

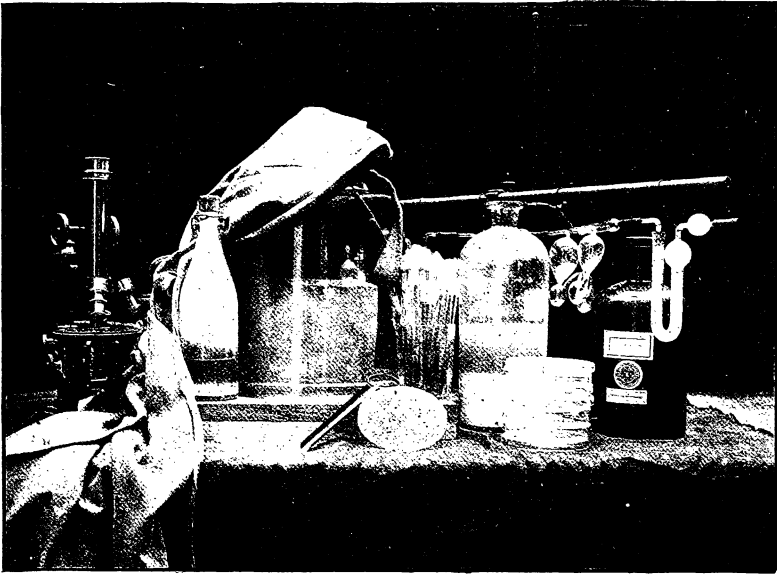
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SOME CHANGES IN A RIPENING CHEESE.

F. H. HALL, L. L. VAN SLYKE, H. A. HARDING AND E. B. HART.

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POPULAR EDITION*
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BULLETINS NOS. 214, 215, 219, 231, 233, 236 AND 237.

SOME CHANGES IN A RIPENING CHEESE.

F. H. HALL.

**Important
and complex
problems.**

The making of first quality cheese is undoubtedly the most interesting and most difficult operation in dairying. It is more interesting than butter-making, since the limits which include "good butter" are narrow; while "good cheese" may mean any one of hundreds of varied products. By slight alterations in the process of manufacture, milk, a liquid with a mild, sweet taste and characteristic, delicious aroma, may be transformed into cheeses of paste-like consistency, like camembert, or

*This is a brief summary of facts developed in recent investigations at this Station and reported in the following bulletins:

No. 214.—A Study of Some of the Salts Formed by Casein and Paracasein with Acids: Their Relations to American Cheddar Cheese, by L. L. Van Slyke and E. B. Hart.

No. 215.—Methods for the Estimation of the Proteolytic Compounds Contained in Milk and Cheese, by L. L. Van Slyke and E. B. Hart.

No. 219.—Some of the Compounds Present in American Cheddar Cheese, by L. L. Van Slyke and E. B. Hart.

No. 231.—The Relation of Carbon Dioxide to Proteolysis in the Ripening of Cheddar Cheese, by L. L. Van Slyke and E. B. Hart.

No. 233.—Rennet Enzyme as a Factor in Cheese Ripening, by L. L. Van Slyke, H. A. Harding and E. B. Hart.

No. 236.—Conditions Affecting Chemical Changes in Cheese Ripening, by L. L. Van Slyke and E. B. Hart.

No. 237.—The Role of Lactic-Acid Bacteria in the Manufacture and in the Early Stages of Ripening of Cheddar Cheese, by H. A. Harding.

Anyone specially interested in the detailed account of the investigations will be furnished, on application, with copies of the complete bulletins. The names of those who so request will be placed on the Station mailing list to receive future bulletins, popular or complete, as desired. Bulletins are issued at irregular intervals as investigations are completed, not monthly.

the hard and stone-like parmesan; may result in a product as mild flavored as sweet cream or pungent enough to bite the tongue, as fragrant as perfect cheddar or as repellent as limburger.

The process is a more difficult one than butter-making, for more of the constituents of milk are intimately involved in making cheese, each with its possibilities of chemical change or bacteria-induced transformations. The rapidity and extent of these transformations are increased by heating the milk; and the work of some of the life forms contained in the milk is continued for weeks instead of for days as in making butter. Additional changes find their source in the rennet introduced to curdle the milk; while the conditions and problems of the curing-room have no parallels in caring for butter.

The art of cheese-making has, possibly, touched its highest point in the hands of a few makers and at rare intervals; for occasionally a cheese is met with that the scorers pronounce perfect; but the time is evidently still to come when even a few cheesemakers can produce perfect cheese all of the time or most makers some of the time. To explain this we must admit that the science of cheese-making is not abreast with the art; for no maker can tell just why he frequently fails to produce the best of cheese even under most favorable conditions, and no student has yet been able to give the world a logical, correct account of the changes which take place during the history of a cheese and of the causes which produce those changes. Until such an understanding of the underlying principles has been more perfectly attained we can only hope for accidental or fortuitous advances in the art; when we have reached such an understanding it will certainly be possible to raise the general level of cheese quality by teaching all makers better methods and closer control of conditions; and it may be possible to make a better cheese even than the one we now call perfect.

But study along these lines requires a rare combination of conditions and abilities. First, there must be a location where milk of the best quality can be obtained in quantity; a place to work where entire cleanliness can be assured and where the other conditions requisite for a good cheese can be perfectly controlled.

Next, there must be available a practical cheesemaker who has at command a wide knowledge of methods coupled with skill and great care in execution; a biologist to study the minute forms of life which play so important a part in the manufacture and ripening of the cheese; a chemist to ascertain and record the changes which take place and to consider their relations, and an expert cheese scorer to weigh and measure those minute differences which separate the perfect cheese from one of lower grade—differences which nothing but human taste, smell and touch have yet been able to measure.

Many, if not all, of these requisites are available at the Station, and for a considerable time they have been united in a study of some of these problems as they arise in the manufacture of American cheddar cheese.

**Slow and
sure.**

Progress is slow—we hope, sure—for such complex relationships are found in the making and ripening of cheese that many repetitions of the work are needed, and numerous intricate modifications of methods, both of manufacture and of study, must be devised to ascertain the effect of particular factors. In this investigation chemistry must take a leading part; for though living organisms or their secretions are probably the active agents in inducing changes, the resulting products, both intermediate and final, are definite chemical compounds. It is only by analysis and study of reactions that these compounds can be identified, their relation one to another ascertained, and their influence upon the digestibility, nutritive value and palatableness of the cheese properly estimated. Consequently this study is, speaking broadly, very technical in its nature and mainly of value as yet to scientists; but some facts of such fundamental importance have been developed in our work that they cannot fail to interest cheesemakers and dairymen.

**Good
progress.**

Possibly most important of these facts is the determination, for the first time in all the years of study upon cheese, of the chemical change which follows coagulation of the milk and formation of curd. The nature of this change has been well established, the compounds produced have been obtained in pure form

and many of the conditions which influence the amount and rapidity of the change have been ascertained, thus establishing a sound foundation upon which to erect a theory of cheese ripening, since this is really the first step in the curing process.

The constituent of milk which is the cornerstone of cheese-making is a substance known as **Casein and paracasein.** This is nitrogenous in character, a material allied to white of egg (albumen) and composed of carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorous, in relations not yet certainly established by chemists. When acted upon by rennet casein changes its form and becomes the coagulated (clotted) mass spoken of in general as curd. Curd, however, contains water, fat and other milk-solids as well as the coagulated casein, so chemists have given a specific name to the casein-derived part of the curd. This name is paracasein; that is, "similar to" casein. This paracasein is insoluble in water, and therefore tasteless and somewhat difficult of digestion. It must be much changed before it becomes a pleasant or desirable article of diet judged by our present standards. This change we now know is not a simple one, is not a physical change merely, but is a succession of chemical transformations. These transformations are induced (1) in part by mere bringing together of two bodies having chemical affinity for each other; (2) in part by the peculiar action of enzymes, which produce chemical changes in other bodies without changing themselves or uniting permanently with the other substances; and (3) in part by bacteria, in living upon some of the compounds.

The first step in this succession of changes—the one revealed for the first time in this series of studies carried on at the Station—is constructive; the others, destructive. In this first change the **Paracasein salts.** paracasein unites with the lactic acid in the curd and whey to form a salt, much as soda combines with sulphuric acid to form Glauber's salts. One of two distinct salts may be formed, which of the two it shall be depending upon the amount of acid present. If the quantity of acid is large a compound called paracasein dilactate is formed; if the acid is present in small amount only, as it usually is in cheddar cheese curd, there is formed a com-

pound called paracasein monolactate. In the monolactate only half as much acid combines with paracasein as in the dilactate. These salts are not crystalline, as are those commonly formed by the union of mineral bases with acids, but they are, nevertheless, definite chemical combinations capable of existing in the free form and showing properties as constant as those of the salt the cheesemaker puts into his curd.

The monolactate in pure form shows such physical and chemical properties that we find in it the explanation of several features observed in cheese-making and cheese-ripening.

It is insoluble in water, but dissolves to some extent in weak brine, such as exists in well-salted curd. It forms when touched with a hot iron beautiful, long, silky threads similar to, but longer and finer than those produced in the well-known "hot iron" test for the ripeness of curd. It has long been evident that this "ripeness" was proportionate to the amount of acid produced; but how or why, no one knew. We now have the true explanation.

When curd is ripening it is kept at a temperature most favorable to the growth of certain bacteria. These minute plants feed upon the milk-sugar dissolved in the curd and transform it mainly into lactic acid. This acid unites with some of the paracasein to form paracasein monolactate. The acid formation is continuous and quite rapid for a time, since the bacteria multiply astonishingly under favorable conditions; and the amount of paracasein monolactate also increases rapidly because the acid quickly unites with the paracasein, free acid never being found in normal cheddar curd or cheese. With this increase of the paracasein monolactate is inseparably connected the increasing length of the threads on the hot iron. At the same time changes take place in the physical properties of the matted curd. It "breaks down" from a tough, rubber-like mass to one having a smooth, velvety appearance and feeling, a softer, somewhat plastic consistency and a peculiar, flaky grain. These changes are now readily accounted for by our knowledge of the formation and properties of this monolactate of paracasein; and are proved to be due to the presence of this salt, since they vary in proportion to the amount of this salt found in the curd by chemical analysis, and do not take place at all in its absence.

The discovery of this compound also explains a phenomenon which sometimes takes place in cheese-making and which has hitherto been a complete mystery. Occasionally when curd is salted it becomes remarkably soft and somewhat slimy, slipping through the fingers when squeezed in the hand. This faulty condition of the curd is undoubtedly due to the change of more than the usual proportion of paracasein to paracasein monolactate. It is shown most noticeably when the curd has become over-ripe through the formation of too much acid. The excess of acid unites with additional amounts of paracasein to form the monolactate, thus diminishing the amount of insoluble, rubber-like paracasein which makes the curd firm. The addition of salt at this time forms a brine in which part of the paracasein monolactate dissolves, giving a slimy feeling to exposed surfaces and at the same time induces physical changes which transform the curd into a soft, mushy mass.

In an experiment in which commercial acid was used instead of that formed in the vat by lactic-acid bacteria an abnormally large amount of the monolactate was formed and when salt was added the curd became a mushy, slippery mass. By adding more acid the soft curd was changed to an exceedingly hard, firm one; that is, the monolactate combined with an additional amount of acid and became dilactate, which does not dissolve in salt solution.

In the ordinary process of making cheddar cheese, paracasein dilactate is not formed. It may be formed, however, if cheese is made from sour milk or if the formation of acid in the curd is allowed to continue too long.

In factory work it is well known that too great a production of acid affects the cheese unfavorably, causing "leakiness," slow curing and hard, mealy texture. It is possible that the formation of paracasein dilactate accounts for some or all of these results.

Cheese ripening. Chemical analysis of many cheeses in different stages of curing shows that the curing process consists principally in the change of a complex nitrogenous compound into a succession of simpler ones. Formerly it was supposed that paracasein was this complex compound, but discovery of the paracasein salts gives a

better basis of explanation. The formation of paracasein becomes, not the first step in the curing process, but a preliminary step, followed by the building up of the paracasein salt of lactic acid, the most complex body found in cheese. With this complex nitrogen compound the curing process may be properly said to begin; and, while we cannot speak as positively on this point as on those which precede, our investigations indicate that the first breaking down results from the action of pepsin—a ferment contained in rennet—upon this paracasein salt.

**Curdling
action
of rennet.**

The first action of rennet is to coagulate the milk and form paracasein. In this work its action is greatly hastened by the formation or the addition of a moderate amount of acid. This has been shown clearly by adding increasing small amounts of acid to sweet milk and noting the time required for coagulation with rennet. Each increase in the amount of acid shortens the time, the first increase most rapidly. When the amount of acid is one-tenth of one per ct. of the milk the coagulation is as rapid as is allowable in making good cheese. Any marked increase of acid beyond this proportion would tend to produce poor quality, as we have already shown. This emphasizes the importance of placing milk in the hands of the cheesemaker before any appreciable amount of acid has been formed.

**Digestive
action
of rennet.**

When rennet was added to pasteurized milk, and cheese-making and curing carried on under conditions which excluded the action of other ripening agencies, such as the natural ferments or enzymes in the milk when drawn and the bacteria normally present or added in "starters," the ripening processes were carried on to a considerable extent if a small amount of commercial acid was added. Many of the compounds formed under these conditions were identical with those found upon analysis of normal cheese at different stages of ripeness; and the changes progressed in the same order. The process, however, is not completed under the action of rennet alone. While the curd ripens so that it would be digestible and nutritious it does not form those compounds which give "nuttness" or normal

cheese flavor—the pleasant smell and taste which we desire in the article on our tables.

When a “starter” was used to give the necessary acidity to the milk, the ripening more nearly approached the normal and some “cheese flavor” developed. The biological factors—bacteria—introduced in the “starter” supplemented the purely digestive action of the rennet and gave, in some degree, all the products found in a properly ripened cheese.

The changes in these cheeses were made under abnormal conditions and were therefore less marked than those caused by the same agencies under the ordinary conditions. The heating necessary to pasteurize milk greatly weakens its power of coagulation, which chemicals must be used to restore; and chloroform was added in some cases, also, to prevent the growth of bacteria introduced in the manipulations of making. The effect of these additions would be to retard rather than to increase the amount of change. We are safe in saying that rennet performs a very important function in cheese ripening, but cannot alone complete the ripening process and develop flavor.

Pepsin the active agent. Commercial pepsin was used in parallel series of tests to compare its effect with that of rennet. The results were very similar and the conclusion is inevitable that it is the pepsin contained in the rennet that causes the changes.

Paracasein monolactate broken down. That the paracasein monolactate is acted upon is shown by its decrease, as found by analysis, with the increase of the compounds indicating ripening of the cheese. Also in the absence of acid—a condition which was quite perfectly secured in some of the cheeses made—the paracasein could not be changed to its lactate salt; and in such cases little, if any, ripening took place, even though the cheese was kept under most favorable conditions.

Bacteria and acid. The importance of the acid both in influencing coagulation and in forming the soluble salt of paracasein has been shown. Back of the acid are the bacteria; for without their work in breaking down the milk-sugar there could be no production of acid

and no formation of paracasein monolactate. We have also seen in Bulletin No. 203 that the enzymes normally found in fresh milk—galactase and its associates—are not capable of carrying the ripening process to completion, and the experiments just discussed show that rennet or pepsin cannot give us a properly flavored cheese, though either carries the process of ripening well toward completion.

Bacteria must come in here and carry the breaking down of products through to the formation of the compounds giving flavor. What these changes and final compounds are we do not yet know, but considerable progress in their investigation has been made.

**Chemical
compounds
formed.**

The chemical compounds arising in the decomposition of paracasein monolactate have been identified in many instances and their relation one to another determined; but it is impossible to describe these in any other than chemical terms, for they are not materials found in free or pure state in nature, nor can they be compared in any way with familiar substances. However, the amount of these substances present at different times tells the rate of the cheese-ripening; and their variations measure the effect of changes in conditions under which cheese-curing is carried on.

**Conditions
affecting
cheese-
ripening.**

From a study of these compounds we now have a better knowledge of the relations of conditions to curing and can state understandingly why certain operations and agencies retard and others hasten the development of cheese. We will speak of these compounds taken together as the "soluble nitrogen compounds," and give very briefly the effect upon them of the principal changeable factors in cheese-making and cheese-curing.

The "soluble nitrogen compounds" increase as the cheese ages, but the rate of formation is more rapid in the early than in the later stages of the process. About two-thirds of the amount of soluble nitrogen compounds formed during an 18-months period of ripening had reached that condition at the end of three months, and 90 per ct. at the end of nine months.

An increase in temperature hastens the breaking-down processes and the amount of material rendered soluble is quite closely proportioned to the increase in temperature. Between 32° F. and 70° F. there was an increase of about one-half of one per ct. of the soluble compounds for an increase of one degree of temperature.

The greater the moisture content of cheese, other conditions being uniform, the greater the amounts of soluble nitrogen compounds, especially after the early stages of curing. This is true for two reasons: (1) The water itself favors activity of the ripening ferments, and (2) it dilutes the products of such fermentation, which, as they increase, tend to check fermentation itself. The water, by diluting such products, lessens their restraining power.

Cheeses of large size form soluble nitrogen compounds somewhat more rapidly than cheeses of small size, mainly because large cheeses hold more water in the later stages of ripening than small cheeses made from the same lot of milk. This greater moisture content is due to the fact that large cheeses have less evaporating surface in proportion to their weight than small cheeses.

Salt tends directly to lessen the activity of one or more of the ripening agents, and thus renders curing less rapid; and it also tends to diminish the water content of the cheese, which, as stated above, also retards the activity of the ferments.

The use of increased quantities of rennet results in more rapid production of soluble products, especially of the products arising earliest in ripening.

A certain amount of acid is absolutely essential in the initial steps of curing, but the amount necessary to secure the best result and the effect of variations in amount on the later changes have not been fully studied.

Quick ripening cheese.

“If a cheese is desired that ripens quickly it should contain more than the usual amount of rennet, a moisture content of about 40 per ct. or more and about 1 to 1½ pounds of salt for 1,000 pounds of milk. Then it should be kept at a temperature between 60° F. and 70° F., if it is to be placed in the hands of consumers in one month or six weeks, and the

atmosphere of the curing-room should have a humidity of 75 to 85 per ct. of saturation. However, it should be stated that cheese made to ripen quickly gives better commercial results when ripened at a lower temperature than 60° F. and held a longer time."

Slow ripening cheese. "For a slow-ripening cheese not more than 2½ ounces of rennet extract, such as Hansen's, should be used for 1000 pounds of milk, and about 2 to 2½ pounds of salt. The other condi-

tions that influence the moisture content of cheese, such as the temperature of heating the curd, the fineness of cutting curd, the amount of acid developed in the curd, cheddaring, etc., should be well under control, so as to produce a cheese containing, when fresh from the press, about 37 per ct. of water. For ripening it should be kept at a temperature below 50° F. in a fairly moist atmosphere for a period of three to six months or more.

"According to results given in Bulletins Nos. 184 and 234 cheese that ripens slowly is of higher commercial value than cheese ripened more quickly. The commercial life of cheese made to ripen quickly is much shorter than that of cheese made to ripen slowly; in other words, quick-ripening cheese must be consumed at an earlier age, since after once reaching its best commercial condition it deteriorates in quality more rapidly than slow-ripening cheese."

Conditions and flavor. "Increase of temperature favors a more rapid development of cheese flavor, but the continuation of such a condition causes rapid deterioration of flavor. Sharpness of flavor is usually

met with only in cheese cured above 60° F. High moisture content favors a more rapid development of cheese flavor and also more rapid development of objectionable flavors, especially when accompanied by higher temperature. Absence of salt in cheese is, in our experience, invariably accompanied by the presence of bitter flavor, the intensity increasing with increase of temperature; and, in the case of high moisture content, is accompanied also by putrefactive flavors after the early stages of ripening. Increased amounts of salt, other conditions being uniform, tend to a slower formation of cheese flavor. Excess of acid in

cheese delays the development of cheese flavor, while the sour taste caused by the excessive acidity is seriously objectionable, especially in the early stages of ripening."

Conditions and texture. "High temperatures in cheese ripening, when continued for a period covering some months, favor the production of a crumbly, dry, mealy texture and also the formation of holes. Excessive moisture with moderately high temperature results in a texture of undesirable pasty softness. Excessive use of rennet extract produces pasty texture. Large amounts of salt produce a texture that is dry, harsh and hard. Excess of acid acts much the same way. It is possible to overcome to some extent the faults of texture produced by excessive use of salt and acid by keeping the cheese for a long time in a moist atmosphere between 40° F. and 50° F."