of salt addition. The mean scores given to flavour of the cheese when 3 per cent (w/w) of fine salt (73 µm) was added was significantly ($p < 0.01$) lower in comparison to the scores given to cheese when 3 per cent (w/w) commercial grade dry vacuum salt (333 µm) was added (Table 31).

The colour of the cheese was not significantly ($p > 0.05$) affected by the amount of salt, and by machine salting as opposed to hand salting. The colour of cheese produced when 3 per cent (w/w) added salt was used was significantly ($p < 0.05$) affected by the salt particle size. The mean score given to cheese produced with 73 µm particle size salt was lower than that given to cheese produced with dry vacuum salt, the respective mean scores were 7.70 and 8.15 points.

The amount of salt added of either particle size affected the final amount of salt retained in the cheese, the salt concentration in aqueous phase and the moisture content. Salt retained in the cheese is significantly ($p < 0.001$) increased with increase of amounts of added salt. There was no significant difference ($p > 0.05$) in the salt retained when the cheese was treated with the same amount of salt of different particle size. The concentration of salt in the aqueous phase was also higher with the increase of added salt. The moisture content of the cheese increased significantly ($p < 0.001$) with a decrease in the amount of added salt. When the level of salt addition was 2 per cent (w/w) the moisture content of cheese made with fine salt (73 µm) was 35.08 per cent. When dry vacuum salt (333 µm) was used the moisture content was 34.64 per cent. The means of the moisture content of the machine-salted cheese was 33.62 compared to that of the rest of the cheese included in the experiment. All the cheese from these treatments were considered as of low moisture content being in the range from 35.16 per cent to 32.85 per cent(Table 34).

The fact that the severe level of seaminess found in the cheese in this experiment was not attained in the cheese made with curd produced under similar experimental conditions even when 4 per cent (w/w) of salt was used suggests that this seaminess was induced by factors other than the amount of added salt. This finding disagrees with view expressed by Czulak (1963).

According to Czulak (1963) seaminess was decreased and almost absent when fine salt (which was not defined) was added to the curd. In this experiment seaminess scores of more than 9 points were attained in the cheese even when 2 per cent (w/w) salt of a particle size of 73 µm was added to milled curd. There was no significant difference ($p > 0.05$) in the firmness or elasticity of cheese produced by different treatments.

In order to demonstrate that the degree of the seaminess obtained under these conditions was due to factors other than the addition of salt to the cheddared curd, it was decided to compare cheese salted by the usual manner of machine salting and others which were unsalted.

C. Sodium chloride

Seaminess was present in the unsalted cheese. The mean scores given at 4 and 8 weeks old were 6.00 and 3 respectively. This degree of seaminess is higher than that obtained in experimental cheese made from curd which had been treated with 4 per cent added salt (Table 36). This result demonstrated that under some conditions factors other than salt may play a role in and may cause the development of seaminess in Cheddar cheese.

D. Additives in commercial salt

The results obtained showed that while there was a slight difference in the mean scores for seaminess of the cheese produced by different qualities of sodium chloride it was not significant ($p > 0.05$) (Table 37). This suggests that Analar grade sodium chloride which is free from impurities caused the same degree of seaminess as commercial types in which additives are used.

E. Acidity of curd at the time of salt addition

E.1. Preliminary experiment. The degree of seaminess present increased with the increase of the acidity of the curd at the time of salt addition (Table 38).

The increase in seaminess in the curd salted at high acidity e.g. 0.9 per cent lactic acid may have been due to the formation of more calcium orthophosphate between the junctions of the curd particles. But the mean scores were not as high as would indicate a very seamy condition in the final cheese. The highest mean score obtained was 6.9 points. This preliminary study suggested that this factor should be investigated, cheese made with either mixed-strain or single-strain starters. The following full scale experiment was designed to investigate the matter further.

E.2. Full scale experiment. The analysis of variance of seaminess when the cheese was 8 weeks old indicated that addition of salt to the curd at higher acidity caused a significant ($p < 0.05$) increase in the mean score for seaminess (Table 40). This is in agreement with the result obtained in the preliminary test described above.

The mean scores of seaminess given to the cheese made with curd salted when the titratable acidity was 0.9 per cent lactic acid indicates that a low level of seaminess was obtained. The resultant cheese was described as non-seamy cheese.

The cheese produced in both vats were of good level of moisture, and salt, but they differed from one treatment to another. The level of salt retained in the final cheese was increased with the increase of curd acidity at milling. The moisture content decreased with an increase of the acidity of the curd at the time of salt addition. The acidity of the final cheese as indicated by pH was increased by milling the curd at higher acidities.

F. Acidity of the curd produced with different strain of starters at the time of salt addition

The analysis of variance indicated that there was a significant difference ($p < 0.001$) between the scores of seaminess given to cheese made with different single-strain starters (Table 42). This high level of significance was due to the very low scores of seaminess given to cheese made with WM1 and AM2 of Str. cremoris. The milk used for cheese making contained a harmful level of antibiotic, and this inhibited the growth of the starters organisms during the manufacturing process and during curing. The mean scores for seaminess present in the Cheddar is 0.89 points compared to 2.19, 2.28, and 2.56 for the seaminess present in cheese made with single-strain starters of Str. cremoris (ML3, AM1), (H2, E8) and (P2, SK11) (Table 43).

In this experiment, the results of the analysis of variance indicated that seaminess was significantly ($p < 0.001$) affected by the acidity of the curd at the time of salt addition. This is in agreement with the result obtained in the previous experiment. Although this high level of significance was obtained, the degree of seaminess induced in the cheese was low and ranged between 1.00 to 4.75 points. This low level did not produce a seamy condition in the matured cheese.

Figure 20 shows the difference in the mean scores for seaminess in cheese made when the salt was added at titratable acidities of 0.5 per cent, 0.7 per cent and 0.9 per cent lactic acid.

The means of acidity which is presented in Table 43, indicates that there was no significant ($p > 0.05$) difference in the degree of seaminess present in the cheese when the salt was added to the curd when its titratable acidity was 0.5 per cent or 0.7 per cent lactic acid. But there was a significant difference ($p < 0.001$) between the scores for seaminess in cheese produced when the salt was added to curd at titratable acidities of 0.5 per cent and 0.9 per cent lactic acid. The difference was also significant ($p < 0.001$) when the salt was added at titratable acidities of 0.7 per cent and 0.9 per cent lactic acid.

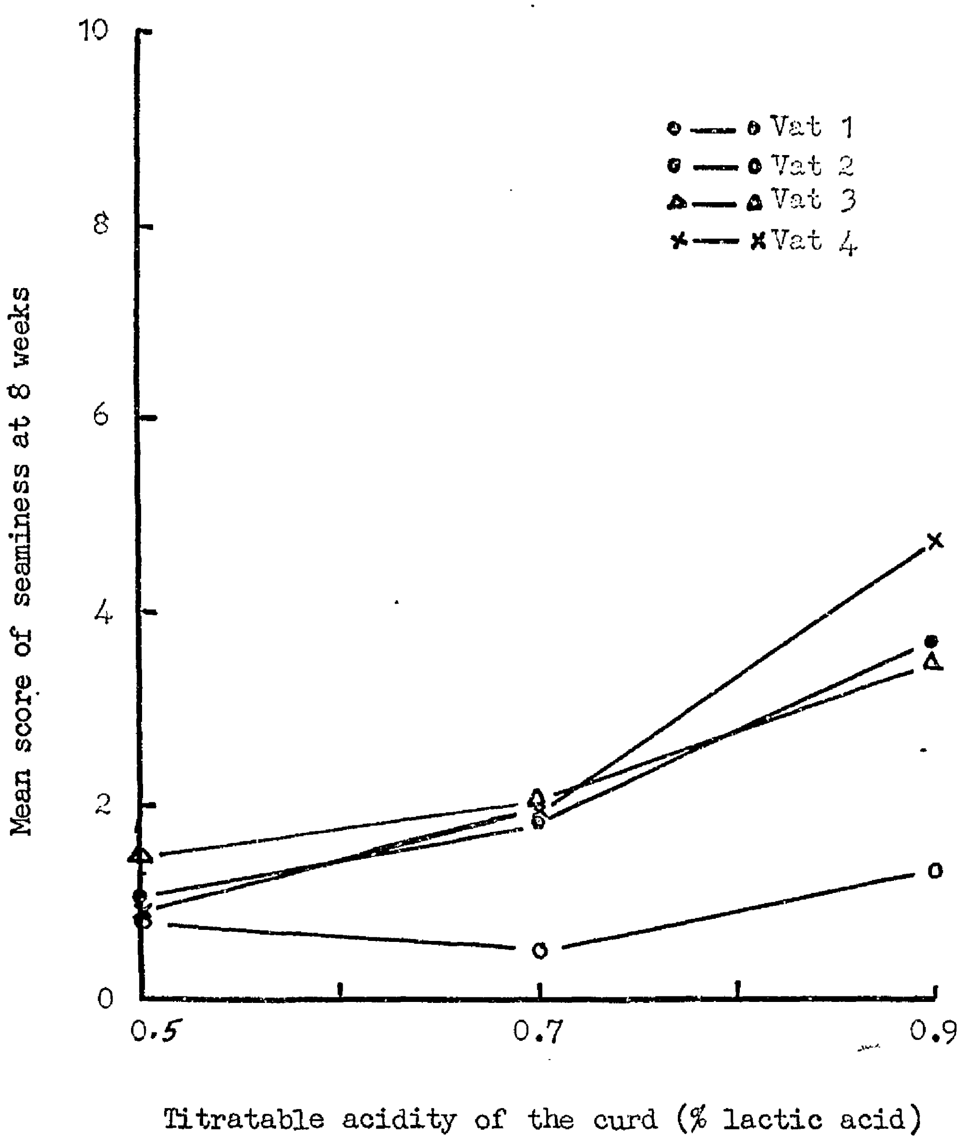
The results obtained suggest that milling of the curd at an acidity of less than 0.7 per cent lactic acid may bring about a decrease in the degree of seaminess induced in the final cheese.

G. Temperature of the curd at the time of salt addition

The results obtained in this test shows that the degree of seaminess induced in all the treatments was as low as that obtained

FIGURE 20

The effect of the acidity of the curd at the time of salt addition and of different strains of starters on the development of seaminess in Cheddar cheese



in the other tests relating to the addition of salt. The means of seaminess ranged from 1.64 to 3.26 with a standard error of difference of ± 1.15 points. This level of seaminess did not cause seamy cheese. Although there was slight difference in the mean of scores, this difference was not significant ($p > 0.05$). Seaminess was slightly higher in Cheddar to which the salt was added at 86°F (30°C) (Table 45)

Fusion, openness, body, flavour and colour means scores shows slight difference, but these are not significant ($p > 0.05$) (Table 47).

The final salt content of the cheese, the salt in aqueous phase, and the pH of the cheese were not significantly ($p > 0.05$) affected by the difference in curd temperature at the time of salt addition.

The decrease in the temperature of the curd at the time of salting caused an increase in the moisture content of the cheese. Moisture content was significantly ($p < 0.001$) affected by the temperature. The means of moisture content in the cheese salted when the curd temperature was 100°F (37.8°C), 86°F (30°C) and 74°F (23.3°C) were 33.69, 34.01, and 35.15 per cent respectively.

H. Mellowing time

The mean scores for seaminess given to the Cheddar cheese made from mellowed and unmellowed curd indicated that there was no difference in the degree of seaminess present in the resultant cheese.

There was no difference in the mean scores given to the cheese for fusion, openness, flavour, and colour, but the score for the body of the cheese made from mellowed curd was slightly higher than those made from the unmellowed curd. The cheese made from mellowed curd tended to be more firm than the other cheese. This corresponds with the fact that the moisture content of these cheese were lower than those from unmellowed curd.

The salt content of the cheese made from mellowed curd and which had more contact time before pressing was higher than that of the cheese made from unmellowed curd. The per cent salt in aqueous phase in the mellowed cheese was significantly higher ($p < 0.05$) in comparison to that in unmellowed cheese (Table 49).

CONCLUSION

A. Amount of added salt

The amount of added salt has a significant ($p < 0.01$) effect on the development of seaminess (3 and 4%). Seaminess increased with the amount of salt added. But the degree of seaminess induced in the cheese by the action of salt was not great and was not enough to produce a condition of seamy cheese as was described by Czulak (1963). The high degree of seaminess reported by Czulak may be caused by factors other than the amount of added salt.

Addition of salt at 4 per cent (w/w) to the milled curd produced cheeses of short body, mottled colour, and of poor fusion. When salt was added at 2 per cent (w/w), the resultant cheeses were of weak body, and of high moisture content. They contained low salt content; lower than the generally accepted optimum level in the final cheese of 1.6 to 1.8 per cent. The cheeses with low salt content developed off-flavour more quickly than those which had a higher salt content.

B. Salt particle size

Seaminess was not significantly ($p > 0.05$) affected by the different salt particle size within the range from 50, 107 and 333 µm.

The severe occurrence of seaminess in commercial Cheddar cheese produced with single-strain starters is caused by factors other than the amount of added salt and salt particle size.

C. Sodium chloride

Seaminess can be induced in Cheddar cheese by factors other than the addition of salt to the cheddared curd.

D. Additives in commercial salt

Additives at the level normally found in commercial salt used by the Cheddar cheese industry do not per se induce seaminess in cheese.

E. Acidity of the curd at the time of salt addition

Seaminess was significantly affected by the acidity of the curd at the time of salt addition. Seaminess was more noticeable with the increase of acidity of curd at salting. However, the level of seaminess obtained in all treatments with experimental cheese made with single or mixed-strain starters remained low, and was not enough to cause seamy cheese.

F. Acidity of the curd produced by different strains of starter

There was no difference in the extent of seaminess of cheese made with pairs of single-strain starters used in a New Zealand 4 - day rotation.

G. Temperature of the curd at the time of salt addition

Seaminess was not significantly ($p > 0.05$) affected when the salt was added to curd of different temperature. The seaminess produced in the cheese in the trials was not severe.

The moisture content of the cheese was significantly ($p < 0.001$) affected but there was no significant ($p > 0.05$) effect on the salt content, the salt in the aqueous phase, or the pH of the cheese.

H. Mellowing time

Mellowing the curd after the salting for 50 min does not effect the level of seaminess induced. But this treatment increased the salt retained in the final cheese.

CHAPTER IV

STUDY OF THE EFFECT OF FACTORS RELATED TO THE PROCESS OF MILLING THE CURD

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STUDY OF THE EFFECT OF FACTORS RELATED TO THE PROCESS OF MILLING THE CURD

INTRODUCTION

Before the addition of the salt in the process of Cheddar cheese manufacture, the cheddared slabs which are about 5 in (12.7 cm) wide, 4 in (10.2 cm) thick, and 15 in (38.1 cm) long are milled by special equipment into small pieces. The main objective is to have smaller pieces of curd so that the salt may penetrate the curd quality and be evenly distributed within the cheese.

Many machines such as the peg mill, the Damrow 'chip' mill and recently the CheeseMaker 3 are in use to achieve this objective. These machines cut the curd, by applying differently a force on the curd, by means of pegs, or knives.

The application of the cutting force produces curd pieces with different surface conditions, some with a smooth surface, others with a rough surface.

In this section the effect of the use of different milling machines on the development of seaminess in Cheddar cheese is examined.

A. Size of milled curd

In the manufacturing process for Cheddar cheese, the cheddared slabs of curd are milled into smaller size pieces of 0.5 x 0.5 in (1.27 x 1.27 cm) or 0.75 x 0.75 in (1.91 x 1.91 cm) cross section, or smaller pieces having no regular dimensions, before the addition of the dry salt to the curd.

It was found in the earlier work in this thesis, that seaminess was increased in cheese by adding greater amounts of salt to the curd. The amount of salt applied on the surface of the curd will be affected by the available surface area on which the salt is applied. Milling the curd into smaller cuts would increase the number of pieces from the same volume of a particular cheddared slab, producing more area, and this will cause the distribution of the same amount of salt to a larger area.

When more particles per slab are produced in the case of the smaller cut, more junction lines are available, and more lines are likely to form in the presence of conditions favourable to the formation of seaminess. The objective of this study was to investigate this effect and to determine the pattern of seaminess that may form in cheese made from small and large pieces of curd.

B. Mill type

In traditional Cheddar cheese making, a peg mill was used to cut the cheddared curd into pieces with no regular shape or dimension (Figure 21). This principle of cutting by rotating pegs is employed at present by commercial firms in a mechanised system for Cheddar cheese manufacture capable of handling more than 60,000 lb (27216 kg) of curd per day.

The circular type mill (e.g. the Damrow mill, frequently referred to as chip mill) is also used in the cutting of the curd in small and large cheese factories. In this type the curd is cut by using rotating circular blades (Figure 21). The resultant curd particle is of 0.75 x 0.75 in (1.91 x 1.91 cm) cross section and a length of about 3 in (7.62 cm). These knives cut perpendicularly the curd when it is fed to the equipment.

The 'Cheddarmaster' system developed in New Zealand uses Berry mill in the mechanised system with capacities of up to 100,000 lb (45359 kg) of curd per day.

The third type of milling machine is that incorporated in the CheeseMaker 3 unit which originated in Australia. In this machine the cheddared slabs of the curd is allowed to fall into a small compartment. The cutting grid (knife) is then forced through the curd which is held in the compartment. The grid is made of sharp stainless steel blades welded together at right angles (Figure 22). The cutting action in this type of mill is different from that used in the peg or Damrow chip mill. The size of the resultant curd pieces depends on the size of the knife employed in the machine. The cross section could be either 0.75 x 0.75 in (1.91 x 1.91 cm) or 0.5 x 0.5 in (1.27 x 1.27 cm) and a length of about 3 in (7.62 cm) (Figure 22).

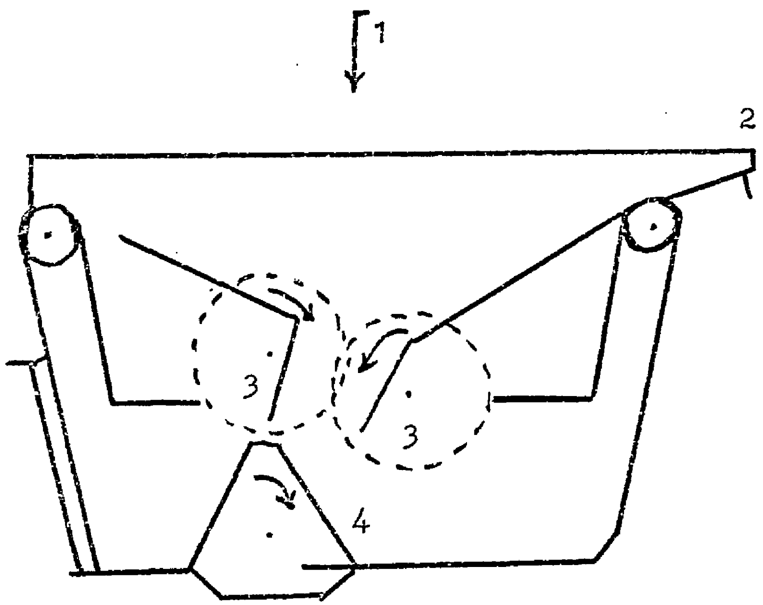
Seaminess always froms in the particle junctions. Well-identified boundaries of the curd particles produced by the Damrow and CheeseMaker 3 provide well-defined lines of junctions between the curd and this may encourage the development of the seams in these areas. Milling the curd to produce irregular shaped pieces may eliminate these distinct junctions.

Each of these methods of milling curd applied the force required for cutting in a different way. The curd is cut by the peg

FIGURE 21

Milling section of Damrow (chip) and Peg mills

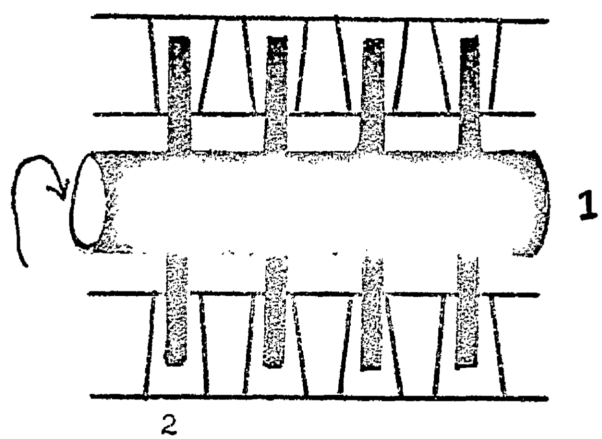
1. Curd slabs in
2. Hopper
3. Disc roller
4. Cutter



A

Damrow (chip) Mill

1. peg
2. openings

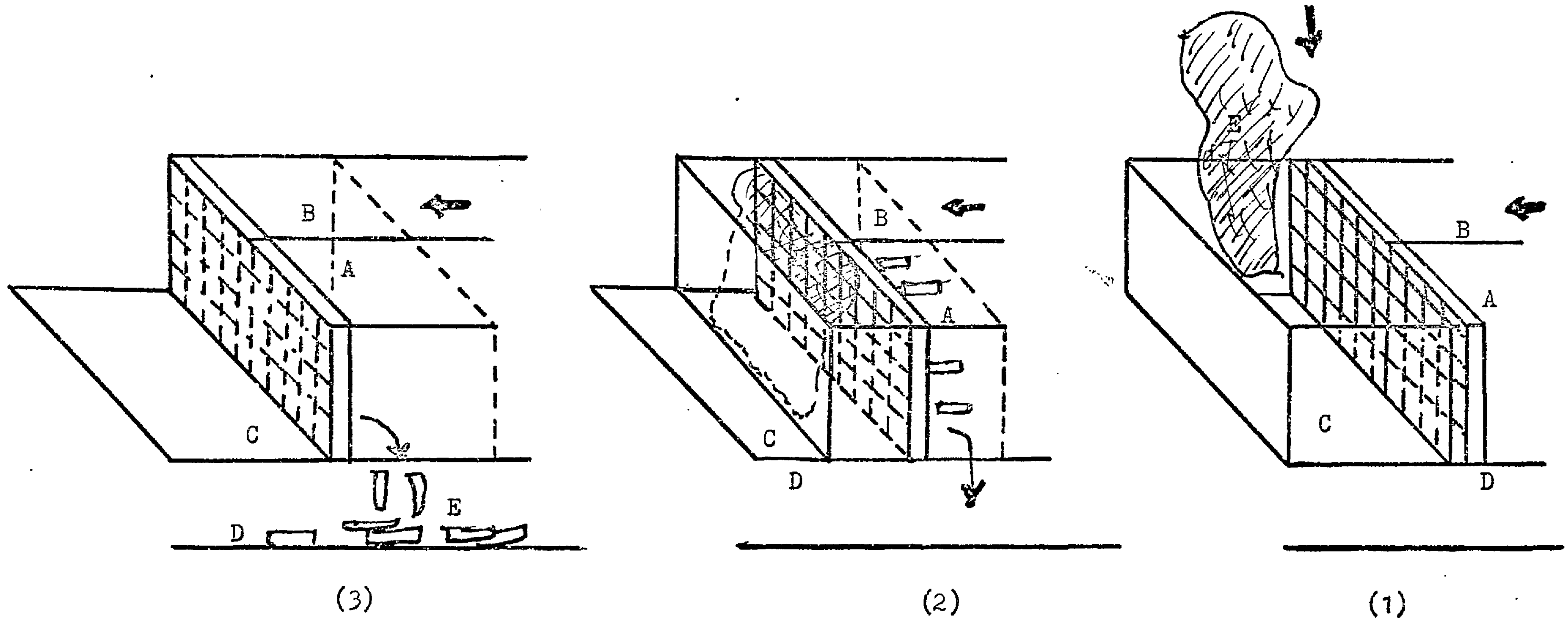


B

Peg mill

FIGURE 22

<u>Steps of curd milling in Bell-Siro CheeseMaker 3</u>



A. CheeseMaker 3 knife

B. Piston

C. Base

D. Conveyor

E. Cheddared curd slab

F. Milled curd

mill is cut by metal pegs rotating in opposite directions and the force applied tears the curd into shreds. The rotating circular cheese knife used in the Damrow mill cuts the curd with less tearing effect. In the CheeseMaker 3 milling section the cheese curd is cut by a grid with sharp edged blades being forced by a reciprocating piston through the curd.

The physical condition of the mills and the state of the resultant curd surface may have an effect on the development of seaminess in Cheddar cheese.

This experiment was planned to investigate the use of the above mentioned types of mill under commercial conditions.

C. Condition of the cutting edge of the CheeseMaker 3 knife

In the commercial version of the Bell-Siro CheeseMaker 3 equipment, the knife operates at 70 strokes per min. It is more likely that when a sharp bladed knife (grid) is used a clean cut surface will result. On the other hand if a blunt bladed knife is used, a rough surface may be produced on the curd pieces.

This experiment was set to investigate the effect of cutting edge of the CheeseMaker 3 of both sizes of 0.5 x 0.5 in (1.27 x 1.27 cm) and 0.75 x 0.75 in (1.91 x 1.91 cm).

D. Curd moisture

Czulak (1963) reported that cheese which contained low moisture tended to be more seamy. The moisture content of the curd at the time of milling differs from one factory to another. Dry curd tends to produce a rougher surface when milled in comparison to curd that contains more moisture. The author has found that the cheese produced in a commercial factory which has a high incidence of seamy cheese, contained a low moisture content (33 to 35 per cent).

In this experiment it was decided to study the effect of the moisture content of curd on the development of seaminess in this particular factory.

E. Time between milling and salt addition

After the curd is milled it is normal for salt to be added to the curd immediately. Thereafter curd and salt are mixed and placed in the moulds. No time is allowed between milling the curd and salt addition or between salt addition and placing the curd in the hoops. When the curd is milled, the resultant surface condition will depend mainly on the moisture content of the curd and on the type of milling machine. Drier curd tends to produce rough surfaced curd particles. When the salt is added immediately to the curd, the surface is hardened and the surface of the curd remains rough. When the milled curd is left for a time the surface tended to be smoother. Many research workers have commented on the importance of the time between milling and the addition of the salt. Sammis (1942) suggested that salting should be done about 20 min after milling. Wilster (1951) advised that the milled curd must be stirred until the cut surface of the curd dried, in about 20 to 30 min. Rice and Morris (1954) suggested that 30 to 45 min should elapse between milling and salting and reported that the addition of salt too soon after milling may cause excessive fat losses and a harsh bodied, open textured cheese. By allowing more time e.g. about 1 h longer, close-textured cheese resulted (Hood and Gibson, 1948). Morris (1966) reported that a mellowing time between milling and salt addition caused an improved body with a reduced moisture content. The texture was significantly improved only when the mellowing time was 30 min or more.

The condition of the cut surface of the curd affects the formation of pockets between the curd and the amount of the whey that could be trapped in these positions. This experiment was intended to investigate the effect of the condition of the surface of the curd on the formation of seams.

EXPERIMENTAL

Cheese making and treatment of the curd

A. Size of the milled curd

In a commercial Cheddar cheese factory, a vat of 2400 gal (10910.4 l) of milk was selected at random from a total of five vats, and was made into white Cheddar cheese according to the system of cheese making described on page 53. The production data is presented in Table 103 (Appendix A). The curd produced in this vat was used in tests.

When the titratable acidity of the curd reached 0.69 per cent lactic acid the curd was milled in 0.5 x 0.5 in (1.27 x 1.27 cm) CheeseMaker 3 milling section. The milled curd was automatically salted with 3.5 per cent (w/w) dry vacuum salt in the CheeseMaker 3, and placed in the moulds. Six moulds were picked at random from the line, and were left for 20 to 25 min before placing them in the air operated horizontal 10 in (25.4 cm) cylinder Crockatt press.

The milling section was then fitted with a 0.75 x 0.75 in (1.91 x 1.91 cm) grid knife, and further slabs of cheddared curd were milled with this knife. The curd was treated in the same way as the first batch. Another six moulds of salted curd were selected at random and left for 20 to 25 min before each batch was placed in the same press.

All the moulds were left in the press operated with compressed air at 80 psi (5.63 kgf/cm^2), for a pressing time of 18 h. The cheese were demoulded, hand wrapped in a waxed cellulose laminate, machine sealed, boxed, labelled and transferred to a curing room maintained at 50°F (10°C) until they were presented to the panel for scoring.

B. Type of mill

B.1. Experimental curd. Three vats each of 400 gal (1818.4 l) of milk were made into uncoloured Cheddar cheese on different occasions according to the system of cheese making described on page 58. The production details for each vat are given in Table 103.

When the titratable acidity of the cheddared curd reached about 0.65 per cent lactic acid, three lots of 44 lb (19.96 kg) were milled using the CheeseMaker 3 mill operated by hand using 0.5 in (1.27 cm) knife. The salt was added to the batches of curd by the procedure described on page 59 at the rate of 3 per cent (w/w) dry vacuum salt. After mixing, the salted curd was placed in the moulds.

By the time this was completed, another three 44 lb (19.96 kg) lots of curd were milled with an electrically operated Damrow mill and thereafter salted and treated in the same way.

A further three 44 lb (19.96 kg) lots of curd were milled with the peg mill, and the curd was treated as before.

All the cheese were then pre-pressed and placed in a horizontal cheese press operated with an air supply of 80 psi (5.63 kgf/cm^2) and a 10 in (25.4 cm) cylinder. The cheeses were left for about 18 h, hand wrapped in waxed cellulose film, machine sealed, boxed, and placed in the curing room at 50°F (10°C) until presented to the panel for scoring.

The same procedure was followed with the second vat (made on a different day) except that the first lot was milled with the peg mill, the second lot with the Damrow mill and the third with the CheeseMaker 3 hand operated mill section.

B.2. Commercial curd. In a commercial Cheddar factory, one vat of 2400 gal (10910 l) of milk was selected at random from a total of four vats, and was made into coloured Cheddar cheese. The method of manufacture was similar to that described on page 58. The complete production data are presented in Table 104 (Appendix A).

When the titratable acidity of the curd reached 0.65 per cent lactic acid, the curd was passed through a CheeseMaker 3 milling unit using 0.5 in (1.27 cm) size knife. From the conveyor belt between the milling and salting points 4 lots of 44 lb (19.96 kg) curd were taken, placed in plastics boxes measuring 16 in (40.6 cm) wide, 10 in (25.4 cm) deep and 24 in (70 cm) long and left aside. In the meantime another 4 lots of the curd were milled using the peg mill and then another 4 lots were milled using the power Damrow chip mill. From each lot, milled by separate mills, 44 lb (19.96 kg) were taken, salted at the same time as described on page 59 with dry vacuum salt at the rate of 3 per cent (w/w). The cheese were then left aside for about 20 to 25 min. Simultaneously one block of cheese was picked at random from the machine salted curd (with CheeseMaker 3) and treated in the same way as the above cheese. All cheese was treated afterwards as described on page 59.

The same procedure was repeated another three times giving four cheeses in each treatment. Dry vacuum salt was added at the rate of 3 per cent (w/w). All the cheese were left in a horizontal Crokkatt cheese press (10 in (25.4 cm) cylinder) at a compressed air supply of 80 psi (5.63 kgf/cm^2) and were left for 18 h. They were hand wrapped in waxed cellulose laminate, machine salted, boxed and placed in the curing room of the factory at 49°F (9.4°C) and 80 per cent RH until they were transferred to the curing room at the Department of Dairy Technology and kept at 50°F (10°C) and 80 per cent RH until they were presented to the panel.

C. Condition of the cutting grid in the Bell-Siro CheeseMaker 3

Two 400 gal amounts of pasteurised milk (161.5°F (72°C) for 15 s) were manufactured into coloured Cheddar cheese following the system of cheese making described on page 58. The production details appear on Table 105 (Appendix A).

When the titratable acidity of the curd in each vat reached 0.7 per cent lactic acid, about one third of the curd was milled with the CheeseMaker 3 milling section equipped with a 0.75 x 0.75 in (1.91 x 1.91 cm) knife grid (A). The mill was assembled in the laboratory as shown in Figure 19 except that a different size of press was used to operate the knife.

The knife was then replaced with another knife (obtained from another cheese factory) of the same size and an equal amount of curd was milled.

The third part was milled with an electrically operated Damrow chip mill.

Three lots of 44 lb (19.96 kg) curd of each part was taken and placed in a salting box as shown in Figure 9. Dry vacuum salt was added at the rate of 3 per cent (w/w), salting was carried out as that described on page 59.

After salting the curd and the resultant cheese was treated as described on page 59.

D. Curd moisture

Using the same milk and starters, as was used in the commercial scale production, three vats of 100 gal (454.6 l) milk were made into uncoloured Cheddar cheese on three separate days following the system of cheese making described on page 54. The production details are presented in Table 106, (Appendix A).

When the titratable acidity of the cheddared curd reached the required level, the curd was milled by a 0.5 in (1.27 cm) milling section of the Bell-Siro CheeseMaker 3. Two 44 lb (19.96 kg) lots of curd were taken and placed in plastic salting boxes. On each occasion milled curd (CheeseMaker 3) from one of the normal factory's production. On two of the three occasions milled curd (CheeseMaker 3) from one vat of the factory's normal production was taken at the same time, salted and treated in the same way.

E. Time between milling and salt addition

One vat of 400 gal (1818.4 l) of pasteurised milk (161.5^{o}F (72^{o}C) for 15 s) was made into coloured Cheddar cheese according to the method described on page 58. The details of the production are given in Table 107, (Appendix A).

When the titratable acidity of the whey from the curd reached 0.7 per cent lactic acid, the curd was milled with 0.5 x 0.5 in (1.27 x 1.27 cm) knife of the Bell-Siro CheeseMaker 3 operated by means of compressed air as shown in Figure 19.

Two 44 lb (19.96 kg) lots of curd were taken and placed in plastic boxes. To the first lot dry vacuum salt was added at the rate of 3 per cent (w/w) as described on page 55, and was placed in a hoop left aside for 25 min and then placed in the 10 in (25.4 cm) cylinder horizontal Crockatt cheese press supplied with air at 80 psi (5.63 kgf/cm^2). The second lot was left aside for 50 min, stirred after an interval of 12 min to prevent the curd from matting. The salt was added at the same rate and manner and was left aside for 20 min before it was placed in the same press.

This procedure was repeated another three times giving 4 cheese in each treatment.

After pressing the cheese were treated as described on page 55, and kept in a curing room maintained at 50°F (10°C) until they were presented to the panel for grading.

Scoring the cheese

All the cheese included in this section were presented to the scoring panel and scored at 8 weeks old according to the procedure described in page 60.

Chemical analysis

Samples from the pieces presented in the scoring were analysed for salt, moisture content, salt in aqueous phase, and pH according to the methods described on pages 47 and 48 respectively.

Determination of the pattern of seams

Representative cuts of 4 x 3.25 in (10.2 x 8.3 cm) were taken from the pieces which were presented to the panel from each treatment in the study of the size of the milled curd. Transparent paper was placed on the top of these pieces, and the seams were traced on them. The number of the curd particles which made the surface was determined, and the numbers of the seams that appeared across the piece were also counted. The total length of the lines in both samples were measured.

From the cut pieces presented to the grading panel for the cheese produced by different types of mill from commercial curd (B2) representative pieces (2 x 3 in (5 x 6 cm) from each treatment were taken and placed together and photographed to compare the intensity of the seams.

RESULTS

A. Size of milled curd

The mean scores given by the panel to the cheeses are presented in Table 50. Results of chemical analysis are presented in Table 51. The analysis of variance is presented in Tables 52 to 55.

The pattern of the seams in each treatment is presented in Figure 23. The number of the seams across the piece taken from the curd milled in 0.5 in (1.27 cm) were 15 compared to 11 present in the curd milled with 0.75 in (1.91 cm). The length of the seams that appears on the cut surface was 68.9 in (175 cm) for the first milling grid compared to 48.8 in (124 cm) for the second. The number of the particles that made up each surface was 61 for the first and 40 for the second treatment.

B. Type of mill

B.1. Experimental curd. The grading scores are presented in Table 56. The results of the analysis of variance of these results are presented in Tables 58 to 61. The results of various chemical determinations are presented in Table 57.

The analysis of variance showed that seaminess was effected significantly ($p < 0.001$) by the type of mill used for milling the curd. The highest level of seaminess (mean 6.6 points) was presented in the cheese prepared from curd milled with the 0.5 in (1.27 cm) CheeseMaker 3 knife operated by hand.

TABLE 50

Mean scores given by the scoring panel (4 judges) to Cheddar cheese (aged 8 weeks) made with curd milled with 0.5 in (1.27 cm) and 0.75 in (1.91 cm) knives of the CheeseMaker 3 equipment

Mill size (in/cm)	Replicate	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
0.5 (1.27)	1	9.75	6.50	2.25	8.00	7.75	6.50
	2	10.00	6.75	3.25	7.75	8.50	6.25
	3	9.75	7.50	3.00	8.40	7.50	6.75
	4	10.00	6.50	2.00	8.00	8.25	6.75
	5	10.00	7.00	2.50	7.25	8.25	6.75
	6	10.00	6.50	2.25	8.25	7.50	6.25
0.75 (1.91)	1	10.00	7.50	2.25	7.75	8.50	6.75
	2	10.00	7.00	1.25	6.75	8.50	6.50
	3	10.00	7.25	2.25	7.00	8.00	7.50
	4	10.00	6.50	0.75	7.00	9.25	6.75
	5	10.00	7.50	2.75	7.25	8.25	7.75
	6	10.00	6.50	2.25	6.75	8.00	6.50

TABLE 51

Chemical analysis of Cheddar cheese (aged 8 weeks) made with curd milled with 0.5 in (1.27 cm) and 0.75 in (1.91 cm) knives of the CheeseMaker 3 equipment

Mill size (in (cm)	Replicate	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
0.5 (1.27)	1	5.28	34.08	1.99	5.84
	2	5.26	34.18	2.01	5.88
	3	5.25	33.78	2.02	5.97
	4	5.21	34.23	2.01	5.87
	5	5.15	34.43	1.85	5.34
	6	5.25	34.05	2.04	5.99
0.75 (1.91)	1	5.16	34.67	1.79	5.16
	2	5.15	34.16	1.74	5.09
	3	5.15	34.87	1.64	4.70
	4	5.16	35.00	1.65	4.71
	5	5.23	34.88	1.68	4.82
	6	5.20	35.01	1.77	5.05

TABLE 52

Analysis of variance; seaminess in commercial Cheddar cheese aged 4 and 8 weeks made with curd milled with 0.5 in (1.27 cm) and 0.75 in (1.91 cm) knives of the CheeseMaker 3 equipment

		4 weeks old		8 weeks old	
Source of variation	D.F.	Mean square	F	Mean square	F (pooled E)
Treatments	1	6.02	-	0.0833	-
Experimental error	10	4.53		0.0334	
Judges	3	35.69	62.61***	0.0278	-
Judges x treatments	3	1.57	-	0.0278	-
Sampling error	30	0.57		0.0444	
Total	47				
Pooled E	40			0.0417	

Means of seaminess	4 weeks old	8 weeks old
0.5 in (1.27 cm) knife	4.96	9.92
0.75 in (1.91 cm) knife	5.67	10.00
Standard error of difference ±	0.61	0.06

- Not significant ($p > 0.05$)

*** Significant ($p < 0.001$)

TABLE 53

Analysis of variance; fusion, openness, body of commercial Cheddar cheese aged 8 weeks made with curd milled with 0.5 in (1.27 cm) and 0.75 in (1.91 cm) knives of the CheeseMaker 3 equipment

		Fusion		Openness		Body	
Source of variation	D.F.	Mean square	F	Mean Square	F	Mean square	F
Treatments	1	1.6876	-	7.52	-	7.52	14.46**
Experimental error	10	0.4872		1.90		0.52	
Judges	3	1.7986	5.42**	1.69	7.04**	13.41	42.80***
Judges x treatments	3	0.9653	-	0.52	-	0.35	-
Sampling error	30	0.3320		0.24		0.36	
Total	47						
Means							
0.5 in (1.27 cm) Knife			6.75		2.71		8.04
0.75 in (1.91 cm) Knife			7.12		1.92		7.25
Standard error of difference ±			0.20		0.40		0.21

- Not Significant ($p > 0.05$)
** Significant ($p < 0.01$)
*** Significant ($p < 0.001$)

TABLE 54

Analysis of variance; flavour and colour of commercial Cheddar cheese aged 8 weeks made with curd milled with 0.5 in (1.27 cm) and 0.75 in (1.91 cm) knives of the CheeseMaker 3 equipment

		Flavour		Colour	
Source of variation	D.F.	Mean square	F	Mean square	F
Treatments	1	2.52	-	1.33	-
Experimental error	10	0.80		0.44	
Judges	3	3.69	5.12**	18.61	62.03***
Judges x treatments	3	0.74	-	1.17	3.90*
Sampling error	30	0.72		0.30	
Total	47				
Means					
0.5 in (1.27 cm) knife		7.96		6.50	
0.75 in (1.91 cm) knife		8.42		6.83	
Standard error of difference ±		0.26		0.19	

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

*** Significant ($p < 0.001$)

TABLE 55

Analyses of variance; salt content, moisture and pH of commercial Cheddar cheese aged 8 weeks made with curd milled with 0.5 in (1.27 cm) and 0.75 in (1.91 cm) knives of the CheeseMaker 3 equipment

		Salt content(%)		Moisture (%)		pH	
Source of variation	D.F.	Mean square	F	Mean square	F	Mean square	F
Treatments	1	0.2269	49.33***	1.2224	15.77***	0.01080	6.14*
Error	10	0.0046		0.0775		0.00176	
Total	11						

Means	Salt content(%)	Moisture (%)	pH
0.5 in (1.27 cm) Knife	1.98	34.12	5.235
0.75 in (1.91 cm) Knife	1.71	34.76	5.175
Standard error of difference ±	0.04	0.16	0.024

- Not Significant ($p > 0.05$)

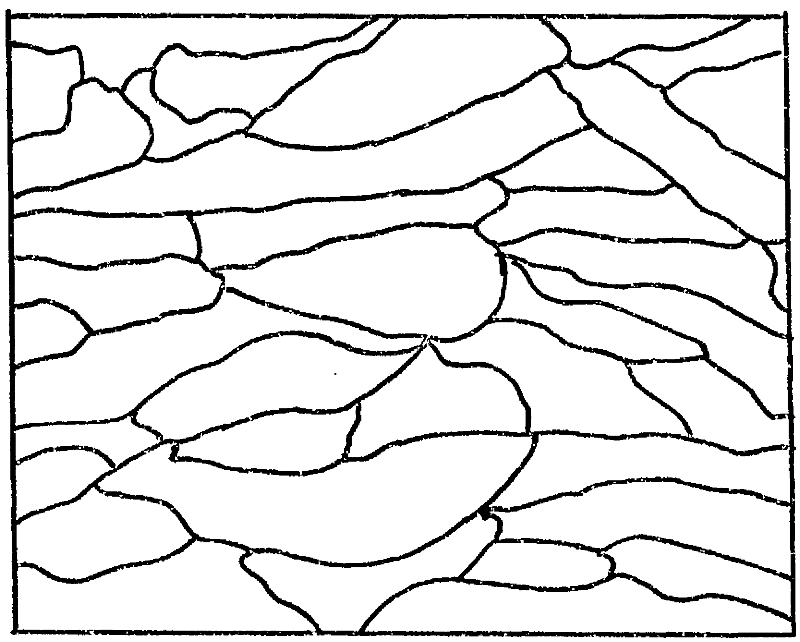
* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

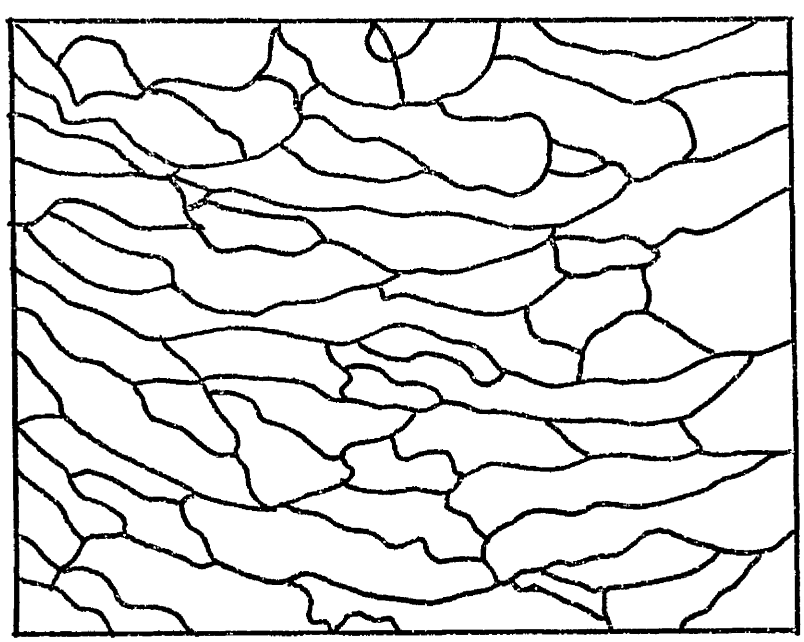
*** Significant ($p < 0.001$)

FIGURE 23

Seams intensity in 4 in long x 3.25 in wide (10.2 x 8.3 cm) Cheddar cheese (commercial curd) cut surface at the age of 8 weeks made from curd milled with 0.5 in (1.27cm) and 0.75 in (1.91 cm) CheeseMaker 3 knife installed commercially



A. 0.75 in (1.91 cm) CheeseMaker 3



B. 0.5 in (1.27 cm) CheeseMaker 3

TABLE 56

Mean scores of the panel (5 judges) given to experimental Cheddar cheese aged 8 weeks made with curd milled with CheeseMaker 3, peg, and Damrow mills

Mill type	Replicate	Vat	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
CheeseMaker 3	1	A	6.0	7.2	1.4	7.8	8.8	7.6
	2	A	4.4	6.6	1.4	7.6	8.2	7.6
	3	A	3.4	6.8	0.4	7.8	8.6	8.0
	4	B	7.8	6.2	0.6	7.2	8.6	7.4
	5	B	7.8	6.0	0.8	7.2	8.2	7.6
	6	B	8.6	6.2	0.6	7.0	7.0	7.4
Peg	1	A	0.2	6.4	0.4	7.8	8.2	8.0
	2	A	0.0	5.8	0.4	8.0	7.8	8.4
	3	A	0.2	5.0	0.6	8.2	8.0	7.2
	4	B	0.8	6.0	1.6	7.4	7.0	7.8
	5	B	0.0	6.6	0.6	7.0	8.0	8.2
	6	B	0.6	5.8	0.4	7.4	7.0	7.4

cont.

TABLE 56

Damrow	1	A	0.4	6.4	1.2	8.4	8.2	7.6
	2	A	0.2	6.2	0.4	8.0	8.0	8.6
	3	A	1.2	6.8	0.4	8.0	7.2	8.2
	4	B	0.6	7.0	0.4	7.0	8.0	8.4
	5	B	0.6	7.0	0.8	7.0	8.6	8.4
	6	B	0.8	7.6	1.4	7.2	8.8	8.2

TABLE 57

Chemical analyses of experimental Cheddar cheese aged 8 weeks made with curd milled with CheeseMaker 3, peg and Damrow mills

Mill type	Replicate	Vat	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
CheeseMaker 3	1	A	5.20	34.24	1.94	5.8
	2	A	5.22	34.50	1.81	5.3
	3	A	5.21	34.38	1.94	5.6
	4	B	5.16	33.78	1.85	5.2
	5	B	5.19	33.55	2.00	6.0
	6	B	5.22	33.94	2.06	6.1
Peg	1	A	5.20	34.10	2.15	6.3
	2	A	5.22	34.92	2.33	6.7
	3	A	5.38	33.10	2.50	7.6
	4	B	5.24	35.59	2.33	6.6
	5	B	5.26	35.62	2.37	6.7
	6	B	5.17	35.62	2.30	6.5
Damrow	1	A	5.20	35.13	1.91	5.4
	2	A	5.21	33.51	1.97	5.9
	3	A	5.19	34.30	1.97	5.2
	4	B	5.15	36.55	1.86	5.1
	5	B	5.15	36.50	2.01	5.5
	6	B	5.19	35.72	2.01	5.6

TABLE 58

Analysis of variance; seaminess in experimental Cheddar cheese aged 4 and 8 weeks made with CheeseMaker 3, Peg and Damrow mills

Source of variation	D.F.	At 4 weeks Mean square	At 4 weeks F	At 8 weeks Mean square	At 8 weeks F
Treatments	2	389.48	160.94***	345.01	171.64***
Vats	1	84.10	34.75***	37.38	18.60***
Treatments x vats	2	93.10	38.47***	26.81	13.33***
Experimental error	12	2.42		2.01	
Judges	4	4.18	13.06***	7.93	18.44***
Judges x treatments	8	1.56	4.87***	6.52	15.16***
Judges x vats	4	1.04	3.25*	0.21	-
Treatments x judges x vats	8	0.88	2.75*	0.19	-
Sampling error	48	0.32		0.43	
Total	89				

Means	At 4 weeks	At 8 weeks
CheeseMaker 3	6.60	6.33
Peg	0.07	0.30
Damrow	0.70	0.63
Standard error of difference ±	0.40	0.37

- Not significant ($p > 0.05$), * Significant ($p < 0.05$), *** Significant ($p < 0.001$)

TABLE 59

Analyses of variance; fusion, openness, body, flavour scores and pH of 8 weeks-old experimental Cheddar cheese made with CheeseMaker 3, peg, and Damrow mills

	Means of scores given by the grading panel				
	0.5 in (1.27 cm) CheeseMaker 3	Peg	Damrow	Standard error of difference ±	Degree of significance
Fusion	6.50	5.93	6.53	0.31	-
Openness	0.87	0.67	0.77	0.26	-
Body	7.43	7.60	7.60	0.18	-
Flavour	8.30	8.00	8.13	0.31	-
pH	5.20	5.18	5.24	0.02	-

\- Not Significant ($p > 0.05$)

TABLE 60

Analyses of variance: colour experimental Cheddar cheese aged 8 weeks made with CheeseMaker 3, Peg and Damrow mills

Source of variation	D.F.	Mean square	F
Treatments	2	3.08	4.27*
Vats	1	0.04	-
Treatments x vats	2	0.41	-
Experimental error	12	0.72	
Judges	4	6.03	27.41***
Judges x treatments	8	0.33	-
Judges x vats	4	0.46	-
Treatments x vats x Judges	8	0.49	2.23*
Sampling error	48	0.22	
Total	89		

Means

CheeseMaker 3	7.60
Peg	8.23
Damrow	7.83
Standard error difference ±	0.22

- Not Significant ($p > 0.05$)

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

TABLE 61

Analysis of variance; salt, salt in aqueous phase and moisture of experimental Cheddar cheese aged 8 weeks made with CheeseMaker 3, Peg and Damrow mills

		Salt (%)		Salt in aqueous phase (%)		Moisture (%)	
Source of variation	D.F.	Mean square	F	Mean square	F	Mean square	F
Treatments	2	0.2984	31.08***	2.3943	20.46***	2.2708	7.74**
Vats	1	0.0040	-	0.2960	-	4.1280	14.07**
Treatments x vats	2	0.0021	-	0.1780	-	2.8478	9.71**
Error	12	0.0096		0.1170		0.2934	
Total	17						

Means	Salt (%)	Salt in aqueous phase (%)	Moisture (%)
CheeseMaker 3	1.93	5.68	34.06
Peg	2.33	6.70	34.81
Damrow	1.96	5.55	35.28
Standard error of difference ±	0.06	0.20	0.31

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

*** Significant ($p < 0.001$)

The colour of the resultant cheeses was significantly ($p < 0.05$) affected by the type of mill used, the cheese made with the CheeseMaker 3 knife grid was given the least scores.

Salt content in the final cheese was significantly ($p < 0.001$) affected. The cheese made with the peg mill retained more salt than cheese made with other types of mill.

The level of salt in the aqueous phase of these cheese was significantly ($p < 0.001$) affected by the type of mill used.

There was a significant difference ($p < 0.01$) between the moisture content of cheese produced with different types of mill. The cheese prepared with the CheeseMaker 3 mill contained the least amount of moisture.

The type of mill had no significant effect ($p > 0.05$) on fusion, openness, body, flavour, or the pH of the cheeses.

B.2. Commercial curd. The results of scoring the cheese are presented in Table 62. The results of chemical analyses of samples taken from the cheese are presented in Table 63.

The appearance of the seaminess induced by different treatments is shown in Figure 24.

The analysis of variance of the scores presented in Tables 64 to 66 indicates a significant ($p < 0.001$) difference in the degree of seaminess present in different treatments.

The body of the cheese was significantly ($p < 0.05$) influenced by the type of mill.

Colour differed significantly ($p < 0.001$) with the treatment.

The pH of cheese was significantly affected ($p < 0.05$) while the moisture content, the salt content and the salt in aqueous phase

TABLE 62

Mean scores of the panel (5 judges) given to Cheddar cheese made with commercial curd milled with Damrow, CheeseMaker 3 and Peg mills at 8 weeks of age

Mill type	Replicate	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
Damrow	1	7.0	6.8	1.4	7.8	9.0	8.0
	2	5.4	6.8	1.4	7.6	9.2	8.2
	3	2.4	6.8	1.8	7.8	8.8	8.8
	4	3.0	5.4	2.4	7.2	8.8	8.0
CheeseMaker 3	1	9.6	6.2	1.8	7.8	9.2	7.4
	2	9.6	6.0	1.2	7.6	9.2	7.6
	3	9.8	6.4	1.2	7.4	9.2	7.6
	4	10.0	6.2	1.2	7.8	9.0	7.4
Peg	1	2.8	6.4	0.8	8.2	9.2	7.6
	2	5.2	5.0	1.0	6.8	8.2	7.8
	3	3.6	5.2	0.4	7.4	8.8	7.6

Cont. TABLE 62

	4	4.2	6.4	0.8	7.6	8.8	7.4
CheeseMaker 3	1	10	6.8	0.6	8.2	9.4	6.4
line	2	10	6.4	1.2	8.2	9.2	7.2
	3	10	6.8	1.6	8.2	9.4	7.0
	4	10	6.2	1.4	8.8	8.8	7.0

TABLE 63

Chemical analyses of commercial Cheddar cheese aged 8 weeks made with curd milled with Damrow, CheeseMaker 3 and Peg mills

Type of mill	Replicate	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
Damrow	1	5.05	34.03	1.70	5.0
	2	5.02	33.68	1.73	5.1
	3	5.05	33.83	1.77	5.2
	4	5.02	34.03	1.72	5.1
0.5 in (1.27 cm)	1	5.02	33.83	1.83	5.4
CheeseMaker 3	2	5.02	33.82	1.79	5.3
	3	5.05	33.96	1.82	5.4
	4	5.00	34.04	1.80	5.3
Peg	1	5.04	33.76	1.83	5.4
	2	5.03	33.98	1.85	5.4
	3	5.03	33.83	1.89	5.6
	4	5.01	33.70	1.90	5.6
Machine salted	1	5.04	33.39	2.01	6.0
0.5 in (1.27 cm)	2	5.11	32.43	2.02	6.2
CheeseMaker 3	3	5.04	33.04	1.99	6.0
	4	5.12	33.10	2.04	6.2

FIGURE 24

Seaminess in commercial Cheddar cheese (aged 8 weeks) made with curd milled with Damrow, CheeseMaker 3 and Peg mills

1. Peg mill
2. CheeseMaker 3, 0.5 in (1.27 cm)
3. Damrow
4. CheeseMaker 3, 0.5 in (1.27 cm) machine salted

TABLE 64

Analyses of variance; seaminess in Cheddar cheese aged 4 and 8 weeks made with commercial curd milled with Damrow, CheeseMaker 3 (2 units) and Peg mills

Source of variation	D.F.	Mean square	F	Mean square	F
Treatment	3	211.10	77.61***	206.79	30.23***
Experimental error	12	2.72		6.84	
Judges	3	23.43	31.24***	18.54	20.37***
Judges x treatment	9	3.76	5.01***	5.22	5.74***
Sampling error	36	0.75		0.91	
Total	63				
Standard error of difference: Treatments ±		0.58		0.92	

*** Significant ($p < 0.001$)

TABLE 65

Analyses of variance: body and colour of Cheddar cheese aged 8 weeks made with commercial curd milled with Damrow, CheeseMaker 3 and Peg mills

		Body		Colour	
Source of variation	D.F.	Mean square	F	Mean square	F
Treatment	3	2.47	3.98*	7.10	14.20***
Experimental error	12	0.62		0.50	
Judges	3	0.77	-	8.89	25.40***
Judges x treatment	9	0.79	-	2.10	6.00***
Sampling error	36	0.40		0.35	
Total	63				
Standard error of difference ±		0.28		0.25	

- Not Significant ($p > 0.05$)

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

TABLE 66

Analyses of variance; pH, Moisture (%), Salt (%) and salt in aqueous phase (%) of Cheddar cheese aged 8 weeks made of curd milled with Damrow, CheeseMaker 3 and Peg mills

Source of variation	D.F.	pH Mean square	pH F	Moisture (%) Mean square	Moisture (%) F	Salt (%) Mean square	Salt (%) F	Salt in aqueous phase (%) Mean square	Salt in aqueous phase (%) F
Treatment	3	0.002523	3.64*	0.7884	14.49***	0.7929	14.34***	0.7225	78.52***
Error	12	0.000694		0.0544		0.0553		0.0092	
Total	15								
Standard error of difference ±		0.019		0.16		0.17		0.07	

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

were significantly ($p < 0.001$) different with the various treatments.

Fusion, openness and flavour were not significantly ($p > 0.05$) affected.

C. Condition of the cutting edge of CheeseMaker 3 knife

The results of the scoring of the cheese are presented in Table 67. The chemical analyses undertaken when the cheese were 8 weeks old are presented in Table 68.

D. Curd moisture

The results of the scoring the cheese at 8 weeks old are presented in Table 69. The results of the chemical analyses of the resultant cheese appear in Table 70.

These results indicated that very seamy cheese resulted when the curd was milled with 0.5 in (1.27 cm) knife of the Cheese-Maker 3 milling section. The moisture content in the final cheese ranged from 35,22 to 38.56 per cent.

E. Time between milling and addition of salt

The scoring results when the cheese aged 8 weeks are presented in Table 71. The chemical analyses of cheese are presented in Table 72.

TABLE 67

Mean scores given by the scoring panel (5 judges) to experimental coloured Cheddar cheese aged 8 weeks made with curd milled with CheeseMaker 3 milling section equipped with two (A and B) 0.75 in (1.91 cm) knives and electrically operated Damrow mills

Type of mill	Replicate	Vat	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
CheeseMaker 3 (A)	1	A	4.0	6.4	1.0	7.6	8.6	8.6
0.75 in (1.91 cm)	2	A	2.2	6.0	2.4	7.8	8.2	8.2
	3	A	1.8	6.2	1.6	8.0	8.4	8.2
	4	B	7.6	5.6	4.2	7.4	8.6	7.4
	5	B	9.2	5.2	4.6	7.4	8.8	7.6
	6	B	8.4	5.4	3.6	7.6	8.2	7.0
CheeseMaker 3 (B)	1	A	1.6	6.0	2.0	7.8	8.8	8.6
0.75 in (1.91 cm)	2	A	2.0	5.8	1.4	7.0	8.4	8.6
	3	A	2.4	5.8	1.6	8.0	8.4	8.6
	4	B	8.8	5.4	3.8	6.4	8.0	7.6
	5	B	7.4	6.6	3.0	6.8	8.2	8.0

Cont. TABLE 67

	6	B	6.6	6.0	2.8	7.4	8.2	7.4
Damrow	1	A	0.6	5.8	2.0	7.6	8.4	8.4
	2	A	1.0	5.8	1.8	8.4	8.6	8.2
	3	A	0.2	5.6	1.0	7.6	8.0	8.4
	4	B	3.4	6.0	3.0	7.6	8.4	7.8
	5	B	4.0	5.6	2.6	7.8	8.4	8.2
	6	B	2.4	5.8	2.6	7.6	8.2	8.0

TABLE 68

Chemical analyses of experimental coloured Cheddar cheese aged 8 weeks made with curd milled with CheeseMaker 3 milling section (equipped with 0.75 in (1.91 cm) knives A and B) and electrically operated Damrow mills

Type of mill	Replicate	Vat	pH	Moisture (%)	Salt (%)	Salt in aqueous phase
CheeseMaker 3 (A)	1	A	5.04	33.92	1.71	5.0
0.75 in (1.91 cm)	2	A	5.05	32.67	1.55	4.8
	3	A	5.05	33.77	1.72	5.1
	4	B	5.15	34.43	1.75	5.1
	5	B	5.15	33.14	1.67	5.0
	6	B	5.13	34.73	1.64	4.7
CheeseMaker 3 (B)	1	A	5.03	33.99	1.75	5.2
0.75 in (1.91 cm)	2	A	5.04	33.92	1.71	5.0
	3	A	5.04	33.84	1.72	5.1
	4	B	5.15	35.32	1.67	4.7
	5	B	5.09	34.02	1.70	5.0
	6	B	5.11	34.97	1.75	5.0
Damrow	1	A	5.06	33.39	1.68	5.0
	2	A	5.06	33.38	1.66	5.0
	3	A	5.06	33.33	1.78	5.3
	4	B	5.11	34.97	1.75	5.0
	5	B	5.11	33.24	1.82	5.5
	6	B	5.12	34.31	1.78	5.2

TABLE 69

Mean scores given by the panel (5 judges) to Cheddar cheese aged 8 weeks made with commercial and experimental curd milled with 0.5 in (1.27 cm) of different moisture content, CheeseMaker 3 mill

Type of curd	Vat	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
Commercial curd	A	5.2	7.2	4.0	7.6	8.4	8.4
	A	5.2	7.4	3.4	7.4	8.8	8.8
	C	8.8	7.0	3.4	7.4	8.0	7.8
	C	10.0	6.8	1.6	8.2	8.4	7.8
Experimental curd	B	9.8	6.6	3.4	7.4	8.4	7.8
	B	9.8	6.4	2.4	7.2	7.8	8.0
	D	9.6	6.4	3.0	7.6	8.0	6.6
	D	10.00	6.2	3.8	7.6	7.6	6.8
	E	9.0	6.2	5.6	7.2	8.4	7.4
	E	10.0	6.2	4.4	7.4	7.4	6.8

TABLE 70

Chemical analyses of Cheddar cheese aged 8 weeks made with commercial and experimental curd of different moisture content milled with 0.5 in (1.27 cm) CheeseMaker 3 mill

Type of curd	Vat	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
Commercial curd	A	5.19	35.74	1.75	4.8
	A	5.18	35.94	1.70	4.7
	C	5.13	35.17	1.76	5.0
	C	5.13	35.22	1.77	5.0
Experimental curd	B	5.19	36.83	1.67	4.5
	B	5.18	36.87	1.65	4.5
	D	5.12	36.52	1.66	4.6
	D	5.13	36.65	1.68	4.6
	E	5.14	38.49	1.45	3.8
	E	5.17	38.56	1.42	3.7

TABLE 71

Mean score given by the panel (4 judges) to coloured experimental Cheddar cheese aged 8 weeks made with milled curd held for 50 minutes before addition of salt

Time milling to salting (mins)	Replicate	Vat	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
No time	1	A	2.3	6.4	2.3	7.8	7.8	7.3
	2	A	2.3	6.8	3.5	7.3	7.8	7.5
	3	A	2.0	6.8	3.8	7.5	7.8	5.3
	4	A	2.5	7.0	3.8	7.3	8.3	6.3
	5	B	2.0	7.5	4.8	7.8	8.5	7.5
	6	B	2.0	6.8	5.3	7.8	7.5	7.0
	7	B	2.3	6.0	4.8	7.5	8.3	7.3
	8	B	2.8	6.5	4.8	7.5	8.3	7.3
50 min	1	A	3.0	7.0	2.3	8.0	8.0	7.3
	2	A	2.0	6.8	3.8	7.8	7.5	7.5
	3	A	3.8	7.0	3.3	8.3	8.5	6.8
	4	A	2.0	7.0	2.5	8.0	8.3	7.5
	5	B	1.8	6.8	4.3	6.8	7.5	7.3
	6	B	2.3	6.3	4.3	7.8	8.3	7.3
	7	B	3.3	6.3	5.0	8.0	8.5	7.5
	8	B	3.0	7.0	3.8	7.0	7.8	7.5

TABLE 72

Chemical analyses of experimental coloured Cheddar cheese aged 8 weeks given 50 minutes mellowing time between milling and addition of salt

Time milling to salting (mins)	Replicate	Vat	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
No time	1	A	5.19	34.53	1.87	5.4
	2	A	5.14	34.42	1.78	5.2
	3	A	5.15	34.40	1.74	5.1
	4	A	5.16	33.68	1.78	5.3
	5	B	5.14	35.07	1.86	5.3
	6	B	5.16	34.71	1.85	5.3
	7	B	5.13	33.71	1.78	5.3
	8	B	5.13	35.41	1.77	5.0
50 min	1	A	5.16	34.34	1.75	5.1
	2	A	5.14	34.54	1.64	4.8
	3	A	5.12	34.20	1.68	4.9
	4	A	5.13	32.70	1.72	5.3
	5	B	5.14	34.67	1.78	5.1
	6	B	5.16	34.55	1.75	5.1
	7	B	5.14	34.34	1.79	5.2
	8	B	5.12	33.50	1.66	5.0

DISCUSSION

A. Size of milled curd

Figure 23 shows that the seams appear more intense in cheese made from curd milled with the 0.5 in (1.27 cm) than that produced from milled curd of larger size. This is also demonstrated by the number of lines across the face of the cheese and also by the length of these lines.

These results indicated that more seams appeared in the cheese made of curd milled in 0.5 in (1.27 cm) knife in comparison to that present in the cheese produced from the same curd milled with 0.75 in (1.91 cm).

The results of the analysis of variance presented in Table 52 indicate that seaminess was not significantly affected ($p > 0.05$) by the size of the knife used in the CheeseMaker 3 milling section. The resultant cheese from both treatments were seamy with a mean score of 9.92 for the cheese milled with the 0.5 in (1.27 cm) knife, and 10.00 for that milled with the 0.75 in (1.91 cm) knife.

The mean score for seaminess in the cheese when scored at 4 weeks and 8 weeks of age shows that seaminess increased significantly ($p < 0.001$) with age. The mean scores for seaminess of the cheese made with 0.5 in (1.27 cm) and 0.75 in (1.91 cm) knives were 4.96 and 5.67 respectively when the cheese were 4 weeks of age, and 9.92 and 10 respectively at 8 weeks of age.

The fusion mean scores for cheese made by both treatments were almost the same with a mean score of 6.75 points (0.5 in (1.27

cm) knife) and 7.12 points (0.75 in (1.91 cm) knife). There was no significant difference ($p > 0.05$) in the degree of openness present in all cheese which were of close texture (2.31 points). The size of the milled curd did not cause a significant difference ($p > 0.05$) in the flavour. The resultant cheese were of good flavour with a mean score of 7.96 for cheese made with a 0.5 in (1.27 cm) knife and 8.43 points for those made with the 0.75 in (1.91 cm) knife.

The body of the cheese was significantly ($p < 0.01$) affected by the size of the milled curd. Slightly weaker bodied cheese (7.25 points - mean score) resulted when a 0.75 in (1.91 cm) knife was used compared to 8.04 points for the cheese resulted when 0.5 in (1.27 cm) was used. This difference was evident even though the curd used in all the treatment was of low moisture content.

The colour of the cheese was significantly ($p < 0.01$) affected by the size of the knife used. A low mean score (6.50 points) was given to the colour of the cheese made with the smaller size mill while a slightly higher mean score was given to cheese produced with the larger size knife (6.83 points). This difference in the mean scores may be caused by the presence of more seams in the cheese when smaller size knife was used compared to the number of seams present when larger size of milled curd was used.

The chemical composition of the resultant cheese was influenced significantly by the different treatments. The amount of salt retained in the final cheese made with the 0.5 in (1.27 cm) knife was significantly ($p < 0.001$) higher (1.98 per cent) than that retained in the other cheese (1.71 per cent).

The moisture content of the cheese (34.76 per cent) made with the 0.75 in (1.91 cm) knife was significantly ($p < 0.01$) higher than that of cheese made with the 0.5 in (1.27 cm) knife (34.12 per cent).

There was a significant ($p < 0.05$) difference in the pH of the cheese. When the 0.5 in (1.27 cm) knife was used, the pH of resultant cheese was higher than that of cheese made with the other knife (0.75 in (1.91 cm). The pH readings were 5.235 and 5.175 respectively. This effect may be due to the higher salt concentration in the aqueous phase in the cheese made with the smaller curd pieces (5.8 per cent) compared to that of cheese made with larger curd (4.91 per cent).

B. Type of mill

A.1. Experimental curd. From the results of scoring, it is evident that seamy cheese were produced in these trials (9.8 points). In these trials the cheese knife was used in the CheeseMaker 3 unit installed in the laboratory.

The force in the CheeseMaker 3 knife applied to the curd may cause the surface of the curd to be more rough than that produced by the other types of mill. Although in the equipment described above the equipment was operated by hand and so the speed of the knife and the force applied was not equal to that applied in the actual mechanically operated machine. Seaminess was present in the resultant cheese.

The analysis of variance of the scores given to seaminess when the cheese was 4 weeks of age showed a significant ($p < 0.001$)

difference between cheese produced from curd milled with CheeseMaker 3, Peg, and Damrow mill. This difference was also significant ($p < 0.001$) when the cheese was scored at 8 weeks of age.

The mean scores of the treatments which are presented in Table 58 , shows the difference in the degree of seaminess found in these cheeses. The mean score for seaminess in the cheese made with the CheeseMaker 3 mill was 6.6 compared to the mean scores of 0.3 and 0.63 given to cheese made with Peg and electrically operated Damrow chip mill respectively.

The higher degree of seaminess reported in the cheese made with the CheeseMaker 3 mill may be caused by the cutting action producing a rough surface on the curd piece. As these pieces later knit together gaps may be formed and the gaps between them, in whey may be trapped. Calcium orthophosphate may form in the area between the pieces from the whey and this could result in the formation of the white lines.

The results also showed that the colour of the cheese which contained more seams was given the least score, indicating that the presence of the seams in the cheese gave an uneven colour which was undesirable to the grading panel.

There was a great difference in the amount of salt retained in the cheese made with the peg mill compared with other two types of mill.

The lowest moisture content was in the cheese made with the CheeseMaker 3 mill.

B. Commercial curd. The results obtained under commercial conditions agreed with those obtained in the smaller scale experiments. The analysis of variance indicated that seaminess was significantly ($p < 0.001$) affected by the type of mill used(Table 64).

The lowest degree of seaminess was present in the cheese produced from curd milled with peg mill (mean score of 3.19 points). This compared with mean scores of 4.13 points and 9.69 points for seaminess in cheese made with the Damrow chip mill and the Bell-Siro CheeseMaker 3 mill respectively. The level of seaminess in the cheese produced with the Peg and Damrow mills did not prove serious enough to cause seamy cheese(Table 62).

These results indicated that the degree of seaminess can be reduced under commercial conditions be using Damrow or Peg mills.

The body of the cheese was also significantly ($p < 0.05$) affected by the type of mill. Cheese from the CheeseMaker 3 had a mean score of 7.81 compared to mean scores of 7.75 and 7.63 points for cheese made with the Damrow and Peg mills respectively(Table 62).

The colour of the cheese was significantly ($p < 0.001$) affected by the different types of mill. The highest score was given to the cheese made with the Damrow mill while the lowest score was given to the cheese made with the Bell-Siro CheeseMaker 3 (Tables 62.65).

C. Condition of the cutting edge of the Bell-Siro CheeseMaker 3 knives.

The results of the scoring of the cheese indicated that there was no significant difference in the degree of seaminess present in the cheese prepared with two knives. The mean scores for seaminess of the cheese produced with knife A was 5.53 points compared to 4.80 points for the cheese produced with knife B. The cheese produced from curd milled with the electrically operated Damrow chip mill contained a lower level of seaminess, (2.32 points)(Table 67).

This result is in agreement with those reported earlier, which showed that seaminess tended to increase in the cheese made from curd milled with the Bell-Siro CheeseMaker 3.

D. Curd Moisture

The mean scores for seaminess in cheese produced from the experimental curd of the first two vats was 9.8 points with a moisture content of 36.72 per cent compared with the mean score of 7.3 points given to cheese from the normal commercial production in the same factory. The commercial cheese had a moisture content of 35.53 per cent. The mean score for seaminess in cheese from the third experimental vat was 9.5 points and the cheese had a moisture content of 38.53 per cent (Tables 69,70).

The results suggested that the seaminess present in all cheeses whether from commercial or experimental curd was due to the effect of factors other than the moisture content of the curd at the time of milling.

E. Time between milling and addition of salt

The mean score given to the cheese produced by the different treatments indicated that more distinct seams occurred in the cheese made from the curd which was allowed 50 min before the addition of the salt. The mean score of 3.02 points for cheese made from mellowed curd compared with 2.27 points for the cheese which was salted and hooped directly after milling (Table 71).

This difference is not great and in both cases, no condition of seamy cheese was obtained. This increase may be attributed to the damaged cut surface of the curd particle during stirring the curd before the addition of the salt to prevent the curd from matting together.

CONCLUSION

Size of the milled curd

The number of the seams which were formed in cheese produced from curd milled with the 0.5 in (1.27 cm) knife of the CheeseMaker 3 was greater than that found in the cheese produced from the same curd milled with a 0.75 in (1.91 cm) knife of the same equipment.

The cheese produced from curd milled with a 0.5 in (1.27 cm) knife of the CheeseMaker 3 had significantly ($p < 0.01$) higher scores for body, ($p < 0.01$) and contained significantly ($p < 0.001$) higher salt content as well as a significantly ($p < 0.01$) lower moisture content and significantly higher pH than curd milled with 0.75 in.

The size of the milled curd had no significant effect ($p > 0.05$) on the fusion, openness, flavour and colour of the cheese.

Type of mill

Seaminess increased significantly ($p < 0.001$) in the cheese produced from curd milled with the CheeseMaker 3 by comparison with the cheese produced from curd milled with the Damrow (chip) mill and Peg mills. The colour of the cheese was significantly ($p < 0.05$) lower than the other cheese.

There was no significant difference ($p > 0.05$) between the fusion, openness, body, flavour of the cheese produced from curd milled with CheeseMaker 3, Damrow and Peg mills.

The amount of salt retained and the salt in aqueous phase of cheese produced with CheeseMaker 3 were significantly lower ($p < 0.001$, $p < 0.001$ respectively) than in cheese produced with Peg and Damrow mills but the moisture content was significantly ($p < 0.01$) lower than the cheese produced from curd milled with the Damrow and Peg mills.

In commercially manufactured curd, seaminess decreased significantly ($p < 0.001$) in the cheese produced from the same curd milled with Damrow (chip) mill and Peg mill in comparison to cheese produced from curd milled with CheeseMaker 3.

Condition of the cutting grid in the CheeseMaker 3 equipment

There was no significant difference ($p > 0.05$) in the mean scores for seaminess given to the cheese made with either of two knives of 0.75 (1.91 cm) of the Bell-Siro CheeseMaker 3.

Curd moisture

Seamy cheese with a moisture content of 38.56 per cent were obtained when the curd was milled with CheeseMaker 3 equipment.

Time between milling and salt addition

Adding salt to the milled curd left for 50 min after milling did not cause a great difference in the mean scores for seaminess given to the resulted cheese.

CHAPTER V

STUDY OF THE EFFECT OF FACTORS RELATED TO THE MOULD FILLING AND PRESSING PROCESS ON THE DEVELOPMENT OF SEAMINESS IN CHEDDAR CHEESE

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INTRODUCTION

After the addition of the salt to the milled curd, the curd is placed in special moulds, left aside for a time, and then pressed for 16 to 18 h. During this step, the curd is subjected to conditions that influence the physical and chemical conditions of the curd. In this section the effect of these factors on the development of seaminess in Cheddar cheese was examined.

A. Time from mould filling to final pressing

After the moulds have been filled with salted curd they are left aside on the conveyor until the required numbers of moulds to fill one press are available. They are then placed under full pressure. The time from filling the moulds to the application of full pressure varies according to the size of the press, but the first filled moulds always stand without pressure for more time than the last moulds in any one press. Under commercial conditions the time may vary from 5 min to about 50 min.

Holding the cheese after salting and before pressing is an essential practice in controlling the amount of the salt retained in the final cheese, and the amount lost in the whey. Czulak, Freeman and Hammond (1961) suggested that the filled moulds should be allowed to stand 30 min and preferably 1 h before pressing. Breene, Olson and Price (1965) found that at least 15 min between salting and pressing was necessary with dry salting to minimize loss of salt during pressing. Sutherland (1974) found that the amount of salt retained increased with the increase of holding time from 10 to 60 min, suggesting a holding time of 30 min for achieving satisfactory salt absorption.

B. Amount of pressure used in pressing the curd

The main objective of pressing the curd is to help the salted curd to knit together completely forming a uniform cheese mass without openings and have proper binding between the curd pieces. In practice the cheddared curd is pressed generally in conventional 40 lb (18.14 kg) rectangular moulds or in large hoop press as that described by Robertson and Bysouth (1971), at a thrust from 2 to 3 tons (2032.10 to 3048 kg). Van Slyke and Price (1952) reported that the use of too much pressure at the beginning of the pressing time caused whey to be trapped in the openings between the curd pieces and tended to cause open texture.

Since the seams are formed between the curd pieces along the lines of their junctions, applying different pressures during pressing the curd may affect the formation of calcium orthophosphate in these lines. According to the findings reported in the study of the chemical composition of seams, more calcium phosphate was present in the seams than the rest of the cheese body.

C. Temperature of the curd during pressing

When the cheddared curd is pressed when cold, the curd tended not to knit together properly so resulting in a more open cheese. Pressing warm curd tended to create better fusion but when very warm curd is pressed the fat melts and accumulates in the area between the curd particles. According to the measurements carried out by the author in several commercial Cheddar cheese factories, the temperature of the rooms in which the cheese presses are housed differs during the seasons of the year. During the winter, the temperature of these rooms drops to almost outside temperature of about $42.8^{o}F$ ($6^{o}C$) or less.

There is a general believe, that the curd during pressing remains warm inside the hoop. There is no available data on the actual conditions of the curd during pressing in these cold rooms. In order to determine this, the following study of the heat loss in the cheddared curd was undertaken as a background to the main experiments.

a. Heat loss from the curd during pressing. Heat loss from any particulate material depends on many factors such as the temperature difference between the temperature of the material and the ambient temperature, the size of the exposed area, the time of exposure, the thickness of the material, and the thermal conductivity coefficient of the material (Farrell, 1968).

Accordingly more heat could be lost from a cheese block of 44 lb (19.96 kg) when the warm cheese curd at 88°F (31.1°C) to 90°F (32.2°C) is pressed for about 20 h in a cold press room. Vedamuthu, Reinbold, Miah, and Washam (1969) reported that the temperature of the cheese blocks in American cheese factories when taken out of the press may range from 69.8°F to 95°F (21°C to 35°C), when pressed in pressing room with a maximum temperature of 80°F (26.6°C) and minimum of 70°F (21.1°C). Although the cheese curd has a poor conductivity (Dunlop, 1971), it is expected to cool down because of the length of time the cheese is kept under these conditions, and also due to the great difference of temperature of the curd and the ambient temperature in the cold days in winter time.

During pressing, the curd temperature should be kept around 69.8 to 73.4°F (21 to 23°C) to ensure proper pressing effect. Miah, Reinbold, Vedamuthu and Hammond (1969) reported that the temperature of warm pressed cheese varied from 21.1 to 29.4°C. Van Slyke and Price (1952) reported that the cold curd tended not to knit together completely during pressing, and the final cheese tended to be more open and of a poor quality. Recently Miah, Reinbold, Harty, Vedamuthu, and Hammond (1974) reported no significant difference in the scores given to the cheese pressed for 4 and 20 h, which was cooled to 45.5°F (7.5 °C) in brine and in air.

b. Temperature of the curd during pressing. The measurements of heat loss showed that, the temperature of the curd during pressing dropped from an initial temperature of 85°F (29.4°C) to 65°F (18.3°C) at the end of pressing. During more than 10 h, the curd was pressed at a temperature of 70°F (21.1°C).

EXPERIMENTAL

Cheese making and treatment of the curd

A. Time from mould filling to final pressing

Three vats of 400 gal (1818.4 l) of pasteurised milk each were made into coloured Cheddar using the system of cheese making described on page 55. The cheese manufacturing data are presented in Table 108 (Appendix A).

The curd produced in each vat was salted as described on page 59, adding 3 per cent (w/w) of dry vacuum salt and the curd was placed in the moulds, pre-pressed and left aside. The filled moulds were then left aside without pressure for varying periods of time before the application of full pressure. The time intervals between pre-pressing and application of full pressure were 5, 15, 25, 35, 45, 55, 65, 75 and 85 min. After pressing all cheese were treated by the methods described on page 59.

B. Amount of pressure used in pressing the curd

Measurements were made of the pressures used for pressing the curd in different commercial Cheddar cheese factories. The measurement was carried out by connecting the compressed air supply to a certified pressure guage and the pressure determined. These measurements indicated that a wide range of pressures were used in commercial factories, ranging from 1.5 to 3 tons (1524.07 to 3048.15

kg) as thrust on the cheese block. In this study four 10 in (25.4 cm) cylinder horizontal Crockatt cheese presses were used supplied with compressed air at 40, 60, 80 and 90 (2.812, 4.218, 5.625 and 6.328 kgf/ cm^2 respectively).

One vat of 2300 gal (10455.8 l) of pasteurised milk (159°F for 15 s) in commercial cheese factory was selected at random from a total of 5 vats and was manufactured into coloured Cheddar cheese according to the system described on page 58. The production details are presented in Table 109 (Appendix A).

The curd was milled with 0.5 in (1.27 cm) CheeseMaker 3 knife. Before salting, four 44 lb (19.96 kg) lots of milled curd were taken and placed in plastics containers 10 in (25.4 cm) deep, 16 in (40.6 cm) wide and 24 in (70 cm) long. Dry vacuum salt, 3 per cent (w/w) was added to each lot of curd simultaneously and treated according to the method described on page 59. One cheese was then set aside on one of the four presses used in this experiment. This procedure was repeated three times using curd from the same vat giving 4 blocks for each of the group. Each group was left aside for 25 min before placing them in the press. Then each group of cheese was treated afterward as that described on page 59. The treatments were as follows:-

Treatment	Compressed air supplied (kgf/ cm^2)	Thrust 1 lb (kg)	Replicate No 1	2	3	4
A	40 (2.81)	2240 (1017)	A1	A2	A3	A4
B	60 (4.22)	3400 (1543.6)	B1	B2	B3	B4
C	80 (5.63)	4600 (2088)	C1	C2	C3	C4
D	90 (6.33)	5100 (2315.4)	D1	D2	D3	D4

C. Temperature of the curd during pressing

a. Heat loss. Measurements were made to determine the pattern of temperature of different commercial press rooms. The temperatures were recorded over a period of 24 h on different days.

A standard commercial aluminium rectangular cheese mould was taken and three holes were drilled in the side sufficient to insert thermo-couples inside the curd during pressing, at 0.5 (1.27 cm) to 3 in (7.62 cm) from the surface and in the centre of the block. The moveable part of the hoop was also modified to avoid interfering with the movement of this part during the pressing. The hoop was lined and prepared.

Two vats of 400 gal (1818.4 l) of pasteurised milk each were manufactured into uncoloured and coloured Cheddar cheese according to the system of cheese making described on page 55. The manufacturing details are presented in Table 110 (Appendix A).

Forty-four pound (19.96 kg) lots of the milled curd were taken from each vat and were hand salted, adding 3 per cent (w/w) dry vacuum salt. Part of the curd was then placed in the hoop, and the thermo-couple of the first applicator was placed in the curd 0.25 in (1.05 cm) above the required depth of 0.5 in (1.27 cm). The other thermo-couples of the applicator were placed in the curd in the same manner. All the thermo-couples were positioned at the centre line of the block and were seen to have contact with the curd to ensure accurate temperature measurement (Slight, 1975).

The hoop was then placed in an air operated 10 in (25.4 cm) cylinder Crockatt cheese press with an compressed air supply of 80 psi (5.63 kgf/cm^2).

Another thermo-couple was set in the room near the cheese block to measure the ambient temperature of the room during the pressing time. The arrangements are shown in Figure 25 and 26.

All the applicators used in this measurement were of TC 67, consisting of copper electrode and all were connected to a TEC electric precision thermometer with accuracy of ± 0.5°C of Ellab Instruments, Copenhagen, Denmark (1969). Before use, all were tested against Standard British Institution thermometer.

The electric thermometer was adjusted to zero, and temperatures at different points at different intervals during pressing were recorded. At the end of the measurement, the cheese was cut and the actual position of the thermo-couples were measured.

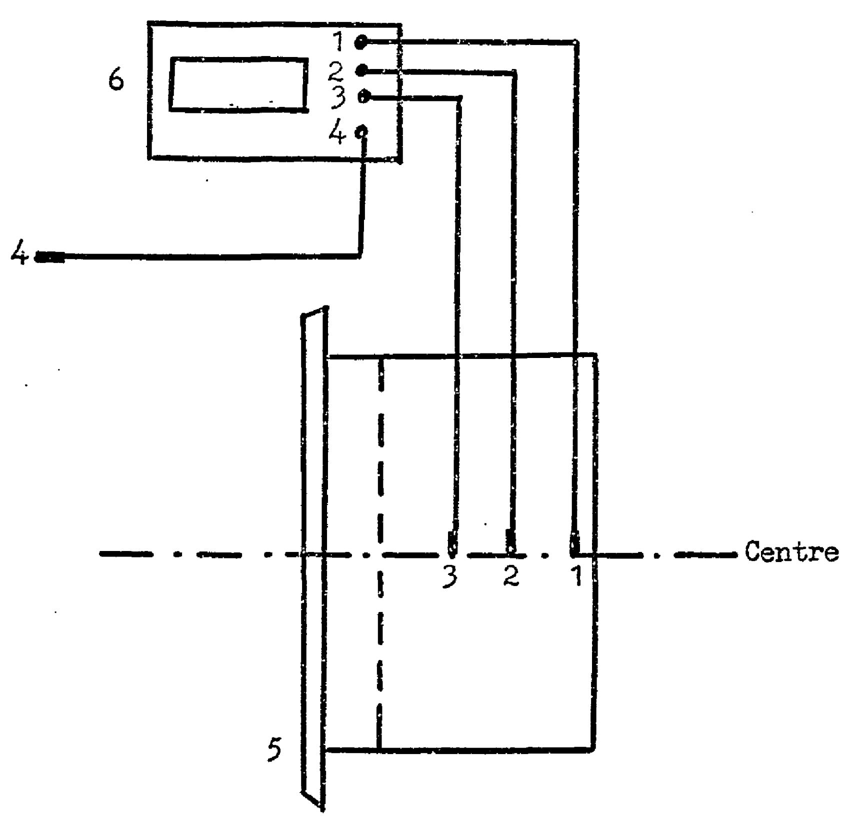
<u>C.b. Temperature of the curd</u>. A vat of 400 gal (1818.4 l) of pasteurised milk was made into coloured Cheddar according to the procedure making described on page 58. The production data are given on Table 111 (Appendix A).

When the titratable acidity of the traditionally cheddared curd reached 0.70 per cent lactic acid, the curd was milled in an electrically operated $\frac{3}{4}$ in (1.91 cm) Damrow chip mill.

Four 44 lb (19.96 kg) lots of the milled curd were taken and placed in the salting boxes as indicated in Figure 9. Commercial dry vacuum salt was added at the rate of 3 per cent (w/w) in two applications and mixed with the curd. Two 44 lb (19.96 kg) lots of salted curd were placed in two prepared moulds, and were pressed with 3600 lb (1632.9 kg) thrust on the cheese. The cheese press was housed in a room maintained at 85°F (30°C). The temperature of the curd at the beginning and end of pressing was determined.

FIGURE 25

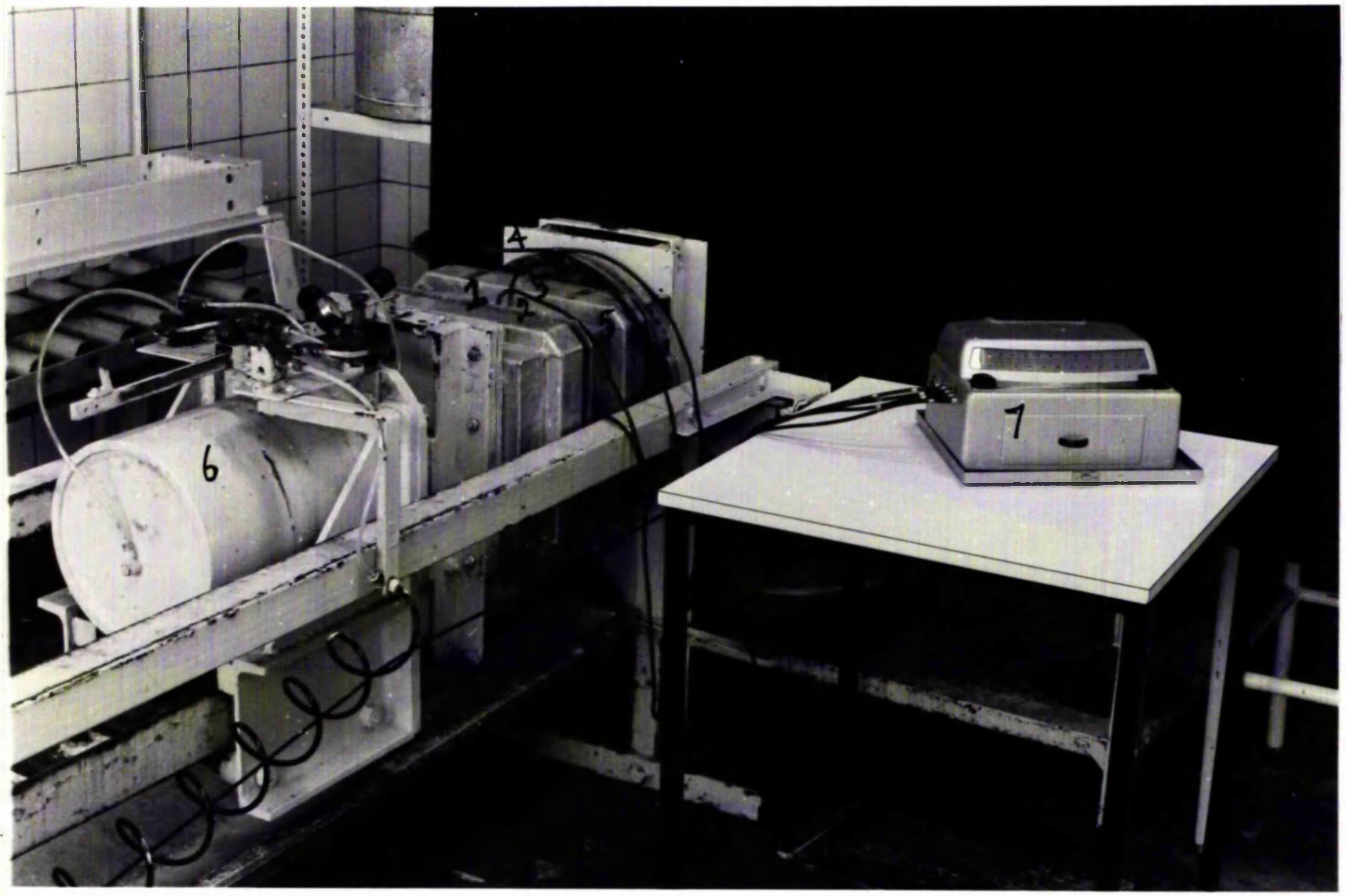
A plan showing the position of the thermo-couples inside the 44 lb (19.6 kg) cheddared curd block during the measurement of heat loss from the curd during the time of pressing



1. Applicator 1
2. Applicator 2
3. Applicator 3
4. Applicator 4
5. Cheese block
6. Electric thermometer

FIGURE 26

<u>The set up used in the measurement of heat loss in 40 lb (18.18 kg) block of cheddared curd during time of pressing</u>



1. Applicator 1
2. Applicator 2
3. Applicator 3
4. Applicator 4
5. Cheese block
6. Cheese press
7. Electric thermometer

The second two lots of salted curd from the same production were then placed in water heated vat. By means of running cold water through the jacket of the vat, the curd was cooled to 62°F (16.7°C). The curd was then placed in two prepared 40 lb (18.14 kg) rectangular moulds, and pressed with 3600 lb (1632.9 kg) thrust on the cheese hoop. The press was housed in a room maintained at 62°F (16.7°C). The temperature of the curd at the beginning and at the end of pressing was determined.

All four cheeses were pressed for 18 h, and then treated according to the methods described on page 59.

Scoring the cheese

All the cheeses included in the studies were presented to the panel and scored according to the procedure described on page 60, when the cheese was 8 weeks old.

Chemical analysis

Salt, moisture content, salt in aqueous phase, and pH of the cheese were determined following the methods described on pages 47, 48, 47, and 48 respectively.

Rheological measurements

The firmness of the cheese and its elasticity were determined with the Ball Compressor as described in page 52.

RESULTS

A. Time from mould filling to final pressing

The results of the scoring were analysed statistically. The analysis of variance (Table 73) showed that seaminess was not significantly ($p > 0.05$) affected by the time from pre-pressing to the application of full pressure.

The results of the chemical analysis are presented in Table 74 and Figures 27 and 28.

B. Amount of pressure

The results of the scoring are presented in Table 75. The results of the chemical analyses are presented in Table 76. The analyses of variance are presented in Tables 77 to 80.

These results shows that seaminess was significantly ($p < 0.001$) affected by the amount of pressure applied. The cheeses tended to be more open in texture when low pressure was used in pressing the curd. This effect was also significant ($p < 0.05$).

Under the experimental conditions, fusion, body, flavour, and colour were not significantly ($p > 0.05$) affected by the different pressures used in pressing the curd.

C. Temperature of the curd at pressing

TABLE 73

The analyses of variance; seaminess in Cheddar cheese aged 8 weeks given different holding time between pre-pressing and pressing

Source of variation	D.F.	Mean square	F
Times	8	0.74	-
Replicates	2	17.47	11.44 ***
Experimental error	16	1.53	
Judges	4	2.64	8.04 ***
Judges x times	32	0.47	-
Sampling error	72	0.33	
Total	134		

Means of seaminess

5 min	1.00
15	1.27
25	0.87
35	0.67
45	1.33
55	1.33
65	1.00
75	1.00
85	1.07

- Not Significant ($p > 0.05$)

*** Significant ($p < 0.001$)

TABLE 74

Chemical analyses of Cheddar cheese given different holding time between mould filling to pressing

Time, mould filling to pressing (min)	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
5	36.21	1.60	4.4
15	35.86	1.64	4.7
25	35.69	1.72	4.8
35	35.64	1.74	4.9
45	35.57	1.77	5.0
55	35.53	1.82	5.1
65	35.44	1.77	5.0
75	35.44	1.83	5.2
85	35.37	1.83	5.2

FIGURE 27

The effect of different time from hoop filling to placing the cheese in the final press on the moisture content (%) of Cheddar cheese aged 8 weeks

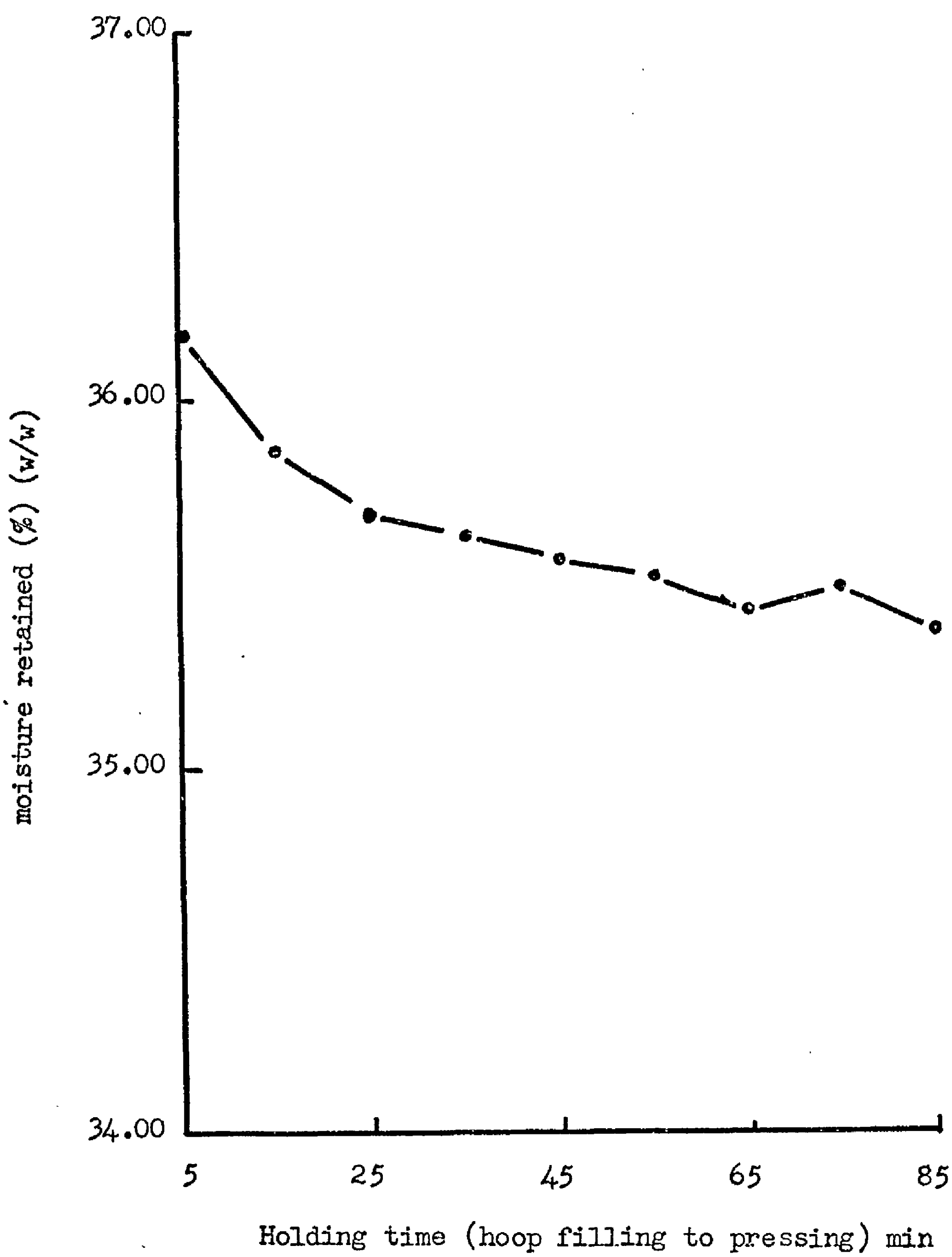


FIGURE 28

Amount of salt retained (%) in Cheddar cheese (aged 8 weeks) given different time from pre-pressing to final pressing

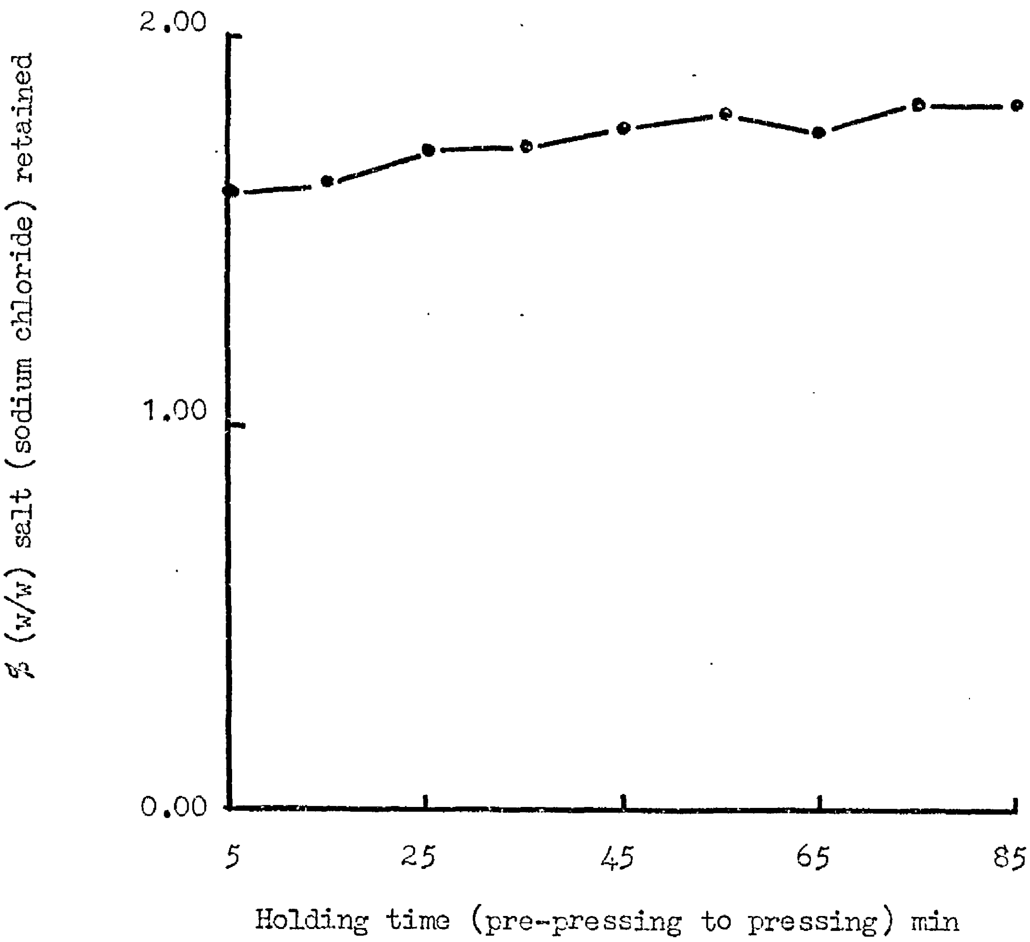


TABLE 75

Mean scores given by the panel (5 judges) to coloured Cheddar cheese (aged 9 weeks) made with commercial curd milled with 0.5 in (1.27 cm) CheeseMaker 3 mill pressed at different pressures

Air pressure used (psi)	Replicate	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
40	A1	8.0	7.6	3.0	7.0	9.0	7.6
(2.81 kgf/cm^2)	A2	8.2	7.2	2.2	7.8	9.0	7.2
	A3	8.6	7.4	2.6	8.0	9.0	7.8
	A4	8.8	7.6	2.4	7.4	9.2	7.4
60	B1	9.6	7.6	1.8	7.6	9.4	7.4
(4.22 kgf/cm^2)	B2	9.8	7.6	3.2	8.2	9.0	7.2
	B3	9.8	7.8	2.6	8.4	9.2	7.8
	B4	9.6	6.8	2.6	7.8	9.4	6.8
80	C1	9.8	7.4	3.2	7.8	9.0	7.6
(5.63 kgf/cm^2)	C2	9.8	6.6	1.0	8.6	9.0	7.6
	C3	9.8	7.6	1.8	8.0	9.0	7.6
	C4	10.0	7.6	2.8	7.8	9.2	7.4
90	D1	10.0	8.4	1.8	8.0	9.2	7.8
(6.33 kgf/cm^2)	D2	9.8	7.8	1.0	8.0	9.2	7.8
	D3	9.8	7.8	0.8	8.2	8.8	7.6
	D4	9.8	8.0	0.8	8.4	9.2	7.6

TABLE 76

Chemical analysis and reological measurement of Cheddar cheese (aged 9 weeks) made with commercial curd milled with 0.5 in (1.27 cm) CheeseMaker 3 mill pressed at different pressures

Pressure (psi)	Replicate	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)	Ball compressor total at 60°F	Elasticity at 60°F
40	A1	5.19	35.05	1.78	5.08	53.3	35.3
(2.81 kgf/cm^2)	A2	5.17	34.96	1.85	5.29	55.3	35.2
	A3	5.24	34.33	2.12	6.18	58.1	38.0
	A4	5.23	33.34	1.89	5.67	54.1	34.9
60	B1	5.21	33.25	2.02	6.08	53.5	35.2
(4.22 kgf/cm^2)	B2	5.17	34.43	1.89	5.49	54.7	35.7
	B3	5.26	32.96	2.00	6.07	58.1	38.0
	B4	5.20	34.31	1.67	4.87	55.4	35.6
80	C1	5.18	33.97	1.85	5.44	62.4	42.8
(5.63 kgf/cm^2)	C2	5.23	33.75	2.09	6.19	54.0	35.2
	C3	5.24	33.65	1.75	5.20	64.1	44.5
	C4	5.19	33.87	1.81	5.34	59.5	40.1
90	D1	5.18	34.05	1.64	4.82	55.3	35.4
(6.33 kgf/cm^2)	D2	5.21	33.96	1.79	5.27	55.1	35.6
	D3	5.25	33.31	1.62	4.86	59.0	39.8
	D4	5.23	34.07	1.73	5.08	56.3	36.6

TABLE 77

Analysis of variance; seaminess in Cheddar cheese (aged 9 weeks) made with curd milled with 0.5 (1.27 cm) CheeseMaker 3 pressed at different pressures

Source of variation	D.F.	Mean square	F
Treatments	3	9.90	47.14 ***
Experimental error	12	0.21	
Judges	4	2.36	13.11 ***
Judges x treatments	12	0.31	-
Sampling error	48	0.18	
Total	79		

Means of seaminess

A (40 psi, (2.81 kgf/cm^2)	8.40
B (60 psi, (4.22 kgf/cm^2)	9.70
C (80 psi, (5.63 kgf/cm^2)	9.85
D (90 psi, (6.33 kgf/cm^2)	9.85
Standard error of difference ±	0.14

- Not significant ($p > 0.05$)

*** Significant ($p < 0.001$)

TABLE 78

Analysis of variance; openness in Cheddar cheese aged 9 weeks made with commercial curd milled with 0.5 in (1.27 cm) CheeseMaker 3, pressed at different pressures

Source of variation	D.F.	Mean square	F
Treatments	3	9.43	4.53 *
Experimental error	12	2.08	
Judges	4	4.70	13.82 ***
Judges x treatments	12	0.42	-
Sampling error	48	0.34	
Total	79		

Means

A (40 psi, (2.81 kgf/cm^2)	2.55
B (60 psi, (4.22 kgf/cm^2)	2.55
C (80 psi, (5.63 kgf/cm^2)	2.20
D (90 psi, (6.33 kgf/cm^2)	1.10
Standard error of difference ±	0.46

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

*** Significant ($p < 0.001$)

TABLE 79

Analysis of variance; fusion and body of Cheddar cheese aged 9 weeks made with curd milled with 0.5 in (1.27 cm) CheeseMaker 3 mill, pressed with different pressures

		Fusion		Body	
Source of variation	D.F.	Mean square	F	Mean square	F
Treatments	3	1.90	-	1.41	-
Experimental error	12	0.68		0.64	
Judges	4	5.54	9.38 ***	14.03	27.51 ***
Judges x treatments	12	0.95	-	0.51	2.15 *
Sampling error	48	0.59		0.51	
Total	79				
Means					
A (40 psi), (2.81 kgf/cm^2)		7.45		7.55	
B (60 psi), (4.22 kgf/cm^2)		7.45		8.00	
C (80 psi), (5.63 kgf/cm^2)		7.30		8.05	
D (90 psi), (6.33 kgf/cm^2)		8.00		8.15	
Standard error of difference ±		0.26		0.25	

- Not significant ($p > 0.05$), * Significant ($p < 0.05$), *** Significant ($p < 0.001$)

TABLE 80

Analysis of variance; flavour and colour of Cheddar cheese aged 9 weeks made with curd milled with 0.5 in (1.27 cm) CheeseMaker 3 mill, pressed with different pressures

		Flavour		Colour	
Source of variation	D.F.	Mean square	F	Mean square	F (Pooled E)
Treatments	3	0.18	-	0.70	-
Experimental error	12	0.12		0.26	
Judges	4	2.82	11.28 ***	35.22	130.44 ***
Judges x treatments	12	0.24	-	0.58	2.15 *
Sampling error	48	0.29		0.27	
Total	79				
Pooled E	60	0.25		0.27	

Means

	Flavour	Colour
A (40 psi), (2.81 kgf/cm^2)	9.05	7.50
B (60 psi), (4.22 kgf/cm^2)	9.25	7.25
C (80 psi), (5.63 kgf/cm^2)	9.05	7.55
D (90 psi), (6.33 kgf/cm^2)	9.10	7.70
Standard error of difference ±	0.16	0.16

- Not significant ($p > 0.05$), * Significant ($p < 0.05$), *** Significant ($p < 0.001$)

a. Heat loss. The temperature recorded by the thermo-graph in different commercial pressing rooms indicated that the temperature drops in the winter to as low as 42.8 to 50°F (6 to 10°C).

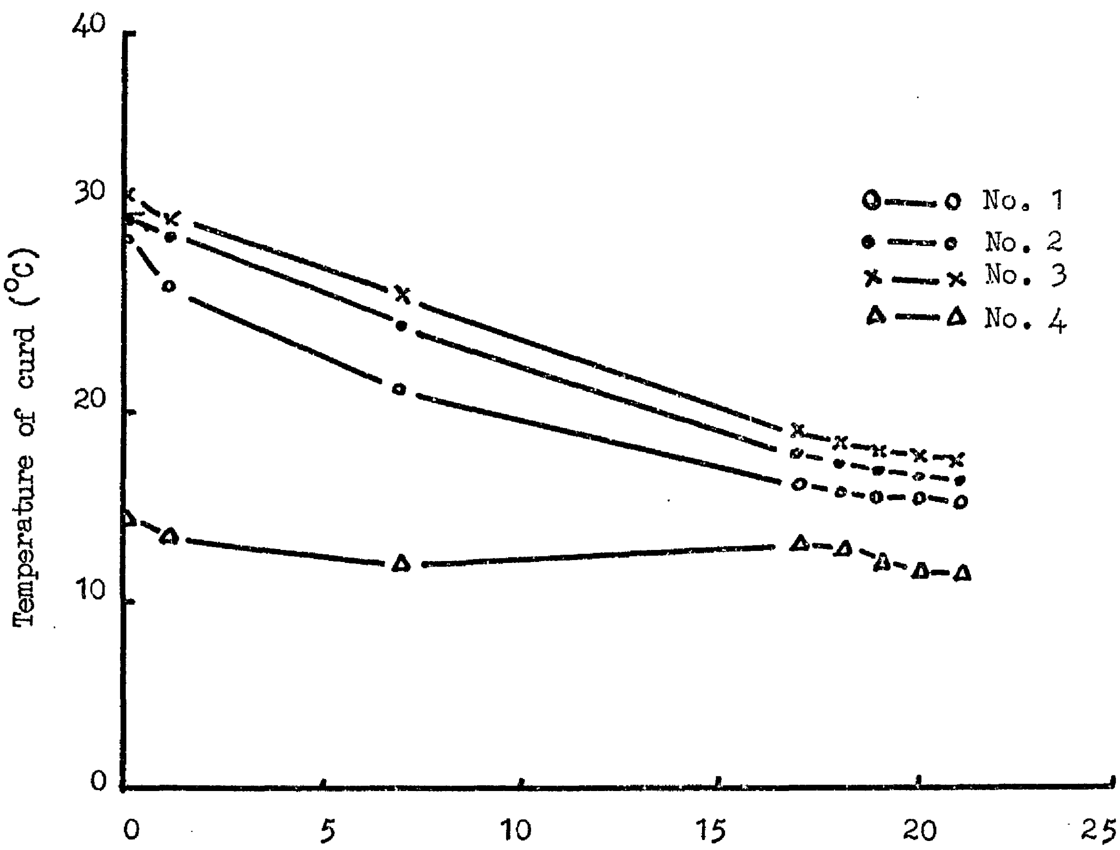
The actual positions of the thermo-couples in the blocks of cheese were measured and were found to be around 0.5, 3, and 6 in (1.27 cm, 7.62 cm and 15.24 cm respectively) from the surface of the mould. The temperatures during the pressing time in each position are presented in Figure 29 A and B.

These show that the curd temperature was less than 70°F (21.1°C) during most of the pressing time.

b. Temperature of the curd during pressing. The mean scores given to the cheeses by the scoring panel are presented in Table 81 The chemical analyses are given in Table 82.

FIGURE 29

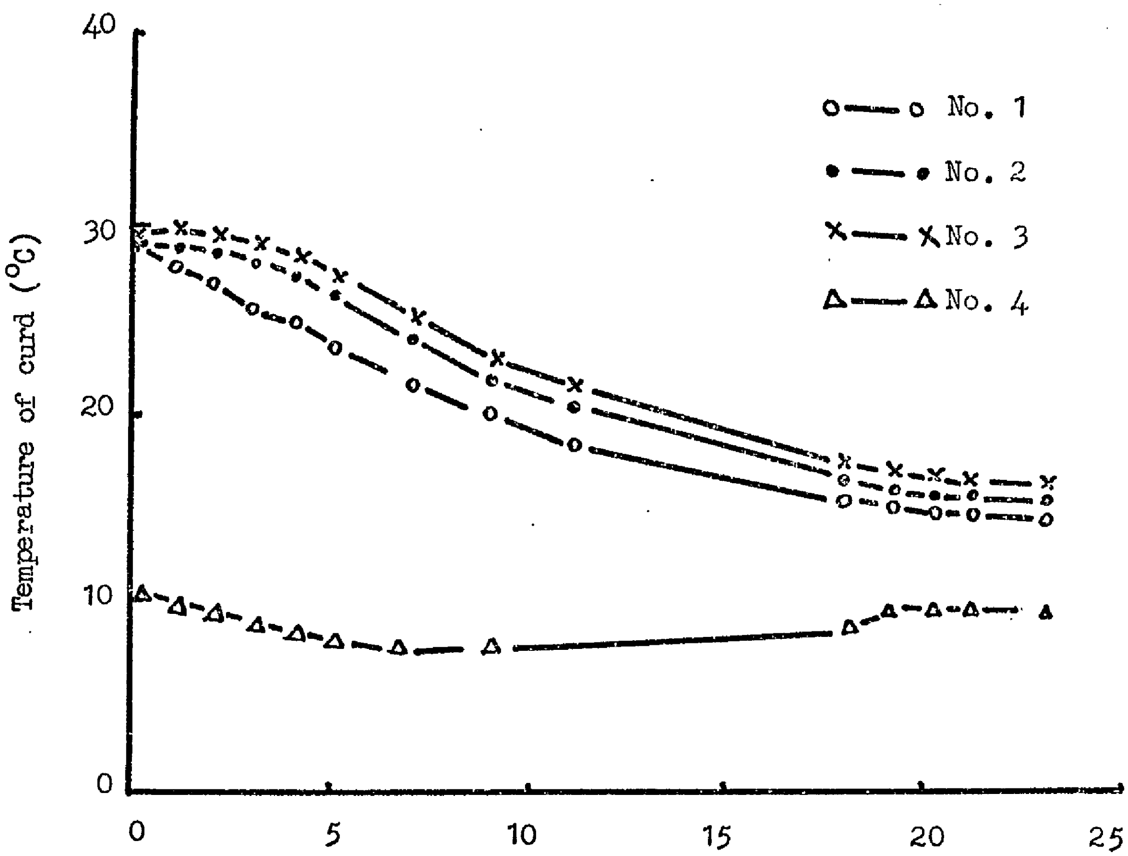
Temperature of curd measured by thermo-couples at 0.50, 3 and 6 in (1.27, 7.62 and 15.24 cm) depth in a 40 lb block during 22 h of pressing time



A. Time - curd in pressing - hours

Cont.

FIGURE 29



B. Time - curd in pressing - hours

TABLE 81

Mean scores given by the scoring panel (5 judges) to Cheddar cheese aged 8 weeks pressed at temperatures of 62 and 85°F (16.5 and 29.4°C)

Temperature at pressing (°F (°C))	Replicate	Seaminess scale 0 – 10	Fusion scale 0 – 10	Openness scale 0 – 10	Body scale 0 – 10	Flavour scale 0 – 10	Colour scale 0 – 10
62 (16.5)	1	1.4	5.4	2.0	7.2	8.0	7.2
	2	1.4	5.4	1.6	7.0	8.0	7.2
85 (29.4)	1	1.4	6.6	1.0	8.0	8.6	8.6
	2	1.6	6.8	1.2	8.2	8.4	8.4

TABLE 82

Chemical analysis of Cheddar cheese aged 8 weeks pressed at different temperatures of 62 to 85°F (16.5 and 29.4°C)

Temperature of the curd at pressing (°F (°C)	Replicate	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
62 (16.5)	1	5.08	36.15	2.29	6.3
	2	5.09	36.35	2.28	6.3
85 (29.4)	1	5.12	34.83	1.71	4.9
	2	5.14	35.18	1.68	4.8

DISCUSSION

A. Time from mould filling to final pressing

The mean seaminess scores obtained in all treatments ranged from 0.67 to 1.33 points, and are considered as low level of seaminess. The difference between the scores of seaminess given to the cheese of the treatments was not significant ($p > 0.05$).

The results of the scoring indicated that the quality of the resultant cheese was generally good and there was no significant ($p > 0.05$) difference between the scores for fusion, openness, body, flavour and colour of cheese produced from different treatments.

The salt retained in the cheese increased significantly ($p < 0.05$) with the increase of the time from filling the mould to pressing the cheese. The moisture content of the same cheeses decreased with the increase of time before pressing. The low moisture present in the cheese left for more time before placing in the press may be related to the increase amount of salt retained in these cheese. The pH of the cheese increased with the increase of time and may have been due to the increased salt retention in the final cheese.

B. Amount of pressure used in pressing the curd

The mean scores for seaminess of all Cheddar cheese included in the trial at the commercial factory showed that they contained a very high degree of seaminess ranging from 8.0 to 10.0 points. All these cheese were described by the panel as seamy cheese. Although the seaminess increased with the pressure used in the pressing of the curd, the difference in the means were very great (1.45 points) with a standard difference of error of ± 0.14. The cheese with the lowest score was also described as seamy.

The analysis of variance of grading scores at 9 weeks old indicated that seaminess was significantly affected ($p < 0.001$) with the amount of pressure applied. The means were from 8.40 when low pressure was used to 9.85 when high pressure was used.

The results showed that there was no level of pressure at which seaminess was absent so indicating that under the commercial conditions encountered other factors induced the high level of seaminess found in the cheese.

The increased score for seaminess in Cheddar cheese prepared at high pressure could have been caused by the increased amounts of whey trapped between the curd pieces and which may have encouraged the formation of calcium orthophosphate.

The level of openness in the cheese was affected by the amount of pressure applied. The means of grading scores showed that at low pressure, more openness was present (2.55 points) than at high pressure (1.10 points). This difference was significant ($p < 0.05$). This finding may be because the curd will tend to be fused more completely when placed under high pressure.

The mean scores for fusion indicated that better fusion resulted when high pressure was used but this difference was not significant ($p > 0.05$).

The commercial curd which was used in the trials was of low moisture content and typical of the curd produced in this particular factory. This curd resulted in a firm-bodied cheese. When low pressure was used, the body of the cheese tended to be weaker but this difference in body scores for different pressures was not significant ($p > 0.05$). The mean scores of all cheeses were greater than 8.0 points.

The mean grade scores for all cheese indicated that all of the resultant cheese were of good flavour, and the use of different pressures did not cause a significant difference ($p > 0.05$) in flavour.

The colour scores for the cheese in all the treatments ranged from 7.25 to 7.70 points and was below the desirable level. The low scores could be due to occurence of a seamy to very seamy condition in the cheese. The difference in the pressure applied caused no significant difference ($p > 0.05$) in the colour.

The chemical analyses showed that the moisture content of the cheese was very low, ranging from 34.42 to 33.74 per cent. This moisture level is considered in the industry to be below the commercially desirable level of around 36.0 per cent in the final cheese. Three per cent (w/w) of dry vacuum salt was added to the curd and the amount of salt present in the final cheese varied from 1.91, 1.90, 1.88 and 1.70 per cent for cheese respectively resulted when air pressure of 40, 60, 80 and 90 psi (2.81, 4.22, 5.63 and 6.33 kgf/cm^2) were used. The results showed that when the pressure was higher the salt in the cheese was lower. This may be due to more of salt crystals being carried away with the whey. Although there was slight difference in the salt present but this difference was not significant ($p > 0.05$). This also was true in the percentage of the salt present in the aqueous phase.

The pH of the cheese measured when the cheese was 9 weeks old were 5.21, 5.21, 5.21 and 5.22 for the cheese resulted from curd pressed at an air supply of 40, 60, 80 and 90 psi (2.81, 4.22, 5.63 and 6.33 kgf/cm^2), and the pressure applied had no significant effect ($p > 0.05$).

The results of the firmness measurements of the cheese showed that the Ball Compressor total of resultant cheese when low pressure (40 psi) was used was 55.20 units compared to 55.42, 60.0 and 56.42 B.C.T. at 60°F for that when 60, 80 and 90 psi (4.22, 5.63 and 6.33 kgf/cm^2) were used. But this difference was not significant ($p > 0.05$). The elasticity of the cheese also was not significantly ($p > 0.05$) affected by the pressure applied.

C. Temperature of the curd during pressing

<u>a. Heat loss from the curd during pressing</u>. The results obtained showed that the temperature of the curd measured at different points in the block had fallen steadily throughout the pressing time. This pattern of cooling was almost identical in both measurements made in both occasion in both uncoloured and coloured Cheddar cheese. The heat loss from the block was greater during the first 8 h of pressing and this was likely to be due to the greater difference in the temperature of the curd and the ambient temperature in the pressing room. During the rest of the pressing period the curd cooled down 7.2°F (4°C) compared to 18°F (10°C) during the first 8 h.

Throughout the pressing time, the temperature of the curd at the three measurement points was different, this may have been related to the thickness of the curd layer which affected the flow of heat. As one would expect, the curd in the first 0.5 in cooled down more quickly than the rest of the cheese.

The temperature of the centre of the block fell rapidly during pressing time in both measurements made on two occasions.

During the test the ambient temperature of the pressing room (at the Department of Dairy Technology, the West of Scotland Agricultural College) ranged between about 51.80 to 57.2°F (11 to 14° C) in the first trial, and between 42.8 to 50°F (6 to 10°C) in the second trial.

b. Temperature of the curd during pressing. The mean score for seaminess given to the cheese pressed at low temperature (62°F) and at high temperature (85°F) showed no significant difference in the seaminess present in all cheese. But the mean scores given to fusion, openness, body, flavour and colour showed that when the curd at pressing time was cold the resultant cheese tended to be poorly fused, more open, of crumbly body, of poor flavour and have uneven colour. These cheeses tended to retain more salt, contain high levels of moisture and contain high salt in the aqueous phase.

CONCLUSION

A. Time from mould filling to final pressing

Seaminess was not significantly affected ($p > 0.05$) by the time allowed from hoop filling to application of pressure with the range of 5 to 85 min. The amount of salt retained in the final cheese increased significantly ($p < 0.001$) when the holding time prior to pressing was increased. The moisture content of the same cheese decreased significantly ($p < 0.001$) when the holding time was increased. When the holding time prior to pressing increased the pH of the cheese increased too.

B. Amount of pressure used in pressing the curd

Seaminess was significantly increased ($p < 0.001$) by the increase in the pressure used, yet the effect of pressure did not bring a great difference in the degree of seaminess present in the final cheese. Application of low pressure did not eliminate the severe condition of seaminess in all resultant cheese.

Application of the higher pressure of 90 psi (6.33 kgf/cm^2) decreased significantly ($p < 0.05$) the openness. But there was no significant effect ($p > 0.05$) of higher pressure on fusion, body, flavour and colour.

C. Temperature of the curd during pressing

a. Heat loss from the curd during pressing. When the cheese is pressed in a room at very low temperature, the temperature of the curd drops quickly during pressing time, and for most of the pressing time may be at less than 70°F (21.1°C). The temperatures of the curd at all measurement points in the cheese were very low.

b. Temperature of the curd during pressing. There was no difference in the level of seaminess present in cheese pressed at low, 62°F (17°C) or high, 85°F (29.5°C) temperatures.

Pressing cold curd resulted in cheese which was poorly fused, more open, crumbly body cheese. The cheese lacked flavour and was of uneven colour. The cheese resulting from pressing curd at 85°F (29.5°C) had better scores for fusion, openness, body, flavour and colour.

CHAPTER VI

STUDY OF THE EFFECT ON SEAMINESS OF CALCIUM PHOSPHATE PRESENT IN MILK AND THE CURD

CHAPTER VI

STUDY OF THE EFFECT ON SEAMINESS OF CALCIUM PHOSPHATE PRESENT IN MILK AND THE CURD

INTRODUCTION

A. Calcium and phosphate content of milk

The results obtained in section 2 of Chapter II, showed that the level of both calcium and phosphate present in the seams is higher than the rest of the cheese. Different amounts of calcium and phosphate are present in different varieties of cheese (Randoin and Jourdan, 1953). These workers also reported that the amount of calcium in the original milk was of importance in relation to their presence in the final cheese. Irvine, Bryant, Sproule, Jackson, Crook and Johnstone (1945) reported that Ca and P content showed slight variations. Zahrnadt, Lane and Hammer (1944) reported that the amounts of both minerals in cheese differed according to the making procedure for the particular type of cheese and was influenced especially by the degree of acid development during the process of manufacture. Classeus (1955) reported that Cheddar cheese contained 1.10 per cent Ca and 0.83 per cent phosphorus in dry matter.

Cow's milk contains about 0.120 per cent calcium, and 0.104 per cent phosphate (Mattick, 1951). Honer and Herzer (1951) reported that the amounts of these minerals present in the milk is subjected to variation during the different seasons of the year. Ellenberger (1942) reported that the presence of both in milk depends on the composition of the cows food.

Casein exists in milk as spherical phosphate micelles of calcium phosphate caseinate particle (Heyndrickx and Vleeschawer, 1952) and Waugh and Hippel (1956) reported that the calcium of k-casein was soluble in water. Both the calcium and phosphate present in the milk are in the form of colloidal calcium phosphate (Pyne and McGann, 1960). Different theories were proposed by McGann and Pyne (1960) and Ter Horst (1963) to explain the nature of their bonding to the casein.

The level of the colloidal phosphate present in the milk was found to influence the time required for milk coagulation with rennin, the time of coagulation increased with the decrease of the amount present in the milk (McGann and Pyne, 1960). Cheeseman (1962) found that many compounds with the ability of reducing coagulation time, Ca^{++} lowered the velocity of whey explusion and reduced the amount of whey expelled. Rowland and Souliders (1942) reported that both the rate of coagulation and also curd firmness are markedly affected by the composition of milk.

Mattick and Hallet (1929) found that heat treatment of the milk caused a retarding effect on the coagulation, Peltola (1957) found that a low level of calcium in the milk caused an increase in the time of coagulation. Davis (1965) reported that 5 per cent of the calcium was rendered insoluble when the milk was heated to 161.5^{o}F (70^{o}C) for 15 s.

In order to improve the coagulation of the milk with rennet, calcium is generally added to the milk in the form of calcium chloride. Babel (1948) reported that the use of calcium chloride to diminish the quantity of rennet needed resulted in cheese of inferior body and texture. Ernstrom, Price and Swanson (1958) reported that curdiness persisted longer in the finished cheese. Peltola and Vogt (1959) related this improvement to the lowering of the pH and increasing the colloidal calcium phosphate content beside the increase of calcium present. Under the influence of increasing hydrogen ion concentration, the calcium phosphate is progressively dissociated from the micellar complex (Webb and Johnson, 1965).

After the coagulum has been cut some of the calcium and phosphate are released into the whey. The amounts released into the whey are found to increase with the increase of the titratable acidity of the whey from cutting to drawing the whey (McDowall and Dolby, 1935). It has been reported (Anon, 1974) that the calcium and phosphorus contents of whey are 51 mg/100 g and 53 mg/100 g respectively.

Since the seams contain more calcium and phosphate than the rest of the cheese the level of the initial content of both in the milk may affect the amount of the calcium orthophosphate that may form in the area between the curd particles (particle junction lines).

In this part of the study it was decided to add to the milk that was used in the cheese making, more calcium and phosphate in the form of calcium orthophosphate, which have a solubility of 0.0361 g/100 ml in water (Hodgman, 1945).

B. Presence of calcium orthophosphate

The chemical analysis of the seams presented in Table 8 shows that the seams contained three times as much calcium as is present in the rest of the cheese. This chemical tended to concentrate in the surface of the curd particles. This experiment was undertaken to demonstrate the role of the amount of calcium present in the junction lines between the curd particles on the formation of seams in the area.

EXPERIMENTAL

Cheese making and treatment of the curd

A. Calcium and phosphate content of the milk. Two vats each containing 50 gal of pasteurised milk were used. To each vat, 500 g of calcium orthophosphate; $CaHPO_4.2H_2O$ of Hopkin and Williams, Essex, England, was added, mixed well for 20 min in the milk. Each vat of milk was made into coloured Cheddar according to the system described on page 54. The production data are presented in Table 112 (Appendix A). Commercial dry vacuum salt was added at 3 per cent (w/w) according to the procedure described on page 59. The curd was treated afterward as described on page 59.

B. Presence of calcium orthophosphate in the curd. Four vats of 400 gal (1818.4 l) of pasteurised milk were made into coloured Cheddar following the system mentioned on page 58. The production data are given in Tables 112 C, 102 (first two) and 107 (other two).

When the curd of the first two vats (A and B) reached a titratable acidity of around 0.7 per cent lactic acid, the curd was milled with CheeseMaker 3, fitted with 0.5 in (1.27 cm) knife and operated as described on page 102. After milling, two 10 lb (4.536 kg) lots of curd were taken from each vat. To one lot, 3 oz (85.05 g) of $CaHPO_4.2H_2O$ was spread on the surface of the curd, mixed well with the curd and then the curd placed in 40 lb (18.14 kg) standard mould. A second lot was left untreated and placed in another mould. Both moulds were placed in an air operated 10 in (25.40 cm) cylinder horizontal Crockatt cheese press supplied with compressed air at 80 psi (5.63 kgf/cm^2). The cheese were pressed for 18 h, placed in 10 lb (4.54 kg) laminate pouches and vacuum sealed and placed in the curing room maintained at 50°F (10°C).

In the case of the third vat, the same procedure was carried out except that two lots of 20 lb each of the curd were taken, salted at the rate of 3 per cent (w/w) dry vacuum salt, and to the first lot 6 oz (170.10 g) of calcium orthophosphate was added.

The curd in the fourth vat was all milled with an electrically operated Damrow mill, and two lots of 26 lb (9.072 kg) each were taken and were treated as that in the third vat.

Scoring the cheese

The cheese produced in part A were presented and scored as described on page 60.

From the cheese produced in part B, 0.5 in (1.27 cm) thick piece of the cheese was cut by means of wire cutter. The resultant pieces were then vacuum sealed in 10 lb (4.536 kg) polythene/nylon laminate pouch. These pieces were then presented to the panel and scored for seaminess as described on page 60. The appearance of the cheese is shown in Figure 30.

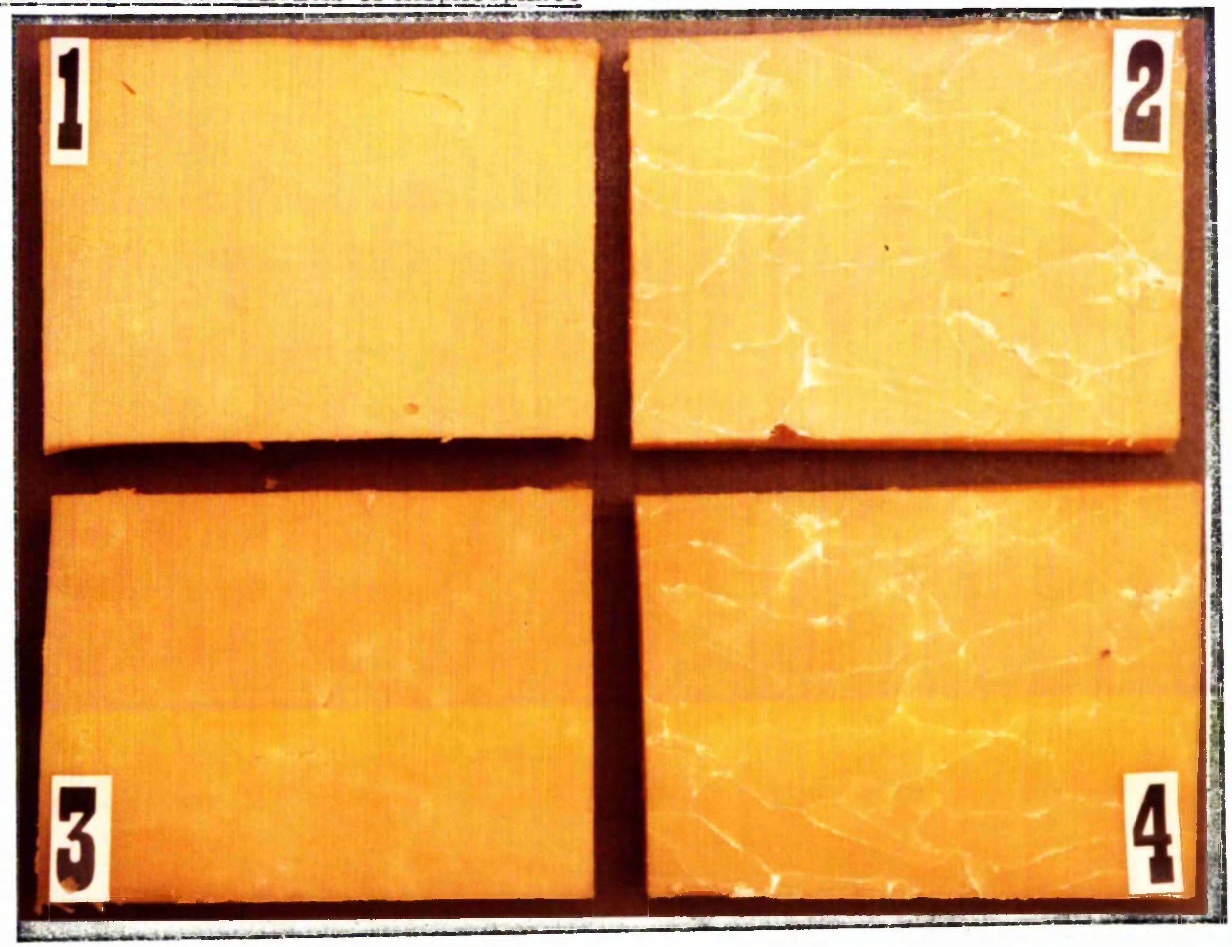
Chemical analyses

Salt, moisture, salt in aqueous phase and the pH of the cheese were determined according to the methods described on page 47, 48, 47, and 48 respectively and are presented in Table 83.

FIGURE 30

<u>Seaminess present in Cheddar cheese aged 2 weeks made of salted and unsalted cheddared curd with and without added calcium orthophosphate</u>

1. Unsalted, untreated
2. Unsalted + calcium orthophosphate
3. Salted, untreated
4. Salted + calcium orthophosphate



RESULTS

A. Calcium and phosphate content of milk

The results of the scoring the cheese at 8 weeks old and its chemical composition are presented in Table 83.

These results showed that the level of seaminess was so low in both cheeses that the condition was virtually absent. The cheese was well fused but was poor in colour, flavour and body.

B. Presence of calcium orthophosphate

The results of scoring the cheese at 2 weeks old are presented in Table 84.

The statistical analysis of these data are given in Table 85 . These results showed that seaminess was induced in both salted and unsalted curd by the application of calcium orthophosphate to the curd, and was significantly affected by its addition ($p < 0.001$).

TABLE 83

Mean scores of the panel (5 judges) given to Cheddar cheese aged 8 weeks made of milk with calcium orthophosphate added and their chemical analyses

Vat	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
1	0.20	6.8	3.4	7.2	7.0	6.0
2	0.40	7.4	2.4	5.0	7.0	7.8

Chemical analyses

	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
1	5.17	34.12	1.75	5.1
2	5.18	34.61	1.86	5.4

TABLE 84

Scores of seaminess given by the scoring panel (4 judges) to Cheddar cheese aged 2 weeks made with salted and unsalted cheddared curd treated with calcium othophosphate

		Scores of seaminess (scale 0 - 10) given by the judges				
Treatments of the curd	Vat	1	2	3	4	Total
1. Unsalted curd, untreated	A	2	2	3	2	9
	B	0	0	0	0	0
Unsalted curd + calcium orthophosphate	A	10	10	10	10	40
	B	10	10	10	10	40
2. Salted curd, untreated	C	1	1	0	3	5
	D	0	1	0	1	2
Salted curd + calcium orthophosphate	C	10	10	10	10	40
	D	10	10	9	10	39

TABLE 85

Analysis of variance; seaminess in Cheddar cheese (aged 2 weeks) made with salted and unsalted curd to which calcium orthophosphate was added

Source of variation	D.F.	Mean square	F
Treatments	3	213.11	75.03***
Experimental error	4	2.84	
Judges	3	0.36	-
Judges x treatments	9	0.45	-
Sampling error	12	0.18	
Total	31		

Standard error of difference ± 0.84

\- Not significant ($p > 0.05$)

*** Significant ($p < 0.001$)

DISCUSSION

A. Calcium and phosphate content of milk

A low level of seaminess was obtained even when calcium was added in the form of calcium orthophosphate to the milk used in making the cheese. Since the seams contained a high level of calcium orthophosphate, it was thought that more calcium would increase the amount of this chemical in the lines between the particles. This result obtained may be due to the loss of most of the chemical in the cheese making process.

Mattick (1951) showed that, about 40 per cent of the inorganic calcium phosphate was lost in the first whey after cutting. The loss of the calcium and phosphate continued during the process with the increase of the acidity of the curd.

B. Presence of calcium orthophosphate

It was clear from the scores given by the panel and also from the general appearance of the cheese (Figure 30) that all the cheese, to which calcium orthophosphate was added contained the maximum degree of seaminess (10 points) and were described by all the members of the panel as very seamy Cheddar cheese. On the contrary, there was very low level of seaminess in the untreated cheese. This difference was significant ($p < 0.001$).

In both salted and unsalted curd, seamy cheese was produced because of the presence of the calcium orthophosphate between the curd particles.

The chemical analysis of samples taken from the seams in section 2 of Chapter II of this thesis indicated that seams contained higher levels of calcium and phosphate and are possibly present in the form of calcium orthophosphate. The formation of the seams in both salted and unsalted curd was due to the presence of insoluble calcium orthophosphate which was added to the curd and accumulated in the lines of junctions between the curd particles.

This result also showed that seaminess can be present in unsalted curd. This finding was demonstrated in Chapter III of this study, in which unsalted Cheddar was made and found to contain a noticeable level of seaminess.

CONCLUSION

Seaminess was not affected by the addition of calcium orthophosphate to the milk used for the production of Cheddar cheese.

The addition of calcium orthophosphate to milled curd resulted in the formation of severe seaminess in Cheddar cheese at the junctions of the curd pieces.

CHAPTER VII

ASSESSMENT OF THE OCCURENCE OF SEAMINESS IN SCOTTISH CHEDDAR CHEESE

CHAPTER VII

ASSESSMENT OF THE OCCURENCE OF SEAMINESS IN SCOTTISH CHEDDAR CHEESE

INTRODUCTION

Cheddar is the only variety of cheese made extensively in Scotland. The occurence of seaminess in Scottish Cheddar cheese was reported by Crawford (1973), who drew the attention of the industry towards this defect. The extent of its occurence in Cheddar cheese produced in different factories in Scotland has not been measured. This study was undertaken to measure the incidence level of seaminess in Cheddar cheese produced by the different Cheddar cheese making systems, which are in use in the area.

Since these factories handle very large quantities of milk daily, a reasonable and practical representation of the cheese production of these factories was desirable. Sampling was extended over six months of production.

EXPERIMENTAL

Sampling

Samples of Cheddar cheese were taken from the following factories:

A. Factory A

B. Factory B

C. Factory C

D. Factory D

E. Factory E

Cheese making procedure

Each of the factories included in the study, represents a different system of Cheddar cheese manufacture. Production methods are summarised below.

A. Factory A. The New Zealand 'Cheddarmaster' Tower system used in this factory is that produced by Mauri Brothers and Thomson (Overseas) Co.

The pasteurised milk was cooled to 88°F (31.1°C) and pumped to 20 vats each of 2000 gal (9092.2 kg) capacity. Mixed-strain starters were added at the rate of 2 per cent (v/v), Annatto at the rate of 4.19 oz per 100 gal (454.6 l) of milk was added when coloured Cheddar was made. Rennet was added at the rate of 4.19 oz per 100 gal (454.6 l) of milk.

When the coagulation was completed, the curd was cut by the knive attachments in the vat, and the curds and whey were heated to 102°F (38.9°C). When the required acidity and time reached, the whey and the curd was pumped to a dewheying conveyor. The whey and with it the curd fines were pumped to a Cyclone separator in which the fines were removed and pumped back to the dewheying belt. The curd moves upwards while being agitated by means of peg stirrers. At the end of the dewheying conveyor the curd falls into a hopper from which the curd was transported pneumatically to the cheddaring tower.

The curd was allowed to 'cheddar' in the tower for a period of 2 h during the travel of the curd to the bottom of the tower. The large cheddared blocks of curd were allowed to fall into a Berry milling machine positioned close to the base of the tower.

The milled curd was transported to the inclined salting conveyor and salted by the addition of dry vacuum salt spread on the curd from special nozzles over the conveyor. The amount of the salt added was regulated according to the depth of the curd on the belt as measured by a special sensing element. The salt was mixed with the curd by a series of peg stirrers at intervals along the belt, the salted curd was then blown to a mould filling unit, and placed in 40 lb (18.14 kg) standard rectangular moulds and then left aside for 10 to 35 min before being placed under full pressure in an air operated (8 in cylinder (20.3 cm) horizontal cheese press operated with compressed air at 90 psi. The cheese were pressed 16 to 18 h and thereafter vacuum sealed in 40 lb (18.14 kg) or 10 lb (4.536 kg) portions in a laminate before being boxed, labelled and cured at 50°F (10°C).

The flow diagram and the arrangement of equipment used are presented in Figure 31.

B. Factory B. Cheddar cheese was produced in this factory according to the system described on page 58 of this thesis.

C. Factory C. This factory employs the New Zealand single-strain starters in rotation.

The pasteurised milk (161°F (72°C) for 15 s) which was cooled to 90°F (31.1°C) was pumped to 20 OST tank of 2600 gal capacity. Single-strain starter was added at the rate of 2 per cent (v/v). Cheese colour (Annatto) was added at the rate of 4 oz per 100 gal (454.6 l) of milk when coloured cheese was made. Rennet solution was added to each vat at the rate of 4 oz per 100 gal (454.6 l) of milk. When the coagulation of the milk was completed in 40 to 50 min, the curd was cut mechanically by the knife attachment in the tank, and was automatically heated to 102°F (38.9°C) in one hour.

The curds and the whey were pumped to the dewheying screen of the CheeseMaker 2 Mark III (Bell Bryant Pty., Ltd.), in which the whey is removed and the curd is cheddared in special moving containers for 1 h 50 min.

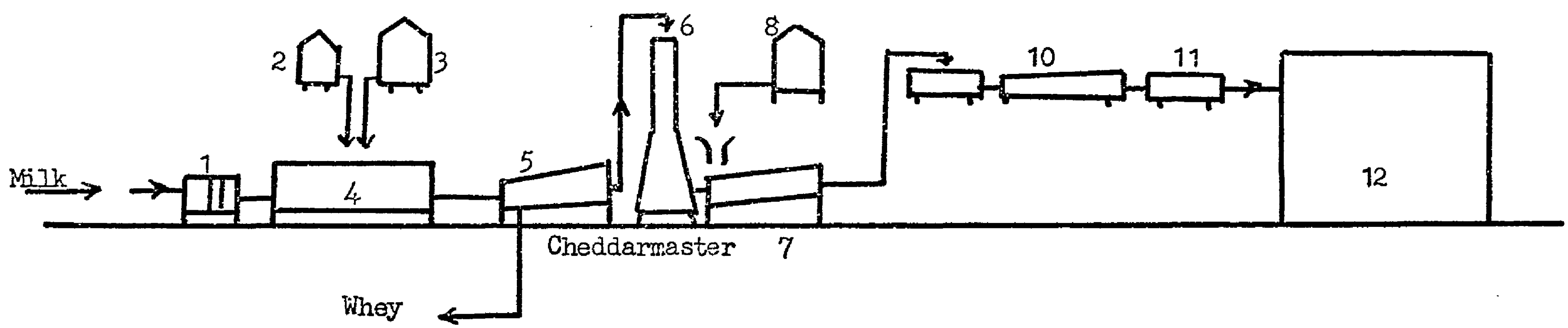
The cheddared slabs were automatically transferred to the CheeseMaker 3; automatic milling, salting and hoop filling unit (Bell Bryant Pty., Ltd.).

The filled moulds were then left aside on the conveyor for about 25 to 30 min and were pressed by means of a vertical press operated with compressed air of 60 psi. The cheese was pressed for 18 h.

The cheese were either vacuum sealed in 40 lb (18.14 kg)

FIGURE 31

The plan of the equipment used in Factory A for manufacturing Cheddar cheese by the New Zealand Cheddarmaster system



1. Pasteurisers
2. Culture
3. Rennet
4. Cheese vats
5. De-wheying table
6. Cheddar tower
7. Salting table
8. Salt silo
9. Mould fill
10. Pressing
11. Wrapping
12. Curing room

blocks or in 10 lb (4.563 kg) in polythene/cellulose laminate bags, the cheeses were boxed, labelled and were stored at a curing room maintained at 50°F (10°C).

The flow diagram of the system is presented in Figure 32.

D. Factory D. The system of cheese making followed is described on page 56.

E. Factory E. The pasteurised milk was cooled to 88°F (31.1°C) and pumped to 10, 4000 gal (1818.4 l) vats. Mixed-strain starters were added at the rate of 2 per cent (v/v). Annatto was added at the rate of 3.6 oz per 100 gal (454.6 l) of milk when coloured Cheddar was made. Rennet was added at the rate of 4 oz per 100 gal (454.6 l) of milk.

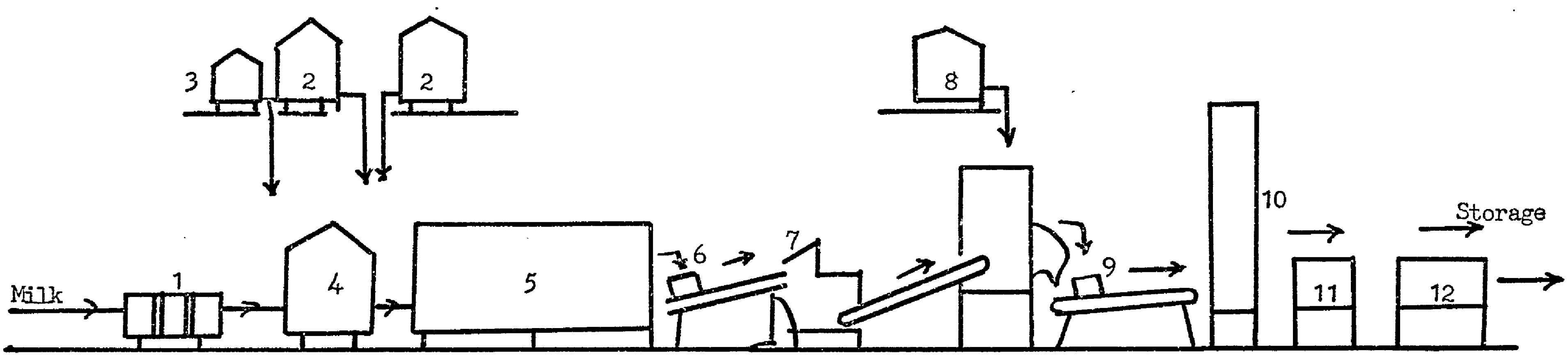
When the milk was coagulated satisfactorily, the curd was cut by the knife attachment of the vat, and was heated to 102°F (38.9 °C) in one hour. The whey and the curd were allowed to flow by gravity to the Tebel-Crockatt coolers when the acidity reached the required level. In the coolers, the separation of the whey from the curd took place and the curd was cheddared in the coolers. In this factory the curd is not piled or cheddared as completely as in traditional methods.

When the cheddaring time was completed, the curd in small blocks was salted by spreading the salt by hand on the curd in three applications to give a rate of 3 per cent (w/w) dry vacuum salt.

The blocks of salted curd were then conveyed to an electrically operated peg type mill, and then a conveyor to 8 large hoops presses such as that described by Mauri Brothers and Thomson (Overseas) Co.

FIGURE 32

The set-up of the equipment used in Cheddar cheese manufacture at Factory C by the CheeseMaker 2 Mark III and CheeseMaker 3



1.	Pasteurisers	5.	CheeseMaker 2 Mark III	9.	Conveyor
2.	Starters	6.	Conveyor	10.	Pressing
3.	Rennet	7.	CheeseMaker 3	11.	Demoulding
4.	OST tanks	8.	Salt	12.	Wrapping and sealing

After the hoops had been filled, the presses were operated and the curd pressed under vacuum for 16 to 18 h.

The cheeses were then taken out in batches from the press, cut into 40 lb (18.14 kg) blocks, hand wrapped in film and boxed using the Unibloc system. Cheese were cured at 50°F (10°C).

The flow diagram of the equipment is given in Figure 33.

Sampling procedure

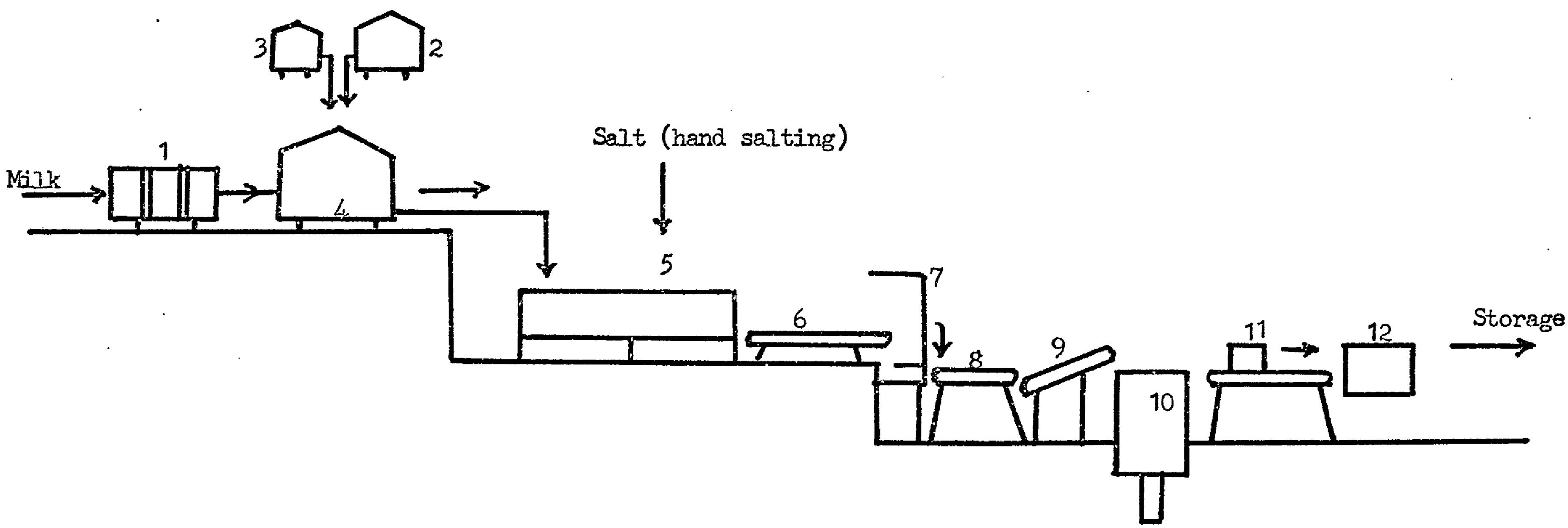
The cheese samples were taken from those used for the routine official grading by The Company of Scottish Cheesemakers Ltd. One 40 lb (18.14 kg) block cheese was sampled from each of two vats selected at random from each day's production. When a refill vat was made with different starters, an additional one block sample was taken at random from the refilled vat.

Testing the samples

The samples were graded by the author when the cheese were about 4 to 5 months old. A 0.5 in (1.27 cm) thick slice was cut off the face of the cheese by a special wire cutter, and the cheese was given scores for seaminess, fusion, openness, body, flavour, and colour according to the procedure and scale described on page 55 and used throughout the study. Because of the number of samples involved and the commercial value of the cheese it was not possible to arrange panel scoring of the samples.

FIGURE 33

<u>The set-up of the equipment used in Cheddar cheese manufacture in Factory E using the Tebel-Crockatt coolers, peg mill, large hoop and Unibloc system</u>



1.	Pasteurisers	5.	Tebel-Crockatt coolers	9.	Movable conveyor
2.	Starters	6.	Stainless steel conveyor	10.	Large hoops
3.	Rennet	7.	Peg mill	11.	Wrapping
4.	Vats	8.	Conveyor	12.	Unibloc system

RESULTS

The results of scoring of all cheeses at 4 to 5 months old made in these five Cheddar cheese factories are presented in Tables 86 and 87.

The mean scores for seaminess showed that there was a considerable degree of seaminess in the Scottish Cheddar cheese made during the six months of the study. These also show differences in the level of seaminess between the cheese made by these different systems.

The distribution of the seaminess in these cheese are also presented in Table 88.

TABLE 86

Mean scores given by one judge to commercial Scottish Cheddar cheese aged 4 to 5 months made during 1st September 1975 to 28th February 1976 in five factories

Factory	Days cheese made	Total vats made	Milk used (gal)	Samples tested	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
A	95	2232	4,687,200	253	1.91	5.57	2.77	8.04	7.96	7.37
B	122	481	1,250,600	227	9.18	5.61	2.31	8.60	8.40	6.42
C	120	1401	3,642,600	316	2.68	5.72	1.57	8.20	8.29	7.56
D	90	854	2,220,400	256	2.62	5.37	5.20	8.30	8.24	6.41
E	87	517	2,068,000	174	0.25	5.12	2.24	7.89	8.27	7.03

TABLE 87

Mean scores given by one judge to commercial Scottish Cheddar cheese aged 4 to 5 months made on September, October, November, December, 1975, January and February, 1976, in five factories

Factory	Days cheese made	Total vats made	Samples tested	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
				September					
A	11	254	29	3.79	4.92	3.52	7.14	6.86	6.45
B	26	100	42	9.14	5.81	1.67	8.15	7.26	6.50
C	26	309	75	2.37	5.06	1.32	7.83	6.68	7.23
D	19	180	50	2.46	5.40	4.26	7.98	7.64	6.66
E	17	82	34	0.29	4.29	2.21	7.62	7.15	6.44
				October					
A	21	704	63	1.56	5.49	4.57	7.92	7.65	7.61
B	17	66	31	9.36	6.42	2.45	8.68	8.94	6.19
C	22	245	59	3.46	5.95	1.46	8.20	7.68	6.86
D	16	162	52	1.92	5.16	5.46	8.41	8.23	6.71
E	15	88	30	0.17	5.60	2.23	7.97	8.00	7.10

Cont. TABLE 87

				November					
A	21	378	42	1.62	5.55	2.07	7.81	8.05	7.33
B	21	84	39	9.56	5.77	2.13	8.80	8.77	6.10
C	16	211	47	2.28	5.89	1.36	8.96	8.92	7.98
D	14	108	36	3.00	4.56	5.67	8.47	8.61	6.33
E	10	59	20	0.35	5.80	1.85	8.20	8.85	7.00
				December					
A	17	272	37	0.92	6.14	1.43	8.46	8.22	7.38
B	23	89	44	9.43	5.48	1.75	8.77	9.11	6.02
C	21	209	47	2.26	5.85	1.40	8.17	9.02	7.94
D	15	134	41	2.56	5.30	4.73	8.51	8.83	7.10
E	19	96	38	0.32	4.84	1.68	7.52	8.61	7.07
				January					
A	11	299	35	1.17	6.31	1.97	8.91	9.11	7.80
B	22	87	44	8.57	5.20	3.09	8.36	7.98	6.18
C	19	202	44	2.09	5.96	1.59	8.48	8.98	7.89
D	18	185	49	2.31	5.86	4.71	8.25	8.31	6.65
E	12	72	24	0.13	4.88	2.58	8.04	8.67	7.54

Cont. TABLE 87

February

A	14	325	47	2.40	4.98	3.06	8.00	7.87	7.62
B	14	55	27	9.00	4.96	2.74	8.78	8.33	5.85
C	16	225	44	3.61	5.61	2.30	7.93	8.45	7.48
D	8	85	27	3.52	6.07	6.45	8.33	7.96	5.11
E	14	120	28	0.21	5.32	2.86	7.96	8.36	7.00

TABLE 88

Seaminess distribution in 4 to 5 month old commerical Scottish Cheddar cheese made during 1st September 1974 to 28th February 1976 in five factories

Seaminess scale (0 - 10)	Factory A	Factory B	Factory C	Factory D	Factory E
0	94	-	61	63	140
1	29	-	44	28	27
2	67	-	70	50	6
3	23	1	50	42	1
4	17	5	34	27	-
5	5	3	16	15	-
6	8	11	18	13	-
7	-	20	17	12	-
8	8	16	3	6	-
9	-	19	3	-	-
10	2	152	-	-	-
Total	253	227	316	256	174

DISCUSSION

The mean scores of seaminess given to the cheese produced in the five factories using different systems of Cheddar cheese manufacture are presented in Table 86 , and indicate that seaminess occurred in the cheese at different levels which resulted in seamy cheese and cheese free from the condition.

A. Factory A. The cheese produced in factory A contained a varied degree of seaminess. Approximately 3.95 per cent (representing 145644 lb of cheese) of the tested cheese contained from 7 to 10 points seaminess and were described as seamy cheese, and 11.86 per cent, representing approximately 555901 lb contained 4 to 6 points. The mean score of all samples tested was 1.91 points. The moisture content of the cheese was 34.94 per cent, with salt content of 1.73 per cent and salt in the aqueous phase of 5.0 per cent. The cheese was slightly open (2.77 points), of good body (8.04 points) of slightly low score of flavour (7.96 points) and of good colour (7.37 points).

B. Factory B. The occurrence of severe conditions of seaminess was consistent in the Cheddar cheese produced by the factory B. The mean score given was 9.2 points and the samples tested were described as seamy. Of the tested samples 91.19 per cent contained from 7 to 10 points seaminess (representing 1140422 lb of cheese). In this factory, the cheddared curd was milled by means of a commercial unit of the Bell-Siro CheeseMaker 3. The cheese was of good body (8.60 points), flavour (8.40 points) but the mean score of colour was very low (6.42 points).

From the analysis of samples taken from the cheese made in this factory it was found that the cheese contained very low moisture, and the salt is added to the milled curd at higher acidities.

C. Factory C. Although factory C employed the Bell-Siro CheeseMaker 3 milling, salting, and hoop filling unit, the mean score of seaminess of the samples tested is very low (2.68 points). Looking to the distribution of the seaminess in the tested cheese which is presented in Table 88, it is evident that about 7.2 per cent of the tested samples contained between 7 and 10 points seaminess and were described as seamy cheese (representing 262267 lb of the cheese). Of the samples tested 21.52 per cent contained between 4 to 6 points of seaminess (representing 783887 lb of cheese). This lower level of seaminess than that reported in the other factory which used the Bell-Siro CheeseMaker 3 may be attributed to the difference in the manufacturing procedure used. The mean of the moisture content of the cheese is 33.98 per cent, with a salt content of 1.70 per cent with a salt concentration in the aqueous phase of 5.0 per cent. Milling in this factory was carried out at low titratable acidity.

D. Factory D. Approximately 7.03 per cent of the samples tested from factory D (representing 156094 lb of cheese) contained from 7 to 10 points seaminess and were described as seamy cheese. About 21.48 per cent of these samples (representing 476942 lb of cheese) contained between 4 to 6 points seaminess. The overall mean of seaminess was 2.62 points. The cheese was given a mean of 5.37 points for fusion, 8.30 points for body, and 8.24 points for flavour. The cheese tended to be more open with a mean score of 5.20 points and of uneven colour (6.4 points). The low score of the colour was due mainly to the discolouration in the openings within the cheese, and to the mottled colour.

E. Factory E. The Cheddar cheese made in factory E contained the least seaminess and none of the samples tested during the study was described as seamy. The mean score for seaminess in the cheese tested was 0.25 points. Of the samples tested 80.46 per cent were free from seams (0 points), and 19.54 per cent contained from 1 to 2 points of seaminess.

The occurrence of this low degree of seaminess in this commercial cheese is in agreement with the results obtained with the experimental curd which was milled with the Peg type mill. The mean moisture content of cheese made at this factory was 36.40 per cent. The mean salt content was 1.69 per cent in the final cheese, so giving a salt concentration in the aqueous phase of 4.6 per cent. The moisture content of the cheese from this factory is higher than that found in the cheese made in other factories. The cheese tested represented half the production in this factory, this represents about 2068000 lb of cheese (14.9 per cent of the tested cheese).

The cheese was found to have low fusion scores (5.12 points) compared to the highest score given of 5.72 points. The mean score for openness in the cheese was surprisingly low (2.24 points). The score given to the body of the cheese was low. Their colour and flavour was good with a mean scores of 7.89 and 8.60 points respectively.

CONCLUSION

The experiment showed that the incidence of seamy cheese varied between the five factories using the different systems.

Seaminess is present in commercial Cheddar cheese produced in Scotland to a considerable level. Approximately 12.29 of the cheese produced contained a seamy condition (represent 1704427 lb), and 13.85 per cent (represent 1921405 lb) contained between 4 and 6 points of seaminess.

Seaminess was found consistent in factory B, absent in factory E, and varied in the factories A, C and D.

CHAPTER VIII

STUDY OF THE EFFECT OF THE OCCURRENCE OF SEAMINESS IN CHEDDAR CHEESE ON CONSUMER REACTION

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STUDY OF THE EFFECT OF THE OCCURRENCE OF SEAMINESS IN CHEDDAR CHEESE ON CONSUMER REACTION

INTRODUCTION

Van Slyke and Price (1952) described seaminess as a defect in both colour and texture of the cheese. Czulak and Conochie (1967) stated that the occurrence of seaminess in coloured Cheddar has great commercial significance. In the United States of America two factories ran into trouble when their cheese became seamy after the introduction of the Bell-Siro CheeseMaker 3, automatic milling, salting and hooping equipment.

In Scotland the incidence of seaminess in Cheddar may have increased since the introduction of the mechanised systems of cheese making. From a survey conducted by the author on cheese sold in the supermarkets in Ayr area, it was found that large quantities of the consumer portions contained different level of seaminess ranging from very low (which is not enough to produce a condition of seamy cheese) to a very high degree (which caused a condition of very seamy cheese).

Under the conditions in Scotland there is no evidence to demonstrate that the presence of seaminess in Cheddar cheese has any significant effect on the consumer.

The objective of this study was to determine the consumer reaction to seaminess based on the visual appraisal at the time of purchase of both white and coloured Cheddar cheese.

EXPERIMENTAL

Preparation of cheese pieces

Very seamy rindless cheese, uncoloured and coloured Cheddar cheese were selected from first grade production at a commercial cheese factory. Another lot of Cheddar cheese both uncoloured and coloured free from seaminess was selected from first grade production at another factory. All of the selected cheese were almost the same age and of comparable quality in terms of openness, body and flavour. The selected cheese were placed in a curing room maintained at 50°F (10°C) until their age reached around 7 months.

Every week three coloured cheese and another two uncoloured 40 lb (18.14 kg) cheese blocks were cut for retail sale.

Each block was cut by a special mechanical cutter into four, 10 lb (4.536 kg) block. These were then cut by another machine of J. W. Flowers and Co., U.K., into small pieces, 5.5 in (14 cm) long, 3.5 in (9 cm) wide, and 0.8 in (2 cm) thick. Each weighed around ½ lb (227.3 g). Each portion was then placed in a laminate pouch and vacuum sealed, labelled variety and price details. This was the usual procedure followed in preparing the cheese for sale in the Friday shop of the Department of Dairy Technology, West of Scotland Agricultural College.

Presentation of the cheese in the shop

The pre-packed retail portions of cheese from each type was stacked in plastics containers of the same type and were placed in the shop at their usual places. During the time of sale, the trays were always kept full with portions ensuring that there was always a sufficient supply of all types of cheese to meet the demand for any particular type of cheese. The number of portions of each type purchased every week was determined and recorded.

Presentation of the different types of cheese was carried out in the shop according to the plan presented in Table 89. The counter placing arrangement for each type was inter changed throughout the test period.

Chemical analysis

Samples of the cheese on sale were analysed for salt and moisture content and pH using the methods described on pages 47, 48 and 48 respectively.

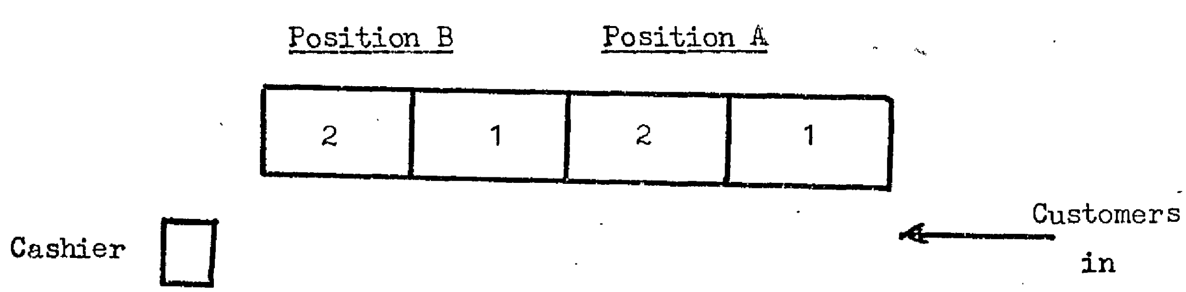
TABLE 89

The set-up of the presentation of seamy and non-seamy coloured and white Cheddar cheese packed pieces in the Friday shop at W. S. A. College during the study of the effect of the occurrence of seaminess on consumer reaction

	Position A		Position B	
Week No.	1	2	1	2
1	NS white		NS coloured	
2	NS white		NS coloured	
3	S white		S coloured	
4	S white		S coloured	
5	NS white	S white	NS coloured	S coloured
6	S white	NS white	S coloured	NS coloured
7	NS coloured	S coloured	NS white	S white
8	S coloured	NS coloured	S white	NS white

NS denotes none seamy Cheddar cheese

S denotes seamy Cheddar cheese



RESULTS

The number of portions of each type of cheese which were sold during the test period is presented in Tables 90 and 91.

The results of the chemical analyses of the cheese is presented in Table 92.

Statistical analysis

The results of the analyses of variance for the data are presented in Table 93. These results showed that there was more consumer preference for the coloured Cheddar than uncoloured Cheddar. Of the total cheese sold in the shop, portions with a seamy condition were in the majority on all occasions and sales of seamy coloured Cheddar were greater than sales of uncoloured seamy cheese. Sale of each type of cheese was also affected by their placing on the counter in the shop, showing that more sales were obtained in position 1.

TABLE 90

Sales of seamy and non-seamy white and coloured Cheddar cheese 0.5 lb (2.27 g) pieces placed at different position in the Friday shop throughout the study of the effect of the occurence of seaminess in Cheddar cheese on the consumer reaction

Week of sale	No of pieces coloured Cheddar sold		No. of pieces white Cheddar sold		Total	Average per week
	Seamy	Non-seamy	Seamy	Non-seamy		
5	91 (1)	63 (2)	60 (1)	22 (2)	236	59.00
6	115 (2)	66 (1)	36 (2)	29 (1)	246	61.50
7	111 (1)	44 (2)	50 (1)	31 (2)	236	59.00
8	99 (2)	89 (1)	24 (2)	50 (1)	262	65.50
Total	416	262	170	132	980	
Average	104.00	65.50	42.50	33.00		61.25

Note: Placing the cheese was according to the following position, denoted in the number between brackets.

White Cheddar		Coloured Cheddar	
1	2	1	2

TABLE 91

Distribution of seamy and non-seamy white and coloured Cheddar cheese pieces sold at different positions on the counter of Friday shop during the study of the effect of the occurrence of seaminess in Cheddar cheese on the consumer reaction

Type of Cheddar	Position in the shop	Total	Average
Coloured	1	357	89.25
	2	321	80.25
White	1	189	47.25
	2	113	28.25
Position total	1	546	68.25
	2	434	54.25

TABLE 92

Analysis of variance; consumer reaction to the occurrence of seaminess in white and coloured Cheddar cheese

Source of variation	D.F.	Mean square	F
1. Weeks	3	37.67	-
2. Types of cheese	3	3993.67	19.19 **
Red x white	1	8836.67	42.45 **
Seamy x non-seamy	1	2304.00	11.07 *
Interaction	1	841.00	-
3. Positions	1	784.00	-
Error	8	208.125	
Total	15		

- Not significant ($p > 0.05$)

* Significant ($p < 0.05$)

** Significant ($p < 0.01$)

TABLE 93

Chemical analyses of commercial Cheddar cheese used in the consumer reaction to seaminess trials

Type of cheese	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
Coloured Non-Seamy	5.19	35.87	1.70	4.7
Coloured Seamy	5.17	34.17	1.79	5.2
Uncoloured Non-Seamy	5.21	35.79	1.70	4.8
Uncoloured Seamy	5.17	34.17	1.83	5.2

DISCUSSION

As the test was conducted in the 'Friday' shop of the Department of Dairy Technology, the sales were restricted to the Staff and the students of the College, who are accustomed to buying their cheese from this shop. The result of this test reflected the reaction of these consumers to seaminess in Cheddar cheese. It would be very interesting to conduct such a study in a normal retail outlet such as a supermarket in which many cheeses are presented and purchased by a real cross section of the consumers. But due to the difficulty of getting these facilities, this test was carried out in the College shop.

The results of the sales indicated that there was more preference for coloured than uncoloured Cheddar cheese. This difference was significant at the level ($p < 0.01$).

The cheese presented were very seamy and were commercially sold in the local market in Scotland. The data obtained showed that the consumer may have prefered other characteristics of the seamy cheese and the seamy condition helped them to identify a particular type of cheese. Since coloured Cheddar is always more popular in Scotland than uncoloured, this probably explained the increased sales of seamy coloured cheese than in seamy uncoloured.

When the cheese was placed at position 1, the total sales was increased significantly compared to those sold when they were placed in position 2. This indicates that placing the cheese on the shelves in the market affects the amount sold.

CONCLUSION

This test indicates that there is no consumer objection to the cheese which have very seamy condition as long as the general quality is good and the cheese can be cut without breaking apart.

Yet in order to assess the reaction of the consumers towards the presence of seaminess in Cheddar, a similar test should be carried out under normal commercial conditions and with a general cross section of consumers.

APPENDIX A

TABLES 94 TO 112

CHEESE MANUFACTURING DATA

TABLE 94

Cheese manufacturing data of Cheddar cheese used for the determination of calcium in salted and unsalted both pressed and unpressed curd

Operation		
Milk	Titratable acidity (% lactic acid)	0.16
Starters	Added at (h - min)	0 - 0
	Rate (%) (w/w)	2.25
	Strains (single *Str. cremoris*)	ML8, AM1
	Ratio of mixing	$\frac{1}{3}$ fast, $\frac{2}{3}$ slow
Rennet	Added at (h - min)	0 - 10
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)
	Temperature, °F (°C)	88 (31.1)
	Titratable acidity (% lactic acid)	0.17
Coagulum	Cut at (h - min)	1 - 00
	Titratable acidity (% lactic acid)	0.12
Maximum scald	Total time (h - min)	one hour
	Temperature, °F (°C)	101.5 (38.6)
Whey run	At (h - min)	3 - 05
	Titratable acidity (% lactic acid)	0.16
Curd milled	At (h - min)	5 - 15
	Titratable acidity (% lactic acid)	0.65
Curd salted	At (h - min)	5 - 20

TABLE 95

Cheese manufacturing data; preliminary experiment of the study of the effect of the amount of added salt on the development of seaminess

Operation		Vat 1	Vat 2
Milk	Titratable acidity (% lactic acid)	0.15	0.145
Starters	Added at (h - min)	0 - 00	0 - 00
	Rate (%) (w/w)	2 (80 lb)	2 (80 lb)
	Strains (single *Str. cremoris*)	E8, C13	P2, SK11
	Ratio of mixing	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$
Rennet	Added at (h - min)	0 - 10	0 - 05
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.16	0.15
Coagulum	Cut at (h - min)	1 - 12	1 - 05
	Titratable acidity (% lactic acid)	0.115	0.115
Maximum scald	Total time (h - min)	1 - 00	1 - 00
	Temperature, ^{o}F (^{o}C)	101 (38.3)	101 (38.3)
Whey run	At (h - min)	3 - 13	3 - 10
	Titratable acidity (% lactic acid)	0.17	0.145
Curd milled	At (h - min)	4 - 30	5 - 25
	Titratable acidity (% lactic acid)	0.72	0.65
Curd salted	At (h - min)	4 - 40	5 - 45

TABLE 96

Cheese manufacturing data; the effect of the amount of added salt and of salt particle size (large scale) on the development of seaminess

Operation		Vat 1	Vat 2	Vat 3	Vat 4	Vat 5
Milk	Titratable acidity (% lactic acid)	0.15	0.15	0.15	0.185	0.17
Starters	Added at (h - min)	0 - 00	0 - 00	0 - 00	0 - 00	0 - 00
	Rate % (w/w)	2	2	2	2	2
	Strains (Single *Str. cremoris*)	P2, SK11	P2, SK11	P2, SK11	P2, SK11	P2, SK11
	Ratio of mixing	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$
Rennet	Added at (h - min)	0 - 05	0 - 05	0 - 12	0 - 15	0 - 10
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)	4 (113.6)	4 (113.6)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)	88 (31.1)	88 (31.1)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.16	0.15	0.15	0.19	0.18
Coagulum	Cut at (h - min)	0 - 55	0 - 57	0 - 58	1 - 07	0 - 55
	Titratable acidity (% lactic acid)	0.11	0.11	0.115	0.115	0.12
Maximum scald	Total time (h - min)	1 - 00	1 - 00	1 - 00	1 - 00	1 - 00
	Temperature, ^{o}F (^{o}C)	101 (38.3)	101 (38.3)	101 (38.3)	101 (38.3)	101 (38.3)
Whey run	At (h - min)	3 - 25	3 - 45	3 - 42	3 - 32	3 - 35
	Titratable acidity (% lactic acid)	0.17	0.16	0.17	0.175	0.17
Curd milled	At (h - min)	5 - 45	5 - 15	5 - 30	5 - 17	5 - 20
	Titratable acidity (% lactic acid)	0.59	0.63	0.58	0.67	0.70
Curd salted	At (h - min)	5 - 55	5 - 30	5 - 50	5 - 37	5 - 38

TABLE 97

Cheese manufacturing data; the effect of salt particle size in commercial curd (mixed, and single strains) on seaminess development

Operation		mixed-strain starter	single-strain starter
Milk	Titratable acidity (% lactic acid)	0.16	0.165
Starters	Added at (h - min)	0 - 00	0 - 00
	Rate % (w/w)	2	2
	Strains	Mauchline starters (mixed)	166, AM1 (Single Str. cremoris
	Ratio of mixing	-	2/5, 3/5
Rennet	Added at (h - min)	0 - 50	0 - 10
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	3.5 (99.4)
	Temperature, °F (°C)	87 (30.6)	88 (31.1)
	Titratable acidity (% lactic acid)	0.17	0.17
Coagulum	Cut at (h - min)	1 - 30	0 - 50
	Titratable acidity (% lactic acid)	0.135	0.125
Maximum scald	Total time (h - min)	1 - 00	1 - 00
	Temperature, °F (°C)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 50	3 - 15
	Titratable acidity (% lactic acid)	0.21	0.25
Curd milled	At (h - min)	5 - 50	4 - 50
	Titratable acidity (% lactic acid)	0.68	0.69
Curd salted	At (h - min)	5 - 50 to 6 - 10	4 - 50 to 5 - 10

TABLE 98

Cheese manufacturing data; the effect of additives in commercial salt on the development of seaminess in Cheddar cheese

Operation		
Milk	Titratable acidity (% lactic acid)	0.17
Starters	Added at (h - min)	0 - 00
	Rate (%) (w/w)	2
	Strains (Single *Str. cremoris*)	P2, SK11
	Ratio of mixing	$\frac{1}{3}$ fast, $\frac{2}{3}$ slow
Rennet	Added at (h - min)	0 - 15
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)
	Titratable acidity (% lactic acid)	0.18
Coagulum	Cut at (h - min)	1 - 50
	Titratable acidity (% lactic acid)	0.13
Maximum scald	Total time (h - min)	one hour
	Temperature, ^{o}F (^{o}C)	101 (38.3)
Whey run	At (h - min)	3 - 20
	Titratable acidity (% lactic acid)	0.18
Curd milled	At (h - min)	5 - 15
	Titratable acidity (% lactic acid)	0.7
Curd salted	At (h - min)	5 - 25

TABLE 99

Cheese manufacturing data; effect of the acidity of the curd at the time of salt addition on seaminess development

Operation		Preliminary	Vat A	Vat B
Milk	Titratable acidity (% lactic acid)	0.20	0.16	0.18
Starters	Added at (h - min)	0 - 00	0 - 00	0 - 00
	Rate (%) (w/w)	2 (single *Str. cremoris*	2 (single *Str. cremoris*	2 (mixed-strains
	Strains	ML8, AM1	P2, SK11	Mauchline
	Ratio of mixing	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	-
Rennet	Added at (h - min)	0 - 40	0 - 12	0 - 10
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.21	0.18	0.18
Coagulum	Cut at (h - min)	1 - 40	1 - 02	1 - 05
	Titratable acidity (% lactic acid)	0.12	0.125	0.12
Maximum scald	Total time (h - min)	1 - 00	1 - 00	1 - 00
	Temperature, ^{o}F (^{o}C)	100 (37.8)	101 (38.3)	101 (38.3)
Whey run	At (h - min)	3 - 50	3 - 12	2 - 52
	Titratable acidity (% lactic acid)	0.15	0.175	0.165
Curd milled	At (h - min)	6 - 10, 7 - 15, 9 - 35	4 - 40, 5 - 50, 7 - 35	4 - 75, 5 - 47, 7 - 47
	Titratable acidity (% lactic acid)	0.5, 0.7, 0.9	0.5, 0.7, 0.9	0.5, 0.7, 0.9
Curd salted	At (h - min)	6 - 25, 7 - 22, 9 - 45	4 - 50, 6 - 00, 7 - 55	5 - 07, 5 - 57, 7 - 57

TABLE 100

Cheese manufacturing data; the effect of the acidity of the curd produced by different single-strain starters at the time of salt addition on seaminess development

Operation		Vat 1	Vat 2	Vat 3	Vat 4
Milk	Titratable acidity (% lactic acid)	0.18	0.17	0.16	0.16
	Fat (%), S.N.F. (%)	3.8, 8.54	3.8, 8.60	3.9, 8.58	3.7, 8.64
Starters	Added at (h - min)	0 - 00	0 - 00	0 - 00	0 - 00
	Rate (%) (w/w)	2	2.25	2	2
	Strains (single Str. cremoris)	ML8, AM1	WM1, AM2	H2, E8	P2, SK11
	Titratable acidity (% lactic acid)	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$
Rennet	Added at (h - min)	0 - 15	0 - 15	0 - 15	0 - 15
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)	4 (113.6)	4 (113.6)
	Temperature, °F (°C)	88 (31.1)	88 (31.1)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.19	0.175	0.175	0.165
Coagulum	Cut at (h - min)	1 - 10	1 - 05	1 - 05	1 - 05
	Titratable acidity (% lactic acid)	0.135	0.13	0.12	0.125
Maximum scald	Total time (h - min)	one hour	one hour	one hour	one hour
	Temperature, °F (°C)	100 (37.8)	100 (37.8)	100 (37.8)	100 (37.8)
Whey run	At (h - min)	3 - 15	3 - 00	3 - 15	3 - 10
	Titratable acidity (% lactic acid)	0.16	0.17	0.17	0.17
Curd milled	At (h - min)	5 - 20, 6 - 05,	4 - 00, 4 - 45,	4 - 15, 5 - 00,	3 - 55, 4 - 40,

Cont.

TABLE 100

		7 - 35	5 - 45	6 - 05	5 - 55
	Titratable acidity (% lactic acid)	0.5, 0.7, 0.9	0.5, 0.7, 0.9	0.48, 0.7, 0.9	0.5, 0.7, 0.9
Curd salted	At (h - min)	5 - 30, 6 - 15	4 - 10, 4 - 55	4 - 25, 5 - 10	4 - 05, 4 - 50
		7 - 45	5 - 55	6 - 15	6 - 05

TABLE 101

Cheese manufacturing data; the effect of the temperature of the curd at the time of salt addition on seaminess development

Operation		Vat A	Vat B
Milk	Titratable acidity (% lactic acid)	0.16	0.16
	Fat (%), S.N.F. (%)	3.7, 8.60	3.80, 8.46
Starters	Added at (h - min)	0 - 00	0 - 00
	Rate (%) (w/w)	2	2
	Strains (single *Str. cremoris*)	P2, SK11	P2, SK11
	Ratio of mixing	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$
Rennet	Added at (h - min)	0 - 12	0 - 12
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.175	0.18
Coagulum	Cut at (h - min)	1 - 00	0 - 50
	Titratable acidity (% lactic acid)	0.12	0.13
Maximum scald	Total time (h - min)	1 - 00	1 - 00
	Temperature, ^{o}F (^{o}C)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 10	3 - 05
	Titratable acidity (% lactic acid)	0.18	0.25
Curd milled	At (h - min)	4 - 45	4 - 35
	Titratable acidity (% lactic acid)	0.65	0.65
Curd salted	At (h - min)	5 - 06	5 - 06

TABLE 102

Cheese manufacturing data; the effect of mellowing time (from salting to hoop filling) on seaminess development

Operation		
Milk	Titratable acidity (% lactic acid)	0.16
	Fat (%), S.N.F. (%)	3.7, 8.6
Starters	Added at (h - min)	0 - 00
	Rate (%) (w/w)	2
	Strains (Single *Str. cremoris*)	H1, AM2
	Ratio of mixing	2/5, 3/5
Rennet	Added at (h - min)	0 - 12
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)
	Temperature, °F (°C)	88 (31.1)
	Titratable acidity (% lactic acid)	0.165
Coagulum	Cut at (h - min)	1 - 02
	Titratable acidity (% lactic acid)	0.11
Maximum scald	Total time (h - min)	one hour
	Temperature, °F (°C)	102 (38.9)
Whey run	At (h - min)	3 - 17
	Titratable acidity (% lactic acid)	0.16
Curd milled	At (h - min)	4 - 57, 5 - 12
	Titratable acidity (% lactic acid)	0.60
Curd salted	At (h - min)	5 - 12, 5 - 27

TABLE 103

Cheese manufacturing data; the effect of size of milled curd and type of mill (experimental scale production) on seaminess development

Operation		A. Size of milled curd (	Mill type B.1. (A)	Mill type B.1. (B)	Mill type B.1. (C)
Milk	Titratable acidity (% lactic acid)	0.17	0.15	0.15	0.16
	Fat (%), S.N.F. (%)	3.8, 8.6	3.70, 8.40	3.7, 8.25	3.70, 8.30
Starters	Added at (h - min)	0 - 00	0 - 00	0 - 00	0 - 00
	Rate (%) (w/w)	2	2	2	2
	Strains (single *Str. cremoris*)	H1, AM1	P2, SK11	ML8, AM1	H1, AM2
	Ratio of mixing	2/5, 3/5	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$
Rennet	Added at (h - min)	0 - 10	0 - 12	0 - 12	0 - 12
	Rate added, oz per 100 gal (ml per 454.6 l)	3.5 (99.4)	4 (113.6)	4 (113.6)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)	88 (31.1)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.175	0.165	0.160	0.170
Coagulum	Cut at (h - min)	0 - 50	1 - 07	1 - 05	1 - 02
	Titratable acidity (% lactic acid)	0.130	0.115	0.120	0.115
Maximum scald	Total time (h - min)	1 - 00	1 - 00	1 - 00	1 - 00
	Temperature, ^{o}F (^{o}C)	102 (38.9)	102 (38.9)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 10	3 - 10	3 - 10	3 - 15
	Titratable acidity (% lactic acid)	0.25	0.22	0.21	0.16
Curd milled	At (h - min)	4 - 55	5 - 10	5 - 10	4 - 50
	Titratable acidity (% lactic acid)	0.70 to 0.82	0.64 to 0.68	0.60 to 0.65	0.63 to 0.68
Curd salted	At (h - min)	4 - 55 to 5 - 20	5 - 10 to 5 - 20	5 - 10 to 5 - 20	4 - 55 to 5 - 08

TABLE 104

Cheese manufacturing data; effect of type of mill in commercial cheddared curd on seaminess development

Operation		
Milk	Titratable acidity (% lactic acid)	0.17
	Fat (%), S.N.F. (%)	3.7, 8.25
Starters	Added at (h - min)	0 - 00
	Rate (%) (w/w)	2
	Strains (single *Str. cremoris*)	P2, SK11
	Ratio of mixing	2/5, 3/5
Rennet	Added at (h - min)	5 - 25
	Rate added, oz per 100 gal (ml per 454.6 l)	3.5 (99.4)
	Temperature, °F (°C)	88 (31.1)
	Titratable acidity (% lactic acid)	0.175
Coagulum	Cut at (h - min)	0 - 45
	Titratable acidity (% lactic acid)	0.12
Maximum scald	Total time (h - min)	one hour
	Temperature, °F (°C)	102 (38.9)
Whey run	At (h - min)	3 - 10
	Titratable acidity (% lactic acid)	0.28
Curd milled	At (h - min)	4 - 45
	Titratable acidity (% lactic acid)	0.78
Curd salted	At (h - min)	4 - 45 to 5 - 15

TABLE 105

Cheese manufacturing data: the condition of the knife used in CheeseMaker 3 in experimental curd on seaminess development

Operation		Experimental curd	Experimental curd
		Vat 1	Vat 2
Milk	Titratable acidity (% lactic acid)	0.15	0.16
	Fat (%), S.N.F. (%)	3.8, 8.79	4.0, 8.65
Starters	Added at (h - min)	0 - 00	0 - 00
	Rate (%) (w/w)	2	2
	Strains (single *Str. cremoris*)	P2, SK11	ML8, AM1
	Ratio of mixing	2/5, 3/5	2/5, 3/5
Rennet	Added at (h - min)	0 - 10	0 - 10
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.165	0.165
Coagulum	Cut at (h - min)	1 - 00	1 - 00
	Titratable acidity (% lactic acid)	0.11	0.11
Maximum scald	Total time (h - min)	one hour	one hour
	Temperature, ^{o}F (^{o}C)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 10	3 - 10
	Titratable acidity (% lactic acid)	0.17	0.18
Curd milled	At (h - min)	5 - 00	5 - 10 to 6 - 00
	Titratable acidity (% lactic acid)	0.72	0.54
Curd salted	At (h - min)	5 - 40 to 6 - 10	5 - 20 to 6 - 15

TABLE 106

Cheese manufacturing data: the effect of curd moisture on the development of seaminess

Operation		Vat 1	Vat 2	Vat 3	Vat 4	Vat 5
Milk	Titratable acidity (% lactic acid)	0.160	0.170	0.165		
	Fat (%), S.N.F. (%)	3.8, 8.59	3.9, 8.68			
Starters	Added at (h - min)	0 - 00	0 - 00	0 - 00	0 - 00	0 - 00
	Rate (%) (w/w)	2	2	2	2	2
	Strains (single *Str. cremoris*)	ML8, AM1	P2, SK11	ML8, AM1	ML8, AM1	P2, SK11
	Ratio of mixing	2/5, 3/5	2/5, 3/5	⅓, ⅔	2/5, 3/5	2/5, 3/5
Rennet	Added at (h - min)	0 - 10	0 - 10	0 - 10	0 - 10	0 - 10
	Rate added, oz per 100 gal (ml per 454.6 l)	3.5 (99.4)	3.5 (99.4)	3.5 (99.4)	3.5 (99.4)	3.5 (99.4)
	Temperature, °F (°C)	88 (31.1)	88 (31.1)	88 (31.1)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.17	0.175	0.170	0.170	0.170
Coagulum	Cut at (h - min)	1 - 00	1 - 00	1 - 00	0 - 50	0 - 50
	Titratable acidity (% lactic acid)	0.115	0.115	0.12		
Maximum scald	Total time (h - min)	1 - 00	0 - 55	0 - 40	1 - 00	1 - 00
	Temperature, °F (°C)	102 (38.9)	101 (38.3)	101 (38.3)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 10	3 - 10	2 - 25	3 - 15	3 - 10
	Titratable acidity (% lactic acid)	0.19	0.18	0.17	0.25	0.25
Curd milled	At (h - min)	5 - 05	4 - 40	4 - 50	4 - 45	4 - 45
	Titratable acidity (% lactic acid)	0.75	0.65	0.65	0.70	0.71
Curd salted	At (h - min)	5 - 10	4 - 50	5 - 03	4 - 55	4 - 50

TABLE 107

Cheese manufacturing data: the effect of time between milling and salt addition on seaminess development

Operation		Vat 1	Vat 2
Milk	Titratable acidity (% lactic acid)	0.16	0.17
	Fat (%), S.N.F. (%)	3.80, 8.86	3.85, 8.87
Starters	Added at (h - min)	0 - 00	0 - 00
	Rate (%) (w/w)	2	2
	Strains (single *Str. cremoris*)	ML8, AM1	P2, SK11
	Ratio of mixing	2/5, 3/5	2/5, 3/5
Rennet	Added at (h - min)	0 - 12	0 - 13
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)
	Temperature, °F (°C)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.165	0.18
Coagulum	Cut at (h - min)	1 - 02	1 - 03
	Titratable acidity (% lactic acid)	0.11	0.14
Maximum scald	Total time (h - min)	one hour	one hour
	Temperature, °F (°C)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 15	3 - 15
	Titratable acidity (% lactic acid)	0.15	0.17
Curd milled	At (h - min)	5 - 35	5 - 05
	Titratable acidity (% lactic acid)	0.60 to 0.74	0.5 to 0.74
Curd salted	At (h - min)	5 - 35 to 7 - 15	5 - 10 to 6 - 10

TABLE 108

Cheese manufacturing data; the effect of time from hoop filling to final pressing on seaminess development

Operation		Vat A	Vat B	Vat C
Milk	Titratable acidity (% lactic acid)	0.18	0.175	0.180
	Fat (%), S.N.F. (%)	3.8, 8.7	3.8, 8.36	3.7, 8.7
Starters	Added at (h - min)	0 - 00	0 - 00	0 - 00
	Rate (%) (w/w)	2	2	2
	Strains (single *Str. cremoris*)	ML8, AM1	P2, AM2	H2, E8
	Ratio of mixing	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$
Rennet	Added at (h - min)	0 - 12	0 - 18	0 - 18
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.19	0.175	0.185
Coagulum	Cut at (h - min)	1 - 07	1 - 05	1 - 13
	Titratable acidity (% lactic acid)	0.125	0.13	0.13
Maximum scald	Total time (h - min)	1 - 00	1 - 00	1 - 00
	Temperature, ^{o}F (^{o}C)	102 (38.9)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 15	3 - 15	3 - 17
	Titratable acidity (% lactic acid)	0.165	0.18	0.17
Curd milled	At (h - min)	5 - 50	4 - 45	5 - 30
	Titratable acidity (% lactic acid)	0.65	0.72	0.69
Curd salted	At (h - min)	6 - 05	5 - 00	5 - 45

TABLE 109

Cheese manufacturing data; the effect of the use of different pressure in pressing the cheese on seaminess development

Operation		
Milk	Titratable acidity (% lactic acid)	0.165
	Fat (%), S.N.F. (%)	3.8, 8.84
Starters	Added at (h - min)	0 - 00
	Rate (%) (w/w)	2
	Strains (single *Str. cremoris*)	H1, AM1
	Ratio of mixing	$\frac{1}{3}$, $\frac{2}{3}$
Rennet	Added at (h - min)	0 - 10
	Rate added, oz per 100 gal (ml per 454.6 l)	3.5 (99.4)
	Temperature, ^{o}F (^{o}C)	88 (31.1)
	Titratable acidity (% lactic acid)	0.17
Coagulum	Cut at (h - min)	0 - 50
	Titratable acidity (% lactic acid)	0.125
Maximum scald	Total time (h - min)	1 - 00
	Temperature, ^{o}F (^{o}C)	102 (38.9)
Whey run	At (h - min)	3 - 10
	Titratable acidity (% lactic acid)	0.25
Curd milled	At (h - min)	4 - 45 to 4 - 60
	Titratable acidity (% lactic acid)	0.72
Curd salted	At (h - min)	4 - 50 to 5 - 10

TABLE 110

Cheese manufacturing data: determination of heat loss from cheddared curd during pressing time

Operation		Vat 1	Vat 2
Milk	Titratable acidity (% lactic acid)	0.17	0.17
	Fat (%), S.N.F. (%)	3.9, 8.68	3.8, 8.75
Starters	Added at (h - min)	0 - 00	0 - 00
	Rate (%) (w/w)	2	2
	Strains (single *Str. cremoris*)	ML8, AM1	H2, E8
	Ratio of mixing	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$
Rennet	Added at (h - min)	0 - 15	0 - 15
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)
	Temperature, ^{o}F (^{o}C)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.175	0.18
Coagulum	Cut at (h - min)	1 - 10	0 - 55
	Titratable acidity (% lactic acid)	0.13	0.125
Maximum scald	Total time (h - min)	1 - 00	1 - 00
	Temperature, ^{o}F (^{o}C)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 15	2 - 40
	Titratable acidity (% lactic acid)	0.165	0.18
Curd milled	At (h - min)	5 - 45	4 - 35
	Titratable acidity (% lactic acid)	0.66	0.60
Curd salted	At (h - min)	6 - 00	4 - 40

TABLE 111

Cheese manufacturing data: effect of temperature of the curd at pressing on seaminess development

Operation		
Milk	Titratable acidity (% lactic acid)	0.160
	Fat (%), S.N.F. (%)	3.7, 8.69
Starters	Added at (h - min)	0 - 0
	Rate (%) (w/w)	2
	Strains (single *Str. cremoris*)	P2, SK11
	Ratio of mixing	2/5, 3/5
Rennet	Added at (h - min)	0 - 10
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)
	Temperature, °F(°C)	88 (31.1)
	Titratable acidity (% lactic acid)	0.170
Coagulum	Cut at (h - min)	1 - 00
	Titratable acidity (% lactic acid)	0.11
Maximum scald	Total time (h - min)	one hour
	Temperature, °F (°C)	102 (38.9)
Whey run	At (h - min)	3 - 00
	Titratable acidity (% lactic acid)	0.17
Curd milled	At (h - min)	5 - 20
	Titratable acidity (% lactic acid)	0.7
Curd salted	At (h - min)	5 - 40

TABLE 112

Cheese manufacturing data; the effect of the presence of calcium orthophosphate in milk and curd particles on seaminess development

Operation		Vat A (in milk)	Vat B (in milk)	Vat C (on curd)
Milk	Titratable acidity (% lactic acid)	0.165	0.16	0.15
	Fat (%), S.N.F. (%)	3.6, 8.40	3.5, 8.32	3.65, 8.82
Starters	Added at (h - min)	0 - 00	0 - 00	0 - 00
	Rate (%) (w/w)	2	2	2
	Strains (single *Str. cremoris*)	P2, SK11	ML8, AM1	P2, SK11
	Ratio of mixing	$\frac{1}{3}$, $\frac{2}{3}$	$\frac{1}{3}$, $\frac{2}{3}$	2/5, 3/5
Rennet	Added at (h - min)	0 - 13	0 - 15	0 - 12
	Rate added, oz per 100 gal (ml per 454.6 l)	4 (113.6)	4 (113.6)	3.5 (99.4)
	Temperature, °F (°C)	88 (31.1)	88 (31.1)	88 (31.1)
	Titratable acidity (% lactic acid)	0.17	0.17	0.16
Coagulum	Cut at (h - min)	1 - 11	1 - 05	0 - 50
	Titratable acidity (% lactic acid)	0.12	0.125	0.11
Maximum scald	Total time (h - min)	1 - 00	1 - 00	one hour
	Temperature, °F (°C)	102 (38.9)	102 (38.9)	102 (38.9)
Whey run	At (h - min)	3 - 13	3 - 15	3 - 03
	Titratable acidity (% lactic acid)	0.22	0.19	0.16
Curd milled	At (h - min)	4 - 43	5 - 05	5 - 08
	Titratable acidity (% lactic acid)	0.67	0.62	0.60
Curd salted	At (h - min)	4 - 45	5 - 15	5 - 18 to 6 - 60

APPENDIX B

TABLES 113 TO 126

RESULTS OF SCORING THE CHEESE AND CHEMICAL ANALYSES

TABLE 113

Mean scores given by the panel (5 judges) to experimental Cheddar cheese made with different amounts of added salt of different particle size at different times during curing

Age of cheese (weeks)	4% added salt of particle size (µm)			2% added salt of particle size (µm)		
	50	107	333 (commercial grade dry vacuum salt)	50	107	333 (commercial grade dry vacuum salt)
			Seaminess (Scale 0 – 10)			
1	2.80	2.67	2.70	1.33	1.00	2.00
4	1.27	1.87	1.57	0.47	0.47	0.60
8	2.10	2.40	2.23	0.40	1.27	1.63
24	2.20	3.67	3.73	1.67	2.47	2.67
52	2.20	1.40	2.47	0.87	1.00	1.47
			Fusion (Scale 0 – 10)			
1	6.13	5.87	6.60	5.67	6.13	6.00
4	6.33	6.27	6.47	6.80	7.20	7.13
8	7.08	7.33	6.73	8.13	7.67	6.83
24	7.60	7.67	7.53	7.07	6.93	7.60
52	4.66	4.47	4.60	4.67	4.67	4.60
			Openness (Scale 0 – 10)			
1	4.53	3.93	3.60	3.87	4.67	4.53
4	5.13	5.33	4.40	5.33	5.87	5.60

Cont. TABLE 113

8	3.80	4.20	3.60	4.33	3.53	4.93
24	1.67	2.07	1.73	3.00	2.73	2.80
52	3.13	3.07	2.73	3.93	2.93	3.87
			Body (Scale 0 - 10)			
1	5.41	6.47	6.61	6.73	6.47	6.47
4	6.80	6.80	7.25	6.60	6.93	6.47
8	7.73	7.33	7.47	6.67	7.00	6.80
24	8.40	8.07	8.06	7.33	7.07	6.80
52	5.53	5.47	6.20	5.13	5.40	4.00
			Flavour (Scale 0 - 10)			
1	7.93	7.87	8.13	7.93	7.87	7.93
4	7.87	9.00	7.67	8.40	8.00	9.00
8	7.87	7.73	7.93	8.13	7.80	7.93
24	7.60	6.80	7.07	7.40	6.87	6.67
52	2.60	2.60	3.27	1.60	2.07	1.47
			Colour (Scale 0 - 10)			
1	6.60	6.93	7.73	8.20	8.47	8.20
4	7.87	7.53	7.47	8.60	8.53	8.53
8	7.87	7.93	7.53	8.67	8.60	8.00
24	7.67	7.33	7.33	7.33	7.40	6.87
52	6.47	7.27	6.67	7.13	6.80	7.07

TABLE 114

Mean scores given by the panel (5 judges) to commercial Cheddar cheese (mixed-strain starters) made with different amounts of added salt of different particle size at different time during curing

Age of cheese (weeks)	2% added salt of particle size (µm)		3% added salt of particle size (µm)		Machine salted commercial grade dry vacuum salt
	73	333 (commercial grade dry vacuum salt)	73	333 (commercial grade dry vacuum salt)	
			Seaminess (Scale 0 - 10)		
1	1.12	0.84	1.44	1.80	2.24
4	3.04	3.40	3.92	4.00	4.72
8	4.00	2.80	4.20	4.60	3.72
24	1.36	1.52	2.00	2.60	2.00
			Fusion (Scale 0 - 10)		
1	6.76	4.88	4.72	4.80	4.36
4	6.80	6.64	6.68	6.64	6.44
8	7.32	7.20	7.00	7.16	7.16
24	5.76	5.48	5.60	6.12	5.96
			Openness (Scale 0 - 10)		
1	8.44	8.00	8.00	8.40	8.76
4	2.88	2.60	3.04	3.04	2.72

Cont. TABLE 114

8	1.24	1.40	1.56	2.00	1.88
24	5.24	5.40	4.24	3.08	4.60
			Body (Scale 0 - 10)		
1	8.24	8.12	8.20	8.52	8.28
4	6.32	6.96	7.68	7.72	7.24
8	7.20	7.40	8.08	7.72	7.56
24	6.12	5.92	6.12	6.24	6.00
			Flavour (Scale 0 - 10)		
1	8.44	8.92	8.64	8.80	8.64
4	8.32	8.52	8.48	8.64	8.60
8	8.08	7.80	7.88	7.68	8.08
24	7.20	6.48	6.84	7.52	7.28
			Colour (Scale 0 - 10)		
1	6.32	5.68	5.08	5.12	5.20
4	7.07	6.84	7.08	5.96	5.96
8	7.40	7.48	6.88	6.60	6.68
24	7.76	7.44	7.76	7.64	7.40

TABLE 115

Mean scores given by the panel to commercial Cheddar cheese (single-strain starters) made with commercial curd with different amounts of added salt of different particle size at different times during curing

Age of cheese (weeks)	2% added salt of particle size 73 (µm)	2% added salt of particle size 333 (µm) commercial grade dry vacuum salt	3% added salt of particle size 73 (µm)	3% added salt of particle size 333 (µm) commercial grade dry vacuum salt	Machine salted with commercial grade dry vacuum salt (333 µm)
			Seaminess (Scale 0 - 10)		
4	9.25	9.50	9.15	9.50	8.95
12	9.30	9.45	9.50	9.60	9.30
24	9.35	9.45	9.40	9.80	9.10
36	8.70	8.70	9.25	9.30	9.20
52	7.20	7.35	8.90	8.80	8.95
			Fusion (Scale 0 - 10)		
4	7.20	7.60	7.55	7.50	7.55
12	7.40	7.25	7.35	7.35	7.30
24	7.20	6.95	7.05	7.45	7.55
36	6.80	6.75	7.35	6.75	7.20
52	5.45	5.60	6.00	5.60	6.30
			Openness (Scale 0 - 10)		
4	2.10	2.70	2.40	2.50	1.65
12	2.70	2.55	2.30	2.50	1.35

Cont.

TABLE 115

24	2.75	3.20	1.70	1.70	0.95
36	2.95	2.30	3.15	2.15	1.05
52	2.65	2.75	1.70	1.60	1.20
			Body (Scale 0 - 10)		
4	7.70	7.55	7.95	8.00	8.45
12	7.65	7.85	8.05	8.15	8.40
24	6.60	6.95	7.10	7.35	7.90
36	7.65	7.40	7.60	7.80	7.70
52	5.80	5.90	6.00	6.00	6.65
			Flavour (Scale 0 - 10)		
4	8.50	8.25	8.30	8.10	8.15
12	8.35	8.35	7.90	8.00	7.85
24	7.66	7.40	7.95	7.90	8.80
36	6.90	6.75	7.10	7.25	6.90
52	6.40	6.80	6.90	7.40	7.75
			Colour (Scale 0 - 10)		
4	7.75	7.60	7.65	7.70	7.85
12	8.10	8.10	7.70	8.15	7.60
24	7.40	7.60	7.20	7.30	7.35
36	6.90	6.75	7.10	7.25	6.90
52	7.10	7.35	7.10	7.30	7.10

TABLE 116

Mean scores of seaminess given by scoring panel (2 judges) to experimental Cheddar cheese at different time of curing with their chemical analysis

Vat 1. White Cheddar	Age of the cheese (weeks)									
	Single-strain (*Str. cremoris*)									
	1	2	3	4	5	6	7	8	12	16
Mean scores (2 judges)										
Seaminess	0	2	2	2	3.5	4	4	4	4	4
Chemical Analysis										
pH	5.42	5.40	5.34	5.33	5.30	5.27	5.21	5.11	4.95	5.01
Moisture (%)	37.13	37.10	37.05	35.45	35.00	36.04	36.75	37.57	37.7	36.07
Salt (%)	1.57	1.57	1.58	1.59	1.66	1.53	1.56	1.48	1.52	1.76
Vat 2 Coloured Cheddar	single-strain (*Str. cremoris*)									
Mean scores (2 judges)										
Seaminess	1	1	2	3	3.5	3	4	4	4	4
Chemical analysis										
pH	5.45	5.40	5.34	5.30	5.25	5.15	5.08	5.05	4.96	4.97
Moisture (%)	37.15	36.89	35.20	35.70	35.88	36.05	36.26	36.33	37.34	36.12
Salt (%)	1.83	1.84	1.87	1.91	1.92	1.92	1.94	1.94	1.94	1.88

TABLE 117

Mean scores given by the panel (5 judges) to commercial Cheddar (single-strain starter) made with salt of different particle size at 8 weeks after manufacture

Added salt (% (w/w))	Salt particle size (μm)	Replicate	Seaminess scale 0 – 10	Fusion scale 0 – 10	Openness scale 0 – 10	Body scale 0 – 10	Flavour scale 0 – 10	Colour scale 0 – 10
2	73	1	9.0	7.2	3.2	7.8	8.6	8.2
		2	9.4	7.8	1.8	7.8	8.4	8.2
		3	9.4	7.0	2.8	7.2	8.2	8.2
		4	9.4	7.6	3.0	7.8	8.6	8.0
2	333	1	9.4	7.0	2.8	7.4	8.2	8.0
	(commercial grade	2	9.6	7.0	2.2	7.8	8.0	8.0
	dry vacuum salt)	3	9.4	7.2	2.8	7.8	8.0	7.4
		4	10.0	7.2	2.0	7.8	8.0	7.4
3	73	1	9.2	7.4	3.8	8.2	7.8	7.6
		2	9.6	7.4	1.8	8.2	8.0	8.0
		3	9.6	7.4	1.6	8.0	7.8	7.8
		4	9.6	7.2	2.0	7.8	8.0	7.4

Cont. TABLE 117

3	333	1	9.6	8.0	2.0	8.2	8.6	8.0
	(commercial grade	2	9.6	7.0	3.2	8.4	8.4	8.0
	dry vacuum salt)	3	9.6	7.0	1.6	7.8	8.2	8.2
		4	9.6	7.4	3.2	8.2	8.8	8.4
Machine	333	1	9.4	6.6	1.6	8.6	8.0	8.2
Salted	(commercial grade	2	9.2	7.6	1.0	8.6	7.4	7.8
	dry vacuum salt)	3	9.2	7.8	1.4	7.8	7.8	8.2
		4	9.4	7.2	1.4	8.6	8.2	7.8

TABLE 118

Chemical analysis of commercial Cheddar (single-strain starter) made with salt of different particle size

			at 4 weeks					at 8 weeks
Added salt (% w/w)	Salt particle size (µm)	Replicate	Moisture (%)	Salt (%)	Salt in aqueous phase (%)	B.C.T. at 60°F	Elasticity at 60°F	pH
2	73	1	35.13	1.35	3.8	60.3	41.8	5.09
		2	35.16	1.40	4.0	46.6	39.6	5.12
		3	35.10	1.41	4.0	60.2	40.7	5.09
		4	34.92	1.32	3.8	60.9	43.7	5.06
2	333	1	34.86	1.57	4.5	59.8	43.1	5.16
	(commercial grade	2	34.48	1.58	4.6	58.1	39.0	5.08
	dry vacuum salt)	3	34.40	1.54	4.5	60.0	41.4	5.10
		4	34.80	1.48	4.3	60.1	40.6	5.09
3	73	1	34.17	1.90	5.6	64.4	44.8	5.11
		2	33.68	2.02	6.0	65.8	43.5	5.31
		3	33.08	1.89	5.7	54.8	37.0	5.29
		4	33.17	1.99	6.0	61.6	43.0	5.09

Cont. TABLE 118

3	333	1	33.52	1.81	5.4	54.6	39.8	5.18
	(commercial grade	2	33.86	1.97	5.8	64.6	43.6	5.26
	dry vacuum salt)	3	33.44	1.85	5.5	59.6	40.0	5.06
		4	33.72	1.87	5.6	66.0	46.5	5.13
Machine	333	1	33.42	2.02	6.1	61.3	44.2	5.31
salted	(commercial grade	2	33.31	1.81	5.4	61.3	43.2	5.10
	dry vacuum salt)	3	32.85	1.84	5.6	57.3	39.1	5.11
		4	34.92	1.32	3.8	59.6	42.8	5.06

TABLE 119

Mean scores of the panel (4 judges) given to Cheddar cheese salted at different acidities and made with different strains of starters

Vat 1. Strains used: ML8, AM1 Single strain: *Str. cremoris*

Acidity at salting (% lactic acid)	Replicate	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
0.5	1	1.5	7.3	1.8	6.8	7.8	8.0
	2	0.8	6.3	2.3	7.3	8.3	7.5
	3	1.0	7.0	2.8	6.8	8.0	7.8
0.7	1	2.3	6.5	2.0	6.8	8.0	7.8
	2	1.8	6.8	2.8	6.5	8.0	7.8
	3	1.5	6.8	2.3	7.3	7.8	7.5
0.9	1	2.8	6.5	2.3	7.0	7.8	7.3
	2	4.3	5.5	2.3	7.5	8.0	7.3
	3	4.0	6.8	2.3	7.8	8.3	7.5

TABLE 120

Chemical analysis of Cheddar cheese salted at different acidity and made with starters of different strains at 8 weeks after manufacture

Vat 1 Strains used ML8, AM1 Single-strains: *Str. cremoris*

Acidity at salting (% lactic acid)	Replicate	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
0.5	1	5.16	37.38	1.63	4.4
	2	5.18	37.50	1.69	4.5
	3	5.15	37.28	1.60	4.3
0.7	1	5.14	37.00	1.60	4.3
	2	5.16	37.14	1.76	4.7
	3	5.17	37.29	1.79	4.8
0.9	1	5.14	36.25	1.78	4.9
	2	5.11	36.46	1.76	4.8
	3	5.15	36.65	1.78	4.9

TABLE 121

Mean scores of the panel (4 judges) given to Cheddar cheese salted at different acidities made with different strains of starters at 8 weeks

Vat 2   Strains used: WM1, AM2   Single-strain: *Str. cremoris*

Acidity at salting (% lactic acid)	Replicate	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
0.5	1	0.8	5.5	1.8	7.5	8.0	7.5
	2	0.8	6.8	1.5	7.0	8.5	7.5
	3	1.0	7.3	1.3	7.0	8.0	7.0
0.7	1	0.5	6.0	1.5	6.8	7.5	7.3
	2	0.5	6.3	1.5	6.8	7.8	6.3
	3	0.5	6.0	1.5	6.8	7.8	7.3
0.9	1	1.8	5.8	1.3	6.5	7.3	6.8
	2	1.0	7.0	1.8	6.8	8.0	7.5
	3	1.3	6.5	1.3	7.0	8.0	7.0

TABLE 122

Chemical analysis of Cheddar cheese salted at different acidities and made with starters of different strains at 8 weeks after manufacture

Vat 2 Strains used: WM1, AM2 Single-strain: *Str. cremoris*

Acidity at salting (% lactic acid)	Replicate	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
0.5	1	5.08	35.92	1.71	4.7
	2	5.14	36.32	1.68	4.6
	3	5.14	35.99	1.62	4.5
0.7	1	5.11	36.20	1.64	4.5
	2	5.13	36.06	1.67	4.6
	3	5.14	36.00	1.71	4.8
0.9	1	5.08	36.62	1.71	4.7
	2	5.05	36.35	1.73	4.8
	3	5.10	36.10	1.74	4.8

TABLE 123

Mean scores of the panel (4 judges) given to Cheddar cheese salted at different acidities and made with starters of different strains

Vat 3 Strains used: H2, E8 single-strain: *Str. cremoris*

Acidity at salting (% lactic acid)	Replicate	Seaminess scale 0 – 10	Fusion scale 0 – 10	Openness scale 0 – 10	Body scale 0 – 10	Flavour scale 0 – 10	Colour scale 0 – 10
0.5	1	2.0	6.0	5.5	8.3	8.5	7.0
	2	1.3	6.5	4.5	7.3	8.5	7.3
	3	1.0	7.0	4.3	7.3	8.0	7.8
0.7	1	1.3	7.3	3.3	7.8	8.5	8.0
	2	3.5	6.0	3.8	8.8	8.3	7.5
	3	1.3	6.3	3.8	8.5	8.5	7.5
0.9	1	3.0	6.5	3.3	8.8	8.5	7.5
	2	4.0	6.0	3.3	7.5	8.5	7.0
	3	3.0	5.8	4.3	8.0	8.5	7.3

TABLE 124

Chemical analysis of Cheddar cheese salted at different acidities and made with starters of different strains at 8 weeks after manufacture

Vat 3 Strains used: H2, E8 Single-strain: *Str. cremoris*

Acidity of salting (% lactic acid)	Replicate	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
0.5	1	5.19	35.68	1.66	4.6
	2	5.27	35.70	1.65	4.6
	3	5.17	35.85	1.68	4.7
0.7	1	5.19	35.78	1.70	4.9
	2	5.15	35.70	1.66	4.6
	3	5.14	35.70	1.68	4.7
0.9	1	5.11	35.07	1.73	4.9
	2	5.11	35.30	1.70	4.8
	3	5.10	35.16	1.72	4.9

TABLE 125

Mean scores of the panel (4 judges) given to Cheddar cheese salted at different acidities and made with starters of different strains

Vat 4 Strains used: P2, SK11 Single-strain: *Str. cremoris*

Acidity at salting (% lactic acid)	Replicate	Seaminess scale 0 - 10	Fusion scale 0 - 10	Openness scale 0 - 10	Body scale 0 - 10	Flavour scale 0 - 10	Colour scale 0 - 10
0.5	1	0.8	6.0	3.0	6.0	6.5	7.3
	2	1.0	4.5	2.0	6.0	6.3	6.8
	3	1.3	4.5	2.3	6.0	6.0	7.0
0.7	1	1.5	5.0	2.0	6.3	7.0	5.5
	2	2.5	5.0	2.0	5.5	6.3	6.3
	3	2.0	4.0	2.0	6.0	6.5	5.3
0.9	1	4.3	3.3	2.3	6.0	6.3	4.8
	2	5.0	3.5	1.5	5.5	6.3	4.3
	3	5.0	2.8	2.3	5.3	6.0	4.0

TABLE 126

Chemical analysis of Cheddar cheese salted at different acidities and made with starters of different strains at 8 weeks after manufacture

Vat 4 Strains used: P2, SK11 Single strain: *Str. cremoris*

Acidity of salting (% lactic acid)	Replicate	pH	Moisture (%)	Salt (%)	Salt in aqueous phase (%)
0.5	1	5.04	35.86	1.61	4.5
	2	5.05	35.71	1.55	4.4
	3	5.06	35.70	1.59	4.5
0.7	1	5.08	35.90	1.66	5.1
	2	5.09	35.88	1.59	4.4
	3	5.03	35.73	1.62	4.5
0.9	1	5.02	35.75	1.65	4.6
	2	5.03	36.14	1.64	4.5
	3	5.00	35.70	1.67	4.7

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