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The Effect of Pressure in the Preservation of Milk.

A Preliminary Report.

BY B. H. HITE.

[The Bulletins and Reports of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of Agricultural Experiment Station, Morgantown, W. Va.]

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THE EFFECT OF PRESSURE IN THE PRESERVATION OF MILK.

A PRELIMINARY REPORT.

The souring of milk being due to the action of bacteria, methods for preserving milk must either destroy the germs or interfere with their work. Barring antiseptics, which are always objectionable, the methods in general use are reduced to three: sterilization, cooling and pasteurization. The first named method attempts to kill all the germs by heating the milk to about the temperature of boiling water, and keeping it at that temperature generally for about half an hour each day for three or four successive days, or by heating it to a somewhat higher temperature for one longer period. Sterilized milk should keep indefinitely, but it has a "cooked" odor and taste. The second method makes no attempt to kill the germs; it simply prevents their rapid multiplication and so interferes with their action. It has one great advantage, in that it does not affect, injuriously, the odor, taste, etc., of milk. Pasteurization, which is a sort of compromise or combination of the other two methods, and consists in heating the milk for ten to thirty minutes at a temperature of 140° to 180° Fahrenheit, and then quickly cooling it, greatly reduces the total germ content of milk, and seems to be particularly effective in destroying the disease germs so often present. This method has many advantages, but as it does not kill all the germs, the milk must be kept at a low temperature, or it will sour in a very short time.

But one of these methods attempts to completely sterilize the milk, and it has a bad effect on the odor and taste of the milk. It will be observed that these methods, in general use, are all simply matters of temperature, and it would seem that in the problem of preserving milk the effect of temperature has been pretty well worked out, and that it might be worth while to study the effect of some other agent.

From time to time since the fall of 1897, but more especially during the past winter, the chemist of this Station has been studying the effect of pressure in the preservation of milk, meats and fruit juices. Some very encouraging results have been obtained with all these materials. The following pages contain a preliminary report of the work on milk.

In the first experiments the milk was placed in a tin tube about a foot long by two inches in diameter, and similar generally to the ordinary collapsible lead (or tin) paint tubes. The tin tube and its contents were then placed in an iron cylinder about eighteen inches long by three inches in diameter, the remaining space in the cylinder being filled with water. The cylinder was connected with a gauge and the pressure applied to the water, and from this to the tin tube and its contents, by means of a heavy screw driven into the cylinder. A long lever was attached to the screw and the theoretical pressure (neglecting friction) was something tremendous. The gauge, however, never registered more than a few hundred pounds to the square inch. As often as higher pressures were attempted, a few drops of water would escape and the pressure would fall. It was hoped that even these pressures might interfere with the multiplication of the germs, and so postpone the souring of the milk. A number of samples were subjected to these pressures for two or three days, during which time they all soured. It was evident that much higher pressures would have to be used and that a much more efficient method for subjecting liquids to pressure would have to be devised.

There was no method, certainly none in general use, by which quantities of liquids, suitable for experimental purposes, could be subjected to very high pressures. The lack of such a method is the more noticable in view of the long list of apparatus to be found in every chemical and bacteriological laboratory for studying the effect of temperature, but the great majority of the transformations with which the chemist or bacteriologist has to do are effected at ordinary or atmospheric pressures, which happen to be really very low pressures. That the great majority of such transformations are far more

susceptible to slight changes in temperature than to what might perhaps be regarded as comparable changes in pressure, is doubtless true, and it may be that the relative importance of the two agents in such operations is indicated fairly enough by the usual laboratory equipment, and yet before taking it for granted that such is the case it would seem that sciences boasting so many duplicate devices for almost every operation, should afford one method at least by which the effect of pressure could be studied through a much wider range than a few hundred pounds to the square inch.

In considering the advisability of continuing the work on milk under pressure, facts, such as those just mentioned, were not encouraging, as they could only argue that the effect of pressure was not generally regarded as being worthy of much attention. This was discouraging, because a line of work promising any very great returns is not likely to be so carefully neglected. On the other hand there was no method or apparatus by which the effect of a very wide range of pressure could be studied had any one considered it worth while to do so, and it might be that this was the reason that the subject had been neglected. If so, the method itself might be worth working out. Devising the method was not then suspected of being a very difficult matter, as the introduction of the collapsible tubes was regarded as a long step towards the solution of the problem. It only remained to find some way to get a high pressure on the water surrounding the tubes. And this, indeed, was *all* that remained to be done, but as one device after another was constructed only to be found wanting in some respect and discarded, this only remaining part of the problem began to assume proportions and a good reason for the lack of such a method in general use would occasionally suggest itself.

In order to subject a liquid to pressure the capacity of the vessel containing the liquid must be decreased, which suggests at once a cylinder and piston. But no simple piston and cylinder could be expected to hold a liquid under the pressures which it was determined this method should yield, for although

the piston might be ground to fit the cylinder ever so accurately before the pressure was applied, such pressures would expand the cylinder, (not to say contract the piston,) thus leaving a space between them through which the liquid would escape. The methods used in hydraulic machinery naturally suggest themselves, but even in these machines the pressure on the water rarely exceeds eight or ten tons. It seems to be practically impossible to obtain such contact between the packing and piston or cylinder that a liquid under high pressure will not force its way out. Indeed about the only contact that is equal to such cases is that between the particles of one continuous piece of metal, from which it would appear that in order to obtain the highest pressures the end of the piston and walls of the cylinder would have to be one solid piece for all positions of the piston; or, that the liquid would have to be completely encased in one unbroken piece of metal. If these conditions could be realized the pressures obtainable ought to be limited only by the crushing strength of the materials (e. g. steel) used in the construction of the cylinder. If the liquid could be sealed up in a cylinder made of some soft metal, such as lead, this lead cylinder placed in a steel cylinder just large enough to receive it, and the pressure applied to the lead cylinder and its contents, it would seem that the above conditions would be practically realized. Simple as such an arrangement is, it required nearly three months to find a firm that would undertake it. With one accord they all proceeded to explain why the method must fail, and to suggest some other arrangement. Finally, Mr. Bert Oliphant, a student in the writer's class in agricultural chemistry, brought the matter to the attention of his father, who was connected with the National Transit Company, of Oil City, Pennsylvania, and in an almost incredibly short time, the cylinder came to hand, with the compliments of that company,—this station's first and finest gift. A verticle section of this device is shown in Fig. 1.

A screw tap, collapsible, block tin tube, T, was filled with milk, closed securely with the cap and placed in the lead tube (indicated in the section by the heavy black lines surrounding

the tube, T,) which was then filled with water, closed with a lead lid, placed in the steel cylinder, C C, the lower end of which was closed with a steel plug, O. The cylinder was then placed between two steel blocks B and R, in a testing machine and the pressure applied to the lead tube and its contents by means of the steel piston, P.

But to take up some of the parts a little more in detail.

The collapsible tube, T, (see also Fig. 2) should be made of block tin and the cap should be provided with a cone, which, as the cap is screwed down, forces its way into the mouth of the tube, thus securely closing it. Many of the tubes on the market are provided with a bit of cork in the top of the cap, but when these are subjected to pressure the cork practically disappears, leaving the tube but partially closed. At first the

Fig. I.

bottom of the tube was pinched or folded together in the usual way, except that the folds were pressed together in a vise. The imperfect joints obtained in this way were doubtless responsible for a large number of very discouraging results. It was a difficult matter to solder a bottom in the tubes as they melt at a lower temperature than the solder, and a soldering iron that is hot enough to take ordinary solder will melt a hole in the tubes before it touches them. Later in the work when it was evident that the bottoms must be closed with a solder joint, a lower melting solder, composed of lead, tin and bismuth was prepared and with this no further difficulties were encountered. All that is required of these tin tubes is that they separate the milk within them from the water surrounding them. The

pressure is the same on both sides of the walls of the tubes, so they do not need to be very strong. Indeed the thinner and softer they are the better.

Fig. 2.

The lead tube is best shown in Fig. 3, which is a full size section. At first the lids were soldered on. This was a tedious and unsatisfactory operation, as the heat from the soldering iron generally succeeded in raising the temperature of the tubes to the point most agreeable to the germs within. Later it was found that if the lids were made as shown in the cut and the contact surfaces of the lid and the tube were scraped clean the pressure would seal them as effectually as the solder, and with none of the disadvantages named.

When the pressure is removed the water in expanding to its original volume will sometimes loosen the lid, and in case a high pressure has been used the lead tube in stretching to its original capacity will sometimes be pulled in two, but as nothing but water can escape in either case these are not serious matters. So long as the pressure is being applied there is *absolutely no trace of a leak*.

The cylinder referred to was six inches long by six inches in diameter, with a hole through it one and fourth inches in diameter, and made of ordinary "low steel" or "machine steel." The plugs and pistons, O. P., were of the same material and fit the cylinder so accurately that although they would slip through it easily, they were practically air tight.

The pressure was applied and measured with a Riehle' testing machine of about twenty tons capacity.

With this equipment, during the winter of '97-8, about seventy samples were subjected to various pressures within the capacity of the machine for periods of five minutes to three

Fig. 4.

hours. Owing to the pressure of other lines of work this work was all done at night. But one determination could be made at a time, so as a rule not more than two determinations could be made in one night.

It was hoped that these pressures would kill the germs, and that by keeping the tubes closed so that no more germs could enter, the milk would remain sweet. Every sample soured. So many samples would not have been subjected to these pressures but for the fact that defects in the method, such as those already mentioned, were being corrected and better results were hoped to follow each improvement. At last when no further fault could be found with the method, it was decided that still higher pressures must be used, and the one hundred ton hydraulic press, shown in Fig. 4 was ordered, but the manufacturers were so far behind with other orders that nearly three months elapsed before the press arrived. This machine is of the "four rod punch type," weighs about 1,000 pounds and has a capacity of considerably more than one hundred tons. The pressure is applied with the upper lever, shown in the cut, and the total pressure, or any part of it, is instantly and easily relieved by means of the same lever. When not under pressure the ram is quickly raised or lowered by means of the lower lever. The end of the ram is made of hard steel, and a block of the same material is embedded in the lower platen of the press. When in operation the plug, O, of the cylinder rests on this hard block of steel.

Fig. 3.

A few applications of thirty to forty tons spread the low steel cylinder mentioned and mashed the pistons until they could not be used. The cylinder was then bored out to three inches, and a tool steel "bush" inserted, which brought the hole down to the original size. Tool steel plugs and pistons were made and with this equipment several samples of milk were subjected to pressures of two hundred thousand pounds to the square inch for a period of one or two minutes, and about fifty samples were subjected to pressures of seventy to ninety tons for five to sixty minutes. In each case, samples ('blanks') of the same milk were sealed up in the same way (in collapsible tubes) and treated in all respects like the samples just mentioned, except that they were not subjected to pressure. No ice was used in any part of this work and all operations were carried out at the temperature of the room, which during by far the greater part of the time stood at 75° to 80° F. The milk was furnished by a local dairy.

The blanks were always sour in twenty-four hours. All of the samples treated to the pressures named kept twenty-four hours longer than the blanks, some of them forty-eight to sixty hours longer. Two samples that had received ninety tons for one hour, remained sweet for more than a week. Thus encouraged an attempt was made to subject other samples to ninety tons, when with a loud report the tool steel bush split from one end to the other. From this it would appear that having "tested" a cylinder to a high pressure once is no guarantee that it will stand such a pressure again. The cylinder was bored out again and a larger (thicker walled) bush inserted, but this went to pieces at seventy tons. Then followed a long list of attempts to construct a cylinder that would stand these high pressures. Most of these cylinders were of the same dimensions as the one described, except that they were about an inch longer. They were all made of the finest tool steel—some of them of one solid piece, others "built up" of a number of concentric cylinders shrunk together. The object in the later case being to make the outer part of the cylinder carry more of the strain than it would if made of one piece. Whether this is

accomplished, at least to any very great extent, would be difficult to say. Some of the highest pressures, however, were obtained with cylinders constructed in this way. During these attempts to find a cylinder that would stand ninety tons, or more, (this being the pressure that had yielded the best results) and while cylinders were going to pieces much more rapidly than the manufacturers could make them, about two hundred determinations were made. The results of these determinations have been tabulated in a number of ways, and these tables, etc., could be used as convenient material with which to inflate this very brief report to several times its present size. It is preferred, however, to simply state such conclusions as may be safely derived from this data which are as follows:

Pressures of over thirty tons per square inch (up to one hundred tons) applied for one hour may generally be relied upon to postpone the souring of milk for twenty-four hours.

Thirty tons for an hour generally delays the souring just about twenty-four hours.

Milk that has been subjected to ninety tons for an hour will generally remain sweet for about four days. And an occasional sample will be found that certainly is not sour even at the end of two weeks, although other changes may have taken place in it.

Very similar results to those just mentioned will generally follow the use of about thirty tons for a period of ten to twelve hours, i. e. they will generally keep sweet for three to five days, and an occasional sample will not be sour at the end of two weeks. From this it would be suspected that in order to obtain similar results with intermediate pressures these should be applied for some intermediate period of time, and to some extent, at least, this appears to be true, although it should be said that it was pressures of twenty-five to thirty-five tons, and eighty-five to ninety-five tons that received the most attention. The first sample subjected to ninety tons happened to give one of the exceptionally good results mentioned above. This led to many attempts to obtain similar results. Some of these were successful; many were

not. Some of the cracked cylinders resulting from these attempts were found to be capable of standing thirty or forty tons, and these low pressures were about the only ones that could be studied while new cylinders were being made. In this way intermediate pressures came to receive somewhat less attention, although forty odd samples were subjected to pressures of forty to seventy tons for some intermediate period of time.

Some of these samples were sweet at the end of five days but the evidence of other changes having taken place was more marked and more frequently observed in these than in the other cases mentioned. Such samples were often thin and blue, or yellow and oily, or sour without a trace of clabber; or possessing some peculiar odor or taste, although normal in appearance and certainly not sour. Such cases could not receive the attention they doubtless deserve, for the reason that the object of the work was to find whether by means of pressure, milk could be prevented from souring, and as no pressure was found that could be relied upon to kill all the germs, it mattered little what germs survived or perished. In view of the fact, however, that certain disease germs, notably those of typhoid fever, so often find their way into milk, it was considered worth while to make a few tests of the effect of pressure on some of these. Pure cultures of typhoid germs were obtained, but in the first attempt to subject an inoculated sample of milk to a pressure of ninety tons, the steel cylinder, the lead tube, the tin tube and one of the pistons went to pieces, scattering the germs all over the room. Before another cylinder could be made a member of the station staff contracted a violent case of typhoid and it was decided to discontinue this feature of the work.

The work with very high pressures offered little hope of a practical method even in case such pressures should prove effective, and as between medium pressures (forty to seventy tons) for shorter periods and lower pressures for a longer period, the chances for a practical method seemed to be decidedly in favor of the latter. So the high pressures were discontinued

and the effect of still lower pressures than those already given were taken up. Pressures of fifteen to thirty tons were applied for three days to twelve hours. This part of the work

Fig. 5.

bottom of the cylinder, however, the hole is abruptly constricted, forming a shoulder, upon which rests the plug, O. The piston, P, is also provided with a shoulder by means of which the pressure, (applied by the press in the usual way) may be carried by the heavy screw, S.

In loading this cylinder the plug, O, is introduced first, then the lead tube and its contents, and the piston, P. The screw is then turned down as far as it will go, and the cylinder placed in the press. After the pressure is applied and the screw turned down securely, the cylinder may be taken out of the press and the pressure continued indefinitely. In order to open the cylinder it will have to be put back into the press, and enough

necessarily moved slowly (at least for awhile) as but one determination could be made at a time. In order to overcome this difficulty the cylinder shown (in vertical section) in Fig. 5, was devised. This cylinder is somewhat longer than the one already described. When loaded (as shown in the cut) it has a total length of nine and a half inches, from which the other dimensions may be obtained; as the section is drawn strictly to scale. The middle part of the cylinder is the same as the one described and receives the plug, O, the lower end of the piston, P, and the lead tube and its contents. A short distance above the bot-

pressure applied to the piston to relieve the screw. After the screw is removed, the entire contents of the cylinder can be pushed out with a steel rod applied to the plug, O, through the hole in the bottom of the cylinder. The cylinder and screw should be made of steel that is hard enough to keep its shape without much tempering. The plugs and pistons should be of tool steel tempered hard.

The cylinder need only be in the press during the minute or two that is required to apply and remove the pressure, so a very large number of determinations can be kept going at the same time.

About thirty samples in all were subjected to the pressures named (fifteen to thirty tons for three days to twelve hours), the results being no better than had been obtained with higher pressures. The samples on being allowed to stand for three or four days after the pressure had been removed, were often spoiled, or if sweet, possessed a peculiar odor, which some persons described as an "old" odor, others as the "disagreeable constituent of the odor of fresh warm milk." A few samples were opened as soon as the pressure was removed. These were in good condition. Three samples were then kept under pressures of ten, fifteen, and twenty tons for ten days. On relieving the pressure these were found to be in good condition. These and the thirty determinations above referred to had simply accumulated as the result of an occasional determination at odd moments during the work on meats and fruit juices, which was promising the best returns, but when the last three samples mentioned were opened every available cylinder in the laboratory, was promptly loaded with milk, and in a comparatively short time over a hundred samples were subjected to pressures of five to thirty tons for one to three weeks. None of these samples were sour when taken from the cylinders. Evidence of other changes however was not always wanting, especially in working with the lower pressures (five or six tons) or longer periods (two to three weeks,) when the milk, though sweet, was often thin and blue, or yellow and oily, or possessed the "old" odor that had been observed so often in other cases

Samples subjected to ten or fifteen tons for ten days to two weeks gave much better results. In these cases a "musty" odor would sometimes be observed when the tubes were opened, but this would generally disappear in a short time on exposing the milk to the air. That many of these samples were very nearly, if not quite normal, in appearance, was proven again and again as follows: Samples of milk that had been under pressure for two weeks were poured into beakers or test tubes and placed beside samples of morning's milk in similar vessels, while every one who came into the laboratory was asked to guess which was which. The majority of the guesses were wrong. With few exceptions the parties guessing stated that they were "simply guessing, and that there was really no difference between the samples." The fact, however, that about eighty per cent. of the guesses were wrong, might nevertheless seem to indicate that there was a difference, although certainly not of the character that would ordinarily be regarded as objectionable.

Some of these samples were examined with a microscope. Bacteria were always scarce, in some cases very hard to find. In a few cases it may as well be confessed none could be found, although they were doubtless present as was shown by the fact that samples of the same milk sealed up at the same time, and subjected to the same pressures, for the same length of time, soured in four days after the pressure was removed. Samples that were allowed to remain unopened for four or five days after removing the pressure were always found to be spoiled, and very unlike ordinary sour milk. The decomposition must have been affected by other germs than those ordinarily instrumental in the souring of milk, or the usual germs must have been present in very different proportions.

Judging from the results of five tons pressure, there was little to expect from the use of lower pressures, and it may as well be stated at once, just as little was accomplished in working with such pressures, although (rather than slight any part of the possible range of pressures) they were carefully tested. In

order that these low pressures might be measured with a fair degree of accuracy it was necessary that the guage be attached directly to the cylinders. With either of the cylinders described this was impossible on account of the lead tubes. A guage was easily attached to the cylinder shown in Fig. 6. It will be observed that this cylinder is provided with a screw by means of which the pressure may be continued indefinitely after removing from the press; also that the hole does not extend all the way through, but stops a short distance from the lower end of the cylinder, leaving a permanent solid bottom.

Fig. 6.

A solid block of lead, indicated in the section by the solid rectangular space, serves as the packing. This block rests on an off set, or shoulder, as shown, the space beneath it being occupied by the tin tube containing the milk and the water surrounding the tube. The pressure applied to the piston (by means of the press in the usual way) forces the lead down into the the cylinder (as indicated by the dotted lines) thus compressing the water and preventing its escape. These cylinders are more easily constructed and consequently much less expensive than the others described. There is but one point in the construction requiring more than ordinary care,—that is fitting the lower end of the piston into the upper end of the hole in the cylinder. The piston must fit smoothly and accurately, otherwise the lead (not the liquid) will leak out around it.

The piston should be made of the hardest tool steel, but for pressures of twenty tons or under the cylinder and screw may be made of ordinary machine steel, good, high grade cold rolled steel shafting being convenient stock from which to make these parts.

In opening the cylinder the piston and lead packing must be pulled out, as they are not accessible from the bottom. It will generally be necessary to fasten the end of the piston in a vise; in the absence of which the hydraulic press may be used as a very convenient and powerful substitute. The principle difficulty in removing the lead packing is to get hold of it. It may be easily removed as follows: Bore a one-fourth inch hole through the packing, insert the screw as far as it will go; through the hole in this screw insert an ordinary machine screw or bolt, turning the threads of the bolt into the hole in the lead. The bolt should be just long enough to reach the bottom of the packing from the top of the screw, and the head of the bolt should be large enough not to slip through the hole in the screw. By removing the screw the bolt and the packing are also removed. A somewhat less refined, but equally effective and far more rapid method, is the following: After removing the screw and piston and boring the hole in the packing, as before, simply insert the bolt and with the aid of a monkey wrench pull it out. These would not be the comparatively easy operations they are but for the fact that on relieving the pressure the liquids (water and milk) in expanding to their original volume give the packing and piston a decided start.

The higher the pressures used the farther the packing will be forced into the cylinder, and it might be supposed that in case higher pressures had been used the packing would be more difficult to remove, but this is not the case. Experience shows that it is the part of the packing remaining above the shoulder that sticks the tightest, and the more of the packing that is forced below the shoulder the easier it will all be to remove. Packings of different thickness could, of course, be used for different pressures, but this would necessitate a number of moulds for casting the packing. The simplest way is to have one mould that will cast a packing capable of developing the highest pressures to be used and then when lower pressures are to be used not to fill the cylinders quite full of water. If but two or three tons are to be used fill up to about the point indi-

cated by the dotted line, and for higher pressures, to some point nearer the shoulder. One person can open and load ten or twelve of these cylinders in an hour. These cylinders are very convenient for working with pressures of twenty-five tons or less. They have been used in this laboratory in hundreds of determinations besides those for which they were designed. Requiring no lead tubes there is practically no expense connected with them. The lead blocks may be recast indefinitely—indeed they may be used a number of times without recasting if they are inverted each time. A gauge is attached by simply drilling a hole in the side of the cylinder and inserting a piece of tubing leading directly to the gauge.

With this arrangement about forty samples were subjected to pressures of one to four tons, only to show that these low pressures can not be relied upon to keep the milk sweet, much less to prevent the other objectionable changes so often referred to.

In as much as pressures of ten to fifteen tons for as many days had given good results, and as there could be no danger whatever of splitting any of the cylinders with such pressures, it was decided to give some of the disease germs another trial, and a number of samples of milk were inoculated with pure cultures of each of the following germs: Anthrax, typhoid, tuberculosis, proteus vulgaris and bubonic plague. After being subjected to pressure of ten to fifteen tons for eight days, they were examined by the Biologist of the University and members of one of his classes. The samples were all reported normal in appearance and they were probably sweet, but in no case had all of the germs introduced been killed. These were the last samples subjected to pressure alone.

The effect of pressure had been studied throughout a range of two hundred thousand pounds to the square inch,—from a few hundred pounds up to a pressure that crushed the hardest tool steel. Some of the germs survived them all.

The best results from a practical standpoint were doubtless those obtained with pressures of ten or fifteen tons for as many

days. That milk under a pressure of ten tons could be shipped a five or ten day's journey there can be little doubt, but the cylinders capable of carrying such pressures would probably weigh more than the milk.

It should be remembered that in the above work every operation was carried out at the temperature of the room,—seventy to eighty degrees fahrenheit. There is every reason to believe that a liberal use of ice after high pressures for a short period were removed, or while lower pressures for longer periods were being applied would have made a wide difference in the results. Pasteurization is justly regarded as a very effective process, especially with disease germs, but let a sample of milk be subjected to the pasteurizing temperature for the usual length of time and then without the rapid cooling leave it at the temperature of the room in which the above samples were kept, and it will be as sour as clabber in twenty-four to thirty-six hours.

THE COMBINED EFFECT OF A LOW PRESSURE AND SLIGHT ELEVATION OF TEMPERATURE.

A pressure of forty tons and temperature of 126° F. for about an hour was found to have a very marked effect on the keeping qualities of meat. Small samples treated in this way being in very good condition when opened three months later. Water that had been placed in the tubes with the meat in order to communicate the pressure uniformly to the meat was highly colored, while the meat was of a light color, but there was no abnormal odor or other evidence of decomposition. Samples of the same meat sealed up in the same way, at the same time, and heated to the same temperature, for the same length of time, but not subjected to pressure were living masses of germs when opened a week later. Encouraged by these results about two dozen samples of milk had been subjected to the same treatment, but the results were little if any better than had been obtained with the same pressure and without the elevation of temperature. This feature of the work was discontinued until, a few months ago, when in looking over the

results given in the preceding pages the fact that the disease germs introduced survived, although the milk did not sour; that other changes giving a peculiar odor or appearance often took place while the milk remained sweet, and that samples subjected to pressure never soured in quite the usual way, seem to leave no way of escaping the conclusion that of all the germs to be found in milk those which are ordinarily instrumental in the souring must be among those most susceptible to pressure. It is generally admitted that the effect of pasteurization is just the reverse of this (or practically so), for while this process greatly reduces the total germ content, it is especially effective in destroying the disease germs. That it is not so effective in destroying the germs that ordinarily contribute to the souring of milk, is shown by the fact that pasteurized milk sours readily and in about the usual way. Pressure seemed to be most effective just where pasteurization was least effective, and *visa versa*. So, notwithstanding the unfavorable results that had been obtained with somewhat lower temperatures this work was taken up again and is still going on. Pressures of five to twenty tons, and temperatures of 140° to 170° F. have been applied for five minutes to three or four hours.

The last cylinder described has been used almost exclusively in this work. Half a dozen or more of these are placed in a large water bath kept at the desired temperature. The bottom of the bath is separated from the bed plate of the press by a heavy sheet of asbestos. This, of course, would not support the bottom of the bath under such pressures, so the circular piece of asbestos that would otherwise receive the pressure (from the bottom of the cylinder) is replaced by a plate of steel of the same thickness. With this arrangement the cylinders may be heated to the proper temperature, loaded, subjected to the pressure and set aside indefinitely without removing them from the bath. Some such arrangement is desirable in order that the temperature may remain constant. It is also desirable in order that the pressure may not change, for a slight change in temperature (after the cylinders are "set aside" so that the pressure can not be controlled by the machine) causes a very

marked change in pressure. The gauges attached to these cylinders are more sensitive to changes in temperature than an ordinary thermometer. A change of about 60° C. caused the needle of a one ton gauge to make a complete circuit of the dial. With the arrangement above described, it was a comparatively easy matter to maintain fairly constant temperatures and pressures.

“Blank” determinations (samples that had received exactly the same treatment in every respect, except that they were not subjected to pressure) were made as often as different temperatures or periods of treatment were used. These blanks when taken from the bath, and the regular samples when taken from the cylinders were simply numbered and placed in a drawer where they remained at the temperature of the room until opened. In a short time about seventy samples were treated to the temperatures and pressures named for the lengths of time named, the results from the first being an improvement on any that had been obtained from the use of pressure alone. Just what combination of temperature, pressure and time will give the best results can not yet be stated. Good results have been obtained from a variety of combinations, and there seems to be good reasons for believing that a practical method may be devised by which milk may be shipped (without ice) for a much longer distance than it would be profitable to ship it. It should not be a difficult matter to subject large quantities of milk to the treatment now applied to the small samples. The small collapsible tin tubes could be replaced by ordinary tin cans, of sizes to suit the trade and these could be placed in a cylinder large enough to hold a number of cans, and the pressure applied by means of a pump. The cans, of course, would not be opened from the time they were filled until they reached the consumer. So much for prospects and possibilities.

So little difficulty had been experienced in keeping the samples sweet, a number of samples were subjected to a special test as follows: A sample of morning's milk (from a dairy) was allowed to stand in the laboratory all day in a loosely covered tin can. At ten o'clock in the evening (May 15th) a number

of tubes were filled with this milk in the usual way and subjected to pressures of seven to twelve tons, and temperatures of 152°—160° F. for one to three hours. The samples were kept at the temperature of the room for ten days, when a number of them were opened and found to be sweet. Six of the remaining samples were then packed in a tin box and shipped to New York City and back by mail. Two of the samples were then opened. They were sweet. Three days later two more samples were opened, with the same result. The other two samples were kept until the morning of June 4th, when this report went to the printer. They were still sweet. The first two samples opened were tasted and carefully examined by an experienced dairyman and pronounced "all right." As for the second (two) samples opened one possessed a decidedly "cooked" odor, the other a somewhat similar odor, but far less marked. One of the last samples opened had a faint musty odor at first, but this practically disappeared in the course of half an hour. The other sample was certainly very nearly normal in every respect.

That the pressure to which these samples were subjected was largely responsible for the above results is shown by the fact that the blanks were all sour in 36 hours after they were taken from the bath.

The results obtained by the use of pressure alone (in the earlier experiments) would seem to indicate that in the usual method of heating milk to temperatures above the boiling point of water the slight pressure developed at these temperatures would, of itself, fall far short of sterilizing the milk. It would also appear that by using much higher pressures (ten tons) sterilization may be effected at much lower temperatures.

The necessary equipment for working with much larger quantities of milk is being provided. Larger quantities of meats and fruit juices will also receive attention. These fields, however, are all large enough to accommodate all who may be disposed to work in them, and this Station does not ask for the exclusive use of any part of them.

The method for subjecting liquids to pressure devised in the

course of the above work may be used in studying the effect of the pressure on chemical reactions. It is only necessary to replace the collapsible tin tube with a similar platinum tube, and to decrease the size of the hole in the cylinder, and chemical reactions may be carried out under pressures approaching half a million pounds to the square inch, as will be shown in the July number of the American Chemical Journal.

NOTICE.

Application for bulletins of this Station should be addressed to the Director of the West Virginia Agriculture Experiment Station Morgantown, W. Va.

(The bulletins named below are available for distribution.)

- No. 4. The Creamery Industry ; Its Adaptability to West Virginia.
- No. 5. The Selection of Milch Cows.
- No. 6. Six Months' Experience in Running a Creamery ; Improved Process of Handling Cream and Churning.
- No. 12. The Canada Thistle.
- No. 14. Farm and Garden Insects and Experiments with Remedies; Notes of the Season.
- No. 15. Raspberry Gouty-Gall Beetle.
- No. 16. Yellow Locust, Insect Ravages upon.
- No. 17. Black Spruce, Insect Ravages.
- No. 19. Your Weeds and Yours Neighbor's, Part 1. Weeds as Fertilizers.
- No. 20. Potato Culture and Fertilization. Tests of Some Varieties of Tomatoes.
- No. 21. Injurious Insects and Plant Diseases.
- No. 25. Plat Experiments with Commercial Fertilizers, on Wheat.
- No. 27. Notes on Pruning.
- No. 28. Plat Experiments with Commercial Fertilizers on Corn.
- No. 29. Experiments with Potatoes at the Station. Experiments on Corn at the Out-Stations.
- No. 30. Address and Notes on Sheep.
- No. 33. Sub-Irrigation in the Green House.
- No. 38. Potato Blight, Potato Scab.
- No. 40. Commercial Fertilizers.
- No. 42. Vegetables.
- No. 43. When, Why, What and How to Spray.
- No. 44. Practicle Entomology.
- Special Bulletin No. 2. Proceeding connected with the celebration upon the completion of the Station Building and the organization of the Sheepbreeders and Wool-Growers' Association and the State Horticultural Society.
- Third Annual Report, 1890.
- No. 51. Commercial Fertilizers, Jan. '98.
- No. 52. Strawberries.
- No. 53. Commercial Fertilizers, Dec. '98.
- No. 54. Nursery Hints.
- No. 55. Sugar Beet Investigation in '98.