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# Some factors affecting the growth of Penicillium roqueforti in cheese

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# SOME FACTORS AFFECTING THE GROWTH OF *PENICILLIUM ROQUEFORTI* IN CHEESE.

BY

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# SOME FACTORS AFFECTING THE GROWTH OF PENICILLIUM ROQUEFORTI IN CHEESE.

## General Introduction.

The mold known as *Penicillium roqueforti* obtains its species name from Roquefort cheese in which it plays an essential part during the ripening. *P. roqueforti* or a closely related species is required in the ripening of all cheese classified as blue veined. In fact the term "blue veined cheese" is derived from the typical blue spores produced by the fruiting of the mold while growing in these varieties of cheese.

The origin of many of the blue veined varieties of cheese, such as Roquefort and Stilton, antedates by many years the sciences of bacteriology and mycology. Therefore, the growth of *P. roqueforti* in these cheese must be considered to have originated by chance, and, as this particular type of fermentation became desired, conditions that favored its development were encouraged. Natural conditions in special districts of certain countries favored the development of blue mold in the cheese and special varieties of cheese became associated with the particular districts. In Europe, several of the districts became famous before 1800 and in most cases retain their prominence today, in spite of the persistent efforts of other countries and districts to imitate their cheese.

Undoubtedly, certain climatic conditions favor the manufacture of blue veined varieties of cheese, but even in the blue veined cheese districts the manufacture is a seasonal industry and cheese are made only during the late spring, summer and early fall. In spite of the favorable climate, the operators of some of the old well known factories are introducing refrigeration to prevent losses in hot weather and speak most highly of the results they are obtaining.

Apart from climate, many statements are made as to the reason a particular variety of blue veined cheese is suited to a district. Of these statements, some of the most common are:

a. The pasture is more suitable for the cows, due to the conditions of soil and climate.

b. There are special ferments that are natural to the district and without their chance inoculation good cheese are not made.

c. Special home made rennets are used which give the right type of coagulation and fermentation.

In actual practice, it is found that there is no uniform reason for success with one particular variety of blue veined cheese. A certain factory or farm dairy has usually been in existence for many years, and a satisfactory method of manufacture has been evolved, in part at least, by a process of trial and error. Unlike Cheddar and many other varieties of hard pressed cheese, standard methods are not practiced. Even in the best factories, the cheese are not uniform, and some buyers will try every cheese before purchasing, to see whether or not blue mold has developed.

The absence of standard methods of manufacture and the cause of the mold development being obscure are the main reasons why other countries have failed to imitate the varieties of blue veined cheese.

The greater remuneration to be secured from blue veined cheese is shown by the facts that:

(a) During the summer of 1928, Stilton cheese factories in Leicestershire were paying 9½d. to 10 d. for an imperial gallon of milk, while the cooperative creameries in Ireland could pay only 6 d. to 6½ d. for the same quantity.

(b) The wholesale price of Roquefort cheese in America is usually twice the price of Cheddar, while the yield of cheese per 100 lbs. of milk is only slightly in favor of the latter.

The manufacture of good blue veined cheese should be profitable, but it would seem that the only hopeful approach to a standard method of manufacture must come from a thorough scientific knowledge of the factors affecting the growth of *P. roqueforti* in cheese.

GENERAL PROBLEM.

The problem of some of the factors that effect the growth of P. roqueforti in cheese has been investigated under three parts, namely:

Part I. The citrates of milk and their possible fermentation products as they affect the growth of P. roqueforti.

Part II. The effect of ammonium salts on the growth of P. roqueforti in cheese.

Part III. Oxygen requirements of P.roqueforti in cheese.

# PART I.

## THE CITRATES OF MILK AND THEIR POSSIBLE FERMENTATION PRODUCTS AS THEY AFFECT THE GROWTH OF P. ROQUEFORTI.

### Introduction

In the manufacture of blue veined cheese, the early fermentation is the formation of acid by the growth of bacteria. As this fermentation occurs before the development of P. roqueforti, it ~~is~~ likely to affect the subsequent growth of the mold.

## Review of Literature.

The presence of citrates in milk has long been established and many investigators have determined the percentage, the results being expressed as citric acid (34) (36) (33). Sommer and Hart (34) have shown that citrates exist in cows milk to the extent of approximately 0.2 percent. Supplee and Bellis (36) gave the average citrate content of cows milk as 0.142 percent citric acid for winter and 0.148 percent for summer. Sherwood and Hammer (33) concluded that the citrates in cows milk varies from a maximum of about 0.33 percent to a minimum of 0.07 percent citric acid. They give the average as 0.18 percent.

As to the combinations of salts of citric acid that exist in cows milk, differences of opinion are shown by the reports of the following investigators. Söldner (31) believed the salts of citric acid exist in a litre of milk as 0.495 grams potassium citrate, 0.367 grams magnesium citrate and 2.133 grams calcium citrate. Porcher and Chavallier (31) regard the salts of citric acid to be present in a litre of milk as 0.67 grams potassium citrate, 0.76 grams magnesium citrate and 1.78 grams calcium citrate. On the other hand, Van Slyke and Bosworth (40) considered the salts of citric acid to exist in milk as 0.222 percent sodium citrate and 0.052 percent potassium citrate. They believed that no calcium or magnesium is united to the citrate radical. Clark (8) considered the acid base equilibria still unknown and the linking up of acids with bases a regrettable practice.

With reference to the type of acid fermentation which is suitable for "blue veined cheese", Matheson (25) recommended a liberal use of starter for the manufacture of Roquefort cheese, but gave no details as to the type of starter to employ. Benson (5) states, "It is possible in the manufacture of Camembert cheese to add a starter containing the desirable ripening ferments of this cheese to the milk, and so secure proper flavour and mould growth in the cheeses made therefrom. I see no reason why the same should not be done with Stilton and Wensleydale cheese. The ordinary commercial starter of bacterium lactis is, however, not the right thing. Probably a combination of this and other ferments is what is required and experiments in this direction are necessary." Evans (12) concluded that the microorganisms essential to the manufacture and ripening of Roquefort cheese are S. lactis and P. roqueforti. S. lactis was found to decompose the lactose during the manufacture of the cheese and thus produce the lactic acid necessary for the cheese making. This organism disappeared from the cheese after about two or three weeks, being killed by the high concentration of sodium chloride. Thom, Currie and Matheson (38) also inferred that no special type of lactic fermentation is required, for they considered that the flora of Roquefort cheese consists of P.roqueforti, bacteria of the common lactic type, the B. bulgarius group in small numbers, some liquefying organisms, yeasts in small numbers and the varied flora of the surface slime.

Hammer (16) (17) showed that pure cultures of S. lactis, when grown in milk, produced only a small quantity of volatile acids while starters which contained associate organisms, namely Streptococcus citrovorus and Streptococcus paracitrovorus along with S. lactis produced considerable volatile acidity. He further demonstrated that the origin of the volatile acidity was in part the fermentation of the citrates of the milk to acetic acid and small amounts of propionic acid.

The significance of the associate organisms of starters in Cheddar cheese ripening has been studied by Hucker and Marquardt (21) who make the following statements: "S. Paracitrovorus Hammer, when added to milk either in conjunction with commercial starters or alone, appeared to have a desirable effect upon the flavor of the cheddar cheese. Cheese made from pasteurized milk which had been inoculated with this particular organism developed a flavor not unlike raw milk cheese." "S. citrovorus Hammer, and S. lactis Löhnis appeared to have no effect upon the production of flavor when added to the milk to be used for cheese making. The latter organism gave as favorable resulrs as commercial starters."

## A. IN MILK AND SYNTHETIC MEDIA.

### Statement of Problem.

The object of the investigation was to determine the influence of acetic and citric acid respectively on the growth of different strains of P. roqueforti using such percentages of the acids as might be found in milk and sour milk (18) (33) (32). Two phases of the subject were considered:

1. The growth of the mold on milk and acidified milks in test tubes at room temperature.

2. The growth of the mold on solid synthetic media in plates where the growth of one colony could be measured.

### Methods.

Cultures. The cultures of P. roqueforti used were:

No. 1. P. roqueforti secured from Dairy Division, Washington, D. C. (14)

No. 16, Isolated from Wensleydale cheese (14)

No. 32, Isolated from Wensleydale cheese inoculated with culture 16 (14)

No. 33. Isolated from Wensleydale cheese inoculated with culture. 1 (14)

Milk. Sweet skim milk in which no bacterial change had taken place was used in every case. Test tubes of uniform diameter were selected, filled with exactly 10 cc. of milk, plugged and sterilized.

Milk + citric acid. A citric acid solution was made of such strength that it contained 0.0327 gram of crystalline citric acid per c c. This was added to test tubes, plugged and sterilized. The milk and acid solution were well cooled and an acid milk prepared by adding 0.5 cc. of the acid solution to each 10 cc. tube of milk, under sterile conditions. The concentration of citric acid was therefore 0.1423 percent.

Milk + acetic acid. An acetic acid solution was made up of such strength that it contained 0.01008 grams of acetic acid per cc. One cc. of glacial acetic acid, assumed to be sterile, was added to 100 cc. of sterile water. The milk and acid solutions were thoroughly cooled and two lots of acid milk were prepared by adding 1.5 and 0.5 cc. respectively of the acid solution to 10 cc. tubes of milk under sterile conditions. The concentrations of acetic acid in the milk were 0.131 and 0.048 percent respectively.

Standard medium. The standard medium, originating in part from Czapek's formula (37) was made up as follows:

| | | |
|---|---|---|
| Distilled water | 2000 | cc. |
| Magnesium sulphate | 1. | gram |
| Dipotassium phosphate | 2. | grams |
| Potassium chloride | 1 | gram |
| Ferrous sulphate | .02 | gram |
| Peptone | 20 | grams |
| Lactose | 50 | grams |
| Agar | 30 | grams |

Standard medium + citric acid. Two concentrations of citric acid in the standard medium were prepared by adding, in the proportion of 1.0 or 0.5 cc., the solution of citric acid (0.0327 gram per cc.) to 10 cc. of the standard medium; the media were then tubed and sterilized. By this method, concentrations of citric acid were obtained of 0.272 and 0.1423 percent respectively.

Standard medium + acetic acid. The acetic acid solution was prepared as in the case of milk and acetic acid previously referred to. To each 10 cc. tube of the sterile standard medium, either 1.5 or 0.5 cc. of the solution (0.01008 gram acetic acid per cc.) were added under sterile conditions. By this method, concentrations of acetic acid were obtained of 0.131 and 0.048 percent respectively.

Inoculation. The test tubes of milk were inoculated with a platinum needle from stock cultures grown on potato agar.

The plate cultures were first poured and allowed to cool on a flat surface. The inoculation was done from the cultures,using a platinum needle, and every endeavor was made to develop but one colony and that in the middle of the plate.

Incubation. All cultures were grown in a room temperature incubator, which averaged 21°C. and maintained a temperature between 22.5 and 20° C.

Measurement of growth in milk. The method used to determine the degree of growth in the milk, and the acidified milk,was to hold the cultures ten days after inoculation and then determine the percentage of casein. Standard Methods of Analysis were used (1) and the Kjeldahl determinations were made by the Gunning method.

Measurement of growth on solid media. The growth on the plates of solid media was recorded after the third day and then daily. This record included:

Margin, average width in m m.

Sige, average diameter of colony in m m.

Color of spores, when spores were present.

Color of reverse of colony.

It was found that the average diameter of the colony in mm.was the most satisfactory way of expressing the rate of growth of the mold.

## Results Obtained.

### Growth of Different Strains of P. roqueforti in Milk and Acidified Milk.

Three varieties of milk media, as previously described, were used in this experiment.

Table 1.

Growth by P. roqueforti in Milk and Acidified Milk at

| Cultures | Milk | | Milk + .048% Acetic Acid | | + .1 |
|---|---|---|---|---|---|
| | % Casein | % Casein digested* | % Casein | % of Casein digested* | % Ca |
| Uninoculated control | 3.10 | | 3.04 | | 3. |
| 1 | 2.20 | 29.0 | 2.35 | 22.7 | 2. |
| 33 | 2.08 | 32.9 | 2.28 | 25.0 | 2. |
| Average | | 30.9 | | 23.8 | |
| 16 | 2.79 | 10.0 | 2.96 | 2.6 | 2. |
| 32 | 2.87 | 7.4 | 2.91 | 4.3 | 2. |
| Average | | 8.7 | | 3.4 | |

* This figure represents the percentage of the total casein that had bee

Table 1.

ilk and Acidified Milk at 21°C for 10 Days.

| ilk + 8% Acetic Acid | | Milk + .131% Acetic Acid | | Milk + .1423% Citric Acid | |
|---|---|---|---|---|---|
| in | % of Casein digested* | % Casein | % of Casein digested* | % Casein | % of Casein digested* |
| | | 3.08 | | 3.03 | |
| | 22.7 | 2.51 | 18.5 | 2.18 | 28.1 |
| | 25.0 | 2.18 | 29.2 | 1.87 | 38.3 |
| | 23.8 | | 23.8 | | 33.2 |
| | 2.6 | 2.83 | 8.1 | 2.68 | 11.6 |
| | 4.3 | 2.82 | 8.4 | 2.67 | 11.9 |
| | 3.4 | | 8.2 | | 11.7 |

total casein that had been rendered soluble.

Quantitative determinations were made after ten days growth of the mold, of the degree to which the cultures of different strains of P. roqueforti digested the casein of these milks.

The conclusions drawn from Table 1 are:

1. The cultures of P. roqueforti 1 and 33 respectively (Roquefort origin) had a greater power to digest the casein than had cultures 16 and 32 (Wensleydale origin); which findings confirm previous work. (14) (15)

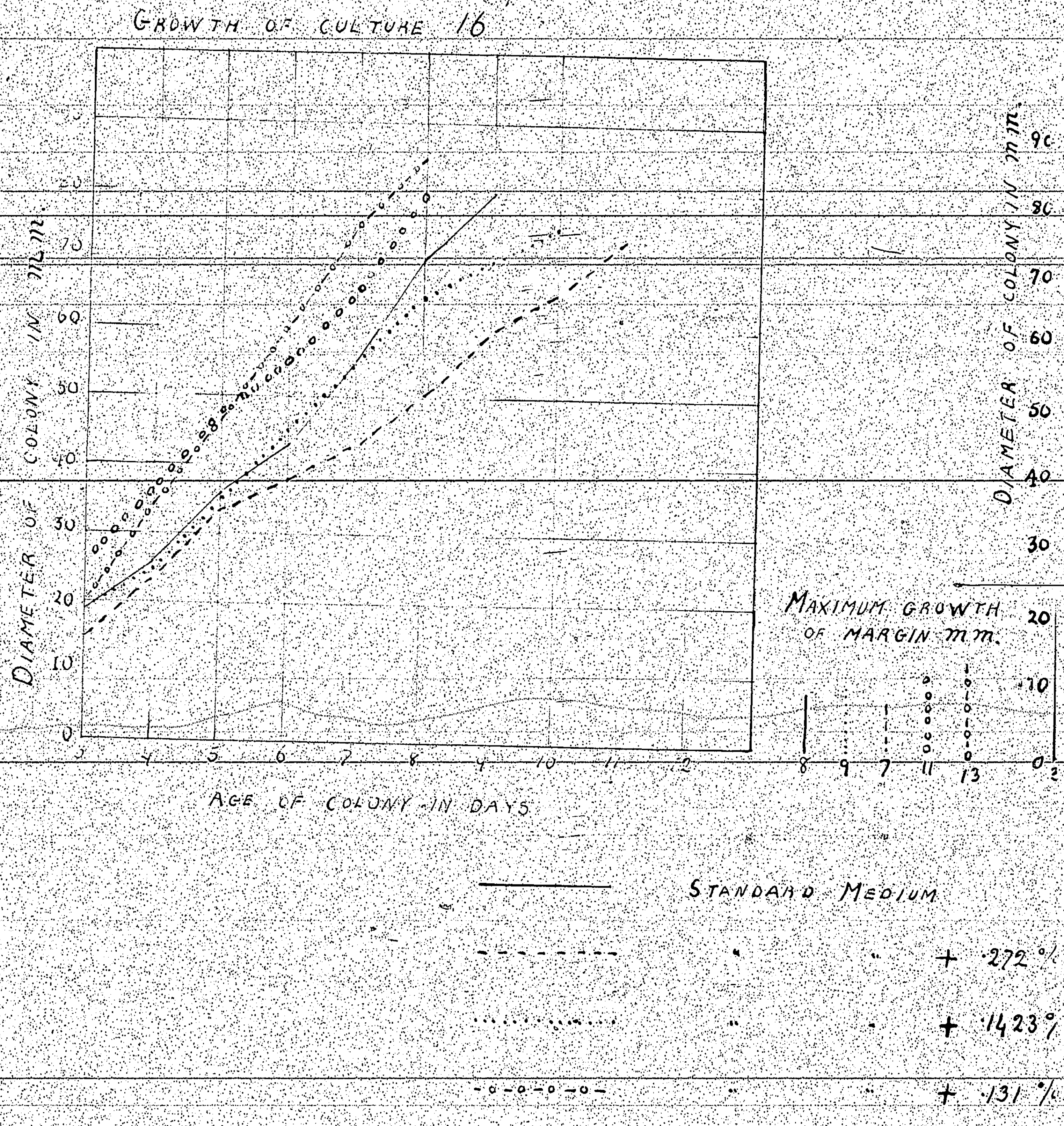
2. There was a tendency for low concentrations of citric and acetic acids to effect the digestion of casein in milk by P. roqueforti.

a. Citric acid tended to increase this digestion of casein.

b. Acetic acid tended to reduce this digestion of casein, particularly in weak concentrations.

Growth of Different Strains of P. roqueforti on the Standard Medium and Acidified Standard Medium.

In the growth of different strains of



GROWTH OF CULTURE 16
DIAMETER OF COLONY IN mm.
AGE OF COLONY IN DAYS
MAXIMUM GROWTH OF MARGIN mm.
STANDARD MEDIUM
+ ·272 %
+ ·1423 %
+ ·131 %
+ ·048 %


FIG. 1

GROWTH OF CULTURE I

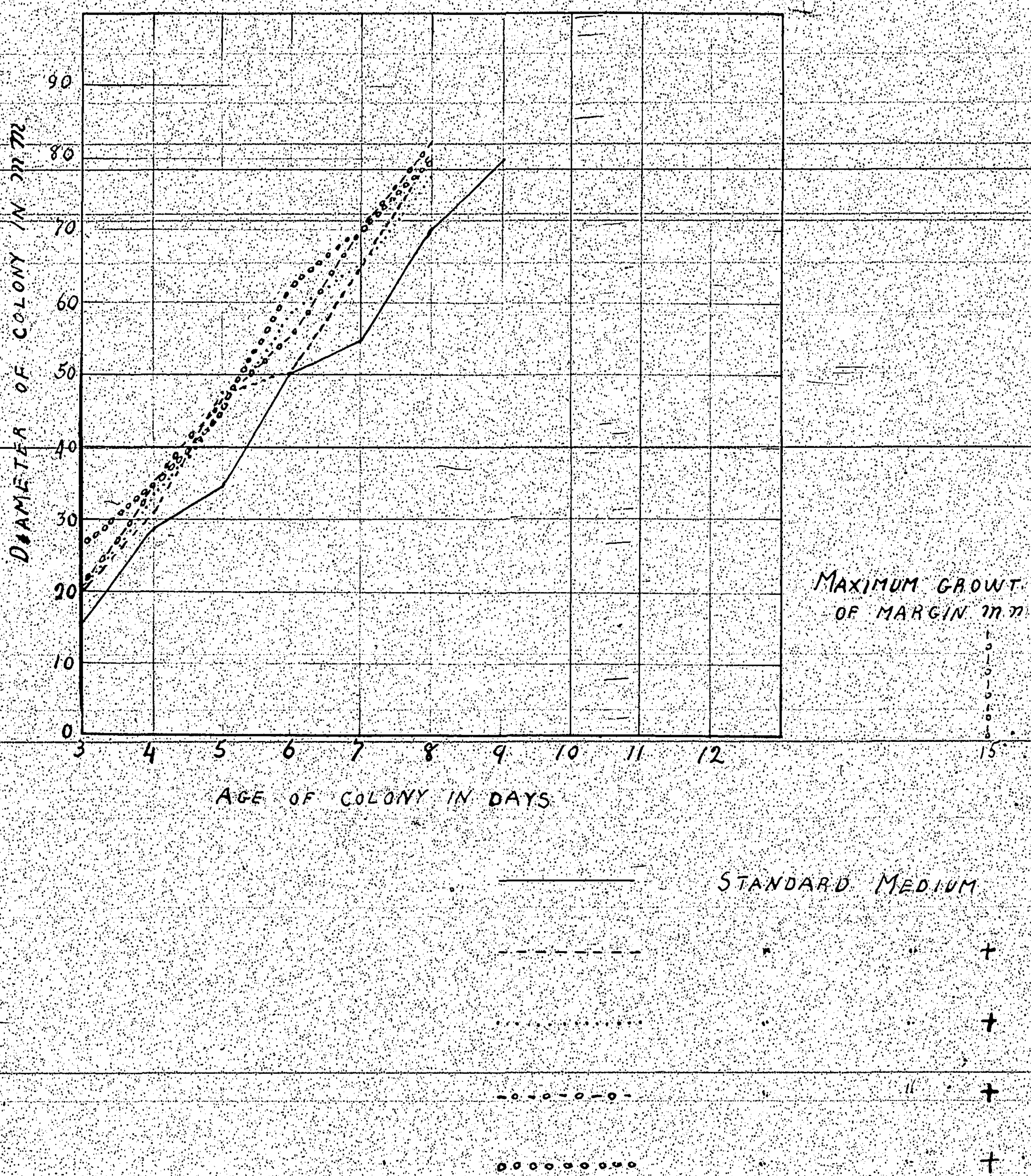
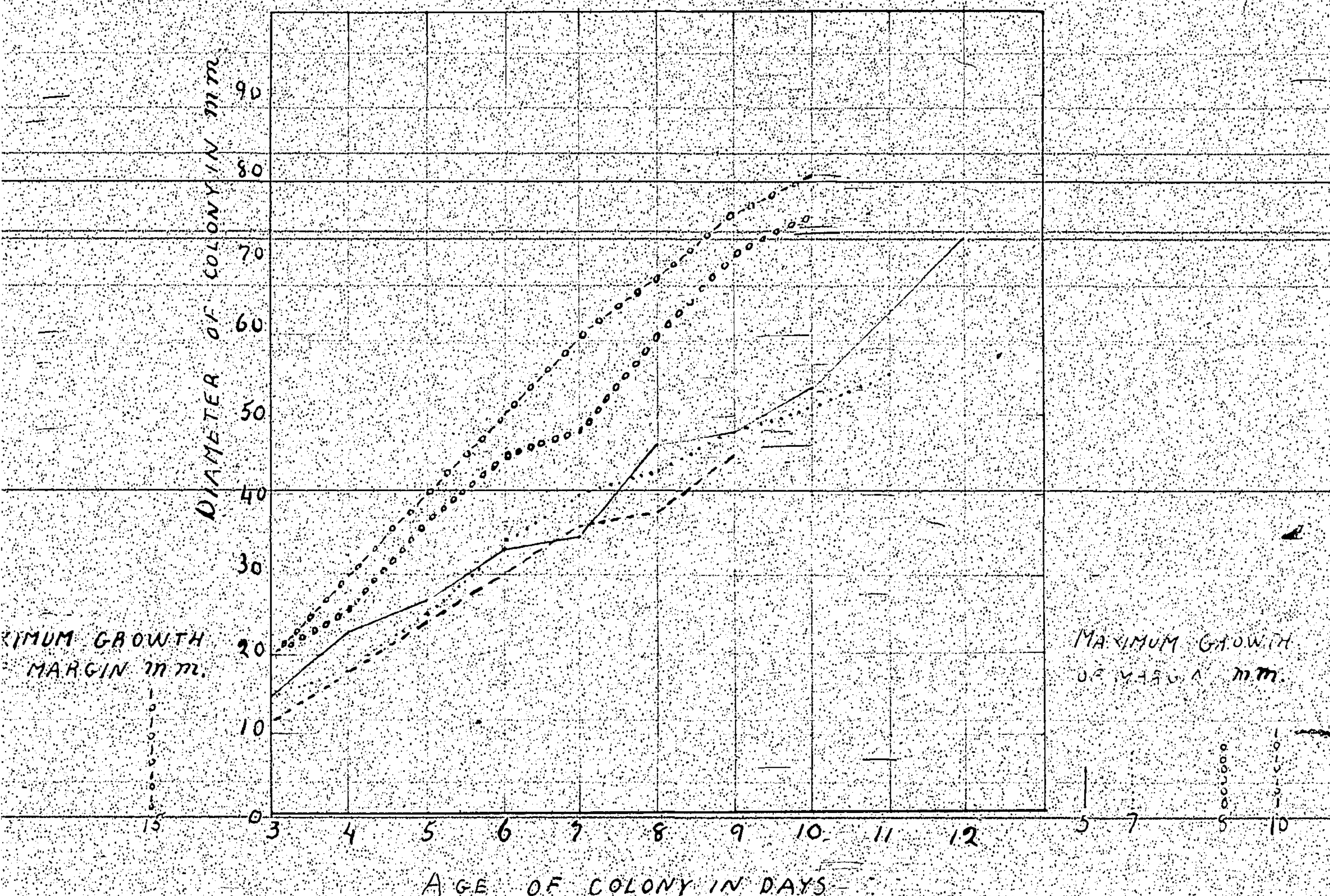



FIG. 2

GROWTH OF CULTURE 33




MEDIUM

+ 272 % CITRIC ACID

+ 1423 % „

" + 131 % ACETIC ACID

+ ·048 % " "

P. roqueforti was examined on five media, the standard medium, a high and low concentration of citric acid in the standard medium and a high and low concentration of acetic acid in the standard medium.

Figs. 1 and 2.

All plates were inoculated in duplicate and the diameter of the colonies on the two plates was measured daily and the average expressed in m m. The rate of growth has been expressed graphically for each culture in Figs. 1 and 2. The conclusions drawn from Figs. 1 and 2 are:

1. Citric and acetic acids in small quantities in the standard medium had a marked effect on the rate of growth of the mold as compared with the control.

2. Cultures 16, 32 and 33 grew much slower than the control when citric acid was supplied to the standard medium and this growth decreased with the higher concentration.

3. Cultures 16, 32 and 33 grew much faster than the control when acetic acid was supplied to the standard medium and this growth increased with the higher concentration.

4. Culture 1 did not follow this rule. It was increased in growth over the control by the presence of either acids, but showed a slight preference for acetic acid.

5. The width of the margin correlated with the rate of growth; the wider the margin, the faster the growth.

From the other data, the following facts are of significance:

1, In the case of cultures 16, 32 and 33, the reverse of the colony was almost white in plates containing the greater citric acid concentrations. This effect was noticed to a less extent with the lower concentration.

Culture 1 did not show this effect.

2. Cultures 16 and 32 produced fewer spores and a quite distinctive hairy growth when grown on the medium containing acetic acid.

## B. IN CHEESE.

### Statement of Problem.

The general increased growth of *P. roqueforti* on synthetic media when acetic acid was added and the reduced growth when citric acid was added, seemed to justify an experiment to see if the fermentation of citric acid to acetic would increase the growth of *P. roqueforti* in cheese. Though these acids did not give similar results when added to milk, the data were necessarily of doubtful value, due to the citrates already present in the milk and the activity of the mold being measured by the casein digested.

Two aspects present themselves:

1. What proportion of the citrates in milk appear in the curd and whey respectively?

2. Would added citrates appear in the curd or whey?

It would of course be useless to consider the fermentation of a substance which was absent from the curd or only present in very minute proportions.

Table 2.
Volatile and Total Acidity of Starter D144 used in Manufacturing Wensleydale Cheese With and Without Added Citrates.

| Date of Inoculation | Date of Determination | Volatile Acidity cc. 0.1 N Acid | | | Total Acidity % Lactic Acid | | |
|---|---|---|---|---|---|---|---|
| | | a | b | Average | a | b | Average |
| Dec. 29, 1926 | Jan. 6, 1927 | 25.5 | 24.5 | 25.0 | 1.075 | 1.04 | 1.057 |
| March 1, 1927 | March 8, 1927 | 26.5 | 29.0 | 27.7 | 1.04 | 1.03 | 1.035 |
| April 20, 1927 | April 27, 1927 | 26.8 | 26.2 | 26.5 | 1.10 | 1.08 | 1.090 |
| Average | | | | 26.4 | | | 1.061 |

## Methods.

Cultures. The culture of *P. roqueforti* used was No. 16 which was isolated from Wensleydale cheese (14).

The starter employed was one developed at the Iowa Agricultural Experiment Station and known as D 144; it was originally made from cultures of *S. lactis* and *S. citrovorus*. During the time this starter was being used for the cheese making, it was tested for volatile and total acidity according to the method given by Hammer and Sherwood (18). Table 2 gives the results of the three determinations in duplicate. The average volatile acidity was 26.4 cc. 0.1 N acid, which was usual for a starter containing associate organisms, and the average total acidity was 1.061 percent lactic acid.

Manufacture of Cheese. The Wensleydale cheese were manufactured from pasteurized milk according to the methods previously described (14). Charts 1 and 2 give in detail the records of each cheese manufactured. A half percent of starter was added to the milk and the short time that elapsed before even the samples of whey were taken for analysis would not have permitted any significant fermentation of the citrates.

Addition of citrates. When sodium citrate or citric acid was added to the milk it was made up in a 10 per-cent solution and added drop by drop to the milk following pasteurization and cooling. The milk was stirred all the time by keeping the vat coils revolving. The citric acid was not sufficient to coagulate the milk but slight and very local coagulation was observed.

## The Determination of the Citric Acid Content of the Milk and Whey.

The method used was Beau's (4) modification of Denige's (10) method, which consists of precipitating as mercury dicarboxy-sulphoacetone, titrating the mercury and calculating to citric acid with a factor. This method was used as described by Sherwood and Hammer (33), who found it generally satisfactory but stated,"it cannot be considered as meeting all the requirements of an ideal quantitative method.". The table prepared by Beau (4) was used to calculate the citric acid in both the milk and whey. This introduced a small error in the whey determinations owing to the removal of the cheese-making solids, chiefly fat and casein. A factor was not introduced to convert the whey determinations to exactly the same basis as the milk, since the percentage of fat was the only determination made on the milk, other than the citric acid. Were an estimate to be made from the fat test of the milk, which averaged 4.8 percent, the factor used would be approximately 1.04, using the method of calculating according to Sherwood and Hammer (33). As slight changes in results might have been introduced with fresh supplies of chemicals, the results are given in group averages as well as in general averages. All determinations were made in triplicate, owing to the impossibility of repeating a determination; but in expressing the results, the nearest two determinations are given.

Table 3.

Distribution of Citrates.

Wensleydale Cheese Made from Milk Without Addition of Cit

| Date Made | Series Number | Citric Acid in Milk Centigrams per litre | Starter Average | Citric Ac Centigra per lit |
|---|---|---|---|---|
| Dec. 29, 26 | 1 | a.239<br>b.235 | 237 | a. 226<br>b. 229<br>c. 232 |
| Jan. 4, 27 | 3 | a.197<br>b.197 | 197 | a. 223<br>b. 216 |
| Feb. 22, 27. | 5 | a.270<br>b.264<br>c.258 | 264 | a. 270<br>b. 270 |
| Average | | | 233 | |
| March 9, 27 | 8 | a.248<br>b.261 | 254.5 | a. 258<br>b. 267 |
| March 15, 27 | 10 | a.251<br>b.251 | 251 | a. 258<br>b. 258 |
| March 22, 27 | 12 | a.255<br>b.248 | 251.5 | a. 258<br>b. 251 |
| Average | | | 252 | |
| April 25, 27 | 15 | a.203<br>b.226 | 214.5 | a. 181<br>b. 187 |
| April 28, 27 | 17 | a.242<br>b.229 | 235.5 | a. 207<br>b. 210 |
| May 10, 27 | 19 | a.194<br>b.194 | 194 | a. 203<br>b. 203 |
| Average | | | 215 | |
| General Average | | | 233 | |

Table 3.

Distribution of Citrates.

Cheese Made from Milk Without Addition of Citrates.

| Citric Acid in Milk Centigrams per litre | Starter Average | Citric Acid in Whey at Cutting Centigrams per litre | Average |
|---|---|---|---|
| a.239<br>b.235 | 237 | a. 226<br>b. 229<br>c. 232 | 229 |
| a.197<br>b.197 | 197 | a. 223<br>b. 216 | 219.5 |
| a.270<br>b.264<br>c.258 | 264 | a. 270<br>b. 270 | 270 |
| | 233 | | 239.5 |
| a.248<br>b.261 | 254.5 | a. 258<br>b. 267 | 262.5 |
| a.251<br>b.251 | 251 | a. 258<br>b. 258 | 258 |
| a.255<br>b.248 | 251.5 | a. 258<br>b. 251 | 254.5 |
| | 252 | | 258 |
| a.203<br>b.226 | 214.5 | a. 181<br>b. 187 | 184 |
| a.242<br>b.229 | 235.5 | a. 207<br>b. 210 | 208.5 |
| a.194<br>b.194 | 194 | a. 203<br>b. 203 | 203 |
| | 215 | | 199 |
| | 233 | | 232 |

## Results Obtained.

### The Distribution of the Citrates When Wensleydale Cheese Was Made Without Added Citrates.

The results of the experiments, to determine the distribution of the citrates in the whey and the curd when Wensleydale cheese was made from normal milk, are expressed in Table 3 from which the following information can be drawn:

1. Although out of nine comparisons, the percentage of citric acid in the whey was higher in six and lower in three, than in the milk from which the cheese were made, the differences cannot be considered beyond the range of experimental error.

2. The general averages of the citric acid in the whey and in the milk were practically the same.

3. If the value for citric acid in whey is multiplied by the factor 1.04 to compensate for the absence of the cheese making solids, the whey is 4.0 percent higher in citric acid than the milk.

4. There appeared to be no citrates in the curd other than those associated with the whey incorporated.

Table 4.

Distribution of (

Wensleydale Cheese - Made From Milk wi

| Date Made | Series Number | Citric Acid in Milk + Starter Centigrams per litre | | Average | Citrate added to 200 lbs. Milk | Expressed as $C_6H_8O_7$ Percent |
|---|---|---|---|---|---|---|
| Dec. 30, 1926 | 2 | a | 229 | 227.5 | 168.8 grams | |
| | | b | 226 | | $2Na_3C_6H_5O_7 11H_2O$ | 0.10 |
| Jan. 6, 1927 | 4 | a | 239 | 237.0 | 84.4 grams | 0.05 |
| | | b | 235 | | $2Na_3C_6H_5O_7 . 11H_2O$ | |
| Average - - - - - | | | | 232.0 | | |
| March 3, 1927 | 7 | Not sampled | | | 45.36 grams $C_6H_8O_7, H_2O$ | 0.0457 |
| March 17, 1927 | 11 | Not sampled | | | 45.36 grams $C_6H_8O_7, H_2O$ | 0.0457 |
| March 24, 1927 | 13 | a | 242 | 246.5 | 45.36 grams | 0.0457 |
| | | b | 251 | | $C_6H_8O_7, H_2O$ | |
| Average - - - - - | | | | 246.5 | | 0.0457 |
| April 27, 1927 | 16 | a | 216 | 216 | 49.62 grams | 0.05 |
| | | b | 216 | | $C_6H_8O_7, H_2O$ | |
| April 29, 1927 | 18 | a | 207 | 207 | 49.62 grams | 0.05 |
| | | b | 207 | | $C_6H_8O_7, H_2O$ | |
| May 13, 1927 | 20 | a | 203 | 201.5 | 49.62 grams | 0.05 |
| | | b | 200 | | $C_6H_8O_7, H_2O$ | |
| Average - - - - - | | | | 208 | | |
| General Average - | | | | 222.5 | | 0.05 |

Table 4.

istribution of Citrates.

de From Milk with Added Sodium Citrate or Citric Acid.

| ed to ilk | Expressed as $C_6H_8O_7$ Percent | Citric Acid in Milk + Starter & added Citrates Centigrams per litre | | Average | Citric Acid in Whey at Cutting Centigrams per litre | | Average |
|---|---|---|---|---|---|---|---|
| ms | | a | 362 | 362 | a | 362 | 362 |
| $11H_2O$ | 0.10 | b | 362 | | b | 362 | |
| ms | 0.05 | a | 292.5 | 292.5 | a | 285.5 | 289 |
| $.11H_2O$ | | b | 292.5 | | b | 292.5 | |
| | | | | 327 | | | 325.5 |
| ms | | a | 283 | 283 | a | 295 | 301 |
| ) | 0.0457 | b | 283 | | b | 307 | |
| ms | | a | 313 | 310 | a | 344 | 344 |
| ) | 0.0457 | b | 307 | | b | 344 | |
| ns | 0.0457 | a | 295 | 295 | a | 325 | 325 |
| ) | | b | 295 | | | | |
| | 0.0457 | | | 296 | | | 323 |
| ns | 0.05 | a | 242 | 242 | a | 236 | 239 |
| ) | | b | 242 | | b | 242 | |
| ns | 0.05 | a | 235 | 237 | a | 248 | 251.5 |
| ) | | b | 239 | | b | 255 | |
| ns | 0.05 | a | 245 | 248 | a | 255 | 255 |
| ) | | b | 251 | | | | |
| | | | | 242 | | | 248 |
| | 0.05 | | | 283.7 | | | 295.8 |

The Distribution of the Citrates When Wensleydale Cheese Was Made with Added Sodium Citrate or Citric Acid.

The results of the experiments to determine the distribution of the citrates in the whey and curd when Wensleydale cheese was made from milk to which citrates were added are expressed in Table 4.

On examining Table 4, it will be noted that the recovery of the citrates added was not very uniform, this in part being accounted for by the small amounts added, the slight coagulation of the milk, and the fact that the samples for examination had to be taken soon after the addition was made.

The following information can be drawn from Table 4:

1. Although out of eight comparisons the percentage of citric acid in the whey was higher in five, the same in one, and lower in two, than in the milk from which the cheese were made, the differences cannot be considered beyond the range of experimental error.

2. The general averages of the citric acid in the whey were slightly higher than in the citrate milk, which was accounted for by the poor recovery of the

added citric acid in the citrate milk.

3. If the value for citric acid in the whey is multiplied by the factor 1.04 to compensate for the absence of the cheese making solids, the whey is 4.0 percent higher than given.

4. As in the previous experiment, there appeared to be no citrates in the cheese other than those associated with the whey incorporated.

The Manufacture of Wensleydale Cheese With and Without Added Citrates.

The records of manufacture of the Wensleydale cheese with and without added citrates are given in Charts 1 and 2. The controls (Chart 1) could not be made the same day as the cheese in which citrates were used but were made from milk of the same origin. The fat tests of the milks in Charts 1 and 2 give an idea as to the possible differences in composition; the relative ages of the milks were the same.

Control Cheese. The control cheese, Chart 1. Series Nos. 1, 3, 5, 8, 10, 12, 14, 15, 17 and 19, were made quite uniformly as to both time and acidity. Therefore, they presented no variation from the usual method of manufacture.

Sodium citrate added. Chart 2, Series Nos. 2, 4, and 6, are the records of cheese made with 168.8, 84.6 and 168.8 grams of crystalline sodium citrate respectively, added to 200 lbs. of milk. From these records, it is evident that the acidities at renneting were normal, but the coagulation as shown by the rennet test and time to cutting were most abnormal, in fact the milk in Series No. 6 never became firm enough to cut. The waiting, in an attempt to obtain a satisfactory rennet test, resulted in over ripe milk before the rennet was added and the subsequent quick cheese making process. Therefore, the cheese were quite abnormal and the use of sodium citrate was discontinued.

Citric Acid Added. The cheese made with citric acid added to the milk, Chart 2, Series Nos. 7, 9, 11 and 13, with 45.36 grams crystalline citric acid added per 200 lbs. of milk and Chart 2, Series Nos. 16, 18 and 20, with 49.62 grams crystalline citric acid added per 200 lbs. of milk, gave normal records; in spite of the initial acidity at renneting. The chief difference from the controls was the softer coagulum at cutting. This does not appear in the records as there was no tangible method of recording the comparison.

Weights of Cheese.

The weights of cheese on July 5th, and on Sept. 20th, 1927, are given in Table 5. From these data, the following deductions were made:

1. When sodium citrate was added to the milk, less cheese was made than with the controls.

2. The addition of citric acid to the milk resulted in 5 out of 6 lots of cheese being greater in weight on both July 7th and Sept. 20th than their controls. The differences in weight were much greater on July 7th than Sept. 20th.

Table 5.

Weights of Wensleydale Cheese as Affected by

Control

| Date Made | Citrates Not Added. | | July 7, 1927. | | | Sept. |
|---|---|---|---|---|---|---|
| | Series No. | Citric Acid in Milk and Starter Centigrams per Litre | Weight Lbs. | Ozs. | Pounds Cheese per 100 lbs. milk | Weight Lbs. |
| Dec.29, 26 | 1 | 237 | 22 | 6 | 11.19 | 21 |
| Jan.4, 27 | 3 | 197 | 21 | 8 | 10.75 | 20 |
| Feb.22, 27 | 5 | 264 | 23 | 8 | 11.75 | 22 |
| Average | | 233 | | | 11.23 | |
| March 9,27 | 8 | 254.5 | 24 | 12 | 12.38 | 23 |
| March 15,27 | 10 | 251 | 25 | 4 | 12.63 | 23 |
| March 22,27 | 12 | 251.5 | 23 | 4 | 11.63 | 22 |
| Average | | 252 | | | 12.21 | |
| April 25,27 | 15 | 214.5 | 22 | 10 | 11.31 | 21 |
| April 28,27 | 17 | 235.5 | 24.5 | | 12.16 | 22 |
| May 10, 27 | 19 | 194 | 23 | 12 | 11.88 | 21 |
| Average | | 215 | | | 11.78 | |

ɪe 5.

ɪ Affected by Added Citrates.

Citrates Added

| ɪnds ɔese ? ) lbs. ɪk | Sept. 20, 1927 Weight Lbs. | Ozs. | Pounds Cheese per 100 pounds milk | Date Made | Series No. | Citric Acid in Milk and Starter and Citrates Centigrams per Litre | July 7th, 1927 Weight Lbs. | Ozs. | Pounds Cheese per 100 pounds milk |
|---|---|---|---|---|---|---|---|---|---|
| ɪ.19 | 21 | 8 | 10.75 | Dec.30,26 | 2 | 362 | 18 | 9 | 9.28 |
| ).75 | 20 | 11 | 10.34 | Jan. 6,27 | 4 | 292.5 | 20 | 0 | 10.00 |
| ɪ.75 | 22 | 0 | 11.00 | | | | | | |
| ɪ.23 | | | 10.70 | Average | | 327 | | | 9.64 |
| ?.38 | 23 | 2 | 11.56 | March 3[illegible],27 | [illegible]7 | 283 | 26 | 2 | 13.06 |
| ?.63 | 23 | 6 | 11.69 | March 17,27 | 11 | 310 | 24 | 2 | 12.06 |
| ɪ.63 | 22 | 2 | 11.06 | March 24,27 | 13 | 295 | 24 | 6 | 12.19 |
| ?.21 | | | 11.44 | | | 296 | | | 12.44 |
| ɪ.31 | 21 | 0 | 10.50 | April 27,27 | 16 | 242 | 24 | 6 | 12.19 |
| ?.16 | 22 | 0 | 11.00 | April 29,27 | 18 | 237 | 24 | 12 | 12.38 |
| ɪ.88 | 21 | 7 | 10.72 | May 13, 27 | 20 | 248 | 24 | 13 | 12.41 |
| ɪ.78 | | | 10.74 | | | 242 | | | 12.32 |

| itric Acid in Milk and Starter and Citrates Centigrams per Litre | July 7th, 1927 Weight Lbs. | Ozs. | Pounds Cheese per 100 pounds milk | Sept. 20, 1927 Weight Lbs. | Ozs. | Pounds Cheese per 100 pounds milk |
|---|---|---|---|---|---|---|
| 362 | 18 | 9 | 9.28 | 17 | 10 | 8.81 |
| 292.5 | 20 | 0 | 10.00 | 19 | 2 | 9.56 |
| 327 | | | 9.64 | | | 9.19 |
| 283 | 26 | 2 | 13.06 | 23 | 14 | 11.94 |
| 310 | 24 | 2 | 12.06 | 22 | 1 | 11.03 |
| 295 | 24 | 6 | 12.19 | 22 | 7 | 11.22 |
| 296 | | | 12.44 | | | 11.40 |
| 242 | 24 | 6 | 12.19 | 22 | 1 | 11.03 |
| 237 | 24 | 12 | 12.38 | 22 | 3 | 11.09 |
| 248 | 24 | 13 | 12.41 | 22 | 4 | 11.13 |
| 242 | | | 12.32 | | | 11.08 |

Scores of Cheese.

The first scores of the cheese are given in Charts 1 and 2. The cheese did not ripen satisfactorily being made in winter or early spring.

These cheese were used later for the oxygen requirement experiments Part III as up to then they had shown no signs of mold growth. The scores of the cheese after treatment are given in Part III, Table 10 and 11, from which the following observations were made.

1. The cheese without citrates added, Table 10, Series No. 8, and with citric acid added, Series Nos. 7 and 16, developed satisfactory mold growth with the assistance of aeration by suction.

2. The cheese without citrates added, Table 11, Series No. 8, and with citric acid added, Series Nos. 7, 11 and 16, developed satisfactory mold growth with the assistance of injected oxygen.

3. In both comparisons, the addition of citric acid resulted in an improvement in the cheese.

## Summary and Conclusions.

Citric acid and acetic acid in amounts comparable with those found in milk and starters (18) (16) (32) had an effect on the growth of different strains of *P. roqueforti*. In milk low concentrations of acetic acid tended to reduce the digestion of casein by strains of *P. roqueforti* while citric acid tended to increase this digestion. On the other hand, in the standard media acetic acid increased the growth while citric acid tended to inhibit it. This work would indicate that the type of starter used in the manufacture of blue veined cheese might have a significant bearing on the subsequent growth of the mold in the cheese.

There appeared to be no citrates in the cheese other than those associated with the whey incorporated. Therefore, the very small proportion of citric acid or its decomposition products are unlikely to be of significance in the ripening of cheese. These findings support the previously mentioned conclusions of Hucker and Marquardt (21) and would explain why they found that *S. citrovorus* appeared to have no effect upon the production of flavor when added to milk to be used for cheese making.

The addition of sodium citrate to milk to be made into cheese retarded the action of rennet, as previously reported by Bosworth and Van Slyke (6).

The process of manufacture had to be so changed that these cheese can hardly be compared with the controls.

The addition of citric acid to milk to be made into cheese softened the coagulum and gave a greater weight of cheese than the controls, possibly due to a higher moisture. The cheese made with added citric acid showed a slight tendency to develop more mold growth.

# PART II.

# THE EFFECT OF AMMONIUM SALTS ON THE GROWTH OF P. ROQUEFORTI IN CHEESE.

## Introduction.

As a result of various investigations, it was considered desirable to determine whether or not the presence of ammonium salts was a significant factor in the ripening of Wensleydale cheese.

## Review of Literature.

The formation of ammonia in cheese has been frequently investigated. As early as 1893, the New York (Geneva) Agricultural Experiment Station (27), reporting on cheese ripening, stated, "The cheese, when green, contained no nitrogen in the form of ammonium compounds, while at five months there were contained from 0.078 to 0.126 lbs. in one hundred pounds of cheese, with an average of 0.103 lbs. which was equivalent to from 2.42 to 3.51 percent of the total nitrogen in the cheese with an average of 2.92 percent." About the same time Patrick (29) also found that ammonia was regularly formed in cheese ripening.

Orla-Jensen (28) noted that the formation of ammonia corresponded closely with the rate of cleavage of fat. The quantity of ammonia présent was never sufficient to give an alkaline reaction with phenolphthalein, although with the soft cheese, especially the outer layers, often reacted alkaline with litmus. Orla-Jensen (28) gave the ammonia per 1000 grams in several varieties of cheese as follows: Roquefort, entire mass, 1.955 grams; Edam, interior, 0.255 gram, Swiss skim milk 4.548 grams.

Ayers and colleagues (2) found that, in suitable media, many streptococci produced ammonia and carbon dioxide. They divided the streptococci studied as follows:

a. Those that produced neither ammonia nor carbon dioxide from peptone.

b. Those that produced both ammonia and carbon dioxide from peptone.

c. Those that produced no ammonia but formed carbon dioxide, which did not come from peptone or dextrose.

d. Those that produced no ammonia but formed carbon dioxide from dextrose.

Neill (26), working with pure cultures of streptococci, found that ammonia production seems to be associated more strictly with the growth and active life of the streptococci, than is the accumulation of amino compounds. Broth cultures of non-hemolytic lactic, hemolytic human, and hemolytic mastitis streptococci showed considerable variation in the increases in $NH_2$ nitrogen and $NH_3$ nitrogen compounds effected by different strains of the same type.

Weisbrodt (41), using the culture of P. roqueforti designated No. 33, (14) carried out several experiments with synthetic media which appear to have a significance from the standpoint of the growth of P. roqueforti in cheese.

Weisbrodt (41) found that using Czapek's medium, as modified by Dox, and substituting ammonium salts for $NaNO_3$ greatly increased the growth of P. roqueforti. The $NH_4Cl$ in the concentration of 1.88 grams per litre gave a slightly greater growth of P. roqueforti than $NH_4NO_3$ in concentrations of 2.83 grams per litre.

A second experiment on the effect of $NH_4Cl$ in concentrations ranging from 0.02 to 0.40 N, on the growth of <u>P. roqueforti</u> in Czapek's medium as modified by Dox showed that a concentration of 0.10 N. $NH_4Cl$ gave the greater weight of dry mycelium and the quickest appearance of spores.

An experiment was made on the influence of pH, between the range of pH 3 and pH 8, on mold growth with synthetic media containing 0.10N. $NH_4Cl$. In this experiment, the optimum growth of <u>P. roqueforti</u> was at pH 4.5. However, the omission of iron salts as Fe $SO_4$ in the medium changed the optimum to pH 6.16.

Weisbrodt (41) summarizes the results as follows:

"Weight of mold felts obtained on Czapek's medium in the presence of 0.10 N. $NH_4$ Cl (optimum),

(a) with $FeSO_4$--------------------0.0328 grams
(b) with $FeSO_4$ at optimum pH 4.5---0.0698 grams
(c) without $FeSO_4$-----------------0.0157 grams
(d) without $FeSO_4$ at optimum pH 6.16----------------0.0498 grams
(e) Czapek's medium as modified by Dox-----------------0.0138 grams

Since these experiments were carried out under the same conditions, the weights of mold felts obtained are comparable, and indicate that optimum $NH_4Cl$, optimum pH and the presence of $FeSO_4$ are all contributory factors tending toward increased growth of mold."

"The experimental work here reported has shown that:

(1) The growth of P. roqueforti was greatly improved by the substitution of $NH_4Cl$ at its optimum concentration (0.10N.) for 2 grams of $NaNO_3$ to Czapek's medium as modified by A.W.Dox.

(2) The growth of P. roqueforti was further improved by the proper adjustment of the pH of Czapek's medium in the presence of 0.10 N $NH_4Cl$ and $FeSO_4$.

(3) The increased growth of P. roqueforti on this improved medium at 30°C. and at optimum pH in the presence of an optimum concentration of ammonium salts produced increased enzymatic activity.

(4) The removal of the mold felts after sporelation showed a greater enzymatic action in the filtrate, the enzyme thus being extracellular."

## Statement of Problem.

The addition of $NH_4Cl$ to cheese presented a more complicated problem than in synthetic media, as the $NH_4Cl$ must be added at salting, which is followed by considerable loss of whey containing dissolved salts. Therefore, an approximate quantity of $NH_4Cl$ must be added with the salt and determinations of the moisture and ammonia made after the cheese is a week old and no more whey is being exuded.

Two preliminary investigations were necessary before the addition of $NH_4Cl$ to the curd to hasten the development of P. roqueforti could be undertaken:

1. An investigation to establish a chemical method for determining ammonia and ammonium salts in cheese.

2. Determinations by the selected method of the amount of ammonia in cheese of various ages.

## Methods.

The determination of ammonia and ammonium salts in cheese. After several unsatisfactory methods had been tried, a modification of Lisk's (22) method for the determination of ammonia in cows milk was adopted. The exact method finally used was as follows: 5 grams of cheese were mixed with 50 cc warm water (not over 50°C) in a glass mortar and the creamed cheese then added to 1000 cc. Erlenmeyer suction flask. The mortar was rinsed with 50 cc. methyl alcohol which was added to the flask followed by 20.0 grams of NaCl and 1.0 gram $Na_2CO_3$. The apparatus was at once connected up and suction applied.* The flask was placed in a constant temperature water bath at 50° C. and the temperature and distillation maintained for 30 minutes. The distillate was passed through 3 gas wash bottles containing standard $H_2SO_4$. At the close of the distillation, the reduction of acidity of the standard $H_2SO_4$ was determined by titration. A photograph of the apparatus in operation is given in Fig. 3.

* Note: The water suction pump used maintained a back pressure of 600 to 700 m m.

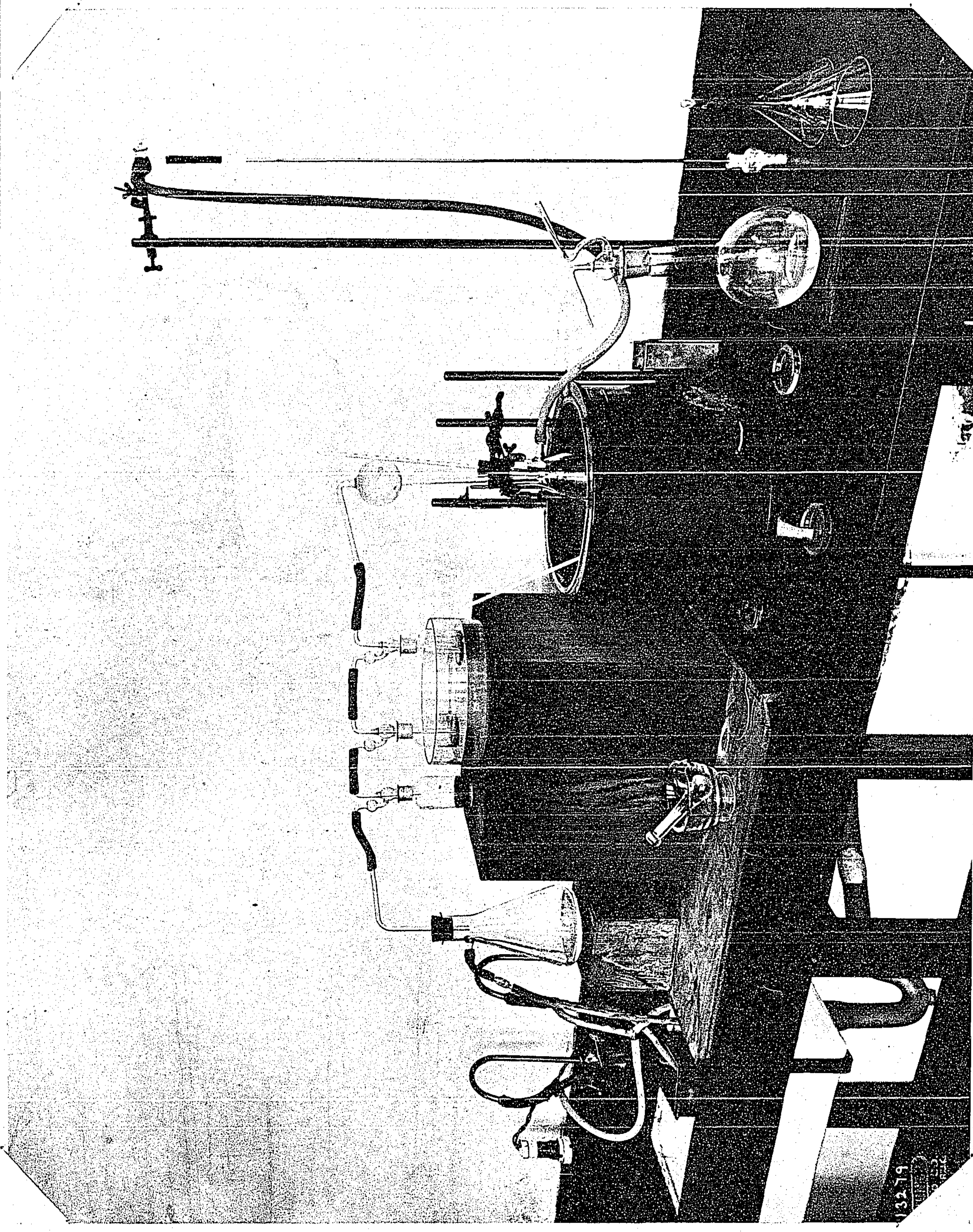


Fig. 3.

Manufacture of cheese. With the exception of the addition of $NH_4Cl$, the cheese were made according to the usual method (14). Chart 3 gives the record of manufacture for each cheese. The cheese were ripened in storage at ($37^{o}F$) from June 14th to Oct. 3rd, 1928, to prevent spoilage in hot weather.

Adding $NH_4Cl$ to curd. At the time of salting, the curd was divided into three groups.

A. The control received the usual proportion of salt (NaCl) to the curd .

B. 1 oz. of $NH_4Cl$ was mixed with the usual proportion of salt (NaCl) and added to 24 lbs. of curd.

C. 1 1/4 ozs. of $NH_4Cl$ was mixed with the usual proportion of salt (NaCl) and added to 24 lbs. of curd.

The weights of 1 oz. and 1 1/4 ozs. of $NH_4Cl$ respectively were selected with the intention of obtaining a 0.10 N. and a slightly over 0.10 N. $NH_4$ Cl concentration in the moisture of the unripened cheese. Due allowance was made for loss of whey and salts while the curd was in the press.

Sampling. Samples of cheese for determinations of moisture and ammonia were taken with a trier one week after manufacture.

Moisture. The moisture determinations were made by the method given by the Association of Official and Agricultural Chemists. (1).

## Results Obtained.

Preliminary Investigation with the Method of Determining Ammonia and Ammonium Salts in Cheese.

The accuracy of the method for determining ammonia and ammonium salts in cheese is shown in Table 6. The Kingston cheese used was a mild cheese just under one month old. This cheese neither contained appreciable quantities of ammonia or affected the determination of the $NH_4Cl$ added. Finally, when $NH_4Cl$ was added in a weighed quantity to 5 grams of cheese, a satisfactory recovery of from 97.65 percent and 99.14 percent of the ammonia added was secured.

## Table 6.

Check of Method for the Determination of Ammonia and Ammonium Salts in Cheese.

| Substance Analysed | Date of Determination 1927 | Period of Distillation Mins. | $NH_4Cl$ Added Gram | $NH_3$ expressed as Gram $NH_4Cl$ | Percent of added $NH_4Cl$ recovered |
|---|---|---|---|---|---|
| True Blank (Standard chemicals used) | Nov. 19 | 30 | Nil | .0005 | |
| True Blank (Standard chemicals used) | Nov. 19 | 30 | Nil | .0015 | |
| Aqueous Solution $NH_4Cl$ | Nov. 19 | 20 | .2314 | .2151 | 92.97 |
| Aqueous Solution $NH_4Cl$ | Nov. 19 | 20 | .2221 | .2108 | 94.87 |
| Kingston Cheese | Nov. 23 | 30 | Nil | .0027 | |
| Kingston Cheese | Nov. 23 | 30 | Nil | .0027 | |
| Kingston Cheese $NH_4Cl$ | Nov. 25 | 30 | .2614 | .2552 | 97.65 |
| Kingston Cheese $NH_4Cl$ | Nov. 25 | 30 | .2277 | .2258 | 99.14 |

Table 7.

The Ammonia in Cheese Expressed as $NH_4Cl$ at Different Degree:

| Date Made | Date Analysed | Variety of Cheese | % Moistu |
|---|---|---|---|
| Oct.26, 27 | Nov. 23, 27 | Kingston | |
| Feb. 22, 27 | Dec. 2, 27 | Wensleydale | |
| March 15, 27 | Dec. 2, 27 | Wensleydale | |
| March 22, 27 | Dec. 12, 27 | Wensleydale | |
| Apr. 25, 27 | Dec. 14, 27 | Wensleydale | |
| Apr. 27, 27 | Jan. 12, 28 | Wensleydale | |
| Mar. 17, 27 | Jan. 13, 28 | Wensleydale | |
| March 3, 27 | Jan. 27, 28 | Wensleydale | |
| March 16, 27 Milk raw | March 10,28 | Cheddar | 28.85 |
| March 16, 27 Milk pasteurized | March 14,28 | Cheddar | 29.35 |
| March 2, 27 Milk pasteurized | March 16,28 | Cheddar | 30.05 |
| March 2, 27 Milk raw | March 16,28 | Cheddar | 30.35 |

Degrees of Ripening.

| Moisture | % $NH_4Cl$ in cheese | Normality of $NH_4Cl$ in moisture of cheese | Remarks |
|---|---|---|---|
| | .0535 | | |
| | .1391 | | Oct.13, 27. Some mold due to cracks. |
| | .14445 | | Oct. 13, 27. Mold only round plugs. |
| | .2033 | | Dec. 12, 27. This cheese showed some blue mold, but not in part used for analysis. |
| | .15515 | | Oct.13, 27. Slight development of mold round plugs. |
| | .30495 | | Well ripened blue Wensleydale. Jan.10,28. Flavor 36, Texture 22, Mold Growth 22, Color 10 |
| | .47615 | | Well ripened blue Wensleydale. Jan.10,28. Flavor 35.5, Texture 22, Mold Growth 22, Color 10 |
| | .5243 | | Well ripened blue Wensleydale. Jan.10,28. Flavor 35.5, Texture 22, Mold Growth 22, Color 10 |
| 28.85 | .41195 | .2665 | |
| 29.35 | .43335 | .2759 | |
| 30.05 | .2782 | .1730 | |
| 30.35 | .5029 | .3096 | |

Ammonia in Cheese of Different Varieties and Age.

The data on cheese of various ages selected for the ammonia determinations are given in Table 7.

Description of Cheese. The seven Wensleydale cheese were from the citric acid experiments and the procedure used in their manufacture is given under their respective dates of make. Charts 1 and 2. Though moisture determinations were not made on these cheese, it can be said from previous work that from 30 to 35 percent represented the moisture content. The Kingston cheese was of the mild quick ripening type and would be considered as ready for sale. The four Cheddar cheese were well matured cheese about one year old; these cheese were of low moisture content and had ripened slowly so that they would not be described as strong.

The ammonia in the cheese just described was determined by the modification of Lisk's method.

The results given in Table 7 showed that:

1. The ammonia in the cheese tended to increase with age from a minimum of 0.0535 percent $NH_4Cl$ in the Kingston to a maximum of 0.5243 percent $NH_4Cl$ in the Wensleydale.

2. The well ripened Cheddar cheese showed about the same percentage of $NH_4Cl$ as the well ripened Wensleydale.

3. The poor quality white Wensleydale cheese were much lower in the percentage of $NH_4Cl$ than the well ripened Wensleydale or Cheddar Cheese.

4. The normality of the $NH_4$ Cl in the moisture of the well ripened cheese was higher than the optimum of 0.10 N. as found by Weisbrodt (41) for synthetic media.

The Addition of $NH_4Cl$ to the Curd at Salting to Increase the Growth or *P. roqueforti*.

An experiment was made to determine whether or note the addition of $NH_4Cl$ to the curd at the time of salting would improve or hasten the growth of *P. roqueforti* in Wensleydale cheese as found by Weisbrodt (41) when using synthetic media.

Six lots of cheese, Chart 3 Series Nos. 21 to 38 inclusive, were made, the curd in each lot being divided into three parts at salting. These parts were treated as follows:

A. The control received no addition of $NH_4Cl$.

B. Received 1 oz. of $NH_4Cl$ to 24 lbs. of curd (1.184 grams per lb.)

C. Received 1 1/4 oz. of $NH_4Cl$ to 24 lbs. of curd (1.477 grams per lb.)

Some of the cheese, Charts 3 Series Nos.21 to 29 inclusive, were inoculated with *P. roqueforti* culture 32, while the remainder, Chart 3, Series Nos. 30 to 38 inclusive, were inoculated with *P. roqueforti* culture 33.

Table 8.

Wensleydale Cheese - Made with Added $NH_4Cl$

| Group | Date Made | Series Number | $NH_4Cl$ added to 1 lb. Curd grams | 1 Week after manufacture: % Moisture in chesse | 1 Week after manufacture: % $NH_4Cl$ in cheese | 1 Week after manufacture: Normality of $NH_4Cl$ in moisture of cheese | Fla 4 |
|---|---|---|---|---|---|---|---|
| A | Dec. 8,1927 | 23 | Nil | 42.7 | .0482 | .0211 | 3 |
| | Dec. 13,1927 | 26 | Nil | 40.9 | .0481 | .0220 | 3 |
| | Jan. 13,1928 | 27 | Nil | 42.0 | .0321 | .0143 | 3 |
| | Average | | Nil | 41.9 | .0428 | .0191 | 3 |
| B | Dec. 8,1927 | 21 | 1.181 | 42.9 | .2461 | .1072 | 3 |
| | Dec. 13,1927 | 24 | 1.181 | 40.6 | .2621 | .1207 | 3 |
| | Jan. 13,1928 | 28 | 1.181 | 41.9 | .2354 | .1050 | 3 |
| | Average | | 1.181 | 41.8 | .2479 | .1110 | 3 |
| C | Dec. 8,1927 | 22 | 1.477 | 43.2 | .3103 | .1343 | 3 |
| | Dec. 13,1927 | 25 | 1.477 | 40.0 | .2514 | .1174 | 3 |
| | Jan. 13,1928 | 29 | 1.477 | 41.7 | .2675 | .1199 | 3 |
| | Average | | 1.477 | 41.6 | .2764 | .1239 | 3 |

* Series Nos. 23, 21, and 22 scored Oct. 5th,1928.
Series Nos. 26, 24, and 25)
Series Nos. 27, 28 and 29 ) scored Dec.19th, 1928.

Table 8.
ed $NH_4Cl$; Inoculation P. Roqueforti, Culture 32.

| e<br>y<br>ure<br>e | Score of Sampled Cheese<br>Date*<br>Flavor<br>40 | Texture<br>25 | Mold<br>Growth<br>25 | Color<br>10 | Total<br>100 | Remarks | Sc<br>Fl |
|---|---|---|---|---|---|---|---|
| | 33 | 20 | 13 | 10 | 76 | F: clean slightly salty.<br>M: probably caused by plugs. | |
| | 34 | 21 | 20 | 10 | 85 | F: Good. | |
| | 36 | 23 | 23 | 10 | 92 | F: Very good. | |
| | 34.3 | 21.3 | 18.7 | 10 | 84.3 | | |
| | 34 | 20 | 15 | 10 | 79 | F: clean.<br>M: probably caused by plugs. | |
| | 32 | 21 | Nil | 10 | 63 | F: well matured. | |
| | 32 | 21.5 | Nil | 10 | 63.5 | F: clean. | |
| | 32.7 | 20.8 | 5 | 10 | 68.5 | | |
| | 32 | 20 | 10 | 10 | 72 | F: clean salty.<br>M: probably caused by plugs. | |
| | 33 | 21 | 15 | 10 | 79 | M: following plugs. | |
| | 32 | 21.5 | Nil | 10 | 63.5 | F: clean. | |
| | 32.3 | 20.8 | 8.3 | 10 | 71.5 | | |

| | Score of Unsampled Cheese Jan. 7th, 1929. | | | | | |
|---|---|---|---|---|---|---|
| | Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
| lty. by plugs. | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | |
| by plugs. | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | |
| by plugs. | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | F: clean well developed. |
| | 32 | 21 | Nil | 10 | 63 | |

Wensleydale Cheese Made With

| Group | Date Made | Series Number | $NH_4Cl$ Added to lb. of Curd grams | 1 Week After Manufacture: % Moisture in Cheese | % $NH_4Cl$ in Cheese | Normality of $NH_4Cl$ in moisture of cheese | Score o: Flavor 40 |
|---|---|---|---|---|---|---|---|
| A | (Feb. 24, 1928 | 30 | Nil | 41.6 | .0428 | .0192 | 30 |
| | (Mar. 1, 1928 | 33 | Nil | 41.4 | .0428 | .0193 | 30 |
| | (Mar. 14, 1928 | 36 | Nil | 42.8 | .0482 | .0211 | 32 |
| | Average | | Nil | 41.9 | .0446 | .0199 | 30.7 |
| B | (Feb. 24, 1928 | 31 | 1.181 | 42.6 | .2461 | .1080 | 30 |
| | (Mar. 1, 1928 | 34 | 1.181 | 41.7 | .2568 | .1151 | 35 |
| | (Mar. 14, 1928 | 37 | 1.181 | 43.0 | .2461 | .1069 | 30 |
| | Average | | 1.181 | 42.4 | .2497 | .1100 | 31.7 |
| C | (Feb. 24, 1928 | 32 | 1.477 | 42.0 | .2889 | .1286 | 30 |
| | (Mar. 1, 1928 | 35 | 1.477 | 41.4 | .2836 | .1280 | 30 |
| | (Mar. 14, 1928 | 38 | 1.477 | 42.0 | .2836 | .1262 | 30 |
| | Average | | 1.477 | 41.8 | .2854 | .1276 | 30 |

Table 9.

Made With Added $NH_4Cl$; Inoculation, P. roquefortí Culture 33.

| | Score of Sampled Cheese; Dec. 19th, 1928. | | | | | |
|---|---|---|---|---|---|---|
| | Flavor | Texture | Mold Growth | Color | Total | Remarks: |
| e | 40 | 25 | 25 | 10 | 100 | |
| | 30 | 18 | Nil | 10 | 58 | T: Hard and Dry. |
| | 30 | 19 | Nil | 10 | 59 | T: Fairly hard. |
| | 32 | 20 | 18 | 10 | 80 | F: Salty. |
| | 30.7 | 19 | 6 | 10 | 65.7 | |
| | 30 | 18 | Nil | 10 | 58 | F: Salty. T: Hard and Dry. |
| | 35 | 22 | 23 | 10 | 90 | F. Culture 33 Type. |
| | 30 | 20.5 | Nil | 10 | 60.5 | F: Slightly Salty. |
| | 31.7 | 20.2 | 7.7 | 10 | 69.5 | |
| | 30 | 18 | Nil | 10 | 58 | F: Salty. T: Hard and Dry. |
| | 30 | 19 | Nil | 10 | 59 | T: Fairly hard. |
| | 30 | 20.5 | Nil | 10 | 60.5 | F: Slightly Salty. |
| | 30 | 19.2 | Nil | 10 | 59.2 | |

| Score o[cut off] | |
|---|---|
| Flavor | Text[cut off] |
| 40 | 2[cut off] |
| 35 | 22. |
| 32 | 21 |
| 35 | 22 |
| 34 | 21. |
| 32 | 21 |
| 32 | 21 |
| 32 | 21 |
| 32 | 21 |
| 32 | 21 |
| 32 | 21 |
| 34 | 21 |
| 32.7 | 21. |

Score of Unsampled Cheese; Jan. 7th, 1929.

| Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks: |
|---|---|---|---|---|---|
| 35 | 22.5 | 21 | 10 | 88.5 | F: Culture 33 Type. M: Probably followi |
| 32 | 21 | 10 | 10 | 73 | F: Clean. M: Slight Growth in places. |
| 35 | 22 | 21 | 10 | 88 | F: Clean, well developed. M: Probably f |
| 34 | 21.8 | 17.3 | 10 | 83.2 | |
| 32 | 21 | Nil | 10 | 63 | F: Clean, well developed. |
| 32 | 21 | Nil | 10 | 63 | F: Clean, well developed. |
| 32 | 21 | Nil | 10 | 63 | F: Clean, well developed. |
| 32 | 21 | Nil | 10 | 63 | |
| 32 | 21 | Nil | 10 | 63 | F: Clean, well developed. |
| 32 | 21 | Nil | 10 | 63 | F: Clean, well developed. |
| 34 | 21.5 | 18 | 10 | 83.5 | M: General but slight. |
| 32.7 | 21.2 | 6 | 10 | 69.8 | |

eese; Jan. 7th, 1929.

| lor | Total | Remarks: |
|---|---|---|
| 10 | 100 | |
| 10 | 88.5 | F: Culture 33 Type. M: Probably following fracture. |
| 10 | 73 | F: Clean. M: Slight Growth in places. |
| 10 | 88 | F: Clean, well developed. M: Probably following fracture. |
| 10 | 83.2 | |
| 10 | 63 | F: Clean, well developed. |
| 10 | 63 | F: Clean, well developed. |
| 10 | 63 | F: Clean, well developed. |
| 10 | 63 | |
| 10 | 63 | F: Clean, well developed. |
| 10 | 63 | F: Clean, well developed. |
| 10 | 83.5 | M: General but slight. |
| 10 | 69.8 | |

The results of the determinations of the percentage of ammonia and moisture after one week are expressed in Tables 8 and 9 and show the following:

1. The moisture contents of all the cheese of a lot were within the range of experimental error; therefore the addition of the $NH_4Cl$ has not affected the moisture content of the cheese. The cheese of the six lots at the age of one week averaged 41.9 percent moisture and ranged from 40.0 to 43.2 percent; this difference was not considered a significant factor.

2. The ammonia, expressed as $NH_4Cl$ in Group A cheese, averaged 0.0437 percent and ranged from 0.0321 to 0.0482 percent, or expressed as normality in the moisture, it averaged 0.0195 N. and ranged from 0.0143 to 0.0220 N. The $NH_4Cl$ in the freshly made cheese was much below the optimum of 0.10 N., as found by Weisbrodt (41) for synthetic media.

3. The ammonia, expressed as $NH_4Cl$ in Group B cheese, averaged 0.2488 percent and ranged from 0.2354 to 0.2621 percent; or, expressed as normality in the moisture, it averaged 0.1105 N. and ranged from 0.1050 to 0.1207 N. These normalities are just above the optimum as given by Weisbrodt (41) for synthetic

media.

4. The ammonia, expressed as $NH_4Cl$ in Group C cheese, averaged 0.2809 percent and ranged from 0.2514 to 0.2889 percent; or, expressed as normality in the moisture, it averaged 0.1257 N. and ranged from 0.1174 to 0.1343 N. These normalities are just above the optimum as given by Weisbrodt (41) for synthetic media.

Scores of the ripened cheese. The cheese, which provided the samples for analysis after one week were scored on Oct. 5th and Dec. 19th, 1928, while the unplugged cheese were scored on Jan. 7th, 1929. Tables 8 and 9 give the scores of the ripened cheese. In general conditions were unfavorable for the development of the mold as the cheese were made in winter.

Table 8, cheese inoculated with culture 32, showed:

1. Of the six cheese which developed mold, three were in Group A, one was in Group B, and two in Group C.

2. As there were twice as many cheese that received $NH_4Cl$ as there were controls, the $NH_4Cl$ tended to retard the growth of P. roqueforti culture 32.

3. The sampling of the cheese assisted the development of the mold.

Table 9, cheese inoculated with culture 33, showed:

1. Of the six cheese which developed mold, four were in Group A, one was in Group B, and one in Group C.

2. As there were twice as many cheese that received $NH_4Cl$ as there were controls, the $NH_4Cl$ tended to retard the growth of P. roqueforti culture 33.

3. The sampling of the cheese did not assist the development of the mold.

## Summary and Conclusions.

There was a considerable but variable quantity of ammonia in the well matured Wensleydale cheese . The Cheddar examined contained about the same quantity of ammonia as the Wensleydales. These quantities were similar in proportion to that found by previous investigators (28) (29) for matured cheese.

Very little ammonia was found in fresh Wensleydale cheese which is quite in accordance with investigations dealing with fresh cheese of other varieties (28)(29). It may be safely concluded that most of the ammonia was produced during ripening.

There was no advantage, either in the rate or extent of growth of P. roqueforti cultures 32 or 33, in the addition of $NH_4Cl$ to the curd at salting, in the proportions as found satisfactory by Weisbrodt (41) in synthetic media. A slight detrimental effect was noticed which may be accounted for by a retarding action of the additional [illegible]Cl added with the $NH_4Cl$.

# PART III.

## THE OXYGEN REQUIREMENTS OF *P. ROQUEFORTI* IN CHEESE.

### Introduction.

The work of Thom and Currie (37) and several other investigators has shown the significance of oxygen for the growth of *P. roqueforti*. The possibility of an absence, or a greatly reduced supply, of oxygen inhibiting the growth of *P. roqueforti* in Wensleydale cheese therefore was considered.

### Review of Literature.

In cultural studies with 27 species of Aspergillus and Penicillium grown on Czapek's media, as given by Dox, Thom and Currie (37) showed that when the carbon dioxide content of the air was increased to 75 percent, which means an oxygen reduction to 5 percent, *P. roqueforti* grew the best of all the species examined and was the only mold showing over a 50 percent normal growth.

The production of carbon dioxide with a corresponding percentage reduction of oxygen is to be expected in cheese. Hammer and Baker (19), in a classification of the *Streptococcus lactis* group, showed that all these organisms, to a greater or less extent, produced carbon dioxide in milk. The significance of this group in the early stages of the ripening of cheese has been demonstrated by Hastings, Evans and Hart (20). Van Slyke and Hart (39) found that the totalweight of carbon dioxide given off from a Cheddar cheese in 32 weeks was 0.5 percent of the weight of the fresh cheese. They found that the carbon dioxide produced in the early stages of ripening came from the decomposition of milk sugar by lactic acid organisms, while that produced after the first few weeks came apparently from reactions taking place in some of the amido compounds, among which they were able to identify the change of tyrosine and arginine into derived products with simultaneous formation of carbon dioxide.

Golding (14) has shown that carbon dioxide was formed by the growth of P. roqueforti on milk (14). Van Slyke and Hart (39) found that mold growing on the surface of cheese produced carbon dioxide.

The work of Clark(7) on Emmental cheese directed the attention of Thom and Currie (37) to the gases as a probable factor in the dominance of P. roqueforti in Roquefort cheese. Thom and Currie found that inoculated Roquefort cheese and uninoculated Gorgonzola and Stilton all contained P. roqueforti in a fairly pure condition.

The study of large numbers of milk samples showed clearly that nearly all milk contains enough spores of various species of Penicillium, as well as other molds, to admit of a wide variety of mold colonies in any cheese, provided conditions are favorable for such molds to grow. Clearly, then, there are factors present which favor P. roqueforti in competition with the many other forms which are initially present in milk and which have been shown to grow fully as readily upon milk and certain milk products as does the Roquefort mold.

In analyzing the gases in Roquefort cheese, Thom and Currie (37) found a low oxygen content and a high content of carbon dioxide, as is shown by their following data.

## Analyses of the Gases of Roquefort Cheese

| Brand | CC. of Gas at 0°C. 760 mm. | | | | | Per Cent | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | Gas Collected | Gas Analyzed | $CO_2$ | $O_2$ | $N_2$ | $CO_2$ | $O_2$ | $N_2$ | |
| 1. Louis Rigal | 18.21 | 18.21 | 5.07 | 0.44 | 12.21 | 27.84 | 2.42 | 69.74 | Slight growth of mold. |
| 2. Société | 123.60 | 44.31 | 11.19 | 1.48 | 31.64 | 25.25 | 3.34 | 71.44 | Slight growth of mold. |
| 3. Veritable Roquefort | 81.73 | 81.73 | 18.07 | 5.72 | 57.94 | 22.11 | 7.00 | 70.89 | Very ripe and moldy. |
| 4. Experimental cheese | 88.25 | 80.29 | 32.88 | 3.64 | 43.77 | 40.95 | 4.53 | 54.52 | Six days old. |
| 5. Experimental cheese | 59.80 | 59.80 | 12.64 | 3.24 | 43.92 | 21.14 | 5.42 | 73.44 | Seven weeks old. |

The method used to collect the gases was to suck them from a cheese heavily coated in paraffin wax.

Though the accuracy of the method may be questioned, the high carbon dioxide and low oxygen content of Roquefort cheese is undoubtedly correct. Thom and Currie (37) give the following paragraph in discussing their data:

"From a study of these results, it appears that ripening is accompanied by a process of respiration which results in the disappearance of oxygen and the production of an equivalent amount of carbon dioxide. In the early period of ripening, the carbon dioxide from this source is augmented by the carbon dioxide produced by bacteria which decompose milk sugar. During this period the carbon dioxide is much higher and the nitrogen lower than would result from a simple process of respiration. The diffusion of gases tends to reduce this excess of carbon dioxide after the disappearance of milk sugar and the mixture of gases approaches the composition which would result from a process removing the oxygen from the air and producing an equivalent amount of carbon dioxide. The percentage of oxygen is always low and any aerobic organism which thrives within the cheese must be capable of obtaining its oxygen from a very dilute atmosphere of oxygen."

Thom and Currie summarized their results as follows:

"A mixture of 75 percent of carbon dioxide with air gives approximately 5 percent of free oxygen. The close correspondence between the results of gas analysis and comparative culture, indicates that the low percentage of oxygen in the open spaces within the cheese accounts for the dominant activity of *Penicillium roqueforti* in Roquefort and related types of cheese."

The diffusion and absorption of gases in cheese have not been investigated to any great extent. Clark (7) found that the percentage of moisture in Swiss cheese had a direct bearing on the rate of diffusion of gases, the drier the cheese, the less the diffusion taking place. Findlay (13) states, "that the solubility of carbon dioxide in colloidal solutions is relatively high at low pressures, and that it diminishes with increasing pressure either to a constant value, or to a minimum value, after which the solubility increases again with rising pressure."

Several authorities (23) (24) report the practice of skewering and scraping cheese to produce aerobic conditions to encourage the growth of *P. roqueforti.*

## Statement of Problem

Several experiments were conducted with what were considered possible ways of increasing the oxygen content of cheese. These experiments were carried out under the following headings:

A. Drawing air into the cheese by suction.

B. Forcing oxygen into the cheese.

C. Alternating reduced and atmospheric pressure on cheese in an iron cylinder.

Experiments I and II.

D. A preliminary experiment to determine the possibility of reducing the $CO_2$ produced by lowering the percentage of milk sugar incorporated in the curd.

## DRAWING AIR INTO THE CHEESE BY SUCTION.

### Introduction.

The removal of $CO_2$ by suction and replacing it by air would appear to be the easiest way of increasing the oxygen in a cheese and favoring the growth of *P. roqueforti.*

### Methods.

Cheese. The cheese selected for the experiment were those from the citric acid experiments which had all failed to blue. Their method of manufacture is given under their respective Series Nos. Charts 1 and 2. These cheese had been previously plugged when scoring them for the citric acid experiment.

Suction Tubes. The suction tubes were made from test tubes (½" x 4¾"), of approximately the same diameter as the trier used for boring the cheese, and had a hole blown in the sides about ½" from the closed ends. The rough holes were fused so that the test tube acted as a catheter tube. These tubes had cotton plugs fitted half way down and were then placed in larger tubes and steam sterilized.

Fitting Tubes into Cheese. The suction tubes were fitted into the cheese by first drawing a plug with the trier and putting the plug in a sterile test tube. Then the prepared suction tube with the catheter end first was forced into the hole in the cheese. About ¾" of the

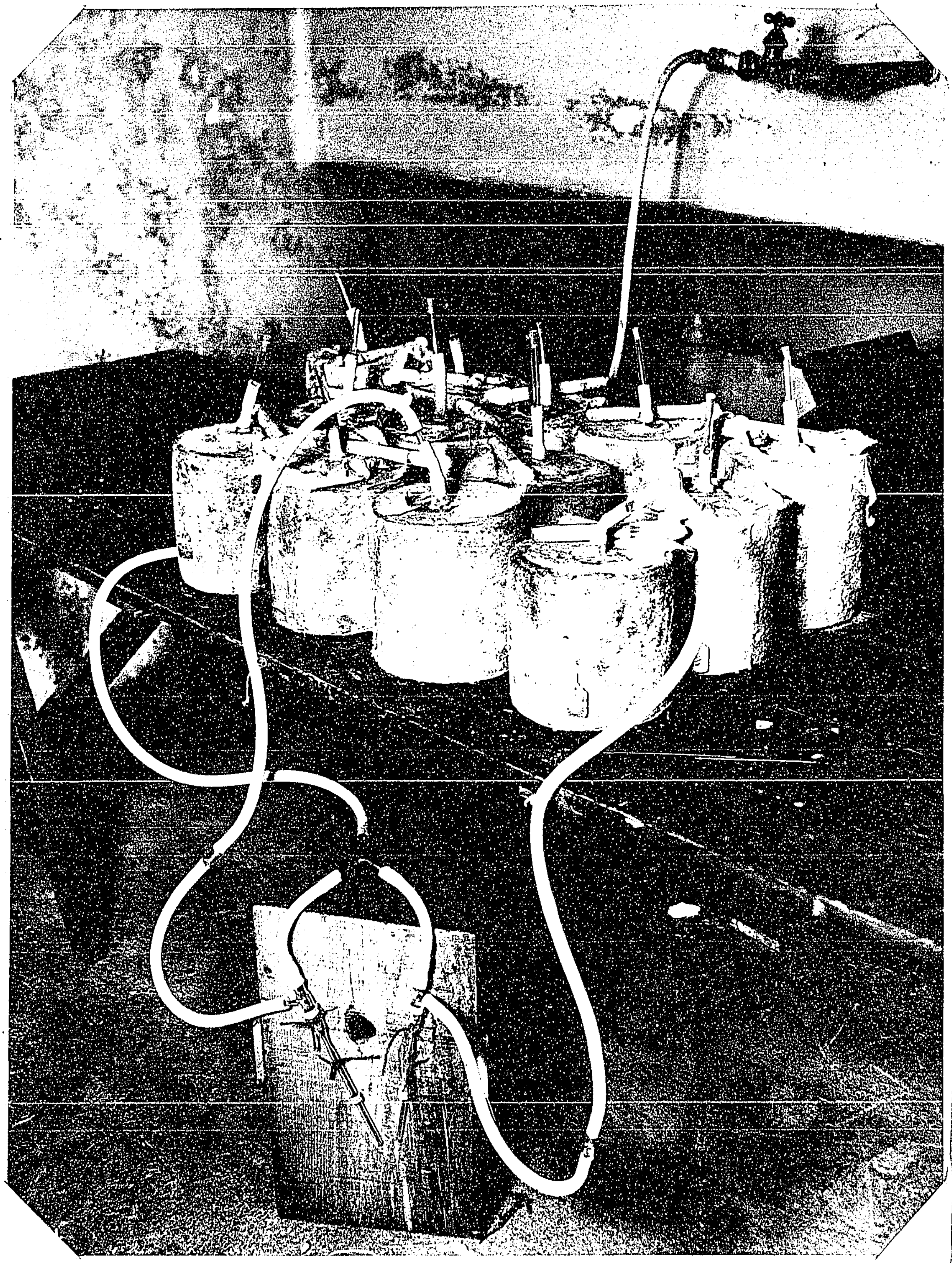


Fig. 4.

tube was left protruding above the surface of the cheese. On to the protruding end was attached a short rubber tube, connected with a glass tube containing a removable cork. Fig. 4 gives the appearance of the cheese bored and fitted with tubes at the beginning of the experiment, Oct. 4th, 1927.

Applying Suction. Two cheese had air sucked through them, at the same time, for a period of 24 hours, the catheter tube being connected up and the suction water pumps run as shown in Fig.4. The suction began with the first two cheese on Oct. 6th, 1927, and was completed on Oct. 13th, 1927. (Table 10). The catheter tubes were then removed and the cheese plugs returned. The method did not prove as satisfactory as was hoped, owing to air leaking down on the outside of the catheter tubes when suction was applied.

## Results Obtained.

The cheese, after having had air sucked through them, were kept until Nov. 24th, 1927, and then all scored the same day. From Table 10 and the fact that the control cheese did not develop mold, the following points may be noted:

Table 10.

Scores of Wensleydale Cheese
Air Drawn into Cheese by Suction

| Date Made | Series No. | Citrate Added to 200 lbs. Milk Grams | Date Aerated | Sco[re] Flavor 40 |
|---|---|---|---|---|
| Dec. 29, 26 | 1 | | Oct. 6, 27 | |
| Jan. 4, 27 | 3 | | Oct. 6, 27 | |
| Feb. 22, 27 | 5 | | Oct. 7, 27 | |
| March 9, 27 | 8 | | Oct. 8, 27 | 34 |
| March 15,27 | 10 | | Oct. 9, 27 | |
| March 22,27 | 12 | | Oct.10, 27 | |
| Apr. 20,27 | 14 | | Oct. 11,27 | |
| Apr. 25,27 | 15 | | Oct. 12,27 | |
| Jan. 6,27 | 4 | 84.4<br>2 $Na_3C_6H_5O_7$, 11 $H_2O$ | Oct. 7,27 | |
| March 3,27 | 7 | 45.36<br>$C_6H_8O_7$, $H_2O$ | Oct. 8,27 | 36 |
| March 10,27 | 9 | 45.36<br>$C_6H_8O_7$, $H_2O$ | Oct. 9,27 | |
| March 17,27 | 11 | 45.36<br>$C_6H_8O_7$, $H_2O$ | Oct. 10,27 | |
| March 24,27 | 13 | 45.36<br>$C_6H_8O_7$, $H_2O$ | Oct. 11,27 | |
| April 27,27 | 16 | 49.62<br>$C_6H_8O_7$, $H_2O$ | Oct. 12,27 | 36 |

-

10.

e Cheese
e by Suction

| ted | Scores of Cheese Nov. 24, 1927 Flavor | Texture | Mold Growth | Color | Total | Remarks |
|---|---|---|---|---|---|---|
| | 40 | 25 | 25 | 10 | 100 | |
| 27 | | | | | | No mold growth except near p |
| 27 | | | | | | No mold growth except near p |
| 27 | | | | | | Some mold due to cracks and |
| 27 | 34 | 22 | 17 | 10 | 83 | Fair Cheese |
| 27 | | | | | | No mold growth except near p |
| 27 | | | | | | No mold growth except near p |
| 27 | | | | | | No mold growth except near p |
| 27 | | | | | | No mold growth except near p |
| 27 | | | | | | Some mold growth due to cra plugs. |
| 27 | 36 | 22 | 20 | 10 | 88 | Good cheese |
| 27 | | | | | | No mold growth except near p |
| 27 | | | | | | No mold growth except near p |
| 27 | | | | | | No mold growth except near p |
| 27 | 36 | 22 | 21 | 10 | 89 | Good mold growth but rather following the open spaces. |

| of Cheese Texture 25 | Nov. 24, 1927 Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|
| | | | | No mold growth except near plug. |
| | | | | No mold growth except near plug |
| | | | | Some mold due to cracks and plugs |
| 22 | 17 | 10 | 83 | Fair Cheese |
| | | | | No mold growth except near plug. |
| | | | | No mold growth except near plug. |
| | | | | No mold growth except near plug. |
| | | | | No mold growth except near plug. |
| | | | | Some mold growth due to cracks and plugs. |
| 22 | 20 | 10 | 88 | Good cheese |
| | | | | No mold growth except near plugs. |
| | | | | No mold growth except near plugs. |
| | | | | No mold growth except near plugs. |
| 22 | 21 | 10 | 89 | Good mold growth but rather following the open spaces. |

1. With the exception of three cheese, Series Nos. 7, 8 and 16, good mold growth did not develop though mold had grown around the plugs. The air leak down the side of the catheter tubes may in part account for the mold growth around the plugs.

2. Of the three cheese which developed satisfactory mold growth, two belong to the group which were made with added citric acid.

3. In general, drawing air into the cheese by suction does not point to a satisfactory way of increasing the growth of P. roqueforti in cheese.

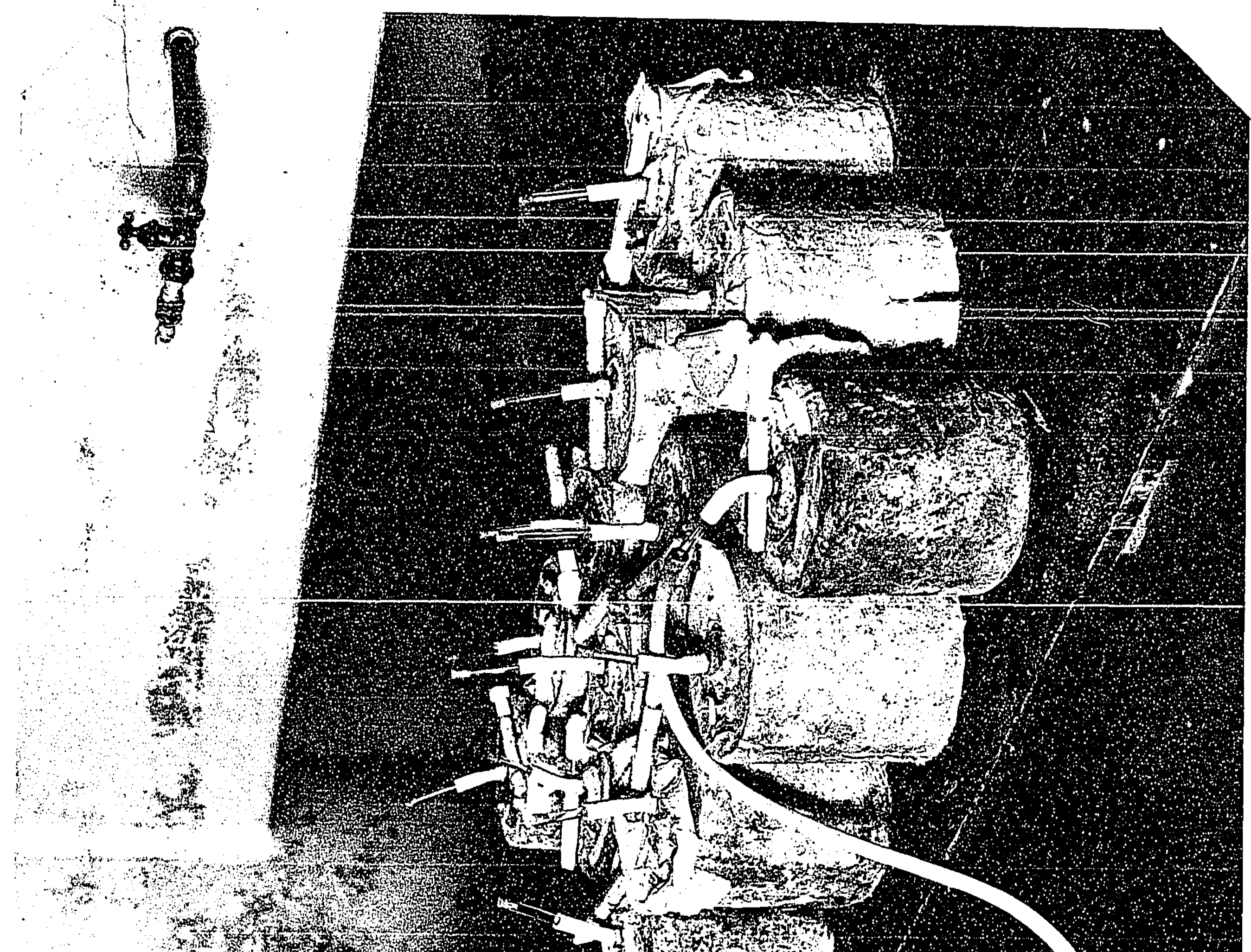


Fig. 5.

## B. FORCING OXYGEN INTO THE CHEESE.

### Introduction.

The forcing of oxygen, from an oxygen cylinder, into a cheese presents a possible way of increasing the oxygen content in the interspaces, and thus favoring the growth of *P. roqueforti.*

### Methods.

Cheese. The cheese selected for the experiment were the duplicates from the citric acid experiments and had not been previously plugged.

Catheter tubes. Catheter tubes, as in the previous experiment, were fitted into each cheese and the tubes sealed into the cheese by pouring hot liquid parawax around the top and allowing it to harden. Fig. 5.

Injecting Oxygen. The method used to inject oxygen is shown in Fig. 5. One cheese at a time was connected up and a slow flow of oxygen allowed to pass into it for 5 minutes. The tube was then disconnected and the cork returned. All cheese in the experiment received a fairly uniform flow of oxygen, as the flow was not changed after the day's injection was started. Twelve 5-minute injections of oxygen were given each cheese between Nov. 25th, 1927 and Dec. 21st, 1927. These injections were given at 3 day intervals except for the last injection which was given at a 2 day interval. On Dec. 21st, the catheter tubes were withdrawn and the plugs, which had all gone moldy, were returned to the cheese.

## Results Obtained.

All the cheese were scored on Jan. 10, 1928, and the results of these scores are given in Table 11. From the experiment, it was difficult to draw conclusions as there are no true controls. On the other hand, it must be remembered that all cheese were plugged on Nov. 24th, at which time natural mold growth should have occurred and showed no sign of mold.

From the data in Table 11, the following points may be noted:

1. With the exception of four cheese Series Nos. 7,8,11 and 16, good mold growth did not develop, though mold had grown out from the plugs in most cases.

2. Of the four cheese which developed satisfactory mold growth, three belong to the group which were made with added citric acid.

3. In general, the injecting of oxygen does not point to a satisfactory way of increasing the growth of P. roqueforti in cheese.

Table 11.
Scores of Wensleydale Cheese
Oxygen Injected into Cheese

| Date Made | Series No. | Citrate Added to 200 pounds milk grams | Scores of Cheese Ja Flavor 40 | Texture 25 | Mol |
|---|---|---|---|---|---|
| Dec. 29, 26 | 1 | | 24 | 15 | |
| Jan. 4, 27 | 3 | | 24 | 16 | |
| Feb. 22, 27 | 5 | | 25 | 15 | |
| March 9, 27 | 8 | | 35.5 | 22 | |
| March 15, 27 | 10 | | 30 | 17 | |
| Apr. 25, 27 | 15 | | 28 | 17 | |
| Jan. 6, 27 | 4 | 84.4 2 $Na_3C_6H_5O_7$ 11 $H_2O$ | 25 | 15 | |
| March 3, 27 | 7 | 45.36 $C_6H_8O_7$, $H_2O$ | 35.5 | 22.5 | |
| March 10, 27 | 9 | 45.36 $C_6H_8O_7$, $H_2O$ | 24 | 16 | |
| March 17, 27 | 11 | 45.36 $C_6H_8O_7$, $H_2O$ | 35.5 | 22 | |
| March 24, 27 | 13 | 45.36 $C_6H_8O_7$, $H_2O$ | 29.0 | 17 | |
| April 27, 27 | 16 | 49.62 $C_6H_8O_7$, $H_2O$ | 36.0 | 22 | |

Table 11.
leydale Cheese
ed into Cheese

| res of Cheese Jan. 10, 1928. | | | | | Remarks |
|---|---|---|---|---|---|
| vor<br>) | Texture<br>25 | Mold Growth<br>25 | Color<br>10 | Total<br>100 | |
| | 15 | 10 | 10 | 59 | F.Only Fair,T.Granular,Hard and Dry. Plug molded. |
| | 16 | Nil | 10 | 50 | Poor quality |
| | 15 | 10 | 10 | 60 | F. Fair, T. Granular, Hard and Dry, Plug molded |
| .5 | 22 | 21.5 | 10 | 89 | M. Not quite typical |
| | 17 | 14 | 10 | 71 | T. Granular, Mold in parts. |
| | 17 | 12 | 10 | 67 | A little mold in one or two places. |
| | 15 | 10 | 10 | 60 | F.Fair, T. Granular, Hard and Dry Plug molded |
| .5 | 22.5 | 21.5 | 10 | 89.5 | Plug moldy, A good Cheese. |
| | 16 | 10 | 10 | 60 | F. Only Fair, T. Granular, Plug molded |
| .5 | 22 | 22 | 10 | 89.5 | A Good Cheese |
| .0 | 17 | 14 | 10 | 70 | T. Granular, Mold in parts. |
| .0 | 22 | 22 | 10 | 90 | Good Cheese |

## C. ALTERNATING REDUCED AND ATMOSPHERIC PRESSURE ON CHEESE IN AN IRON CYLINDER.

### Introduction.

Henry's Law states: "The Quantity of a gas (either weight or volume) at N. T. P. dissolved by a given volume of a given liquid at a given temperature is directly proportional to the pressure under which the absorption takes place." It was thought that this principle might possibly be used to increase the oxygen content of the cheese, provided the rind was pervious, and that, when the pressure was reduced on a cheese in an enclosed vessel, the absorbed gases would be liberated in proportion to the composition of the surrounding gases and their absorption coefficients. Assuming the rind pervious and a high content of $CO_2$ to be present in the interspaces in the cheese, the $CO_2$ would be given off by a reduction in pressure. The $CO_2$ could be collected by passing it through a standard solution of Ba $(OH_2)$ and the amount determined. After the cheese had been held for some time at reduced pressure, air could be allowed to enter the cylinder and atmospheric pressure slowly resumed.

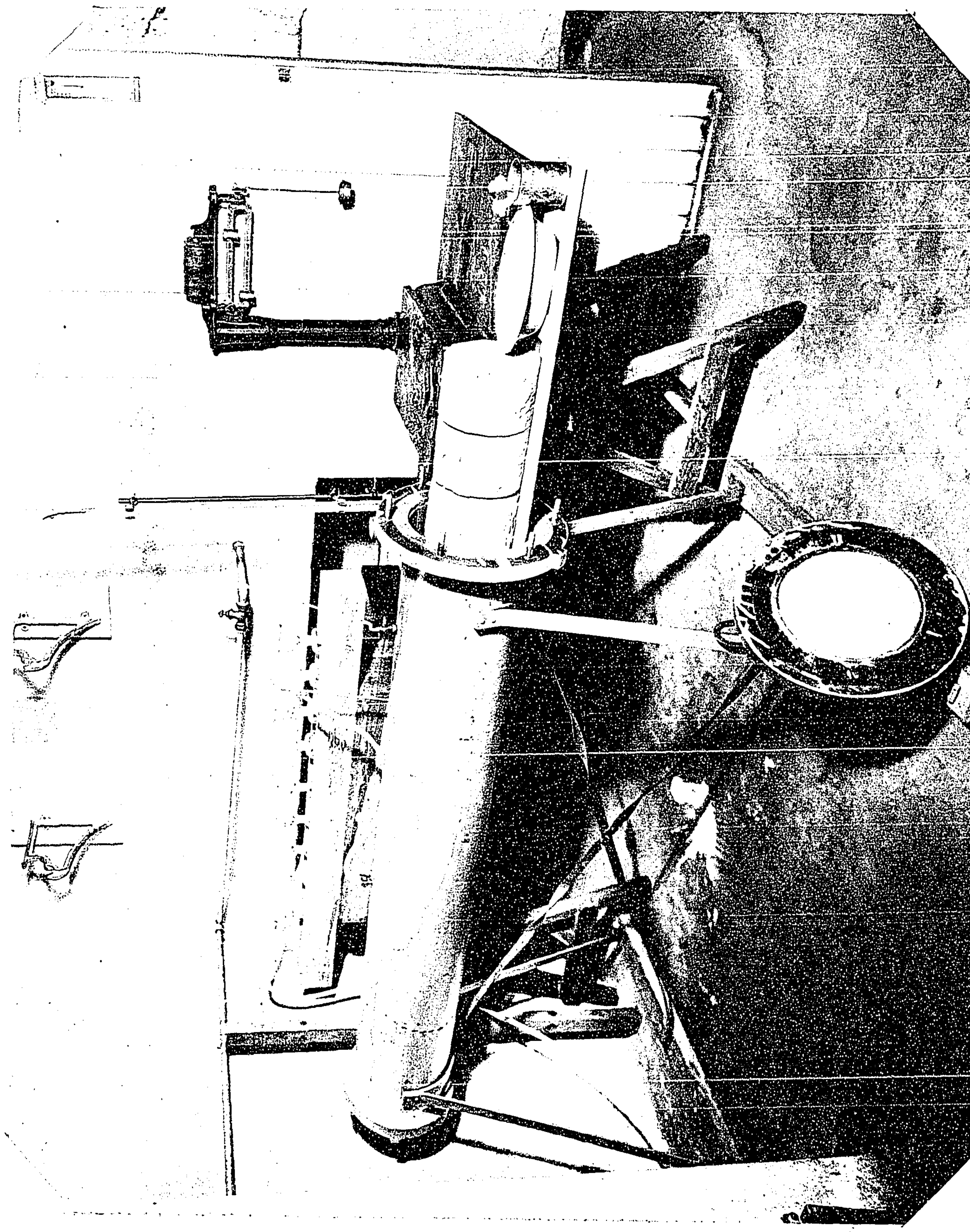


Fig. 6.

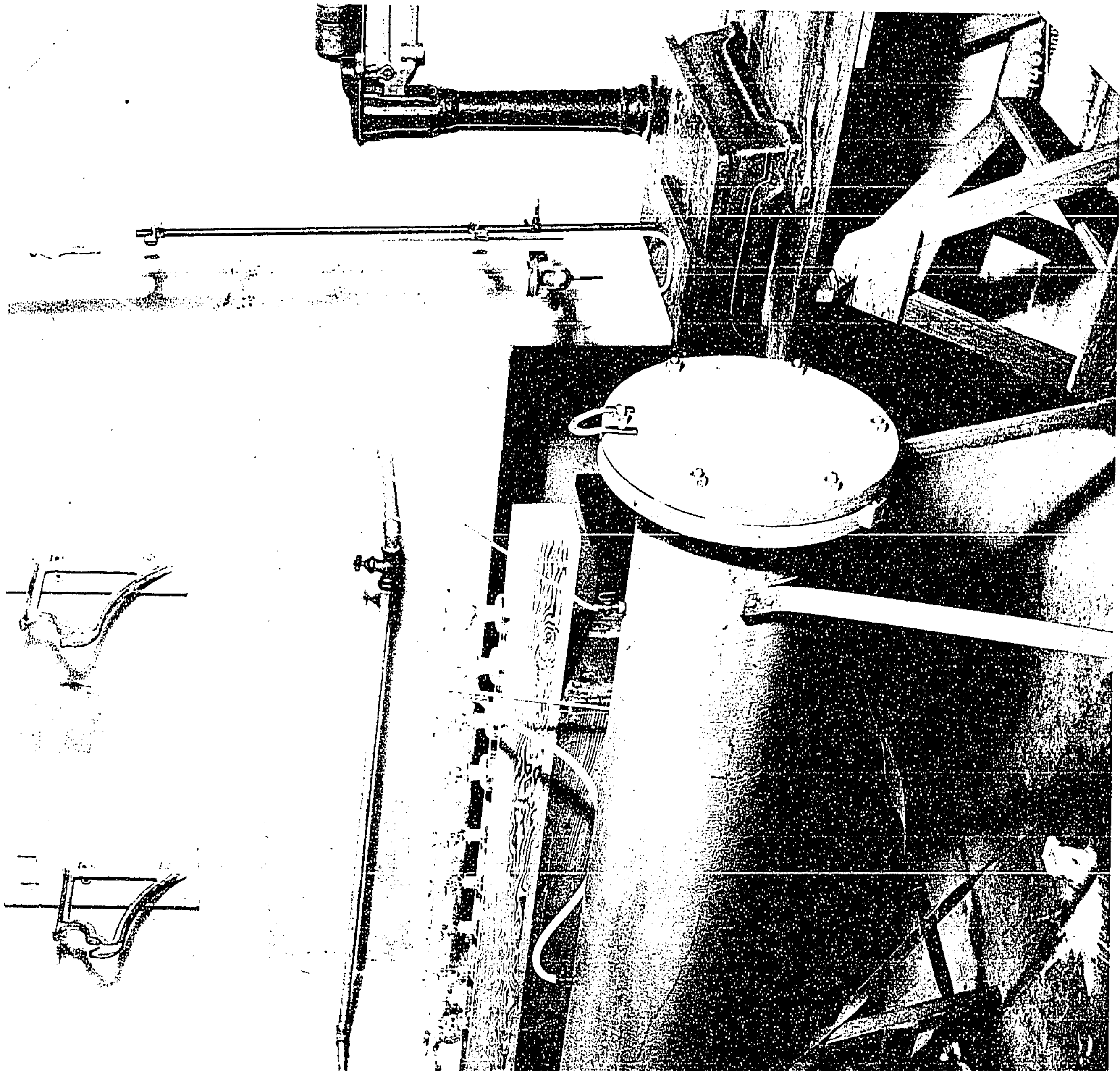


Fig. 7.

By this increase back to atmospheric pressure, the gases of the air would be absorbed in proportion to the composition of the air, the absorption coefficient of the gases and the difference in pressure between the reduced pressure and that of the atmosphere. Theoretically, by this method, oxygen would largely replace the $CO_2$. The theory applies only to the water of which a Wensleydale cheese contains from 33 to 40 percent.

## Methods.

Apparatus. The apparatus designed to test the practical working of the above theory is shown in Figs. 6 and 7. It consisted essentially of a 6 ft. length of 10 inch steam pipe capped at one end and with a removable air tight door fitted to the other.

Operation. To operate the apparatus, the wooden rack was filled with the experimental cheese, usually 7, see Fig. 6. 250 cc. of tap water were put into each water bath and the rack was then pushed into the 10" pipe. The round door, see Fig. 6., was placed on the protruding bolts and the nuts tightened. See Fig. 7. The nine gas wash bottles were partly filled with standard $Ba(OH)_2$ solution, 1000 cc. in all, and then connected up by rubber tubes to the pumps and the centre tap of the 10" pipe. With the centre tap open and the pressure guage tap closed, the pumps were started and run for 7 hours.

At the close of the operation, the reduced pressure was recorded in mm. of mercury. The solution in all the gas wash bottles was carefully washed into two 2000 cc. flasks and titrated for excess of Ba $(OH)_2$, using standard HCl solution and phenolphthalein as an indicator. The cheese were removed from the apparatus after it had been allowed to gradually come back to atmospheric pressure.

Blank for $CO_2$ in Air in 10" Pipe. The blanks, that is the determinations of $CO_2$ in the 10" pipe without cheese present, were run for the same time as the cheese were subjected to reduced pressure. The amount of $CO_2$ in the blank was subtracted from each run made with cheese present. By this method, the $CO_2$ in the volume of air displaced by the cheese was included in the blank. This introduces an error, which, though considerable, was of less significance than the unavoidable leakage of air by the door.

Cheese. The Wensleydale cheese used in both experiments were seven lots of cheese made during Aug. and Sept.

1928. The records of their manufacture and inoculation are given in Chart 4, under their respective Series Nos.

## Results Obtained.

### Experiment I.

The $CO_2$ Collected from Wensleydale Cheese.

Seven Wensleydale cheese, one from each lot of the above makes of cheese, were subjected to 23 operations of reduced pressure in the iron cylinder. The seven control cheese of the same make were kept on the shelves in the same room. The weights of $CO_2$ collected for each operation are recorded in Table 12, which shows the following results:

1. The total $CO_2$ collected by reduced pressure (23 operations, 7 hours each) was 25 grams from 66 lbs. 9 ozs. of cheese or less than .1 percent by weight. An average of about 1 gram of $CO_2$ was removed by each operation.

2. Owing to variations in the reduced pressures from day to day, as a result of uneven water pressure, individual operations were difficult to compare.

3. Considerably the greatest loss of $CO_2$ from the cheese was in the first operation.

4. The loss of $CO_2$ increased slightly towards

Table 12.

The $CO_2$ Collected from Wensleydale Cheese.

Experiment I.

Cheese Series Nos. 40,46, 52, 58, 64, 70 and 76.    Weight of Chees

| Date 1928 | Temp. of Room °F. Min. | Max. | Time Hours | Minutes | Re Pr |
|---|---|---|---|---|---|
| Oct. 24 | | | 7 | | |
| Oct. 25 | | | 7 | | |
| Oct. 26 | 52 | 54 | 7 | | |
| Oct. 27 | 54 | 55 | 7 | | |
| Oct. 29 | 53 | 56 | 7 | | |
| Oct. 30 | 54 | 56 | 7 | | |
| Oct. 31 | 54 | 56 | 7 | | |
| Nov. 1 | 54 | 57 | 7 | | |
| Nov. 2 | 55 | 57 | 7 | 5 | |
| Nov. 3 | 55 | 57 | 7 | | |
| Nov. 5 | 55 | 58 | 7 | | |
| Nov. 6 | 54 | 57 | 7 | | |
| Nov. 7 | 53 | 55 | 7 | 5 | |
| Nov. 8 | 53 | 55 | 7 | | |
| Nov. 9 | 52 | 55 | 7 | | |
| Nov. 10 | 53 | 55 | 7 | | |
| Nov. 12 | 53 | 55 | 7 | | |
| Nov. 13 | 53 | 55 | 7 | | |
| Nov. 14 | 51 | 54 | 7 | | |
| Nov. 15 | 50 | 52 | 7 | 15 | |
| Nov. 16 | 49 | 52 | 7 | | |
| Nov. 17 | 51 | 52 | 7 | | |
| Nov. 19 | 50 | 53 | 7 | | |
| Nov. 20 | 50 | 53 | 7 | | |
| Total | | | | | |
| Average | | | | | |

Table 12.

e Cheese.

t I.

64, 70 and 76. Weight of Cheese, 66 lbs. 9 ozs.

| Time Hours | Time Minutes | Reduced Pressure mm. | $CO_2$ Collected Grams |
|---|---|---|---|
| 7 | | 625 | +1.7349 |
| 7 | | 565 | .7093 |
| 7 | | 530 | .9469 |
| 7 | | 675 | 1.1361 |
| 7 | | 653 | 1.0644 |
| 7 | | 650 | 1.0578 |
| 7 | | 655 | 1.1414 |
| 7 | | 675 | 1.1425 |
| 7 | 5 | 680 | 1.2089 |
| 7 | | 490 | .7689 |
| 7 | | 667 | .9843 |
| 7 | | 650 | 1.0589 |
| 7 | 5 | 670 | 1.0336 |
| 7 | | 630 | .8642 |
| 7 | | 600 | 1.0065 |
| 7 | | 620 | .9981 |
| 7 | | 530 | .9156 |
| 7 | | 630 | 1.1224 |
| 7 | | Not determined | |
| 7 | 15 | 620 | .9629 |
| 7 | | 570 | 1.1693 |
| 7 | | 520 | 1.0402 |
| 7 | | 650 | 1.2802 |
| 7 | | 625 | 1.2509 |
| | | | 24.5982 |
| | | 616 | 1.0695 |

the end of the experiment. The cause of this greater production of $CO_2$ may have been the slight growth of P. roqueforti in Cheese Series Nos. 40,52 and 58.

Discussion.

In a preliminary experiment, such as this, it is as well to discuss the results before doing a further experiment. The following calculation is conducted to decide if $CO_2$ is being produced during the time the experiment was being conducted.

A Wensleydale cheese 2 to 3 months old contains approximately 35 percent of water. Then the 66 lbs. 9 ozs. in 1065 ozs. of Wensleydale cheese that were aerated contained 372.75 ozs. of water, i. e., 10,565 cc.

The figures of Thom and Currie (37) show the composition of the gases in a new cheese to be approximately:

| | |
|---|---|
| $CO_2$ | 41 percent by vol. |
| $O_2$ | 4.5 " " " |
| $N_2$ | 54.5 " " " |

Further assuming the same absorption coefficient for the water in the cheese as ordinary pure water, namely 1.194 at $10^{\circ}$ C. for $CO_2$, the 10,565 cc. of water in the cheese should contain:

$$\frac{41 \times 1.194 \times 10{,}565}{100} \text{ cc. } CO_2$$

$$= 5173 \text{ cc of } CO_2$$

The volume occupied by the gram molecular weight of a gas at N. T. P. is 22.4 litres.

Therefore: 22,400 cc. $CO_2$ = 44 grams

$$5173 \text{ cc. } CO_2 = \frac{44 \times 5173}{22{,}400} \text{ grams}$$

$$= 10.17 \text{ grams } CO_2$$

It is seen from this calculation that in the 23 operations of reducing the pressure, $2\frac{1}{2}$ times as much $CO_2$ is removed as would probably be in the cheese; provided the cheese had no special absorption power for $CO_2$. Neglecting for the moment the possibility of a greater absorption power in the cheese, the $CO_2$ is being produced during the experiment. Therefore the origin of the $CO_2$ collected must be from $CO_2$ formed in the cheese which could hardly have all come from the small amount of mold growth recorded in the three cheese. The growth of the mold or other organisms on the rind of the cheese is a possible additional source of $CO_2$, but as the production of $CO_2$ does not decline with the reduced activity on the rind of the cheese, it cannot be significant.

Table 13.

Scores and Weights of Wensleydal

CONTROL

| | | Weight | | | | Scores of Cheese Nov. 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date Made 1928 | Series Number | Start lbs. | ozs. | Finish lbs. | ozs. | Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Tota 100 |
| Aug. 21 | 41 | 8 | 6 | 8 | 2 | 30 | 20 | Nil | 10 | 60 |
| Aug. 23 | 47 | 8 | 13 | 8 | 7 | 30 | 20 | Nil | 10 | 60 |
| Aug. 30 | 53 | 8 | 13 | 8 | 4 | 30 | 20 | Nil | 10 | 60 |
| Sept. 6 | 59 | 9 | 14 | 9 | 8 | 31 | 21 | Nil | 10 | 62 |
| Sept.12 | 65 | 9 | 9 | 9 | 3 | 30 | 19 | Nil | 10 | 59 |
| Sept. 14 | 71 | 10 | 2 | 9 | 10 | 30 | 19 | Nil | 10 | 59 |
| Sept. 19 | 77 | 10 | 6 | 9 | 13 | 30.5 | 19 | Nil | 10 | 59. |
| Total | | 66 | 1 | 62 | 15 | | | | | |

Note: The cheese made from Aug.21st to Sept. 6th, 1928 inclusiv

Table 13.

Wensleydale Cheese. Experiment I.

R E D U C E D P R E S S U R E

se Nov. 21st.1928.

| Color 10 | Total 100 | Remarks | Date Made 1928 | Series Number | Weight Start lbs. | Weight Start ozs. | Weight Finish lbs. | Weight Finish ozs. | Sco... Flav 40 |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 60 | F. New cheese | Aug.21 | 40 | 8 | 7 | 8 | 2 | 32 |
| 10 | 60 | F. New cheese | Aug.23 | 46 | 8 | 13 | 8 | 8 | 30 |
| 10 | 60 | F. New cheese | Aug.30 | 52 | 8 | 11 | 8 | 5 | 31 |
| 10 | 62 | (F. New Cheese) (T. Smooth) | Sept.6 | 58 | 10 | 4 | 9 | 15 | 33 |
| 10 | 59 | (F. New Cheese) (T. Not Wet) | Sept.12 | 64 | 9 | 10 | 9 | 4 | 29 |
| 10 | 59 | F. New Cheese | Sept.14 | 70 | 10 | 5 | 9 | 12 | 30 |
| 10 | 59.5 | F. New Cheese | Sept.19 | 76 | 10 | 7 | 9 | 14 | 30 |
| | | | Total | | 66 | 9 | 63 | 4 | |

928 inclusive, were inoculated with *P. roqueforti* culture 32
the remainder with *P. roqueforti* culture 33

Scores of Cheese Nov. 21st, 1928.

| Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|---|
| 32 | 20 | 15 | 10 | 77 | F. New Cheese M. Slightly developed |
| 30 | 20 | Nil | 10 | 60 | F. New cheese |
| 31 | 20 | 10 | 10 | 71 | F. New cheese M. Trace of mold |
| 33 | 22 | 12 | 10 | 77 | F. New cheese T. Smooth |
| 29 | 18 | Nil | 10 | 57 | F. New cheese T. Wet and leaky |
| 30 | 19 | Nil | 10 | 59 | F. New cheese |
| 30.5 | 19 | Nil | 10 | 59.5 | F. New cheese |

Scores and Weights of the Wensleydale Cheese.

The score and weights of the cheese are recorded in Table 13, which shows the following results:

1. There was a slight growth of P. roqueforti in three cheese that had been aerated by reduced pressure. There was no growth in any of the control cheese.

2. The cheese were all rather new and it was noted that only the older aerated cheese showed any mold growth. On the other hand, the difference in the strain of the two cultures 32 and 33 might account for variation in growth, though in a previous investigation (14) it has been shown that culture 33 usually grew more rapidly than culture 32, which was not the case in these results.

3. The total loss of weight for all aerated cheese during the month was 3 lbs. 5 ozs.; that of the control was 3 lbs., 2 ozs. The difference of 3 ozs. was within the range of experimental error. Therefore, the loss of weight due to aeration by suction was insignificant.

4. The flavor and texture of the aerated cheese was almost identical with that of the control

except where the blue mold had developed.

Note: Aeration of P. roqueforti Cultures on Potato Agar. P. roqueforti cultures 32 and 33 inoculated on potato agar and subjected to reduced pressure with the cheese showed normal growth as compared with the control. Two sets of inoculations were tried at different times.

## Experiment II.

The $CO_2$ Collected from Wensleydale Cheese.

A second experiment was conducted with the remaining four cheese of each make to determine the value of less frequent suction periods over an extended period, the permeability of the rind to gases, and the significance of skewering the cheese. The methods of aeration, collection and determination of the $CO_2$ and the length of each suction period were maintained the same.

The groups were treated as follows:

Group A Cheese, Chart 4, Series Nos. 45. 51. 57. 63. 69. 75 and 81, were the controls for the three other groups.

Group B. Cheese, Chart 4, Series Nos. 42. 48. 54. 60. 66. 72 and 78, were subjected to reduced pressure twice a week for six weeks.

Group C. Cheese, Chart 4, Series Nos. 43. 49, 55, 61. 67. 73 and 79, had the bandages removed and were then subjected to reduced pressure twice a week for six weeks.

Group D. Cheese, Chart 4, Series Nos. 44. 50. 56. 62. 68. 74 and 80, had the bandages removed and were skewered from one end (28 holes 1/16 of an inch) and then were subjected to reduced pressure twice a week for six weeks.

The weights of $CO_2$ collected for each operation are recorded in Table 14, which shows the following results:

Tal

The $CO_2$ Collected f

| Group B | Bandage On | | | | Group C | Bandage Rem | | |
|---|---|---|---|---|---|---|---|---|
| Cheese Series Nos. 42,48,54,60,66,72, and 78. | | | | | Cheese Series Nos. 43,49,5 | | | |
| Weight of Cheese 63 lbs. 4 oz. | | | | | Weight of Cheese 63 lbs. 5 | | | |
| Date 1928 | Time Hrs. | Time Min. | Reduced Pressure mm. | $CO_2$ Collected grams | Date 1928 | Time Hrs. | Time Min. | Reduc Pressu |
| Nov.26 | 7 | 10 | 605 | 1.7235 | Nov.27 | 7 | 0 | 580 |
| Nov.29 | 7 | 1 5 | 600 | 1.0025 | Nov.30 | 7 | 0 | 575 |
| Dec. 3 | 7 | 0 | 630 | .7212 | Dec. 4 | 7 | 0 | 650 |
| Dec. 6 | 7 | 5 | 530 | | Dec. 7 | 7 | 0 | 665 |
| Dec.10 | 7 | 0 | 640 | 1.3457 | Dec.11 | 7 | 0 | 640 |
| Dec.13 | 7 | 5 | 650 | 1.2780 | Dec.14 | 7 | 0 | 660 |
| Dec.17 | 7 | 0 | 560 | 1.2164 | Dec.18 | 7 | 0 | 665 |
| Dec.20 | 7 | 0 | 635 | .8184 | Dec.21 | 7 | 5 | 695 |
| Dec.24 | 7 | 0 | 540 | 1.3167 | Dec.25 | 7 | 5 | 655 |
| Dec.27 | 7 | 0 | 660 | 1.2705 | Dec.28 | 7 | 0 | 665 |
| Dec.31 | 7 | 0 | 670 | 1.5609 | Jan. 1 | 7 | 0 | 665 |
| Jan. 3 | 7 | 0 | 680 | 1.2230 | Jan. 4 | 7 | 0 | 665 |
| | | | | 13.4768 | | | | |
| Average | | | 616.6 | 1.2252 | Average | | | 648. |

Table 14.
.ected from Wensleydale Cheese. Experiment II.

| ıdage Removed 43,49,55,61,67,73, and 79. ;3 lbs. 5 oz. | | Group D Bandage Removed. Cheese Skewered Cheese Series Nos. 44,50,56,62,68,74 and 80. Weight of Cheese 63 lbs. 5 oz. | | | | |
|---|---|---|---|---|---|---|
| Reduced Pressure mm. | $CO_2$ Collected grams | Date 1928 | Time Hrs. | Time Min. | Reduced Pressure mm. | $CO_2$ Collected grams |
| 580 | 1.3939 | Nov. 28 | 7 | 0 | 610 | 1.7065 |
| 575 | .9099 | Dec. 1 | 7 | 0 | 580 | .7352 |
| 650 | | Dec. 5 | 7 | 0 | 500 | |
| 665 | .8617 | Dec. 8 | 7 | 0 | 610 | .9827 |
| 640 | 1.0978 | Dec. 12 | 7 | 0 | 510 | .4741 |
| 660 | 1.0261 | Dec. 15 | 7 | 0 | 645 | 1.7241 |
| 665 | 1.0131 | Dec. 19 | 7 | 0 | 665 | 1.4003 |
| 695 | .9537 | Dec. 22 | 7 | 0 | 685 | 1.2441 |
| 655 | .9299 | Dec. 26 | 7 | 5 | 640 | .9273 |
| 665 | .7821 | Dec.29 | 7 | 0 | 665 | .9761 |
| 665 | .9933 | Jan. 2 | 7 | 0 | 670 | 1.0197 |
| 665 | .8481 | Jan. 5 | 7 | 0 | 680 | .7953 |
| | 10.8096 | | | | | 11.9854 |
| 648.3 | .9827 | Average | | | 621.6 | 1.0896 |

1. The $CO_2$ collected from Group B was the greatest; that from Group D was next, and that from Group C was the least. The differences may possibly be due to a greater diffusion taking place in Group C and D where the bandages of the cheese were removed. The greater growth of P. roqueforti in Group D may account for the greater $CO_2$ production in Group D than in Group C.

2. Owing to variations in the reduced pressure from day to day as a result of uneven water pressure, individual operations were difficult to compare.

3. As in Experiment I, a large quantity of $CO_2$ was collected during the first operation.

4. There was a considerable difference in the daily weights of $CO_2$ collected in different operations in the same group, which cannot all be accounted for by variations resulting from uneven pressure, temperature or intervals of four and three days.

5. The amounts of $CO_2$ collected following the four and three day periods between operations showed no significant difference.

6. With Group C, there was an average collection of $CO_2$ of .9827 grams for each operation which was fairly constant. With Group D, there was an average collection of $CO_2$ of 1.0896 grams per operation, which, with the exception of Dec. 8th and 12th, was fairly constant.

7. Group B is comparable with the Experiment I except for age of cheese and length of period between operations. The average collection of $CO_2$ per operation in Experiment I was 1.0695 grams; in Experiment II, 1.2252 grams. The individual values on the amount of $CO_2$ exhausted from the cheese (Table 12 and Table 14 Groups B) showed no tendency to increase or decrease as the cheese aged.

The longer periods between operations did not greatly increase the $CO_2$ collected per operation. This can be accounted for largely by the diffusion of $CO_2$ from the cheese at atmospheric pressure.

Table 15.
Scores of Wensleydale Cheese Subjected …
January 7th, 1…

GROUP A. CONTROL.

| Date Made 1928 | Series No. | Flavor 40 | Texture 25 | Mold Growth 25 | Co… 1… |
|---|---|---|---|---|---|
| Aug. 21 | 45 | 31 | 20 | Nil | 1… |
| Aug. 23 | 51 | 31 | 20 | Nil | 1… |
| Aug. 30 | 57 | 31 | 20 | Nil | 1… |
| Sept. 6 | 63 | 31 | 21 | Nil | 1… |
| Sept. 12 | 69 | 31 | 19 | Nil | 1… |
| Sept. 14 | 75 | 31 | 20 | Nil | 1… |
| Sept. 19 | 81 | 31 | 20 | Nil | 1… |
| Average | | 31 | 20 | Nil | 1… |

GROUP B BANDAGE ON.

| Date Made 1928 | Series No. | Flavor 40 | Texture 25 | Mold Growth 25 | C… 1… |
|---|---|---|---|---|---|
| Aug. 21 | 42 | 36 | 23 | 23 | 1… |
| Aug. 23 | 48 | 31 | 20 | Nil | 1… |
| Aug. 30 | 54 | 32 | 21 | 15 | 1… |
| Sept. 6 | 60 | 31 | 19 | Nil | 1… |
| Sept. 12 | 66 | 34 | 22 | 23 | 1… |
| Sept. 14 | 72 | 30 | 20 | Nil | 1… |
| Sept. 19 | 78 | 33 | 21 | 18 | 1… |
| Average | | 32.4 | 20.9 | 11.3 | 1… |

Note: The cheese made from Aug. 21 to Sept. 6, 1928, inclusive, wer…
The remainder were inoculated with _P. roqueforti_ culture 33.

Table 15.
of Wensleydale Cheese Subjected to Reduced and Atmospheric Pressure.
January 7th, 1929. Experiment II.

| Texture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|
| 20 | Nil | 10 | 61 | F. Clean mild. |
| 20 | Nil | 10 | 61 | F. Clean mild |
| 20 | Nil | 10 | 61 | F. Clean mild |
| 21 | Nil | 10 | 62 | F. Clean<br>T. Soft |
| 19 | Nil | 10 | 60 | T. Wet Close |
| 20 | Nil | 10 | 61 | F. Clean |
| 20 | Nil | 10 | 61 | F. Clean |
| 20 | Nil | 10 | 61 | |

| Texture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|
| 23 | 23 | 10 | 92 | F. Very good<br>T. Good M. Well developed |
| 20 | Nil | 10 | 61 | F. Clean Mild |
| 21 | 15 | 10 | 78 | F. Clean<br>M. in one place |
| 19 | Nil | 10 | 60 | T. Wet close |
| 22 | 23 | 10 | 89 | F. Typical culture 33<br>M. Well developed |
| 20 | Nil | 10 | 60 | F. Clean |
| 21 | 18 | 10 | 82 | M. One end. |
| 20.9 | 11.3 | 10 | 74.6 | |

to Sept. 6, 1928, inclusive, were inoculated with P. roqueforti culture 32
with P. roqueforti culture 33.

Table 15 (Continued)
Scores of Wensleydale Cheese Subjected to Reduced
January 7th, 1929.

GROUP C BANDAGE REMOVED.

| Date Made 1928 | Series No. | Flavor 40 | Texture 25 | Mold Growth 25 |
|---|---|---|---|---|
| Aug. 21 | 43 | 33 | 22 | 20 |
| Aug. 23 | 49 | 33 | 21 | 15 |
| Aug. 30 | 55 | 31 | 20 | Nil |
| Sept. 6 | 61 | 31 | 19 | Nil |
| Sept. 12 | 67 | 31 | 19 | Nil |
| Sept. 14 | 73 | 32 | 21 | 15 |
| Sept. 19 | 79 | 31 | 20 | Nil |
| Average | | 31.7 | 20.3 | 7.1 |

GROUP D BANDAGE REMOVED CHEESE SKEWERED

| Date Made 1928 | Series No. | Flavor 40 | Texture 25 | Mold Growth 25 |
|---|---|---|---|---|
| Aug. 21 | 44 | 34 | 21 | 20 |
| Aug. 23 | 50 | 33 | 22 | 18 |
| Aug. 30 | 56 | 32 | 21 | 15 |
| Sept. 6 | 62 | 31 | 19 | Nil |
| Sept. 12 | 68 | 33.5 | 22 | 21 |
| Sept. 14 | 74 | 33 | 21.5 | 18 |
| Sept. 19 | 80 | 32 | 21 | 15 |
| Average | | 32.6 | 21.1 | 15.3 |

Note: The cheese made from Aug. 21 to Sept. 6, 1928, inclusive, were
The remainder were inoculated with P. roqueforti culture 33.

ıble 15 (Continued)
Subjected to Reduced and Atmospheric Pressure.
nuary 7th, 1929. Experiment II.

| ɜxture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|
| 22 | 20 | 10 | 85 | F. Good<br>M. Chiefly one end. |
| 21 | 15 | 10 | 79 | F. Clean<br>M. Developed in one place |
| 20 | Nil | 10 | 61 | F. Clean Mild |
| 19 | Nil | 10 | 60 | T. Wet close |
| 19 | Nil | 10 | 60 | T. Wet close |
| 21 | 15 | 10 | 78 | M. Slight in one place |
| 20 | Nil | 10 | 61 | F. Clean Buttery |
| 20.3 | 7.1 | 10 | 69.1 | |

| Texture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|
| 21 | 20 | 10 | 85 | F. Fairly good<br>T. Waxy |
| 22 | 18 | 10 | 83 | F. Clean |
| 21 | 15 | 10 | 78 | F. Fair<br>M. Slight |
| 19 | Nil | 10 | 60 | T. Wet Close |
| 22 | 21 | 10 | 86.5 | F. Typical Culture 33 |
| 21.5 | 18 | 10 | 82.5 | M. Slowly developing |
| 21 | 15 | 10 | 78 | M. Slight development |
| 21.1 | 15.3 | 10 | 79.0 | |

1928, inclusive, were inoculated with P. roqueforti culture 32.
queforti culture 33.

Scores of Wensleydale Cheese.

The score of the cheese directly after the completion of the six weeks treatment by reduced pressure are given in Table 15; the following points appear:

1. The mold growth with each group of cheese was as follows:

| Group | Average Score For Mold Growth Maximum pts.25 | Number of Cheese Showing Mold Growth |
|---|---|---|
| A (Control) | Nil | Nil |
| B Bandage on | 11.3 | 4 |
| C Bandage removed | 7.1 | 3 |
| D Bandage removed and skewered | 15.3 | 6 |

These figures showed that the reduced pressure alternated with atmospheric pressure hastened the mold growth. With Groups B and C, there was some slight improvement by leaving the bandage on. With Group D, the skewered cheese, there was considerable improvement over Group C, which can be looked on as the control, the only difference being the skewering.

The score of the cheese 10 weeks after the completion of the six weeks treatment by reduced pressure, are given in Table 16; the following points appear:

Table 16.

Scores of Wensleydale Cheese Subjected to Reduced and Atm
March 16, 1929.

GROUP A CONTROL

| Date Made 1928 | Series No. | Flavor 40 | Texture 25 | Mold Growth 25 |
|---|---|---|---|---|
| Aug. 21 | 45 | 35.5 | 21 | 23 |
| Aug. 23 | 51 | 31.5 | 20 | 15 |
| Aug. 30 | 57 | 31 | 19.5 | 10 |
| Sept. 6 | 63 | 30 | 20 | Nil |
| Sept. 12 | 69 | 31 | 21 | 15 |
| Sept. 14 | 75 | 31 | 20 | 18 |
| Sept. 19 | 81 | 33 | 21 | 21 |
| | | 31.9 | 20.4 | 14.6 |

GROUP B BANDAGE ON.

| Date Made 1928 | Series No. | Flavor 40 | Texture 25 | Mold Growth 25 |
|---|---|---|---|---|
| Aug. 21 | 42 | 35 | 21 | 23 |
| Aug. 23 | 48 | 31 | 19.5 | 10 |
| Aug. 30 | 54 | 30 | 19 | 15 |
| Sept. 6 | 60 | 30 | 20 | Nil |
| Sept. 12 | 66 | 35 | 22 | 22.5 |
| Sept. 14 | 72 | 30 | 19 | Nil |
| Sept. 19 | 78 | 34 | 21 | 22 |
| | | 32.1 | 20.2 | 13.2 |

Note: The cheese made from Aug. 21 to Sept. 6, 1928, inclusive, were i
The remainder were inoculated with P. roqueforti culture 33.

Table 16.
Subjected to Reduced and Atmospheric Pressure.
March 16, 1929. Experiment II.

| Texture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|
| 21 | 23 | 10 | 89.5 | F. Very good |
| 20 | 15 | 10 | 76.5 | T.<br>M. |
| 19.5 | 10 | 10 | 70.5 | T. Hard and dry<br>M. One end. |
| 20 | Nil | 10 | 60.0 | |
| 21 | 15 | 10 | 77.0 | F. Typical culture 33 |
| 20 | 18 | 10 | 79.0 | F. Typical culture 33 |
| 21 | 21 | 10 | 85.0 | F. Typical culture 33 |
| 20.4 | 14.6 | 10 | 76.8 | |

| Texture 25 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|
| 21 | 23 | 10 | 89 | Slightly overripe |
| 19.5 | 10 | 10 | 70.5 | T. Hard and dry |
| 19 | 15 | 10 | 74.0 | M. One end only |
| 20 | Nil | 10 | 60.0 | |
| 22 | 22.5 | 10 | 89.5 | F. Typical culture 33 |
| 19 | Nil | 10 | 59.0 | T. Hard and dry |
| 21 | 22 | 10 | 87 | F. Typical culture 33 |
| 20.2 | 13.2 | 10 | 75.6 | |

. 6, 1928, inclusive, were inoculated with P. roqueforti culture 32.
roqueforti culture 33.

Table 16 (Continued)
Scores of Wensleydale Cheese Subjected to Reduced
March 16, 1929.

GROUP C BANDAGE REMOVED.

| Date Made 1928 | Series No. | Flavor 40 | Texture 25 | Mold Growth 25 | Co 1 |
|---|---|---|---|---|---|
| Aug. 21 | 43 | | | | |
| Aug. 23 | 49 | 35 | 21.5 | 21 | 1 |
| Aug. 30 | 55 | 32 | 21 | 18 | 1 |
| Sept. 6 | 61 | 30 | 20.5 | Nil | 1 |
| Sept. 12 | 67 | 33 | 21 | 15 | 1 |
| Sept. 14 | 73 | 35 | 21 | 22 | 1 |
| Sept. 19 | 79 | 31 | 20.5 | 10 | 1 |
| | | 32.7 | 20.9 | 14.3 | 1 |

GROUP D BANDAGE REMOVED CHEESE SKEWERED.

| Date Made 1928 | Series No. | Flavor 40 | Texture 25 | Mold Growth 25 | Col 1 |
|---|---|---|---|---|---|
| Aug. 21 | 44 | 34 | 21 | 21 | 1 |
| Aug. 23 | 50 | 33 | 20.5 | 18 | 1 |
| Aug. 30 | 56 | 33 | 20 | 18 | 1 |
| Sept. 6 | 62 | 30 | 20 | 10 | 1 |
| Sept. 12 | 68 | 33 | 21.5 | 20 | 1 |
| Sept. 14 | 74 | 33 | 21.5 | 22 | 1 |
| Sept. 19 | 80 | 35 | 21.5 | 23 | 1 |
| | | 33.0 | 20.9 | 18.9 | 1 |

Note: The cheese made from Aug. 21 to Sept. 6, 1928, inclusive, were
The remainder were inoculated with P. roqueforti culture 33.

Table 16 (Continued)
ese Subjected to Reduced and Atmospheric Pressure
March 16, 1929. Experiment II.

| ture 5 | Mold Growth 25 | Color 10 | Total 100 | Remarks |
|---|---|---|---|---|
| 1.5 | 21 | 10 | 87.5 | F. Typical of culture 32 |
| 1 | 18 | 10 | 81 | |
| 0.5 | Nil | 10 | 60.5 | |
| 1 | 15 | 10 | 79 | F. Typical culture 33 |
| 1 | 22 | 10 | 88 | F. Typical culture 33 |
| 0.5 | 10 | 10 | 71.5 | M. at one end. |
| 0.9 | 14.3 | 10 | 77.9 | |

| ture 5 | Mold Growth 25 | Color 10 | Total 100 | Remarks. |
|---|---|---|---|---|
| 1 | 21 | 10 | 86 | M. Irregular |
| 0.5 | 18 | 10 | 81.5 | T. Firm |
| 0 | 18 | 10 | 81 | |
| 0 | 10 | 10 | 70 | |
| 1.5 | 20 | 10 | 84.5 | F. Typical culture 33. |
| 1.5 | 22 | 10 | 85.5 | F. Typical culture 33 |
| 1.5 | 23 | 10 | 89.5 | F. Typical culture 33 |
| 0.9 | 18.9 | 10 | 82.7 | |

6, 1928, inclusive, were inoculated with P. roqueforti culture 32.
roqueforti culture 33.

1. The mold growth with each group of cheese was as follows:

| Group | | Average score for mold growth Maximum pts.25 | Number of cheese showing mold growth |
|---|---|---|---|
| A | Control | 14.6 | 6 |
| B | Bandage on | 13.2 | 5 |
| C | Bandage removed | 14.3 | 5 out of 6 |
| D | Bandage removed and skewered | 18.9 | 7 |

These figures showed that the reduced pressure, alternated with atmospheric pressure, had not finally increased the mold growth; for Groups A, B and C were very similar. With Group D, the skewered cheese, there was considerable improvement over the other three groups.

Considering Table 15 and Table 16, two significant points are brought out:

1. The alternation of reduced and atmospheric pressure hastened the mold growth but did not permanently improved it.

2. Skewering produced a permanent increase in mold growth for the cheese in Group D, as shown by the final scores.

## D. A PRELIMINARY EXPERIMENT TO DETERMINE THE POSSIBILITY OF REDUCING THE $CO_2$ PRODUCED BY LOWERING THE PERCENTAGE OF THE SUGAR INCORPORATED IN THE CURD.

### Introduction.

The constituents of the milk that mainly go to form the cheese are those that are colloidal. In addition to these, a normal Wensleydale cheese curd contains about 43 percent moisture, in which is dissolved a proportion of soluble milk constituents. Therefore, with a normal rich milk, containing 5.0 percent of milk sugar, the cheese made from it will contain about 2.0 percent of milk sugar, or fermentation products of it. Were it possible to dilute the milk with water, or acidified water, before the rennet was added, and still make a satisfactory cheese, the content of sugar in the cheese would be reduced in proportion to the dilution. If the milk sugar in the cheese is fermented to yield $CO_2$ as previously shown by Thom and Currie (37), a reduction in the milk sugar incorporated in the curd would mean a corresponding reduction of the $CO_2$ formed. For this reason, it was decided to undertake the experiments to see whether or not such cheese could be made.

### Methods.

After several preliminary trials with rennet tests on various diluted milks, the following procedure was adopted.

Acidified water for dilution. A starter can was filled with water which was pasteurized to a temperature of 170° F., held for 10 minutes, and cooled. Immediately before the water was added to the milk, lactic acid (U.S.P. VIII) was added until the water gave the same acidity as the milk, as shown by the Mann's acid test.

Milk. After pasteurization and cooling to 84° F., the milk was divided into two equal quantities. One vat of milk was diluted by added 50 percent acidified water and the other was used as control.

Method of Manufacture. The Wensleydale cheese were made as far as possible according to the usual method of manufacture, both with diluted milk and the control.

## Results Obtained.

### The Manufacture of the Wensleydale Cheese.

Between Dec. 10th and 17th, six lots of diluted milk and their controls were made into Wensleydale cheese. From Chart 5, which is the record of manufacture, the following points are seen.

1. The diluted milk gave a much quicker rennet test than the control; the usual volume of milk or diluted milk was used.

2. The acidity and time of process up to drawing the whey were practically the same for both vats.

3. The percentage of butter fat in the whey was much higher in the control vat than in that made from diluted

milk. However, if the results were expressed as the total fat lost in the whey, there would not be a marked difference.

4. The control vat developed acidity faster in the second half of the making process, and therefore was made quicker than the cheese from the diluted milk.

5. With the control, the iron test averaged just under 1 inch when the whey from the curd showed an acidity of 0.365 percent. With the diluted milk, the average iron test was just under $1\frac{3}{4}$ inches when the whey from the curd showed an acidity of 0.347 percent. From the Chart, it is seen than an endeavor was made to get the same acidity in the curds at milling for both control and diluted vats, irrespective of the abnormal iron test.

Weights of Wensleydale Cheese.

The weights of all cheese were recorded approximately two, eight and sixteen weeks after manufacture. Table 17 gives the weights on the dates recorded, and shows that:

1. The total weight of the control cheese on Jan. 3rd was 153 lbs. 14 ozs., and that from the diluted milk 154 lbs. 6 ozs., a difference of 8 ozs. On Feb. 16th, this difference was increased to 15 ozs., and on April 12th it was 1 lb. 13 ozs.

Table 17.
Weights of Cheese
From Normal and Diluted

Normal

| Date Made 1928 | Series No. | Jan. 3, 1929 Weight lbs. | ozs. | Feb. 16, 1929 Weight lbs. | ozs. | April 12, 1929. Weight lbs. | ozs. |
|---|---|---|---|---|---|---|---|
| Dec. 10 | 83 | 29 | 2 | 27 | 14 | 26 | 6 |
| Dec. 11 | 85 | 24 | 0 | 22 | 10 | 21 | 5 |
| Dec. 12 | 87 | 23 | 10 | 22 | 7 | 21 | 7 |
| Dec. 14 | 89 | 23 | 14 | 22 | 10 | 21 | 10 |
| Dec. 15 | 91 | 23 | 10 | 22 | 8 | 21 | 5 |
| Dec. 17 | 93 | 29 | 10 | 28 | 4 | 27 | 2 |
| Total | | 153 | 14 | 146 | 5 | 139 | 3 |

Table 17.
s of Cheese
l and Diluted Milks.

Diluted

| April 12, 1929. Weight lbs. | ozs. | Date Made 1928 | Series No. | Jan.3,1929 Weight lbs. | ozs. | Feb. 16,1929. Weight lbs. | ozs. | April 12, 1929. Weight lbs. | ozs. |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 6 | Dec. 10 | 82 | 30 | 2 | 28 | 15 | 27 | 12 |
| 21 | 5 | Dec. 11 | 84 | 23 | 8 | 22 | 6 | 21 | 6 |
| 21 | 7 | Dec.12 | 86 | 23 | 6 | 22 | 4 | 21 | 6 |
| 21 | 10 | Dec. 14 | 88 | 23 | 2 | 22 | 1 | 21 | 2 |
| 21 | 5 | Dec. 15 | 90 | 24 | 12 | 23 | 8 | 22 | 6 |
| 27 | 2 | Dec. 17 | 92 | 29 | 8 | 28 | 2 | 27 | 0 |
| 139 | 3 | Total | | 154 | 6 | 147 | 4 | 141 | 0 |

Quality of Wensleydale Cheese.

The cheese of both groups were examined on April 12th, 1929, when they showed very little sign of ripening, due to having been held at a low temperature. The general differences between the control group of cheese and the group made with diluted milk were:

a. The cheese in the control group were more acid in taste and firmer in texture than those made with diluted milk.

b. The cheese made with diluted milk appear to be of a type that would ripen to a more satisfactory Wensleydale cheese.

## Summary and Conclusions.

The experiments on oxygen requirements thus far showed that: Sucking air into cheese; injecting oxygen; removing $CO_2$ by reduced pressure and allowing air to take its place; and skewering cheese; all either hastened or hastened and increased mold growth. The $CO_2$ continued to be formed in cheese for at least four months after manufacture. The general trend of the $CO_2$ production indicated that the chief origin of $CO_2$ was not the growth of P. roqueforti. The score of the several lots of cheese showed there were other factors than mold growth that go to constitute a prime cheese.
The manufacture of cheese from milk greatly diluted with acidified water was shown to be possible. A greater reten-

tion of the weight of the cheese made from diluted milk was observed during the ripening.

## DISCUSSION OF RESULTS.

A study of the effect of adding small amounts of citric and acetic acids to milk on the growth of *P. roqueforti* cultures 1,16,32 and 33, showed that acetic acid tended to reduce the digestion of the casein by *P. roqueforti* while citric acid tended to increase the digestion of casein by *P. roqueforti*. The activity of the mold was expressed as the relative amount of casein digested; an enzyme action on one constituent of milk, casein. Therefore, in their interpretation the results should be considered cautiously. In the results obtained, the variations from the controls were of such magnitude that the addition of citric or acetic acids could not be said to increase or inhibit mold growth.

It is regretted that other methods, such as the weight of felt and size of colony, could not be used with milk. The method of determining the percentage of casein digested by mold in this case introduced two serious factors, local coagulation of the casein when the acids were added rendering the casein less available for mold growth, and an effect of the acid on the pH of the milk, which, in turn, affected the action of the protease liberated by the mold.

There was no indication from the results as to whether or not the fermentation of citrates to acetates in milk would increase the growth of P. roqueforti.

In a study of the effect on the growth of P. roqueforti cultures 1, 16, 32 and 33 of adding citric and acetic acids to synthetic media, it was fully realized that the synthetic media in no way approached the composition of milk; on the other hand, many of the complications which arose with milk did not occur with synthetic media.

The method of growing one colony in a plate afforded a procedure for measuring growth from day to day and the results did not depend on the activity of one particular enzyme. In the data obtained P. roqueforti cultures 16, 32, and 33,and, to a much lesser extent, culture 1, showed a greater growth in the synthetic medium containing the higher percent of acetic acid, while in the citric acid media growth was inhibited in proportion to the concentration. Had the increased growth been only a question of higher acidity, both acids should have increased growth.

The question of the availability of the salts in the media would not appear significant, because the salts were not precipitated, and the higher acid usually tended to clear up the medium. With these considerations in mind, it would appear that P. roqueforti showed a greater growth due to the presence of acetic acid and an inhibited growth due to the presence of citric acid irrespective of subsidiary factors. Therefore, these findings present a possibility that the fermentation of the citrates of milk to acetates will increase mold growth.

With cheese making, it is recognized that the colloidal constituents of milk mainly go to form the curd, while the material in true solution is mostly found in the whey. Therefore, in the particular problem it is of great significance to know whether or not the citrates in milk are in solution. If the citrates exist in the milk largely as calcium citrate, in accordance with the idea of Söldner (31), it would seem that a very considerable proportion will be undissolved. On the other hand, if the citrates exist in the milk as potassium or sodium citrate, according to Van Slyke and Bosworth (40), all the citrates will be in solution. The conflict in these two ideas makes it impossible to conclude whether or not the curd will contain a greater proportion of citrates than the whey.

The determinations for citric acid in milk and whey from Wensleydale cheese showed that all the citrates were associated with the aqueous portion of the milk and mainly appeared in the whey. In addition, a number of Wensleydale cheese made from milk to which sodium citrate or citric acid had been added confirmed these findings when the milk and whey were analysed for citric acid. Therefore, the citrates of milk are present in the cheese in such small proportions that their direct effect is likely to be insignificant.

When sodium citrate was added to milk in small quantities, it was found that coagulation of the milk by rennet was almost prevented. The failure to coagulate was due probably to a complicated change in the salt balance. The addition of citric acid to milk to the extent of 0.05 percent anhydrous citric acid did not retard the coagulation of the milk by rennet, but a much softer curd was produced. The cheese made from the milk to which citric acid had been added were heavier than the controls, particularly during the early stages of ripening, possibly accounted for by a greater percentage of moisture in the curd.

The cheese made with citric acid added to the milk tended to produce a more satisfactory mold growth than the controls; had seasonal conditions been more favorable the difference might have been more pronounced.

The ammonia in freshly made cheese was found by analysis to be extremely small, while cheese that had matured showed considerable ammonia. These findings were quite in conformity with the results reported in the literature (28); together with the work of Weisbrodt, which showed the need of ammonium salts for the satisfactory development of _P. roqueforti_ when grown on synthetic media. They suggested that the absence of ammonia in fresh cheese might well account for the failure of _P. roqueforti_ to grow in Wensleydale cheese.

The addition, of $NH_4Cl$, in quantities found satisfactory by Weisbrodt(41) for synthetic media, to the Wensleydale curd at salting did not increase the growth of _P. roqueforti_ in the cheese. In fact, the growth of _P. roqueforti_ was slightly retarded by the addition of $NH_4Cl$, which might be accounted for by the higher percentage of chlorides.

The inference to be drawn from these results is that sufficient ammonia is formed to meet the growth requirements of P. roqueforti in the cheese, or that P. roqueforti can use other sources of nitrogen for growth in cheese.

The oxygen requirements of P. roqueforti have long been recognized, as shown by the literature (37), experiments were devised with the object of supplying more oxygen to the cheese, either as oxygen or air. The drawing of air into Wensleydale cheese by suction resulted in mold growth around the plugs of the cheese, but this growth did not extend far, showing that whatever air was drawn into the cheese tended to follow the sides of the tubes and not to penetrate through the rind. The injection of oxygen into the Wensleydale cheese again resulted, with a few exceptions that were good cheese, in mold developing around the sides of the catheter tube but not penetrating far into the body of the cheese. The results tend to show that there were either conditions which rendered the cheese very impervious to oxygen or that $CO_2$ was formed so fast the oxygen supply was inadequate for the growth of P. roqueforti.

Subjecting Wensleydale cheese, at intervals, to reduced pressure showed that $CO_2$ was steadily being formed in Wensleydale cheese for a considerable period (at least four months) and that its mechanical removal and replacement by air would hasten the growth of P. roqueforti. Skewering the cheese further assisted in the removal of $CO_2$ and proved an additional advantage. Mechanical means of increasing the oxygen in cheese present a possible way of increasing the growth of P. roqueforti in Wensleydale cheese.

However, two main questions are as yet unanswered:

1. The physical condition of the cheese that will favor the diffusion of gas to and from the cheese.
2. The source of the $CO_2$.

The physical condition of the cheese is shown to be of significance by the greater mold growth in the skewered cheese. Whether or not skewering cheese is a question of more surface exposed to the air, a greater moisture content in the newly produced surfaces, or a combination of several factors remains obscure until further investigations are conducted.

If the milk sugar or its fermentation products in the cheese are the source of the $CO_2$ it must originate from the milk sugar (about 2 percent) incorporated with the curd. Therefore, a preliminary study was conducted as to the possibility of removing part of the milk sugar from the curd by diluting the milk to be made into cheese. It was found possible to make a satisfactory cheese from milk which had been diluted with 50 percent of water acidified with lactic acid. This dilution process did not reduce the yield of cheese or increase the total loss of fat in the whey. The process of manufacturing the diluted milk into Wensleydale cheese was not strikingly abnormal except for one outstanding point, namely the iron test. This test, which is supposed to correlate with the acid test at milling the curd, had entirely changed. Instead of correlating with the usual acidity, the length of the threads produced on the hot iron by the curd from the diluted milk had doubled, showing that there was an outstanding factor other than acidity which influenced the iron test. Though the acidity, as obtained by Mann's acid test, was followed, there may be some doubt as to whether or not the iron test was more correct. Further, it is highly probable that normal milks of different composition produce curds with relatively abnormal acid and iron tests.

At the present time, the ripening of the cheese, both from the diluted milk and the control, is not sufficiently advanced to draw conclusions. The loss of weight from the two lots of cheese during ripening is significant, the cheese from the diluted milk retaining the weight much better than the control. Until this work is repeated in conjunction with complete analytical data, the definite reason for the diluted cheese retaining the weight better than the control cannot be given. However, it is probable that there is a relationship between the acid formed from the milk sugar and the salts to act as buffers.

DISCUSSION OF PRACTICAL APPLICATION.

The practical applications of the findings in this work are one of the significant features to be considered. The results from the standpoint of the practice of cheese making must be considered under two headings, namely:

1. The significance to cheese making as a whole.

2. The development of blue mold in cheese.

With reference to cheese making, the citrates of milk, though they do not appear in the curd to a significant extent, would seem to have an important relation to the water holding capacity of the cheese during ripening. The literature cited reports the percentage of citric acid in the milk and shows no great difference in the percents for summer and winter, but it does not fully emphasize the relation of citrates to cheese making solids, particularly casein.

The addition of .05 percent citric acid to high testing winter milk would seem to be of less significance than keeping the percentage of citrates the same and reducing the casein by 1.00 percent as in the case of natural summer milk. It would appear that the natural citrates of milk have a real significant bearing on the seasonal variation of cheese making.

The variations in acidity and rennet action when citrates were added to milk and the difference shown in acidity and iron test, in the milk dilution experiment, show the practical cheese maker that the tests commonly relied upon to control the process are not infallible, and that more reliable tests are urgently needed.

The reasons for the development of blue mold in cheese have not been established.

The citrates of milk, though not present in the curd in significant quantities, undoubtedly play an indirect part in the production of blue mold growth in cheese. The relatively slow loss of weight of the cheese made from milk with citric acid added would appear to be the significant factor. The seasonal variation of mold growth referred to in previous work (14) would conform to these findings, for the relatively high citrate content of natural milk occurs in spring and summer. The summer and fall cheese would be assisted in holding moisture by favorable ripening room temperatures. The cheese made in summer and fall, which are usually the best, have both these factors in their favor for blue mold growth.

Though blue mold growth was favored by additions of $NH_4Cl$ to synthetic media, the opposite appeared to be the case when $NH_4Cl$ was added to curd for cheese making. A synthetic media in biological studies answers the very desirable purpose of examining one factor at a time. On the other hand, the addition of the one desirable factor to a complex ripening process of an organic substance, such as cheese, has every probability of introducing several other factors. For example, had the work reported been conducted on a much more complete and extensive basis, it might have been possible to say that the addition of $NH_4Cl$ increased mold growth, but at the same time introduced two inhibiting factors, for example, a lower moisture content, and a decreased early fermentation. The practices, which are sometimes disparagingly termed "test tube cheese making experiments" are of considerable value but their application to the practical process is extremely complicated.

The oxygen requirements of P. roqueforti can, to some extent, be met by mechanical means of introducing oxygen or air, the old practice of skewering cheese being as satisfactory as any of the other methods tried. The reason for the more satisfactory results from skewering are most likely due to the slow diffusion of oxygen through the cheese; the small holes in skewering bring a little oxygen to all parts of the cheese. The factors which limit diffusion of gases to the cheese are not answered, but there are indications that the moisture holding capacity is significant. The practices, which tend to retain the weight of the cheese during ripening, probably by increased water holding capacity, appear to produce more suitable cheese for mold growth. On the other hand, the practices which are known to reduce the water holding capacity, such as the addition of salts (e. g. $NH_4Cl$) to the curd, produce less suitable cheese for mold development. Therefore, it would appear that experiments to increase moisture holding capacity might be fertile in improving conditions for air diffusion and mold growth.

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## Bibliography.

1. Association of Official Agricultural Chemists. Official and tentative methods of analysis. Association of Official and Agricultural Chemists, Washington, D. C. 1920.

2. Ayers, S. Henry; Rupp, Philip and Mudge, Courtland S. Production of ammonia and carbon dioxide. Jour. Infect. Diseases, XXIX., pp. 235 - 260. Chicago, 1921.

3. Babcock, S. M.; Russell, H. L.; Vivian, A. and Hastings, E. G. Influence of sugar on the nature of the fermentations occurring in milk and cheese. 18, Ann. Rept. Wis. Agric. Exp. Sta. pp. 162 - 176, 1901.

4. Beau, M. Rev. Gén du Lait. II. p. 385 through Sherwood, F. F. and Hammer, B. W. Citric acid content of milk. Res. Bul. No. 90, Iowa Agric. Exp. Sta. 1926.

5. Benson, John, The manufacture of Stilton and Wensleydale cheese. Jour. Brit. Dairy Farmer's Assoc., XXV., pp. 13 - 20. London. 1911.

6. Bosworth, A. W. and Van Slyke, L. L. 1. Why sodium citrate prevents curdling of milk by rennin. Tech. Bul. No. 34, N. Y. (Geneva) State Agric. Exp. Sta. 1914.

7. Clark, W. M. A study of the gases of Emmental cheese. Bul. 151. U. S. Bur. Anim. Indus. 1912.

8. Clark, W. M. "Synthetic Milk" as a basis for research. Jour. Dairy Sci. X., pp. 195 - 201. 1927.

9. Currie, J. N. The flavor of Roquefort cheese. Jour. Agric. Res. II., pp. 1 - 14. Washington, D. C. 1914.

10. Deniges, M. G. Sur de nouvelles classes de combinaisons mercurico - organiques et sur leurs applications. Ann. Chim. et Phys. XVIII., pp. 382 - 432. Paris. 1899.

11. Doane, C. F. Varieties of Cheese: Descriptions and analysis. Bul. No. 608, U. S. Dept. Agric. 1918.

12. Evans, Alice C. Bacterial flora of Roquefort cheese. Jour. Agric. Res. XIII., pp. 225 - 233. Washington, D. C. 1918.

13. Findlay, Alexander and Williams, Thomas. "The influence of colloids and fine suspensions on the solubility of gases in water. Part III. Solubility of carbon dioxide at pressures lower than atmospheric." Proc. Chem. Soc. XXIX., p. 115. London. 1913.

14. Golding, N. S. Wensleydale cheese. Part I. Manufacture on the Coast of British Columbia. Part II. Mycological and chemical studies. Unpublished Thesis. Library, Iowa State College, Ames, Iowa. 1924.

15. Golding, N. S. The mold associated with the ripening of blue veined cheese. Mycologia XVII., pp. 19 - 32. 1925.

16. Hammer, B. W. and Bailey, D. E. The volatile acid production of starters and of organisms isolated from them. Res. Bul. No. 55, Iowa Agric. Exp. Sta. 1919.

17. Hammer, B. W. Volatile acid production of S. lacticus and the organisms associated with it in starters. Res. Bul. No. 63, Iowa Agric. Exp. Sta. 1920.

18. Hammer, B. W. and Sherwood, F. F. The volatile acids produced by starters and by organisms isolated from them. Res. Bul. No. 80, Iowa Agric. Exp. Sta. 1923.

19. Hammer, B. W. and Baker, M. P. Classification of the Streptococcus lactis group. Res. Bul. No. 99, Iowa Agric. Exp. Sta. 1926.

20. Hastings, E. G.; Evans, Alice C. and Hart, E. B. Studies on the factors concerned in the ripening of cheddar cheese. Res. Bul. No. 25, Wis. Agric. Exp. Sta. 1912.

21. Hucker, G. J. and Marquardt, J. C. The effect of certain lactic acid producing streptococci upon the flavor of cheddar cheese. Tech. Bul. No. 117, N. Y. (Geneva) Agric. Exp. Sta. 1926.

22. Lisk, Henrietta. A quantitive determination of the ammonia, amino nitrogen, lactose, total acid, and volatile acid content of cow's milk. Jour. Dairy Sci. VII., pp. 74 - 82. 1924.

23. Long, J. Gorgonzola or molded cheese. Cultivator and Country Gentleman, LX., pp. 587 - 588. N. Y. 1895.

24. Marre, E. Le Roquefort. E. Carrère Rodez. 1906.

25. Matheson, K. J. Manufacture of cow's milk Roquefort cheese. Bul. No. 970, U. S. Dept. of Agric. 1921.

26. Neill, James A comparative study of different types of Streptococci, Scientific Proc. Soc. of Bact. (author's abst.) No. 85, p. 32. 1922.

27. N. Y. (Geneva) Agric. Exp. Sta. Experiments in the manufacture of cheese. Part I. Manufacture of cheese from normal milk rich in fat. Part II. Study of cheese-ripening process. Bul. No. 54, New Series. New York (Geneva) Agric. Exp. Sta. 1893.

28. Orla-Jensen, S. Biological studies of the cheese-ripening process with special reference to the volatile fatty acids. (Landw. Jahrb. Schweiz., XVIII., (1904), pp. 319 - 405; Ann. Agr. Suisse. V., (1904), pp. 229 - 326; Abst. in Exp. Sta. Rec. Vol. XVI., pp. 705 - 706. 1904. Original paper not examined.

29. Patrick, G. E. Changes during cheese-ripening. Bul. No. 24, pp. 969 - 984. Iowa Agric. Exp. Sta. 1894.

30. Pirtle, T. R. History of the dairy industry. p. 220. Mojonnier Bros. Co., Chicago. 1926.

31. Porcher, C. and Chavallier, A. Le répartion des matières salines dans le lait. Leurs relations physiques et chemiques avec les autres principes du lait. Le Lait III., pp. 97 - 163. Paris. 1923.

32. Richmond, Henry Droop. Dairy Chemistry, p. 37. Charles Griffin and Co., Ltd., London. 1923.

33. Sherwood, F. F. and Hammer, B. W. Citric acid content of Milk. Res. Bul. No. 90, Iowa Agric. Exp. Sta. 1926.

34. Sommer, H. H. and Hart, E. B. Effect of heat on the citric acid content of milk. Isolation of citric acid from milk. Jour. Biol. Chem. XXXV., pp. 313 - 318. 1918.

35. Steuart, Dan. W. Mould of blue veined cheese. Jour. Dairy Sci., II., pp. 407 - 414. 1919.

36. Supplee, G. C. and Bellis, B. Citric acid content of milk and milk products. Jour. Biol. Chem. XLVIII., pp. 453 - 461. 1921.

37. Thom, Charles and Currie, James N. The dominance of Roquefort mold in cheese. Jour. Biol. Chem. XV., pp. 249 - 258. 1913.

38. Thom, Charles; Currie, J. N. and Matheson, K. J. Studies relating to the Roquefort and Camembert type of cheese. Bul. 79. Conn. (Storrs) Agric. Exp. Sta. 1914.

39. Van Slyke, L. L. and Hart, E. B. The relation of carbon dioxide to proteolysis in the ripening of cheddar cheese. Bul. No. 231, N. Y. (Geneva) Agric. Exp. Sta. 1903.

40. Van Slyke, Lucius L. and Bosworth, Alfred W. Condition of casein and salts in milk. Tech. Bul. No. 39, N. Y. (Geneva) Agr. Expt. Sta. 1914.

41. Weisbrodt, L. L. Studies on media for the development of enzyme by growth of the mold. Penicillium Roqueforti. Unpublished Thesis. Library, Iowa State College, Ames, Iowa. 1927.

**EXPERIMENT** AMMONIUM CHLORIDE ADDED TO CURD AT SALTING.

| Date Made | Series Number | PASTEURIZED °F. | Min. Held | MILK Weight lbs. | Fat % | Acidity % | STARTER Ozs. Per 100 lbs. | Amount Ozs. | Time Added | STAR |
|---|---|---|---|---|---|---|---|---|---|---|
| 8/12/27 | 21 | | | 500 | | .84 | 8 | 40 | 9-40 | D 1 S. |
| ,, | 22 | | | | | | | | | |
| ,, | 23 | | | | | | | | | |
| 13/12/27 | 24 | | | 500 | | .86 | 8 | 40 | 9-30 | ,, |
| ,, | 25 | | | | | | | | | |
| ,, | 26 | | | | | | | | | |
| 13/1/28 | 27 | | | 500 | | .88 | 8 | 40 | 9-35 | ,, |
| ,, | 28 | | | | | | | | | |
| ,, | 29 | | | | | | | | | |
| 24/2/28 | 30 | | | 465 | | .9 | 8 | 36 | 9-55 | ,, |
| ,, | 31 | | | | | | | | | |
| ,, | 32 | | | | | | | | | |
| 1/3/28 | 33 | | | 445 | | .78 | 8 | 36 | 10-5 | ,, |
| ,, | 34 | | | | | | | | | |
| ,, | 35 | | | | | | | | | |
| 14/3/28 | 36 | | | 390 | | .86 | 8 | 32 | 10-0 | ,, |
| ,, | 37 | | | | | | | | | |
| ,, | 38 | | | | | | | | | |
| Average | | | | | | .85 | | | | |

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

CHART 3.

| | | MILK AT TIME RENNET ADDED | | | | | | | STARTED TO STIR | | SCALD | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time dded | STARTER. | Rennet Test secs. | Acidity % | Rate of Rennet drams to lbs. | Amount of Rennet drams | Time | Temp. °F. | *CUT TIME | Time | Acidity % | Time Started | Acidity % | Time Finished | Acidity % |
| -40 | D 144 S.1. | 17 | .2 | 1-30 | 17 | 10-10 | 84 | 10-58 | 11-20 | .13 | 12-20 | .135 | 12-40 | .14 |
| -30 | ,, | 16 | .2 | 1-30 | 17 | 10-5 | 84 | 11-10 | 11-30 | .13 | 12-30 | .14 | 12-50 | .15 |
| -35 | ,, | 15 | .2 | 1-30 | 17 | 10-15 | 84 | 11-15 | 11-40 | .13 | 12-40 | .135 | 1-0 | .14 |
| -55 | ,, | | .195 | 1-30 | 15½ | 10-30 | 84 | 11-30 | 11-50 | .13 | 12-50 | .135 | 1-10 | .14[illegible] |
| 0-5 | ,, | 16 | .2 | 1-30 | 15 | 10-45 | 84 | 11-50 | 12-10 | .125 | 1-10 | .135 | 1-30 | .14 |
| 0-0 | ,, | | .2 | 1-30 | 13 | 10-40 | 84 | 11-40 | 12-0 | .125 | 1-0 | .135 | 1-20 | .14 |
| | | 16 | .20 | | | | 84 | | | | | | | |

*Cut three times, allowing 10-minute intervals.

RE

TABLE

| Acidity % | SCALD Time Finished | SCALD Acidity % | SCALD Final Temp. °F. | PITCHED Time | PITCHED Acidity % | Hours from Setting | WHEY DRAWN Time | WHEY DRAWN Start Acidity % | WHEY DRAWN Finish Acidity % | CUT IN CUBES AND TURNED Time | CUT IN CUBES AND TURNED Acidity % | TURNED AND BROKEN Time | TURNED AND BROKEN Acidity % | TURNED Time | TURNED Acidity % | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .135 | 12-40 | .14 | 90 | 1-30 | .14 | 3-20 | 1-35 | .145 | .155 | 2-5 | .175 | 2-30 | .22 | 2-50 | .24 | 3 |
| .14 | 12-50 | .15 | 90 | 1-30 | .15 | 3-35 | 1-40 | .155 | .165 | 2-10 | .2 | 2-40 | .24 | 3-10 | .27 | 3 |
| .135 | 1-0 | .145 | 90 | 1-45 | .15 | 3-35 | 1-50 | .15 | .16 | 2-20 | .185 | 2-50 | .24 | 3-20 | .28 | |
| .135 | 1-10 | .145 | 90 | 1-45 | .15 | 3-30 | 2-0 | .155 | .16 | 2-30 | .18 | 3-0 | .22 | 3-30 | .29 | 3 |
| .135 | 1-30 | .14 | 90 | 2-5 | .145 | 3-25 | 2-10 | .145 | .15 | 2-40 | .17 | 3-10 | .21 | 3-40 | .24 | 4 |
| .135 | 1-20 | .14 | 90 | 2-10 | .15 | 3-30 | 2-20 | .15 | .16 | 2-50 | .18 | 3-20 | .21 | 3-50 | .24 | 4 |
| | | | 90 | | | 3-29 | | .150 | .158 | | | | | | | |

tervals.

## TABLE

| | PITCHED | | | WHEY DRAWN | | | CUT IN CUBES AND TURNED | | TURNED AND BROKEN | | TURNED | | TURNED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Final Temp. °F. | Time | Acidity % | Hours from Setting | Time | Start Acidity % | Finish Acidity % | Time | Acidity % | Time | Acidity % | Time | Acidity % | Time | Acidity % |
| 90 | 1-30 | .14 | 3-20 | 1-35 | .145 | .155 | 2-5 | .175 | 2-30 | .22 | 2-50 | .24 | 3-5 | .26 |
| 90 | 1-30 | .15 | 3-35 | 1-40 | .155 | .165 | 2-10 | .2 | 2-40 | .24 | 3-10 | .27 | 3-40 | .3 |
| 90 | 1-45 | .15 | 3-35 | 1-50 | .15 | .16 | 2-20 | .185 | 2-50 | .24 | 3-20 | .28 | | |
| 90 | 1-45 | .15 | 3-30 | 2-0 | .155 | .16 | 2-30 | .18 | 3-0 | .22 | 3-30 | .29 | 3-40 | .32 |
| 90 | 2-5 | .145 | 3-25 | 2-10 | .145 | .15 | 2-40 | .17 | 3-10 | .21 | 3-40 | .24 | 4-0 | .3 |
| 90 | 2-10 | .15 | 3-30 | 2-20 | .15 | .16 | 2-50 | .18 | 3-20 | .21 | 3-50 | .24 | 4-20 | .28 |
| 90 | | | 3-29 | | .150 | .158 | | | | | | | | |

**EXPERIMENT** AMMONIUM CHLORIDE ADDED TO CURD AT SALTING.

Continued from Table CHART 3.

MILLED

| Series Number | Hours from Setting | Time | Iron Test | Acid-ity % | Curd lbs. | Salt Ozs. | INOCULATION P. Roqueforti Culture No. | Time |
|---|---|---|---|---|---|---|---|---|
| 21 | 5-5 | 3-15 | 3/4 | .29 | 24 | 7 | 32 | 4-5 |
| 22 | | | | | 24 | 7 | 32 | 4-5 |
| 23 | | | | | 34 | 9 3/4 | 32 | 4-5 |
| 24 | 5-40 | 3-45 | 3/4 | .31 | 24 | 7 | 32 | 4-40 |
| 25 | | | | | 24 | 7 | 32 | 4-40 |
| 26 | | | | | 24 | 7 | 32 | 4-40 |
| 27 | 5-15 | 3-30 | 3/4 | .29 | 24 | 7 | 32 | 4-5 |
| 28 | | | | | 24 | 7 | 32 | 4-5 |
| 29 | | | | | 24 | 7 | 32 | 4-5 |
| 30 | 5-15 | 3-45 | 3/4 | .32 | 24 | 7 | 33 | 4-10 |
| 31 | | | | | 24 | 7 | 33 | 4-10 |
| 32 | | | | | 24 | 7 | 33 | 4-10 |
| 33 | 5-25 | 4-10 | 3/4 | .33 | 22 | 6½ | 33 | 4-45 |
| 34 | | | | | 22 | 6½ | 33 | 4-45 |
| 35 | | | | | 22 | 6½ | 33 | 4-45 |
| 36 | 5-40 | 4-20 | 3/4 | .29 | 21 | 6 1/4 | 33 | 4-50 |
| 37 | | | | | 21 | 6 1/4 | 33 | 4-50 |
| 38 | | | | | 18 | 4½ | 33 | 4-50 |
| Average | 5-23 | | 3/4 | .305 | | | | |

# WENSLEYDALE CHEESE
## RECORD OF PROCESS OF MANUFACTURE

| OCULATION . Roqueforti Culture No. | PUT TO PRESS Time | Acidity % | Pressure lbs. | *TURNED Time | Pressure lbs. | TURNED INTO FINE CLOTHS Time | Pressure lbs. | Pressure Off | ~~Bandaged~~ NH4'CL. ADDED GRAMS | Individual Cheese Number | GREEN CHE[ESE] Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 4-5 | | 200 | 5-0 | 200 | | | | 28.35 | | |
| 32 | 4-5 | | 200 | 5-0 | 200 | | | | 35.44 | | |
| 32 | 4-5 | | 200 | 5-0 | 200 | | | | NIL. | | |
| 32 | 4-40 | .49 | 200 | 5-30 | 300 | | | | 28.35 | | |
| 32 | 4-40 | .49 | 200 | 5-30 | 300 | | | | 35.44 | | |
| 32 | 4-40 | .49 | 200 | 5-30 | 300 | | | | NIL. | | |
| 32 | 4-5 | .51 | 200 | | | | | | NIL. | | |
| 32 | 4-5 | .51 | 200 | | | | | | 28.35 | | |
| 32 | 4-5 | .51 | 200 | | | | | | 35.44 | | |
| 33 | 4-10 | .52 | 200 | 5-0 | 300 | | | | NIL. | | |
| 33 | 4-10 | .52 | 200 | 5-0 | 300 | | | | 28.35 | | |
| 33 | 4-10 | .52 | 200 | 5-0 | 300 | | | | 35.44 | | |
| 33 | 4-45 | .58 | 200 | 5-30 | | | | | NIL. | | |
| 33 | 4-45 | .58 | 200 | 5-30 | | | | | 26.00 | | |
| 33 | 4-45 | .58 | 200 | 5-30 | | | | | 32.50 | | |
| 33 | 4-50 | .48 | 100 | 5-30 | 100 | 9.A.M. | 200 | | NIL. | | |
| 33 | 4-50 | .48 | 100 | 5-30 | 100 | 9.A.M. | 200 | | 24.80 | | |
| 33 | 4-50 | .48 | 100 | 5-30 | 100 | 9.A.M. | 200 | | 26.60 | | |

.516

TABLE

| GREEN CHEESE | | RIPE CHEESE | | | SCORE OF RIPE CHEESE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Weight lbs. ozs. | Date | Weight lbs. ozs. | Shrink-age % | Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 | REMARKS |

EXPERIMENT AERATION BY SUCTION.

| | | PASTEURIZED | | MILK | | | STARTER | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date Made | Series Number | °F. | Min. Held | Weight lbs. | Fat % | Acid-ity % | Ozs. Per 100 lbs. | Amount Ozs. | Time Added | STARTE |
| 21/8/28 | 40-45 | | | 460 | 4.8 | .86 | 8 | 38 | 9-20 | D 144 S.T. |
| 23/8/28 | 46-51 | | | 500 | 4.9 | .88 | 8 | 40 | 9-15 | ,, |
| 30/8/28 | 52-57 | | | 500 | | .89 | 6 | 30 | 9-30 | ,, |
| 6/9/28 | 58-63 | | | 500 | 4.9 | .77 | 4 | 20 | 10-0 | ,, |
| 12/9/28 | 64-69 | | | 470 | 4.8 | .84 | 4 | 19 | 10-15 | ,, |
| 14/9/28 | 70-75 | | | 500 | 4.9 | .86 | 4 | 20 | 9-30 | ,, |
| 19/9/28 | 76-81 | | | 500 | 5.0 | .82 | 4 | 20 | 9-30 | ,, |
| Average | | | | | 4.88 | .846 | 5.4 | | | |

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

CHART. 4.

| Time Added | STARTER. | MILK AT TIME RENNET ADDED: Rennet Test secs. | Acidity % | Rate of Rennet drams to lbs. | Amount of Rennet drams | Time | Temp. °F. | *CUT TIME | STARTED TO STIR: Time | Acidity % | SCALD: Time Started | Acidity % | Time Finished |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9-20 | D 144 S.1. | 18 | .195 | 1-30 | 15½ | 10-10 | 84 | 10.55 | 11-15 | .125 | 12-15 | .13 | 12-35 . |
| 9-15 | ,, | 17 | .19 | 1-30 | 16½ | 9-50 | 84 | 10-35 | 10-40 | .125 | 12-0 | .13 | 12-20 . |
| 9-30 | ,, | | .2 | 1-30 | 16-40 | 10-10 | 84 | 11-0 | 11-20 | .125 | 12-20 | .135 | 12-40. |
| 10-0 | ,, | 17 | .195 | 1-30 | 16½ | 10-30 | 84 | 11-15 | 11-35 | .13 | 12-35 | .135 | 12-55. |
| 10-15 | ,, | 18 | .19 | 1-30 | 15½ | 10-45 | 84 | 11-25 | 11-45 | .12 | 12-45 | .125 | 1-05. |
| 9-30 | ,, | 19 | .2 | 1-30 | 16½ | 10-0 | 84 | 10-45 | 11-5 | .12 | 12-5 | .125 | 12-25. |
| 9-30 | ,, | 18 | .2 | 1-30 | 16-40 | 10-0 | 84 | 10-55 | 11-15 | .12 | 12-15 | .12 | 12-35. |

17.8.196 84

*Cut three times, allowing 10-minute intervals.

RE

TABLE

| Acidity % | SCALD Time Finished | Acidity % | Final Temp. °F. | PITCHED Time | Acidity % | Hours from Setting | WHEY DRAWN Time | Start Acidity % | Finish Acidity % | CUT IN CUBES AND TURNED Time | Acidity % | TURNED AND BROKEN Time | Acidity % | TURNED Time | Acidity % | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.13 | 12-35 | .135 | 90 | 1-10 | .15 | 3-10 | 1.20 | .155 | .17 | 1-50 | .22 | 2-20 | .33 | 2-40 | .38 | |
| .13 | 12-20 | .14 | 90 | 12-45 | .145 | 3-00 | 12-50 | .15 | .17 | 1-15 | .205 | 1-35 | .25 | 2-0[illegible] | .33 | 2 |
| 0.135 | 12-40 | .14 | 91 | 1-15 | .145 | 3-15 | 1-25 | .15 | .18 | 1-45 | .22 | 2-5 | .3 | 2-25 | .45 | 2 |
| 5.135 | 12-55 | .125 | 90 | 1-40 | .135 | 3-35 | 2-05 | .15 | .165 | 2-20 | .185 | 2-40 | .245 | 3-5 | .27 | 3 |
| 5.125 | 1-05 | .13 | 90 | 1-50 | .14 | 3-25 | 2-10 | .14 | .16 | 2-40 | .18 | 3-0 | .2 | 3-25 | .26 | 3 |
| .125 | 12-25 | .13 | 89 | 1-20 | .135 | 3-50 | 1-50 | .145 | .16 | 2-15 | .18 | 2-40 | .23 | 3-0 | .29 | |
| 5.12 | 12-35 | .125 | 90 | 1-25 | .135 | 3-45 | 1-45 | .145 | .16 | 2-15 | .19 | 2-45 | .24 | 3-0 | .28 | |
| | | | 90 | | | 3-30 | | .148 | .166 | | | | | | | |

ntervals.

TABLE

| | | PITCHED | | | WHEY DRAWN | | | CUT IN CUBES AND TURNED | | TURNED AND BROKEN | | TURNED | | TURNED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| l- | Final Temp. °F. | Time | Acidity % | Hours from Setting | Time | Start Acidity % | Finish Acidity % | Time | Acidity % | Time | Acidity % | Time | Acidity % | Time | Acidity % |
| 35 | 90 | 1-10 | .15 | 3-10 | 1.20 | .155 | .17 | 1-50 | .22 | 2-20 | .33 | 2-40 | .38 | | |
| 1 | 90 | 12-45 | .145 | 3-00 | 12-50 | .15 | .17 | 1-15 | .205 | 1-35 | .25 | 2-0 | .33 | 2-30 | .47 |
| 4 | 91 | 1-15 | .145 | 3-15 | 1-25 | .15 | .18 | 1-45 | .22 | 2-5 | .3 | 2-25 | .45 | 2-40 | .5 |
| 25 | 90 | 1-40 | .135 | 3-35 | 2-05 | .15 | .165 | 2-20 | .185 | 2-40 | .245 | 3-5 | .27 | 3-30 | .38 |
| 3 | 90 | 1-50 | .14 | 3-25 | 2-10 | .14 | .16 | 2-40 | .18 | 3-0 | .2 | 3-25 | .26 | 3-40 | .34 |
| 3 | 89 | 1-20 | .135 | 3-50 | 1-50 | .145 | .16 | 2-15 | .18 | 2-40 | .23 | 3-0 | .29 | | |
| 25 | 90 | 1-25 | .135 | 3-45 | 1-45 | .145 | .16 | 2-15 | .19 | 2-45 | .24 | 3-0 | .28 | | |
| | 90 | | | 3-30 | | .148 | .166 | | | | | | | | |

**EXPERIMENT** AERATION BY SUCTION.

Continued from Table CHART 4.

MILLED

| Series Number | Hours from Setting | Time | Iron Test | Acid-ity % | Curd lbs. | Salt Ozs. | INOCULATION P. Roqueforti Culture No. | T |
|---|---|---|---|---|---|---|---|---|
| 40--45 | 4-35 | 2-45 | | .44 | 67 | 16 3/4 | 32 | 3 |
| 46--51 | 4-50 | 2-40 | 3/4 | .48 | 70 | 17½ | 32 | 3 |
| 52--57 | 4-50 | 3-0 | 1 | .56 | 69 | 17 | 32 | 3 |
| 58--63 | 5-15 | 3-45 | 3/4 | .38 | 74 | 21 | 32 | 4 |
| 64--69 | 5 | 3-45 | 3/4 | .35 | 70 | 20 | 33 | 4 |
| 70--75 | 5-15 | 3-15 | 3/4 | .34 | 76 | 21 | 33 | 3 |
| 76--81 | 5-10 | 3-10 | 3/4 | .29 | 76 | 21 | 33 | 3 |
| Average | 4-59 | | | .406 | | | | |

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

| INOCULATION P. Roqueforti Culture No. | PUT TO PRESS Time | PUT TO PRESS Acid-ity % | PUT TO PRESS Pressure lbs. | TURNED Time | TURNED Pressure lbs. | TURNED INTO FINE CLOTHS Time | TURNED INTO FINE CLOTHS Pressure lbs. | Pressure Off | Bandaged | Individual Cheese Number | GREEN Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 3-10 | .62 | 100 | 4-0 | 100 | 5-0 | 200 | 8.00.P.M. | | 40--45 | |
| 32 | 3-10 | .66 | 100 | 4-30 | 300 | 5-10 | | 8.30.P.M. | | 46--51 | |
| 32 | 3-25 | .7 | 100 | 4-0 | 150 | | | 8.40.P.M. | | 52--57 | |
| 32 | 4-15 | .58 | 33 | 5-15 | 100 | | | 9.00.P.M. | | 58--63 | |
| 33 | 4-15 | .53 | 33 | 5-0 | 100 | | | 9.00.P.M. | | 64--69 | |
| 33 | 3-45 | .51 | 33 | 4-30 | 100 | | | 8.30.P.M. | | 70--75 | |
| 33 | 3-30 | .41 | 33 | 4-15 | 100 | | | 8.00.P.M. | | 76--81 | |

.573

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TABLE

| vidual eese mber | GREEN CHEESE | | RIPE CHEESE | | | SCORE OF RIPE CHEESE | | | | | REMARK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Weight lbs. ozs. | Date | Weight lbs. ozs. | Shrink-age % | Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 | |
| -45 | | | | | | | | | | | |
| -51 | | | | | | | | | | | |
| -57 | | | | | | | | | | | |
| -63 | | | | | | | | | | | |
| -69 | | | | | | | | | | | |
| -75 | | | | | | | | | | | |
| -81 | | | | | | | | | | | |

## EXPERIMENT MADE WITH AND WITHOUT ADDING WATER TO THE MILK.

| | Date Made | Series Number | PASTEURIZED °F. | Min. Held | MILK Weight lbs. | Fat % | Acidity % | STARTER Ozs. Per 100 lbs. | Amount Ozs. | Time Added | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CONTROL. | 10/12/28 | 83 | | | 200 | 5.5 | .94 | 8 | 16 | 10-30 | HANS |
| | 11/12/28 | 85 | | | 160 | 5.6 | .87 | 8 | 13 | 10-20 | ,, |
| | 12/12/28 | 87 | | | 160 | | .82 | 8 | 13 | 10-0 | ,, |
| | 14/12/28 | 89 | | | 160 | 5,2 | | 8 | 13 | 10-10 | ,, |
| | 15/12/28 | 91 | | | 160 | 5.2 | | 8 | 13 | 9-55 | ,, |
| | 17/12/28 | 93 | | | 200 | 5.2 | .94 | 8 | 16 | 10-0 | ,, |
| | AVERAGE | | | | | 5.34 | .89 | | | | |
| 50 PER CENT ACIDIFIED WATER ADDED. | 10/12/28 | 82 | | | 200 | | .94 | 8 | 16 | 10-30 | HANS |
| | 11/12/28 | 84 | | | 160 | | .87 | 8 | 13 | 10-20 | ,, |
| | 12/12/28 | 86 | | | 160 | | .82 | 8 | 13 | 10-0 | ,, |
| | 14/12/28 | 88 | | | 160 | 3.4 | | 8 | 13 | 10-10 | ,, |
| | 15/12/28 | 90 | | | 160 | 3.4 | | 8 | 13 | 9-55 | ,, |
| | 17/12/28 | 92 | | | 200 | 3.55 | .94 | 8 | 16 | 10-0 | ,, |
| | Average | | | | | 3.45 | .89 | | | | |

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

### CHART 5.

| me led | | Rennet Test secs. | Acid-ity % | Rate of Rennet drams to lbs. | Amount of Rennet drams | MILK AT TIME RENNET ADDED Time | Temp. °F. | *CUT TIME | STARTED TO STIR Time | Acid-ity % | SCALD Time Started | Acid-ity % | Time Finished | Acid-ity % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -30 | HANSEN'S | 17 | .195 | 1--30 | 6-40 | 11-8 | 85 | 11-45 | 12-15 | .125 | 1-15 | .14 | 1-45 | .14 |
| -20 | ,, | 17 | .195 | 1--30 | 5-20 | 11 | 85 | 11-30 | 12-0 | .12 | 1-0 | .135 | 1-30 | .145 |
| -0 | ,, | 17 | .195 | 1--30 | 5-20 | 10-40 | 85 | 11-10 | 11-40 | .12 | 12-40 | .135 | 1-10 | .14 |
| -10 | ,, | 17 | .20 | 1-30 | 5-20 | 10-45 | 85 | 11-17 | 11-47 | .12 | 12-47 | .13 | 1-17 | .135 |
| -55 | ,, | 17 | .195 | 1--30 | 5-20 | 10-35 | 85 | 11-5 | 11-30 | .12 | 12-30 | .14 | 1-0 | .15 |
| -0 | ,, | 17 | .20 | 1--30 | 6-40 | 10-45 | 85 | 11-15 | 11-40 | .12 | 12-40 | .14 | 1-10 | .145 |
| | | 17 | .197 | | | | 85 | | | | | | | |
| | | | | | | | | | | | | | | |
| -30 | HANSEN'S | [illegible] | .19 | 1--30 | 6-40 | 11-8 | 85 | 11-45 | 12-15 | .125 | 1-15 | .135 | 1-45 | .135 |
| -20 | ,, | 10 | .195 | 1--30 | 5-20 | 11-0 | 85 | 11-30 | 12-0 | .13 | 1-0 | .135 | 1-30 | .14 |
| -0 | ,, | 10 | .195 | 1--30 | 5-20 | 10-40 | 85 | 11-10 | 11-40 | .12 | 12-40 | .135 | 1-10 | .14 |
| -10 | ,, | 8 | .20 | 1--30 | 5-20 | 10-45 | 85 | 11-17 | 11-47 | .12 | 12-47 | .135 | 1-17 | .14 |
| -55 | ,, | 8 | .195 | 1--30 | 5-20 | 10-35 | 85 | 11-5 | 11-30 | .13 | 12-30 | .14 | 1-0 | .14 |
| -0 | ,, | 8 | .20 | 1-30 | 6-40 | 10-45 | 85 | 11-15 | 11-40 | .125 | 12-40 | .14 | 1-10 | .145 |
| | | 8.8 | .197 | | | | 85 | | | | | | | |

*Cut three times, allowing 10-minute intervals.

TABLE

| Acid-ity % | SCALD Time Finished | SCALD Acid-ity % | SCALD Final Temp. °F. | PITCHED Time | PITCHED Acid-ity % | PITCHED Hours from Setting | WHEY DRAWN Time | WHEY DRAWN Start Acid-ity % | WHEY DRAWN Finish Acid-ity % | CUT IN CUBES AND TURNED Time | CUT IN CUBES AND TURNED Acid-ity % | TURNED AND BROKEN Time | TURNED AND BROKEN Acid-ity % | TURNED Time | TURNED Acid-ity % | T… Tim… |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .4 | 1-45 | .14 | 88 | 2-10 | .145 | 3-37 | 2-45 | .15 | .185 | 3-10 | .21 | 3-45 | .325 | | | |
| 35 | 1-30 | .145 | 88 | 2-5 | .145 | 3-40 | 2-40 | .155 | .19 | 3-10 | .24 | 3-40 | .320 | | | %/ |
| 35 | 1-10 | .14 | 88 | 1-45 | .145 | 3-40 | 2-20 | .155 | .195 | 2-45 | .245 | 3-15 | .320 | IN WHEY AT F | | |
| 3 | 1-17 | .135 | 88 | 1-50 | .145 | 3-40 | 2-25 | .155 | .20 | 2-55 | .235 | 3-25 | .33 | | | |
| 14 | 1-0 | .15 | 88 | 1-35 | .145 | 3-30 | 2-5 | .16 | .21 | 2-35 | .25 | 3-5 | .32 | | | |
| 14 | 1-10 | .145 | 88 | 1-47 | .140 | 3-35 | 2-20 | .155 | .195 | 2-50 | .23 | 3-20 | .305 | | | |
| | | | | | | 3-37 | | .155 | .196 | | | | | | | |
| 135 | 1-45 | .135 | 88 | 2-10 | .135 | 3-32 | 2-40 | .14 | .165 | 3-10 | .19 | 3-45 | .245 | | | |
| 135 | 1-30 | .14 | 88 | 2-5 | .14 | 3-35 | 2-35 | .14 | .16 | 3-05 | .205 | 3-35 | .275 | | % FA | |
| 135 | 1-10 | .14 | 88 | 1-45 | .140 | 3-35 | 2-15 | .15 | .17 | 2-45 | .21 | 3-15 | .265 | WHEY AT P | | |
| 135 | 1-17 | .14 | 88 | 1-50 | .15 | 3-40 | 2-25 | .155 | .18 | 2-55 | .22 | 3-25 | .29 | | | |
| 14 | 1-0 | .14 | 88 | 1-35 | .14 | 3.30 | 2-5 | .15 | .175 | 2-35 | .22 | 3-5 | .275 | | | |
| 14 | 1-10 | .145 | 88 | 1-47 | .140 | 3-35 | 2-20 | .15 | .18 | 2-50 | .21 | 3-20 | .265 | | | |
| | | | | | | 3-35 | | .148 | .172 | | | | | | | |

als.

## TABLE

| PITCHED | | | WHEY DRAWN | | | CUT IN CUBES AND TURNED | | TURNED AND BROKEN | | TURNED | | TURNED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | Acid-ity % | Hours from Setting | Time | Start Acid-ity % | Finish Acid-ity % | Time | Acid-ity % | Time | Acid-ity % | Time | Acid-ity % | Time | Acid-ity % |
| 2-10 | .145 | 3-37 | 2-45 | .15 | .185 | 3-10 | .21 | 3-45 | .325 | | | | |
| 2-5 | .145 | 3-40 | 2-40 | .155 | .19 | 3-10 | .24 | 3-40 | .320 | | | % FAT | |
| 1-45 | .145 | 3-40 | 2-20 | .155 | .195 | 2-45 | .245 | 3-15 | .320 | IN WHEY AT PITCHING | | | |
| 1-50 | .145 | 3-40 | 2-25 | .155 | .20 | 2-55 | .235 | 3-25 | .33 | | | | .28 |
| 1-35 | .145 | 3-30 | 2-5 | .16 | .21 | 2-35 | .25 | 3-5 | .32 | | | | .24 |
| 1-47 | .140 | 3-35 | 2-20 | .155 | .195 | 2-50 | .23 | 3-20 | .305 | | | | .24 |
| | | 3-37 | | .155 | .196 | | | | | | | | .253 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-10 | .135 | 3-32 | 2-40 | .14 | .165 | 3-10 | .19 | 3-45 | .245 | | | | |
| 2-5 | .14 | 3-35 | 2-35 | .14 | .16 | 3-05 | .205 | 3-35 | .275 | | % FAT IN | | |
| 1-45 | .140 | 3-35 | 2-15 | .15 | .17 | 2-45 | .21 | 3-15 | .265 | WHEY AT PITCHING | | | |
| 1-50 | .15 | 3-40 | 2-25 | .155 | .18 | 2-55 | .22 | 3-25 | .29 | | | | .14 |
| 1-35 | .14 | 3.30 | 2-5 | .15 | .175 | 2-35 | .22 | 3-5 | .275 | | | | .14 |
| 1-47 | .140 | 3-35 | 2-20 | .15 | .18 | 2-50 | .21 | 3-20 | .265 | | | | .13 |
| | | 3-35 | | .148 | .172 | | | | | | | | .136 |

**EXPERIMENT** MADE WITH AND WITHOUT WATER ADDED TO THE MILK.

Continued from Table CHART 5.

MILLED

| | Series Number | Hours from Setting | Time | Iron Test | Acidity % | Curd lbs. | Salt Ozs. | INOCULATION P. Roqueforti Culture No. |
|---|---|---|---|---|---|---|---|---|
| CONTROL. | 83 | 4-57 | 4-5 | 7/8 | .365 | 35 | 7 3/4 | 32 |
| | 85 | 4-50 | 3-50 | 7/8 | . | 29 | 7 1/4 | 32 |
| | 87 | 4-50 | 3-30 | 1 1/4 | .360 | 28 | 7 | 32 |
| | 89 | 4-55 | 3-40 | 7/8 | .365 | 28 | 7 | 33 |
| | 91 | 4-50 | 3-25 | 1 | .385 | 28 | 7 | 33 |
| | 93 | 5-00 | 3-45 | 7/8 | .35 | 34.5 | 8½ | 33 |
| | AVERAGE | 4-54 | | | .365 | | | |
| 50 PER CENT ACIDIFIED WATER ADDED. | 82 | 5-22 | 4-30 | 2 | .34 | 35½ | 8 | 32 |
| | 84 | 5-10 | 4-10 | 1 3/4 | .335 | 27½ | 6 3/4 | 32 |
| | 86 | 5-10 | 3-50 | 1 3/4 | .335 | 27 | 6 3/4 | 32 |
| | 88 | 5-10 | 3-55 | 1 3/4 | .35 | 27 | 6 3/4 | 33 |
| | 90 | 5-10 | 3-45 | 1½ | .375 | 29 | 7 1/4 | 33 |
| | 92 | 5-20 | 4-5 | 1½ | .345 | 33 | 8 1/4 | 33 |
| Average | | 5-14 | | | .347 | | | |

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

| INOCULATION P. Roqueforti Culture No. | PUT TO PRESS | | | *TURNED | | TURNED INTO FINE CLOTHS | | | | | GREEN C |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Time | Acid-ity % | Pressure lbs. PER CHEESE. | Time | Pressure lbs. | Time | Pressure lbs. | Pressure Off | Bandaged | Individual Cheese Number | Date |
| 32 | 4-25 | | 50 | | | | | | | | 3/1/29 |
| 32 | 4-10 | | 50 | | | | | | | | ,, |
| 32 | 3-55 | | 50 | | | | | | | | ,, |
| 33 | 4-5 | | 50 | | | | | | | | ,, |
| 33 | 3-45 | | 50 | | | | | | | | ,, |
| 33 | 4-5 | | 50 | | | | | | | | ,, |
| | | | | | | | | | | | |
| 32 | 4-50 | .48 | 50 | | | | | | | | 3/1/29 |
| 32 | 4-25 | | 50 | | | | | | | | 3/1/29 |
| 32 | 4-10 | | 50 | | | | | | | | ,, |
| 33 | 4-20 | | 50 | | | | | | | | ,, |
| 33 | 4-5 | | 50 | | | | | | | | ,, |
| 33 | 4-30 | | 50 | | | | | | | | ,, |

RE

## TABLE

| ual e er | GREEN CHEESE | | RIPE CHEESE | | | SCORE OF RIPE CHEESE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Weight lbs. ozs. | Date | Weight lbs. ozs. | Shrink-age % | Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 | REMARKS |
| | 3/1/29 | 29--2 | | | | | | | | | |
| | ,, | 24--0 | | | | | | | | | |
| | ,, | 23--10 | | | | | | | | | |
| | ,, | 23--14 | | | | | | | | | |
| | ,, | 23--10 | | | | | | | | | |
| | ,, | 29--10 | | | | | | | | | |
| | | | | | | | | | | | |
| | 3/1/29 | 30--2 | | | | | | | | | |
| | 3/1/29 | 23--8 | | | | | | | | | |
| | ,, | 23--6 | | | | | | | | | |
| | ,, | 23--2 | | | | | | | | | |
| | ,, | 24--12 | | | | | | | | | |
| | ,, | 29--8 | | | | | | | | | |

EXPERIMENT CITRATES NOT ADDED.

| EXPERIMENT | Date Made | Series Number | PASTEURIZED °F. | Min. Held | MILK Weight lbs. | Fat % | Acid-ity % | STARTER Ozs. Per 100 lbs. | Amount Ozs. | Time Added |
|---|---|---|---|---|---|---|---|---|---|---|
| | 29/12/26 | 1 | 140 | 30 | 200 | 4.7 | .7 | 8 | 16 | 10 |
| | 4/ 1/27 | 3 | | | 200 | 4.7 | .85 | 8 | 16 | 10 |
| | 22/ 2/27 | 5 | | | 200 | 4.8 | .79 | 8 | 16 | 9-50 |
| | 9/ 3/27 | 8 | | | 200 | 4.7 | .87 | 8 | 16 | 9.45 |
| | 15/ 3/27 | 10 | | | 200 | 4.8 | .82 | 8 | 16 | 9-45 |
| | 22/3/27 | 12 | | | 200 | 5.0 | .96 | 8 | 16 | 9-30 |
| | 20/4/27 | 14 | | | 200 | 4.6 | .82 | 8 | 16 | 9-30 |
| | 25/4/27 | 15 | | | 200 | 4.8 | .9 | 8 | 16 | 9-40 |
| | 28/4/27 | 17 | | | 200 | 4.9 | .92 | 8 | 16 | 9-30 |
| | 10/5/27 | 19 | | | 200 | 4.9 | 1.0 | 8 | 16 | 9-10 |
| Average | | | | | | | | | | |

S

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

CHART 1.

| t | Time Added | Starter | Rennet Test secs. | Acidity % | Rate of Rennet drams to lbs. | Amount of Rennet drams | Milk at time rennet added: Time | Temp. °F. | *Cut Time | Started to stir: Time | Acidity % | Scald: Time Started | Acidity % | Time Finished |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | D 144 | 20 | .18 | 1-40 | 5 | 10-45 | 84 | 11-55 | 12-20 | .10 | 1-20 | .12 | 1.45 |
| | 10 | D.144 | 21 | .175 | 1-40 | 5 | 10-45 | 84 | 11-30 | 11-55 | .11 | 12-50 | .12 | 1-10 |
| | 9-50 | D 144 | 17 | .22 | 1-40 | 5 | 10-50 | 84 | 11-45 | 12-5 | .14 | 1-5 | .155 | 1.25 |
| | 9.45 | D 144 | 18 | .215 | 1-40 | 5 | 10-45 | 84 | 11-40 | 12-0 | .14 | 1-0 | .15 | 1-20 |
| | 9-45 | D 144 | 17 | .22 | 1-40 | 5 | 10-45 | 84 | 11-45 | 12-5 | .135 | 1-5 | .145 | 1-25 |
| | 9-30 | D 144 | 17 | .215 | 1-40 | 5 | 10-30 | 84 | 11-30 | 11-50 | .14 | 12-50 | .145 | 1-10 |
| | | | FULLWOOD AND BLAND | | | | | | | | | | | |
| | 9-30 | D 144 | 28 | .21 | 1-30 | 6½ | 10-30 | 84 | 11-35 | 11-55 | .145 | 12-55 | .15 | 1-15 |
| | | | HANSEN'S | | | | | | | | | | | |
| | 9-40 | D 144 | 17 | .2 | 1-30 | 7 | 10-35 | 84 | 11-15 | 11-35 | .13 | 12-35 | .14 | 12-55 |
| | 9-30 | D 144 | 17 | .21 | 1-30 | 7 | 10-0 | 84 | 10-55 | 11-15 | .14 | 12-15 | .15 | 12-35 |
| | 9-10 | D 144 | 16 | .22 | 1-30 | 7 | 9-35 | 84 | 10-15 | 10-35 | .135 | 11-35 | .15 | 11-55 |

*Cut three times, allowing 10-minute intervals.

SE

CTURE

TABLE

| SCALD | | | | | PITCHED | | | WHEY DRAWN | | | CUT IN CUBES AND TURNED | | TURNED AND BROKEN | | TURNED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time Started | Acid-ity % | Time Finished | Acid-ity % | Final Temp. °F. | Time | Acid-ity % | Hours from Setting | Time | Start Acid-ity % | Finish Acid-ity % | Time | Acid-ity % | Time | Acid-ity % | Time |
| 1-20 | .12 | 1.45 | .125 | 88 | 2-05 | .13 | 3-15 | 2-35 | .135 | .15 | 3.20 | .21 | 3-35 | .24 | 4-00 |
| 12-50 | .12 | 1-10 | .125 | 88 | 1-30 | .13 | 2-45 | 2-00 | .135 | .14 | 2-20 | .17 | 2-45 | .20 | 3-05 |
| 1-5 | .155 | 1.25 | .155 | 88 | 1-50 | .155 | 3-50 | 2-30 | .16 | .18 | 3.0 | .22 | 3-20 | .26 | 3-40 |
| | | | | | | | | | | | | | | | |
| 1-0 | .15 | 1-20 | .15 | 88 | 1-55 | .155 | 3.30 | 2-15 | .155 | .165 | 2-45 | .2 | 3-15 | .24 | 3-45 |
| 1-5 | .145 | 1-25 | .15 | 88 | 2-10 | .155 | 3-25 | 2-20 | .165 | .17 | 2-50 | .2 | 3.20 | .23 | 3-50 |
| 12-50 | .145 | 1-10 | .15 | 88 | 1-55 | .155 | 3-40 | 2.10 | .16 | .175 | 2-40 | .21 | 3-10 | .24 | 3.40 |
| 12-55 | .15 | 1-15 | .155 | 88 | 1-40 | .165 | 3-45 | 2-15 | .165 | .19 | 2-45 | .24 | 3-5 | .28 | 3-25 |
| | | | | | | | | | | | | | | | |
| 12-35 | .14 | 12-55 | .14 | 89 | 1-45 | .15 | 3-20 | 1-55 | .165 | .175 | 2-25 | .21 | 2.55 | .27 | 3.25 |
| 12-15 | .15 | 12-35 | .15 | 88 | 1-20 | .16 | 3.30 | 1.30 | .165 | .185 | 2.0 | .2 | 2.30 | .24 | 3.0 |
| 11-35 | .15 | 11-55 | .16 | 89 | 12-25 | .16 | 3 | 12-35 | .16 | .17 | 1.5 | .2 | 1.35 | .24 | 2.5 |

10-minute intervals.

## TABLE

| ld- y % | Final Temp. °F. | PITCHED Time | Acid-ity % | Hours from Setting | WHEY DRAWN Time | Start Acid-ity % | Finish Acid-ity % | CUT IN CUBES AND TURNED Time | Acid-ity % | TURNED AND BROKEN Time | Acid-ity % | TURNED Time | Acid-ity % | TURNED Time | Acid-ity % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 88 | 2-05 | .13 | 3-15 | 2-35 | .135 | .15 | 3.20 | .21 | 3-35 | .24 | 4-00 | .30 | | |
| 25 | 88 | 1-30 | .13 | 2-45 | 2-00 | .135 | .14 | 2-20 | .17 | 2-45 | .20 | 3-05 | .24 | 3-30 | .29 |
| 55 | 88 | 1-50 | .155 | 3-50 | 2-30 | .16 | .18 | 3.0 | .22 | 3-20 | .26 | 3-40 | .3 | | |
| | | | | | | | | | | | | | | | |
| 15 | 88 | 1-55 | .155 | 3.30 | 2-15 | .155 | .165 | 2-45 | .2 | 3-15 | .24 | 3-45 | .28 | | |
| 15 | 88 | 2-10 | .155 | 3-25 | 2-20 | .165 | .17 | 2-50 | .2 | 3.20 | .23 | 3-50 | .27 | | |
| 15 | 88 | 1-55 | .155 | 3-40 | 2.10 | .16 | .175 | 2-40 | .21 | 3-10 | .24 | 3.40 | .27 | | |
| 55 | 88 | 1-40 | .165 | 3-45 | 2-15 | .165 | .19 | 2-45 | .24 | 3-5 | .28 | 3-25 | .31 | 3-40 | .35 |
| | | | | | | | | | | | | | | | |
| 14 | 89 | 1-45 | .15 | 3-20 | 1-55 | .165 | .175 | 2-25 | .21 | 2.55 | .27 | 3.25 | | | |
| 15 | 88 | 1-20 | .16 | 3.30 | 1.30 | .165 | .185 | 2.0 | .2 | 2.30 | .24 | 3.0 | .3 | | |
| 16 | 89 | 12-25 | .16 | 3 | 12-35 | .16 | .17 | 1.5 | .2 | 1.35 | .24 | 2.5 | .27 | 2-30 | .29 |

**EXPERIMENT** CITRATES NOT ADDED.

CHART 1.

Continued from Table

MILLED

| Series Number | Hours from Setting | Time | Iron Test | Acid-ity % | Curd lbs. | Salt Ozs. | INOCULATION P. Roquefortl Culture No. |
|---|---|---|---|---|---|---|---|
| 1 | 5-30 | 4-15 | 3/4 | .36 | 34 | 8½ | 16 |
| 3 | 5-15 | 4-00 | 3/4 | .39 | 31 | 8 | 16 |
| 5 | 5-10 | 4-00 | 3/4 | .32 | 34 | 8½ | 16 |
| 8 | 5-15 | 4-00 | 3/4 | .33 | 32 | 8 | 16 |
| 10 | 5-20 | 4-5 | 3/4 | .31 | 33 | 8 | 16 |
| 12 | 5-40 | 4-10 | 3/4 | .29 | 33 | 8 1/4 | 16 |
| 14 | 5-30 | 4-0 | 3/4 | .37 | 31 | 8 | 16 |
| 15 | 5-5 | 3-40 | 3/4 | | 30 | 7½ | 16 |
| 17 | 5-0 | 3-0 | 3/4 | .31 | 31 | 7½ | 16 |
| 19 | 5-0 | 2-35 | 3/4 | .3 | 31 | 7 3/4 | 16 |

Average

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

| | | PUT TO PRESS | | | *TURNED | | TURNED INTO FINE CLOTHS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Salt Ozs. | INOCULATION P. Roqueforti Culture No. | Time | Acid-ity % | Pressure lbs. | Time | Pressure lbs. | Time | Pressure lbs. | Pressure Off | Bandaged | Individual Cheese Number |
| 8½ | 16 | 4-30 | .49 | 50 | 5-05 | 50 | | | 30/12/26 9.A.M. | 9-10.A.M. | |
| 8 | 16 | 4-25 | .60 | 50 | 5-00 | 50 | | | 6/1/27 11.A.M. | 11-15.A.M. | |
| 8½ | 16 | | .52 | | | | | | | | |
| 8 | 16 | 4-30 | .45 | 50 | 5-5 | 100 | | | | | WHEY 38 |
| 8 | 16 | 4-25 | .44 | 50 | 5-0 | 100 | | | 9.P.M. | | |
| 8 1/4 | 16 | 4-35 | .45 | 50 | 5.0 | 100 | | | 9.30 '' | | |
| 8 | 16 | 4-20 | .62 | 50 | 5-0 | 150 | | | 9.P.M. | | VERY FAS |
| 7½ | 16 | 4-5 | .64 | 100 | 5-0 | 150 | | | 9.P.M. | | VERY FAS |
| 7½ | 16 | 3-20 | .54 | 100 | 4-0 | 150 | | | 9.P.M. | | |
| 7 3/4 | 16 | 2-50 | .49 | 100 | 3-50 | 200 | 300 | | 10.P.M. | 11.5.27. | FAIRL |

FOR WEIGHTS OF CHEESE SEE SEPARATE TABLE

ALL CHEESE SCORED SEPT.,20.,1927.

HEESE

ANUFACTURE

TABLE

| | Bandaged | Individual Cheese Number | GREEN CHEESE Date | GREEN CHEESE Weight lbs. ozs. | RIPE CHEESE Date | RIPE CHEESE Weight lbs. ozs. | Shrinkage % | SCORE OF RIPE CHEESE Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26<br>, 9-10.A.M. | | | | | | | | 30 | 15 | NIL. | 10 | 55 |
| 27<br>M. 11-15.A.M. | | | | | | | | 30 | 16 | NIL. | 10 | 56 |
| | | | | | | | | 31 | 16 | NIL. | 9 | 56 |
| | | WHEY 38 | | | | | | 29 | 18 | NIL | 10 | 57 |
| M. | | | | | | | | 30 | 20 | NIL. | 10 | 60 |
| ,, | | | | | | | | 30 | 19 | NIL. | 10 | 59 |
| M. | | VERY FAST AFTER WHEY OFF. | | | | | | 28 | 16 | NIL. | 10 | 54 |
| M. | | VERY FAST AFTER FIRST TURNING. | | | | | | 29 | 19 | NIL. | 10 | 58 |
| M. | | | | | | | | 30 | 20 | NIL. | 10 | 60 |
| M. 11.5.27. | | FAIRLY GOOD PROCESS THROUGHOUT. | | | | | | 30 | 20 | NIL. | 9 | 59 |

E SEPARATE TABLE

T 20 1927

## TABLE

| ...EESE | RIPE CHEESE | | | SCORE OF RIPE CHEESE | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Weight lbs. ozs. | Date | Weight lbs. ozs. | Shrinkage % | Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 | REMARKS |
| | | | | 30 | 15 | NIL. | 10 | 55 | T. DRY AND CLOSE. |
| | | | | 30 | 16 | NIL. | 10 | 56 | T. DRY AND CLOSE. |
| | | | | 31 | 16 | NIL. | 9 | 56 | T.SLIGHTLY DRY AND CLOSE. |
| | | | | 29 | 18 | NIL | 10 | 57 | T. OPEN AND LEAKY. |
| | | | | 30 | 20 | NIL. | 10 | 60 | F. CLEAN AND FAIRLY OPEN. |
| | | | | 30 | 19 | NIL. | 10 | 59 | T. CLOSE. |
| WHEY OFF. | | | | 28 | 16 | NIL. | 10 | 54 | T. VERY DRY. |
| FIRST TURNING. | | | | 29 | 19 | NIL. | 10 | 58 | T. CLOSE. |
| | | | | 30 | 20 | NIL. | 10 | 60 | T. OPEN. |
| ROCESS THROUGHOUT. | | | | 30 | 20 | NIL. | 9 | 59 | T. A LITTLE CLOSE. |

**EXPERIMENT** CITRATES ADDED.

| EXPERIMENT | | | PASTEURIZED | | MILK | | | STARTER | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Date Made | Series Number | °F. | Min. Held | Weight lbs. | Fat % | Acid-ity % | Ozs. Per 100 lbs. | Amoun Ozs. | Time Added |
| | 30/12/26 | 2 | 140 | 30 | 200 | 4.7 | .75 | 8 | 16 | 10. |
| | 6/1/27 | 4 | | | 200 | 4.6 | .85 | 8 | 16 | 9.45 |
| | 24/2/27 | 6 | | | 200 | 4.8 | .78 | 8 | 16 | 9-30 |
| | 3/3/27 | 7 | | | 200 | 4.9 | .9 | 8 | 16 | 10-43 |
| | 10/3/27 | 9 | | | 200 | 5.0 | .91 | 8 | 1[illegible] | 9-30 |
| | 17/3/27 | 11 | | | 200 | 4.9 | .76 | 8 | 16 | 9-30 |
| | 24/3/27 | 13 | | | 200 | 4.9 | .88 | 8 | 16 | 9-20 |
| | 27/4/27 | 16 | | | 200 | 4.7 | .8 | 8 | 16 | 9-30 |
| | 29/4/27 | 18 | | | 200 | | .91 | 8 | 16 | 9-15 |
| | 13/5/27 | 20 | | | 200 | 5 | .91 | 8 | 16 | 9-0 |
| Average | | | | | | | | | | |

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

CHART 2.

| ER | | | MILK AT TIME RENNET ADDED | | | | | | | STARTED TO STIR | | | SCALD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| noun Ozs. | Time Added | STARTER | Rennet Test secs. | Acid-ity % | Rate of Rennet drams to lbs. | Amount of Rennet drams | Time | Temp. °F. | *CUT TIME | Time | Acid-ity % | Time Started | Acid-ity % | Time Finish |
| 16 | 10. | D 144 | 40 | .20 | 1.30 | 6 2/3 | 1-50 | 84 | 3-20 | 3-40 | .185 | 3-55 | .19 | 4-0 |
| 6 | 9.45 | D 144 | 35 | .18 | 1-40 | 5 | 12-15 | 84 | 1-10 | 1-35 | .11 | 2-10 | .15 | 2-2 |
| 6 | 9-30 | D 144 | | .21 | 1-40 | 5 | 10-30 | 84 | | VERY SOFT COAGULUM | | | | TOO |
| 6 | 10-43 | D 144 | | .235 | 1-40 | 5 | 11-43 | 84 | 12-40 | 1-0 | .18 | 2-0 | .19 | 2-2 |
| 6 | 9-30 | D 144 | | | 1-40 | 5 | 10-30 | 84 | 11-25 | 11-45 | .175 | 12-45 | .185 | 1-5 |
| 6 | 9-30 | D 144 | | | 1-40 | 5 | 10-30 | 84 | 11-45 | 12-5 | .18 | 1-5 | .195 | 1-2 |
| 6 | 9-20 | D 144 | | .26 | 1-40 | 5 | 10-25 | 84 | 11-25 | 11-45 | .18 | 12-45 | .19 | 1-5 |
| 6 | 9-30 | D 144 | | .27 | 1-30 | 7 | 10-25 | 84 | 11-20 | 11-35 | .18 | 12-35 | .19 | 12-5 |
| 6 | 9-15 | D 144 | | | 1-30 | 7 | 9-45 | 84 | 10-40 | 11-0 | .18 | 12-0 | .19 | 12-2 |
| 6 | 9-0 | D 144 | | | 1-30 | 7 | 9-25 | 84 | 10-10 | 10-30 | .18 | 11-30 | .19 | 11-5 |

*Cut three times, allowing 10-minute intervals.

E

TURE

TABLE

| SCALD | | | | | PITCHED | | | WHEY DRAWN | | | CUT IN CUBES AND TURNED | | TURNED AND BROKEN | | TURNED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time Started | Acid-ity % | Time Finished | Acid-ity % | Final Temp. °F. | Time | Acid-ity % | Hours from Setting | Time | Start Acid-ity % | Finish Acid-ity % | Time | Acid-ity % | Time | Acid-ity % | Time | Aci ity % |
| 3-55 | .19 | 4-05 | .20 | 88 | 4-05 | .20 | 1-30 | 4-10 | .23 | .25 | 4-25 | .33 | 4-40 | .40 | | |
| 2-10 | .15 | 2-25 | .155 | 88 | 2-35 | .155 | 2-05 | 2-50 | .160 | .18 | 3-10 | .23 | 3-25 | .26 | 3-40 | .3 |
| OAGULUM TOO SOFT TO CUT <L.C.> | | | | | | | | | | | | | | | | |
| 2-0 | .19 | 2-20 | .19 | 88 | 2-40 | .19 | 3-0 | 2-45 | .19 | .19 | 3-15 | .21 | 3-45 | .24 | 4-15 | . |
| 2-45 | .185 | 1-5 | .19 | 88 | 1-40 | .19 | 3-10 | 1-45 | .19 | .195 | 2-15 | .2 | 2-45 | .23 | 3-15 | . |
| 1-5 | .195 | 1-25 | .2 | 88 | 2-0 | .2 | 3-30 | 2-10 | .2 | .2 | 2-40 | .22 | 3-10 | .25 | 3-40 | . |
| 2-45 | .19 | 1-5 | .2 | 89 | 1-35 | .2 | 3.20 | 1-45 | .2 | .205 | 2-15 | .23 | 2-45 | .26 | 3-15 | . |
| 2-35 | .19 | 12-55 | .2 | 89 | 1-55 | .21 | 3-35 | 2-0 | .215 | .225 | 2-30 | .26 | 3-0 | .32 | 3-20 | . |
| 2-0 | .19 | 12-20 | .2 | 88 | 1-5 | .2 | 3-30 | 1-15 | .2 | .21 | 1.45 | .24 | 2-15 | .29 | 2-30 | . |
| 1-30 | .19 | 11-50 | .2 | 90 | 12-35 | .2 | 3-10 | 12-40 | .2 | .21 | 1-10 | .23 | 1-40 | .26 | 2-10 | . |

-minute intervals.

TABLE

| i- | Final Temp. °F. | PITCHED Time | PITCHED Acidity % | Hours from Setting | WHEY DRAWN Time | WHEY DRAWN Start Acidity % | WHEY DRAWN Finish Acidity % | CUT IN CUBES AND TURNED Time | CUT IN CUBES AND TURNED Acidity % | TURNED AND BROKEN Time | TURNED AND BROKEN Acidity % | TURNED Time | TURNED Acidity % | TURNED Time | TURNED Acidity % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 88 | 4-05 | .20 | 1-30 | 4-10 | .23 | .25 | 4-25 | .33 | 4-40 | .40 | | | | |
| 55 | 88 | 2-35 | .155 | 2-05 | 2-50 | .160 | .18 | 3-10 | .23 | 3-25 | .26 | 3-40 | .33 | | |
| T TO CUT <L.C.> | | | | | | | | | | | | | | | |
| 9 | 88 | 2-40 | .19 | 3-0 | 2-45 | .19 | .19 | 3-15 | .21 | 3-45 | .24 | 4-15 | .27 | | |
| 9 | 88 | 1-40 | .19 | 3-10 | 1-45 | .19 | .195 | 2-15 | .2 | 2-45 | .23 | 3-15 | .26 | 3-40 | .29 |
| | 88 | 2-0 | .2 | 3-30 | 2-10 | .2 | .2 | 2-40 | .22 | 3-10 | .25 | 3-40 | .28 | | |
| | 89 | 1-35 | .2 | 3.20 | 1-45 | .2 | .205 | 2-15 | .23 | 2-45 | .26 | 3-15 | .3 | 3-40 | .33 |
| | 89 | 1-55 | .21 | 3-35 | 2-0 | .215 | .225 | 2-30 | .26 | 3-0 | .32 | 3-20 | .36 | | |
| | 88 | 1-5 | .2 | 3-30 | 1-15 | .2 | .21 | 1.45 | .24 | 2-15 | .29 | 2-30 | .31 | | |
| | 90 | 12-35 | .2 | 3-10 | 12-40 | .2 | .21 | 1-10 | .23 | 1-40 | .26 | 2-10 | .28 | | |

## EXPERIMENT CITRATES ADDED.

Continued from Table CHART 2.

MILLED

| Series Number | Hours from Setting | Time | Iron Test | Acidity % | Curd lbs. | Salt Ozs. | INOCULATION P. Roqueforti Culture No. |
|---|---|---|---|---|---|---|---|
| 2 | 2-55 | 4-45 | 2½ | .45 | 36 | 8½ | 16 |
| 4 | 3-35 | 3-50 | 1½ | .5 | 33 | 8 1/4 | 16 |
| 6 | NIL | | | | | | |
| 7 | 4-57 | 4-40 | 3/4 | .285 | 34 | 8½ | 16 |
| 9 | 5-45 | 4-15 | 3/4 | .3 | 34 | 8½ | 16 |
| 11 | 5.30 | 4-0 | 3/4 | .3 | 32 | 8 | 16 |
| 13 | 5-30 | 3-55 | 3/4 | .34 | 33 | 8 1/4 | 16 |
| 16 | 5-0 | 3-25 | 3/4 | .37 | 30 | 7½ | 16 |
| 18 | 5-0 | 2-45 | 3/4 | .32 | 31 | 7½ | 16 |
| 20 | 4-45 | 2-10 | 3/4 | .29 | 32 | 8 | 16 |

Average

# WENSLEYDALE CHEESE

## RECORD OF PROCESS OF MANUFACTURE

| | INOCULATION P. Roqueforti Culture No. | PUT TO PRESS Time | Acid-ity % | Pressure lbs. | *TURNED Time | Pressure lbs. | TURNED INTO FINE CLOTHS Time | Pressure lbs. | Pressure Off | Bandaged | Individual Cheese Number | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ½ | 16 | 5-05 | .62 | 50 | 5-35 | 50 | | | 31/12/26 10.30.A.M. | 11.A.M. | | |
| 1/4 | 16 | 4-10 | .61 | 50 | 4-40 | 50 | | | 7/1/27 3.00.P.M. | 4.P.M. | | |
| | | | | NOT COMPLETED. | | | | | | | | |
| | 16 | 5.0 | .4 | 50 | 5.30 | 100 | | | 9.P.M. | | WHEY .36 | |
| | 16 | 4.30 | .41 | 50 | 5-0 | 100 | | | 9.P.M. | | | |
| | 16 | 4.20 | .46 | 50 | 4.45 | 100 | | | 8.P.M. | | | VERY |
| 1/4 | 16 | 4-15 | .5 | 50 | 5.0 | 100 | | | 9-P.M. | NICER CURD THAN | | |
| | 16 | 4-0 | .53 | 100 | 5-0 | 150 | | | 10.P.M. | | FAIRLY FAST | |
| | 16 | 3-10 | .46 | 100 | 4-0 | 150 | | | 8.30.P.M. | | FAIRLY FAST | |
| | 16 | 2-35 | .38 | 150 | 3-30 | 300 | | | 8.P.M. | | FAIRLY GOOD | |

FOR WEIGHTS OF CHEESE SEE SEPARATE TABLE.
ALL CHEESE SCORED SEPT.20.,1927.

ESE

FACTURE

TABLE

| ged | Individual Cheese Number | GREEN CHEESE Date | Weight lbs. ozs. | RIPE CHEESE Date | Weight lbs. ozs. | Shrinkage % | SCORE OF RIPE CHEESE Flavor 40 | Texture 25 | Mold Growth 25 | Color 10 | Total 100 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.A.M. | | | | | | | | | | | | ROTT |
| 4.P.M. | | | | | | | 28 | 16 | NIL | 9 | 53 | T.DRY |
| WHEY .36 | | | | | | | 31 | 20 | NIL | 10 | 61 | T. MOI |
| | | | | | | | 29 | 18 | NIL | 10 | 57 | T. LEA |
| VERY SOFT AND WET CURD. | | | | | | | 30 | 20 | NIL | 10 | 60 | F. CLE |
| NICER CURD THAN NO. 11.''FAIRLY FIRM CURD.'' | | | | | | | 30 | 19 | NIL | 10 | 59 | T. CLO |
| FAIRLY FAST. | | | | | | | 30 | 20 | NIL | 10 | 60 | T. OPE |
| FAIRLY FAST BUT CHECKED. | | | | | | | 30 | 20 | NIL | 10 | 60 | F. CLE |
| FAIRLY GOOD PROCESSS THROUGHOUT. | | | | | | | 30 | 20 | NIL | 9 | 59 | T. OPE |

SEPARATE TABLE.
,1927.

## TABLE

| E | | RIPE CHEESE | | SCORE OF RIPE CHEESE | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| eight ozs. | Date | Weight lbs. ozs. | Shrinkage % | Flavor 40 | Texture 25 | *Mold* Growth 25 | Color 10 | Total 100 | *REMARKS* |
| | | | | | | | | | ROTTEN. |
| | | | | 28 | 16 | NIL | 9 | 53 | T.DRY CLOSE.C.SLIGHTLY BROWN |
| | | | | 31 | 20 | NIL | 10 | 61 | T. MOIST AND OPEN. |
| | | | | 29 | 18 | NIL | 10 | 57 | T. LEAKY AND OPEN. |
| AND WET CURD. | | | | 30 | 20 | NIL | 10 | 60 | F. CLEAN AND OPEN. |
| .''FAIRLY FIRM CURD.'' | | | | 30 | 19 | NIL | 10 | 59 | T. CLOSE. |
| | | | | 30 | 20 | NIL | 10 | 60 | T. OPEN. |
| IECKED. | | | | 30 | 20 | NIL | 10 | 60 | F. CLEAN. T. OPEN. |
| ISS THROUGHOUT. | | | | 30 | 20 | NIL | 9 | 59 | T. OPEN. |