Composition

Nutritive Value and Cost of Milk

...BY...

JOHN A. LATZER

THESIS

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Before entering upon the subject proper let us see what milk really is. It is a whitish opaque liquid, appearing to the ordinary observer and especially at first thought to be a perfect solution. It is usually regarded as such and is generally bought and sold by liquid measure. When milk is examined by the aid of high magnifying powers such as are afforded only by our modern microscope we find that there are small particles in suspension, or particles which are not in solution. These small particles are always globular and vary greatly in size and number, in samples of milk from the same cow. This is especially true at different periods of lactation. However, this variation is still greater in milk from different cows.

The whiteness or opaqueness of milk is largely due to these fat globules which are held in suspension. But this is not the only thing that gives color to the milk, for when all
or nearly all the fat is removed there is still an opaqueness left, which is probably due to one of the mineral salts, phosphate of lime, which exists only in small quantities.

In considering a subject like this we dwell upon one that interests all, for the milk produce in 1889 was estimated to be worth not less than $37\text{,}000\text{,}000, estimating in the average that each person in the U. S. consumed annually 25.5 gallons of milk. The exact extent of the dairy industry is not known but according to Farmers Bulletin No. 42 it is safe to say that it exceeds any other branch of industry. Now that we have seen what milk is, let us learn a few facts about it.

The curdling of milk is generally due to the action of acids upon the casein. The casein is that part of the milk which is employed in cheese making. The curd produced in cheese making is due not to the acid but to the action of rennet, an unorganized ferment found in the stomach of the calf. The curd produced by acid is generally dissolved by the addition of alkalies, but that produce by rennet is unaffected. By dissolving the curd it is sometimes made possible to get a partial analysis of milk which could otherwise not be tested. The natural curdling or souring of milk is due to the lactic acid which is found in the milk as a result of the decomposition of the milk sugar, through the action of \textit{S. B.} bacteria.

Every body that has used milk to any extent has seen a scum on the milk after boiling. This is due to the heat
coagulating the protein of the milk, the greater part of which is albumen although casein may enter into it to some extent.

It will be seen from the following data that the variation in the chemical composition is great. Milk probably varies in composition and nutritive value more than any other food product. Not only does milk vary greatly in its chemical composition but it is a well known fact that milk is an excellent medium for the growth and development of bacteria. Although the bacteria do not affect the chemical composition, or at most only to a slight extent, or probably change the nutritive value of milk, they do endanger the health of the consumer. For this reason the milk supply of our cities should be carefully and thoroughly examined and tested.

All the females of the mammalian group support their young for a shorter or longer time upon their own milk. The composition of these milks varies greatly as can be seen from the analysis of König, who analysed milk from about a dozen different species of this group. But these milks will not be considered in this paper for they are seldom if ever sold on the markets for food. Although a few are used on rare occasions they are never extensively used.

Chemical analysis is the only accurate way to determine the composition, and in part the nutritive value, and cost of milk. A number of methods have been proposed for determining the content of fat in milk. Fat, however, is not the
only constituent of milk that is of value for food and therefore such methods are inefficient for the purpose of this study.

Such methods as the creamometer and lactometer and Babcock test have been and are still used. The last mentioned is very rapid and fairly accurate for the determination of the amount of fat in milk.

The following method of analysis was used in the work here reported.

DETERMINATION OF THE SPECIFIC GRAVITY.

The most common way of getting the specific gravity is by the use of the hydrometer. The lactometer is more convenient in that the specific gravity can be taken within ten degrees of the required temperature. There is a thermometer in connection so that the correction for higher or lower temperature is made immediately by subtracting .0001 for each degree below 60 and adding .0001 for each degree above.

The method for the determination of water or total solids will be considered next. The simplest and most direct method is to dry a small quantity in a flat bottomed dish, preferably in an aluminum dish. Heat until apparently dry on a water bath, then heat exactly one hour at the temperature of boiling water, cool in a desiccator and weigh quickly. The drying may be done better by adding the milk to a dish containing some absorbent, such as sand or asbestos. There have been many other methods devised but this is probably the simplest and best for ordinary analysis.
DETERMINATION OF FAT.

The Babcock method for the determination of fat which is quite accurate and also rapid was used. The method is as follows. First a bottle is provided containing approximately 40 c.c. This bottle is one with a long thin neck graduated so as to read per cent of fat direct. The neck must be of uniform diameter so as to make it possible to make use of a graduated scale. The amount in the neck represents .04 c. c. and in order to make reading easy the neck should be of such diameter as to make the divisions 1.5 m. m. apart. When the amount of milk in the bottle is a little less than 17.5 c. c. or just about 18 grams it takes 5 of these divisions to make one per cent of fat.

The bottles from the shops are seldom accurate and need calibrating before using. This is done by measuring a volume of mercury which will exactly occupy the space between the upper and lower marks of the graduate scale or 26.35 grams of mercury for the entire scale of 10%.

The pipette or milk measure should be marked at 17.6 c. c. for it will not quite deliver 17.5 c. c. of milk, the amount required as pointed out above.

The acid measure should be marked at 17.5 c. c.

The centrifuge is a machine which is able to make from 800 to 900 revolutions per minute, and having sockets or cups to receive the bottles. It should also be provided with a cover so that if a bottle breaks in the machine the acid will
not be thrown over the operator, and it also aids in keeping
the inside warm when steam or hot water is admitted.

TESTING:— In order to make a good test, the milk must be thor­
roughly sampled. To get a proper sample it is well to pour the
milk from which the sample is to be taken from one vessel to
another, a few times thus insuring thorough mixture. Now meas­
ure out the milk with the 17.6 c.c. pipette. The sample may be
left in the test bottle or be tested immediately. If left stand­
ing until curdled the curd should be broken before adding the
acid.

The acid to be used is common commercial sulphuric
acid and a volume equal to the volume of the milk should be
used. If too little is added not all the casein will be dissolv­
and if too much is added the fat is likely to be attacked.

When the acid has been added the milk and acid should
be thoroughly mixed with a gentle rotary motion. The bottles
are then ready to be placed in the centrifugal. The speed
should be brought up to about 500 or 800 revolutions per min­
depending upon the diameter of the wheel
ute, and kept up for 4 or 5 minutes. Water is then added until
the contents of the flask is raised to the neck, whirl for one
minute and add water to raise the fat well into the neck, then
whirl another minute. The fat is now ready to measure and read
on the graduate scale. The temperature at this stage should be
150 degrees and preferably a little higher.

A more tedious and somewhat more accurate method is
by means of extraction with ether. Strips about 2 or 2.5 inches wide and about 20 or 24 inches long are cut from a good quality of filter paper. These strips are thoroughly extracted with ether or a few are extracted and the amount of fat subtracted from the others. Five c.c. of milk measured in a pipette are run onto one of these strips of paper. The paper is dried over a heated iron plate. After it is apparently dry it is rolled up in a coil and dried at the temperature of boiling water for one hour. The coil is then extracted with ether for about six hours.

This is done by connecting a 125 c.c. flask with a Soxhlet extractor, and the paper coil placed in this extractor. After the extraction is complete, that is all the fat washed into the flask, the ether is distilled off and the flask and contents heated in an oven at the temperature of boiling water.

DETERMINATION OF ASH.

Into a weighed dish preferably platinum place 25 c.c. of milk, evaporate to dryness, then ignite slowly at first and when perfectly free from carbon cool in a desiccator and weigh.

The albuminoids and casein are generally determined as proteids. The object in the determination is to find the amount of nitrogen and calculate from this. Take 5 c.c. of milk and place in a long necked Kjeldahl digestion flask; 20 c.c. of c. p. concentrated sulphuric acid and 65 grams of mercury are added. The simplest and most convenient way of measuring the mercury is by Hopkins method, that of using a J shaped capillary
tube. After thoroughly mixing the contents of the flask, the flask is placed on a digestor applying heat slowly at first to prevent frothing and lumping. After about 15 minutes the heat may be increased and then digested until the liquid in the flask is perfectly clear. Now cool and add about 200 c.c. of ammonia free distilled water and about 25 c.c. of K₂S of the following strength: 40 grams of K₂S to the liter of water.

When this is thoroughly mixed enough Greenbank alkali solution, made by taking 600 grams per liter, is slowly added. This should be connected with a condenser before mixing to prevent neutralization and escape of ammonia gas. When all the connections are well made the contents of the flask are well shaken, then heat is applied gently. Care must be taken at first for the mixture easily froths especially when it first starts to boil. If any of the liquid of the flask which is strongly alkaline should pass over into the condenser it would collect in the flask and thus neutralize the acid spoiling the experiment. The lumping of the flask may be prevented by adding a few small pieces of pumice stone or some granulated zinc. After the first frothing ceases the heat may be increased, thus making the distillation faster. When about 150 c.c. of the liquid has distilled over, all the ammonia or nitrogen will have passed over and be neutralized by the acid. There should be enough acid taken at the beginning so that there will be an excess of acid after all the ammonia is neutralized. The solution in the flask re-
ceiving the distillate should be titrated back with a standard solution of alkali. A good indicator for neutralizing the solution is methyl orange. The difference between the amount taken and the amount of alkaline solution used in titrating back, is the amount neutralized by the ammonia distillate, and if the solutions were both of the same strength it represents the amount of ammonia, and if not it can easily be figured by making the necessary corrections. From the amount of ammonia the amount of nitrogen can easily be calculated and multiplying this by 6.25 gives the amount of proteids.

DETERMINATION OF SUGAR.

Sugar is often determined by difference but it can quite easily be determined by the use of the polariscope or by the use of Fehlings solution either volumetrically or gravimetrically. In the use of the polariscope the milk should first be boiled to insure perfect polarization, then cool and clarify the milk.

The method most commonly used for charring the milk is with mercuric iodide solution, made by dissolving 27 grams of potassium iodide in hot water; add 16 c.c. glacial acetic acid; when all is in solution add 11 grams of mercuric chloride which had previously been dissolved in hot water, add slowly and stir constantly. The solution is the made up to 500 c.c. To about 30 c.c. of milk which was placed in a 100 c.c. measuring flask, 10 or 15 c.c. of this solution is added; mix well and add about
an equal quantity of alumina cream, which is made by dissolving potassium alum in water and add ammonia until precipitation ceases or until the mixture is slightly ammoniacal. Then wash the cream well and it is ready for use. It should be well stirred before using each time. When the cream has been added the mixture is made up to 100 c.c. and then filtered through a dry filter. The filtrate is ready for reading with the polariscope. The reading is per cent, if the amount of milk taken weighed 32.975 grams, if not the correction must be made.

The gravimetric method by the use of Fehling's solution is as follows: The milk for this determination is prepared by clearing with copper sulphate. 25 c.c. of milk are diluted with 400 c.c. of water; then add 10 c.c. of copper sulphate solution of the same strength as for Allihn's method used for volumetric purposes which is thus:

1st. solution, 34.6 grams pure copper sulphate made up to 500 c.c.
2nd. solution, 173 grams potassium sodium tartrate
125 grams potassium hydroxide made up to 500 c.c.

10 c.c. of the 1st. solution should be added to the above mentioned dilution and also 8.8 c.c. of half normal solution of sodium hydroxide. After the addition of the alkali, the solution must still have an acid reaction and contain copper in solution. Fill the flask to the mark and filter.

25 c.c. each of solution 1 and 2 mentioned above are heated to boiling, and while boiling briskly 100 c.c. of the milk solution prepared as stated above are added and boiled for
six minutes. The filter is immediately washed with hot water, dried and placed in a crucible, burned at red heat until weight is constant and all the copper will be changed to copper oxide. Then determine the amount of lactose from the table prepared by E. Wein and F. Soxhlet given on page 61 of U. S. Bul. No. 46, Methods of analysis adopted by the association of official Agricultural Chemists, 1895.

When the determination is made volumetrically the milk is cleared the same as for the use of the polariscope. Place 10 c.c. of each of the solutions of Allihn's into a caserole; add some distilled water; heat to boiling and then add small quantities of the solution to be tested keeping the solution constantly boiling. When the end reaction is near the amount of solution to be added can no longer be judged by color. A test used is to saturate a piece of filter paper with a dilute solution of potassium ferricyanide; another piece acidulated with acetic acid is placed over this and touch a drop of the solution to the top paper; if any copper is left it will turn the potassium ferricyanide brown. 10 c.c. of the above solution equals 67.8 milligrams of milk sugar. If there is any sucrose present the work is more tedious and it is a longer process to separate the two. First the reducing sugar is determined as described above. The sucrose must now be changed before the copper solution will be acted upon by the sugar solution. The change can be brought about in several ways. Adding hydrochloric acid or
citric acid and then heating at the temperature of boiling water for about a half hour. The same results may be accomplished by heating the milk with half a cake of compressed yeast at the temperature of 55 degrees C. for about 5 hours. After this, it is treated like any other milk solution and the % of sucrose calculated from the difference between the second and first determination.

The method I followed in the analysis, the result of which will be given later, has been already described with possibly some variation. First the specific gravity was taken by means of a lactometer.

Total Solids:- 3 c.c. of milk were placed in an aluminum dish, evaporated to dryness on a water bath heated at the temperature of boiling water for one hour, cooled and weighed.

Ash:- 25 c.c. placed in platinum dish, evaporated to dryness; then ignited the residue at low temperature at first, then heated at high temperature until all carbonaceous matter was destroyed.

Fat:- by means of Babcock method.

Total Albuminoids:- by Kjeldahl method.

Sugar:- in ordinary milk by difference.

ANALYSIS OF CONDENSED MILK.

The entire contents of can was well mixed, then 40 grams weighed off in a 100 c.c. measuring flask. The weighing was done in a glass stoppered weighing tube. The flask was fill-
ed to mark with water. The specific gravity was then taken and the analysis was continued as before. The sugars were not determined by difference but the polariscope was used. The method of procedure has already been given.

In the analysis of sugared condensed milk more difficulty was encountered but the general method was about the same as for unsweetened milk. The fat could not be determined by the Babcock method because the sugar was charred and made everything black so that a correct reading could not be secured. The ether extract method was used in such cases.

The reducing sugars were determined as in the other condensed milk. The sucrose was determined by digesting 25 or 30 grams with yeast for five hours. Then proceeded as before. The per cents of sugar were calculated as follows:

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\begin{align*}
26.048 \text{ grams of cane sugar} & \rightarrow \text{read } \% \\
32.975 \text{ } & \text{Lactose } \% \\
\text{Am't of milk taken: } 26.048 & : 1\text{st. reading} : 1\text{st. reading corrected} \\
& : 26.048 : 2\text{nd. reading} : 2\text{nd. reading corrected} \\
% \text{of sucrose} &= \frac{1\text{st. reading} - 2\text{nd. reading}}{144 - \text{temperature}} \\
% \text{of lactose} : \text{rotation due to lactose} &= 66.4 : 52.5 \\
\text{Rotation due to lactose} &= 1\text{st. reading} - \% \text{of sucrose} \\
\text{All my work was carried on in duplicate and the results given are the averages of the duplicates.}
\end{align*}
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We have already seen that milk is composed of quite a
number of different constituents, of these water occurs in greatest quantity forming about 87 percent of the milk. The remainder or total solids constitute about 13%, which consists of fat 3.6%, casein 3.3%, albumen 7%, lactose or milk sugar 4.7% and ash or mineral constituents .7%. The percentage of the various constituents of milk vary greatly from the figures given above, which represent the standard usually adopted. Fat varies greatly not only in size and number of fat globules, but in amount. The number of fat globules contained in a definite volume of milk may give some idea as to their size. One ten-thousandth of a cubic millimeter of milk was found at the New York station to contain 152 fat globules, and according to the Wisconsin station the average number in a quart of milk is not less than 2,000,000,000,000. The number as well as the size of fat globules varies greatly in milk from different breeds and in different cows. These differences can easily be seen by examining a drop of milk under the microscope.

The fat of milk is composed principally of stearin, palmatin and olein and others but more volatile fats are present which give the aroma to our butter.

Now as to the amount of fat it was mentioned that this varies greatly and so it does. The results of the twenty or so samples gathered in Champaign and Urbana for this subject, just as they were sold by retailers for human consumption, show a variation from 2.75% to 5%, a difference of 2.25%; but these var-
lations are very small when compared with results of the work done by the Department of Chemistry of the University of Illinois and Hull House on the analysis of Chicago milk as it was retailed. One sample sold as whole milk only tested .5% or equivalent to poor skim milk, on the other hand one sample tested as much as 10.4% of fat equivalent to fairly good cream. In this case there was a difference of 9.9% between the highest and lowest. We could hardly expect that this represents the milk as it is drawn from the cow but even if it does or does not, it does show what the consumer got as milk.

The other constituents will also vary but not near as much as that of fat. Casein and albumen together are generally known as protein, and varied from 2.75% to 4.53% in the samples analysed from Champaign and Urbana, that is a difference of 1.78%. In the Chicago milk the variation was from 2.62% to 3.63%, the difference being 1.01%. In neither case was the difference as great as that of fat. It might be well to state that the number of Chicago milks in which casein was determined was not near as large as fat but still the variation of fat in the samples in which casein was determined was very much more greater.

The sugar in the Champaign and Urbana milk ranged from 4.07% to 5.72%. The sugar in the Chicago milk was not determined. The mineral constituents vary very little, from .6% to .75%. It is at once evident why only the fat is considered in the comparisons of milk. It is because it varies more than any other
constituent or because the others are very nearly constant. Practically all the other variations may be attributed to the amount of water, varying. In some breeds especially the % of water is increased. The solids will thus vary inversely as the % of water.

On account of these great variations especially in fat, different states and some cities have found it necessary to have laws fixing the % of solids and fat, below which a dealer is not allowed to sell. If the milk goes below a certain % the dealer is liable to the law. The requirements of the law in different states vary. The highest requirements being 13 % of total solids and 3.7 % of fat in Mass., 13 % of solids and 3.5 % of fat in Minn. The lowest being in Ohio, 11.5 % of solids during May and June and 12 % the rest of the time. The lowest % of fat required is 2.5 % in R. I.

Some states have no law and a man can sell as milk anything the people will buy. Chicago has a milk inspector whose business it is to look after the milk supply of the city, but it is astonishing that such poor milk is sold for human food.

We have seen that there are great variations and we will try to discover what they are due to. We all know that there is a great difference between the animals of different breeds. Jerseys and Guernseys produce very rich milk, that is milk with a high per cent of fat averaging nearly 5 % as shown from the results of stations that have conducted breed tests.
Holsteins are considered as producing poor milk and their records show about 3.5% but often they go below this. These are probably the extremes and the other breeds range between these. Some breeds such as Short Horns not generally considered as dairy cattle, range quite high in fat. At the N. Y. and N. J. stations where they were tested they averaged nearly 4%.

But great as are the variations between the breeds, the records show us that nearly as great are the variations between different animals of the same breed.

It is generally supposed that the kind of food affects the quality of the milk. It is thought that when more succulent food is fed the milk will be thinner, that is more water and less solids present. The Ohio dairy law even considers the standard of milk in May and June .5% lower than the rest of the year. Upon what this is based except general opinion I have not been able to find out. All experiments ever conducted seem to show that there is no change in per cent of fat due to different food. There are changes from day to day and it seems to go in but periods, these are due to unknown reasons. There are slight increases in some cases on change of food but it soon settles back to the old standard and it is thought that this is due only to a nervous reaction. Experiments have been tried to increase the % of fat by feeding oil or tallow but without effect. To show that there are changes in the cases where cows are fed the same I will sight Ill. bulletin No. 51, page 84. From the evening of the 30th to the morning of the 31st the % of fat varied from
2.7 to 4%. The reason for this great difference is not known but the difference is greater than any that could be produced by different feed.

There is also a great difference between the first and last milk drawn. At the N. Y. station they found when milk was drawn pint by pint, it tested as follows: .85 - 1.43 - 1.68 - 2.02 - 2.23 - 2.65 - 3.27 - 3.74 - 4.05 - 4.86 - 4.48 - 4.30 - 5.23. This shows an increase of nearly 500% over the first pint.

There is also a difference between the old and the young cow. Young cows generally produce richer milk than old ones.

The first milk or colostrum contains large quantities of proteids amounting in some cases to 15%. More than half of this is albumen generally, while in normal milk it is very small. The per cent of sugar is generally very low, the fat is about normal. This milk is only fit for the new born calf, and it acts as a laxative which is necessary after the calf is born. The milk, however, soon becomes normal. It was found at our station that when the milking periods are unequal the longer period though not always give the larger yield of milk and of fat.

Abnormal variations sometimes occur and there is generally something the matter with the cow's health so if such a thing is noticed it is advisable to investigate the matter.

We have seen that there are great variations in milk
which can not be controlled by the dairyman; there are varia-
tions which do occur and only too often which can be controlled
or rather prevented. It is very tempting for a dairyman when
he sees the cream all separated in the morning to take off part
of it so that he can make butter and still have all his milk to
sell, especially is this so if he knows that the consumer has no
means of testing the milk or of finding out that it has been
tampered with. Another means of adulteration is very common,
that is adding water. If a man has a larger market than his
dairy will supply it is an easy matter to add water and make the
mixture go round. If he does not do this he will disappoint
some of his customers and he will have more trouble than by add-
ing a little water. Not only one of these may be done but both,
and it id then no wonder that some of the milk thus treated
looks very thin.

These adulterations are often the customer's fault
more than the dairyman's. They want the milk at such figures
that he can not afford to sell, and rather than to lose the
customer he will try a scheme like this. If the customer would
insist on good milk rather than a lower price the adulterating
would not occur near so often. The consumer should, however,
not be unreasonable in his askings for if he is, the dealer is
tempted to rob some other man's milk of the cream.

There may be unwillful difference due to separation
of milk; especially is this true in the shop. If the dealer has
a can of milk standing on the counter the cream quickly rises and he is drawing skim milk off at the bottom while the last man will get all the cream. Stirring before each time of drawing milk would prevent this. The unfairness in this case would come in not on account of the dishonesty of the dealer but on account of his ignorance or carelessness.

According to the experiment tried at the N. Y. station the jar of the wagon would be enough to keep the milk well stirred, when delivering. This point was also tested in connection with this work, and the results were somewhat different from those at N. Y.

It was noticed in the delivering of milk in glass bottles which were full, the cream separated in spite of the shaking.

An eight gallon can was then taken with a faucet at the bottom. The can was filled perfectly full and a sample of the milk taken before starting. The roads were very muddy and the team could not go very fast, still there was quite a little bumping. After a half an hour a sample was taken, then three quarts were drawn off at intervals of seven or eight minutes. Twenty minutes later another sample was drawn, then a quart was drawn every five minutes and a sample taken every half hour. When the seventh sample was taken all the milk except about a pint was drawn off and the pint tested.

The results are as follows:
No. of Sample. 1 2 3 4 5 6 7 8
% of fat 4.35 3.70 3.20 4.45 4.45 4.35 4.35 4.35

This seems to show that as long as the can is nearly full and not enough room for shaking the milk will separate as seen in the bottles and in samples 2 and 3 of the test. After a certain amount is out of the can there is enough room to thoroughly beat up the milk.

Another means of adulterating is by the additions of preservatives to save the milk from one day to another. This does not affect the composition very much, but it often does the nutritive value and it will be considered more fully under that head.

NUTRITIVE VALUE OF MILK.

Milk without a doubt comes nearer being a balanced ration than any other food we have, that is life could be sustained upon it longer than upon any other one material. By balanced ration we mean one in the which the food constituents, that is fat, carbohydrates, proteids and mineral matter, are present in nearly the same proportion as found in the body. Milk is for this reason admirably adapted for the building of body structure and consequently for growing animals, and it is well known that young animals can be raised on milk. It is an ideal food for children but when the body has ceased to grow the nutritive ratio or that between protein and carbohydrates is too narrow, because the adult has very little building of body to do
and the protein is not needed for this purpose. It is also well adapted for use with other materials and its nutritive value is not interfered with in the least.

We all know that milk is the best food for children, but why? Not only on account of its almost perfect composition for food, but just as much on account of its being easily digested. Milk is without a doubt the easiest digestable food we have. The fat is already in the form of an emulsion and all that needs to be done with it is to pass through the tissue and it is carried by the blood to the parts where it is needed in a condition all ready to do its work. The sugar and mineral matters are in solution and only need to osmose through the tissues. The protein of milk is the easiest digested of any animal protein and by far easier than any vegetable protein. There is, however, another phase of this to be considered, that is the digestability for different people. Not all people have the same power to digest food. Some people can digest much easier one kind of food than another and the conditions may be just the opposite for another person. According to the old saying "We live not upon what we eat but upon what we digest", it is evident that the composition is not the only thing to be considered. It is certain that not all parts of the milk are digested equally well by everyone, for milk does not agree with some people, and this immediately raises the question which is more digestable boiled or unboiled milk. Unboiled milk agrees better with some people
and boiled better with others. It is evident from experiments that the protein of boiled milk is less digestable than that of unboiled. The objection to unboiled milk will be mentioned a little further on.

When milk is taken into the stomach it immediately curdles and often forms into large lumps making it very hard to digest. This formation of large lumps is true under certain conditions more than under others. Human milk differs in this respect from cows milk, never forming into lumps but always a flocculent curdle. This is one reason why women’s milk is better for the infant. When cows milk has been boiled it will seldom curdle in such lumps, or it will become more flocculent and for this reason agrees better with some people than unboiled milk. It is supposed by some chemists that phosphate of lime is precipitated during boiling, and that it was the cause of all the mischief. It is supposed that lime will cause more flocculence in the curdling, and this is the reason why it is recommended, to add lime water to milk. Probably the lime neutralizes part of the acid and the curdling will not proceed so fast.

It is evident that the nutritive value of milk primarily depends upon its composition for if it were entirely composed of water, it would have no nutritive value. From this will follow, the larger the per cent of water the smaller is its nutritive value, or in other words the greater the per cent of solids the greater is its nutritive value.
The value of the different food constituents are not the same, nor is their purpose the same. The prime object of food is to build up the body and to furnish energy to keep it going. Proteids are the constituents which form the material to build up the body and after it has ceased to grow to do the repairing that is to make good the waste. We can thus see why a young or growing person needs more protein than the older or full grown person. The protein in the milk is practically in the same proportion in the milk as it is in the body, and therefore enough for the growing animal.

Milk would therefore seem too rich in protein for adults and so it is. The protein is, however, not wasted if there is no repairing to be done, neither is it stored up for future use, but goes to produce energy the same as the other food constituents. Protein of the market is very costly and also those foods rich in protein are high priced. The purchasing of large quantities of protein is therefore hard upon the pocket book and the use of unnecessary quantities of this food constituent is also hard upon the body especially in the process of eliminating the waste products. Meat is an example of this highly nitrogenous food.

Looking for a moment at the composition of carbohydrates we can see that it is composed of C, H and O, the last two mentioned are always in the same proportion as in water. Now when this is oxidized either by burning or by consumption in the
body, the compound will break up, water is set free and Oxygen unites with C to form CO₂. The carbonic acid gas is gotten rid of through the breathing, and the water through perspiration and by passing through the kidneys. With the proteids it is very different, the kidneys and liver have a great deal to do in separating out the nitrogenous waste matter from the blood. This may overtax these organs and then will cause some kidney disease or some bilious trouble.

As to the mineral constituents they are very small in proportion and their principal use is in the construction of bone, but also entering into the construction of tissue, but only to a limited extent. However small may be the amounts used, they must be present and an excess generally does no harm.

When we turn to the energy producing side we have a longer list to deal with, carbohydrates, fat and the excess of protein. It was said we take food to produce energy to keep the body going like the fuel of an engine. We know that there are different kinds of fuel, or fuel producing different amounts of steam, for example coal produces more steam than the same amount of wood, so it is also with the fuel of the body.

The fuel value of our food is measured by calories, a term adopted to show the relation between different foods. A calorie designates the amount of heat required to raise one kilogram of water one degree Centigrade, or one pound of water four degrees F. The mechanical energy is generally measured by the
term foot tons, and a calorie corresponds to 1.53 foot tons.

The fuel value for the different food constituents has been worked out and below will be given the table:

1 gram of carbohydrates is equal to 4.1 calories or 6.3 foot tons.
1 gram of fat is equal to 9.3 calories or 14.2 foot tons.
1 gram of protein is equal to 4.1 calories or 6.3 foot tons.

We see from the table that a gram of protein is equivalent to a gram of carbohydrates in amount of heat or energy produced, and is therefore more costly for production of energy. We also see that fat produces about 2.25 times as much energy pound for pound as either carbohydrates or proteins. Now remembering that food is primarily taken for energy it produces, it is at once evident that slight variations in fat make a great difference in its nutritive value. Comparing it on the standard of carbohydrates we see that a difference of 9.9% of fat would be equivalent to a difference of 22.3% in terms of carbohydrates. Now let us compare the fuel value of the highest and lowest analysis of milk from the Champaign and Urbana milk.

Analysis. 3% of fat - 2.75% of protein - 4.07% of sugar - lowest.
5% " " - 4.53% " " - 5.4% " " - highest.

Taking for the consideration a pound of milk or a little less than a pint. A pound of carbohydrates equals 1860 calories and one of fat 4220 calories. .03 lbs. of fat = 126.60 C. and .0275 lbs. protein plus .0407 lbs. of sugar = 116.85 C.

Total fuel value 243.45 calories.
.05 lbs. of fat = 211 C. and .0453 lbs. protein plus .056 lbs. of sugar = 134.91 C. Total fuel value 395.91 calories. The first having only 61% the fuel value of the second, a difference of 39%.

The difference in analysis of the Chicago milk is very much greater but the per cent of sugar is not given so the general average or 4.7% will be substituted in both cases. .5% fat - 3.25% protein - 4.7% sugar - lowest.

The highest not having the per cent of protein given the next highest will be used. 9.95% of fat - 3.13% protein - 4.7% sugar.

Taking a pound in both cases as in the other we have.

.005 lbs. of fat = 21.10 C. and .0325 lbs. protein plus .0470 lbs. of sugar = 147.87 calories and a total of 168.97 calories.

.0995 lbs. of fat = 419.89 C. and .0315 lbs. protein plus .047 lbs. of sugar = 145.63 C. and a total of 665.52 calories.

In this case the lowest was only 25% of the highest or the highest is four times as great in fuel value as the lowest.

Now comparing milk as regards nutritive value with other foods from the table on page 15 of Farmers Bulletin No. 74 U. S. Dep't of Agriculture we see the value of milk as a food. The table gives the average composition of the foods, that is the percentage of the constituents and the fuel value is given in calories. The fuel value of milk is given as 325 calories, of skim milk 170 calories or a little more than half the value of whole milk, but this does not represent the true worth of skim
milk especially to the growing animal. Skim milk is generally not well taken care of and is therefore very wasteful business. Butter consisting almost entirely of fat is very high in fuel value, 3605 calories. Round steak has a value of 870 calories or a little more than twice as much as milk, while ham has 1655 calories or about five times as much. Chicken, 325 calories or equal to milk. Bread, 1,205 calories. Potatoes, 325 calories and turnips 135 calories; we see from these that some of our foods are not worth as much pound for pound as milk and yet it is considered by many merely as a beverage rather than a food. It is very rich in protein and it is an excellent adjunct with some other of our starchy foods. The extra amount of protein in skim milk makes it valuable in cooking or preparing dishes which are poor in protein.

A man doing moderately hard work as for example a carpenter requires .28 pounds of protein and 3,500 calories of food value per day. With this information it is easy to calculate how much food is required to produce energy enough for a man. Knowing the value of the different foods the meals can easily be prepared accordingly. Working out a menu for a family of man and wife and children we will have to figure the factor on the basis of the above menu considering that,

A woman requires .8 the food of man,

A boy 14 to 16 years requires .8 the food of man,

A girl 14 to 16 " " .7 " " " ",
A child 10 to 13 years requires .6 the food of man, and so on down making allowance for more protein for the child than for the adult. These conditions need not be followed exactly but they should be studied more than they are, so that the amount and kind of food will be somewhat near right.

We know that the cow gave milk in the first place to support her young, but through careful selection and breeding man has been able to produce cows which give more milk than the calf will consume and man takes advantage of this and uses what the calf can not consume. We have gone farther than this, we now milk the cow, take away the cream and feed the skim milk to the calf, thus robbing him of the most nutritive portion. The feeding of calves on skim milk is fast becoming more popular. The different stations have been trying to increase the nutritive value of skim milk and the addition of corn meal has been found the best so far, but we can never replace the fat by any such means.

Bacteria are generally found in milk and through them the milk is rendered worthless. The milk itself is only partly deprived of the nutritive value but the milk is in such form that it can not be digested when taken into the body, and even more dangerous results have already been pointed out. To prevent the growth of these bacteria preservatives such as borax, salicilic acid, formalin and others are often added. These are not generally regarded as poisons but when taken into the body
constantly even in small doses, they will have an injurious effect upon the system. The effect is sometimes only noticed after years or when the person gets to be old.

COST OF MILK.

The retail price of milk varies with different dealers as every one knows. There are generally two or three different prices among the dealers of the same town. Take for instance Champaign and Urbana, the price ranges from 5 to 8¢ a quart. The greater part of them selling at 6¢ a quart. The price varies a great deal more in larger cities. The price in Chicago varies from 2 to 7 cents and a few dealers who are reliable and have their regular customers receive as much as 12 cents per quart. According to bulletin No. 20, Bureau of Animal Industry, milk in Greater Boston retails at 6, 7 and 8 cents per quart. The average of Chicago milk is somewhat higher than that of Champaign, being probably due to the increased consumption, and the disadvantage of producing all the milk close by. The greater part of it has to come in by the railroad. The milk of Boston seems to run quite a little higher than that of Chicago, due undoubtedly to the increased cost of production, land and feed being higher probably makes the difference. We can also see from this that milk prices vary in different localities, being higher in the east than in the middle west.

We have seen that milk varies in price per quart, now let us see if it varies as much or more when compared with nu-
tritive value or composition. We noticed the difference between highest and lowest price in Champaign was 3 cents per quart. Now let us see if the nutritive value affects this by making the difference in price justifiable. Let us take for comparison the same samples as before, the fuel value of which was figured out and which showed the greatest extremes of price. The one with the lowest fuel value showed 243.45 calories per pound or pint and it cost 4 cents, the one with the highest fuel value of 395.91 calories per pint and cost 2.5 cents. The poor milk was higher priced and makes the difference all the greater. Reducing both to the same factor, say the 4 cent milk, we received in the first instance 243.45 calories for 4 cents and 633.45 in the second. Thus receiving in the second case 2.6 times as much fuel value as in the first or equivalent to 2.6 times as high a price paid for the first as for the second.

In the Chicago milk the price is not given for the samples compared in nutritive value. The price is not given in any case where the per cent of protein and sugar are given. There it will have to be based upon the fat constituents entirely. Sample No. 243 cost 6 cents and had 2.2% of fat; sample 38 cost 3 cents and contained 6% of fat. This shows that the first mentioned sample cost twice as much as the second and had only 36% as much fat. Reducing to one standard we can see that it cost 5 times as much in the second case to get an equivalent amount of nutrient. That is the second man had to pay more than
5 times as much for an equivalent amount of fat.

We can easily see that by selling milk for so much a quart, is not fair; in the first place the buyer does not know what he gets or he will not get what he pays for. A different standard ought to be adopted for the sale of milk. One based upon the nutritive value and preferably upon fat, for that varies more than any other constituent, and it can be easier determined than any other. This method is actually adopted in localities more especially where milk is sold in large quantities as in creameries, and where the sole object of the milk is fat for butter making. This method is not altogether fair for if a man had cows testing low in fat but well up in protein and sugar, he would only get paid for the fat and would give away a lot of nutritive material and not get paid for it. Or if they tested high in fat and low in protein and sugar he would deliver the same amount of fat as the other man but much smaller amount of the other two constituents. Under such circumstances creaming would be prevented, for if a dealer does take off cream he sells skim milk for nothing, and if he adds water he only increases the bulk to handle and haul.

On account of the great variation in milk as above pointed out and in order to better know the milk supply of these two towns this work was planned. The above mentioned methods were employed in the analysis of the milk. The milk was collected at random from either town and generally only one sample at a
time, to allow analysis before the milk would sour. The milk was collected at any time or place just so the purpose of the sample was not known to the dealer. The milk of each town will be taken up separately but it might be well to say that most of the retailers sold milk in both towns. The analysis of the Champaign milk will be given first. The date of collection ranged between Jan. 18 and March 2.

**ANALYSIS OF CHAMPAIGN MILK.**

<table>
<thead>
<tr>
<th>Number of sample</th>
<th>Price per quart</th>
<th>Specific gravity</th>
<th>Total solids %</th>
<th>Fat %</th>
<th>Protein %</th>
<th>Sugar %</th>
<th>Ash %</th>
</tr>
</thead>
<tbody>
<tr>
<td>502</td>
<td>6.25</td>
<td>1.0326</td>
<td>13.00</td>
<td>3.75</td>
<td>3.25</td>
<td>5.31</td>
<td>.69</td>
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<td>5.00</td>
<td>1.0315</td>
<td>11.35</td>
<td>2.75</td>
<td>3.28</td>
<td>4.60</td>
<td>.72</td>
</tr>
<tr>
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<td>6.00</td>
<td>1.0318</td>
<td>11.64</td>
<td>3.50</td>
<td>2.89</td>
<td>4.60</td>
<td>.65</td>
</tr>
<tr>
<td>505</td>
<td>6.00</td>
<td>1.0334</td>
<td>12.52</td>
<td></td>
<td></td>
<td>3.04</td>
<td>.69</td>
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<td>1.0320</td>
<td>12.09</td>
<td>3.60</td>
<td>2.89</td>
<td>4.97</td>
<td>.62</td>
</tr>
<tr>
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<td>5.00</td>
<td>1.0330</td>
<td>12.28</td>
<td>4.10</td>
<td>3.03</td>
<td>4.50</td>
<td>.65</td>
</tr>
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<td>1.0310</td>
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<td>4.94</td>
<td>.56</td>
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<td>4.71</td>
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<td>4.07</td>
<td>.60</td>
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<td>12.05</td>
<td>3.50</td>
<td>3.59</td>
<td>4.74</td>
<td>.67</td>
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</tbody>
</table>

The average of these samples coincide very closely to the general average composition of the analysis of the milks of this country. There are two samples that are very low and it is known that in both cases the herd is almost entirely composed of Holstein cattle, thus accounting for the low analysis rather
than creaming or the addition of water. These two samples, however, reduce the average considerably. We see that quite rich milk is sold in Champaign for a little less than six cents on the average. The most interesting part about the results is that they vary very little from the average, indicating that the same grade of cattle are kept by the retailers. It is known that no special breed exists and mostly scrub cows are kept on the dairy farms. This closeness to the average also indicates that very little watering or creaming has been done and that the milk is sold the way it is drawn from the cow.

Probably one reason why good milk is sold at the reasonable price is the competition. There are quite a few people in town who keep one or two cows and then deliver milk to a few neighbors. The practice of delivering milk in glass bottles is becoming more popular and the milk thus delivered is prefered, because it readily shows any dirt that may be in the milk and it will thus insure the delivery of cleaner milk. The dealer from which the last sample was secured is in the wholesale business depending almost entirely upon that market. He supplies milk to restaurants and hotels and seldom sells milk by the quart. The milk from Urbana will now be considered. These samples were collected between January 16 and March 21st.
ANALYSIS OF URBANA MILK.

<table>
<thead>
<tr>
<th>Number of sample.</th>
<th>Price per quart.</th>
<th>Specific gravity.</th>
<th>Total solids %</th>
<th>Fat %</th>
<th>Protein %</th>
<th>Sugar %</th>
<th>Ash %</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>6.25</td>
<td>1.0338</td>
<td>10.99</td>
<td>3.10</td>
<td>3.22</td>
<td>3.72</td>
<td>.85</td>
</tr>
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<td>506</td>
<td>5.00</td>
<td>1.0298</td>
<td>13.23</td>
<td>Spoiled</td>
<td>3.53</td>
<td>3.72</td>
<td>.85</td>
</tr>
<tr>
<td>509</td>
<td>5.00</td>
<td>1.0338</td>
<td>13.67</td>
<td>3.35</td>
<td>3.65</td>
<td>5.72</td>
<td>.65</td>
</tr>
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<td>1.0337</td>
<td>13.44</td>
<td>4.05</td>
<td>3.61</td>
<td>5.13</td>
<td>.65</td>
</tr>
<tr>
<td>512</td>
<td>5.00</td>
<td>1.0348</td>
<td>15.33</td>
<td>4.95</td>
<td>4.25</td>
<td>5.39</td>
<td>.74</td>
</tr>
<tr>
<td>514</td>
<td>5.00</td>
<td>1.0352</td>
<td>15.68</td>
<td>5.00</td>
<td>4.53</td>
<td>5.40</td>
<td>.75</td>
</tr>
<tr>
<td>529</td>
<td>6.25</td>
<td>1.0330</td>
<td>12.63</td>
<td>4.35</td>
<td>3.21</td>
<td>4.40</td>
<td>.67</td>
</tr>
<tr>
<td>530</td>
<td>6.25</td>
<td>1.0318</td>
<td>12.65</td>
<td>4.35</td>
<td>3.22</td>
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<td>.63</td>
</tr>
<tr>
<td>Average</td>
<td>5.7</td>
<td>1.0331</td>
<td>13.15</td>
<td>4.11</td>
<td>3.57</td>
<td>4.72</td>
<td>.70</td>
</tr>
</tbody>
</table>

It is apparent that the averages are quite a little higher than the ones of Champaign and the general average. The price is somewhat lower thus making the difference in the nutritive value and cost all the larger. The first two and last two were obtained from the University dairy and the first two were used in testing the method and may be somewhat subject to error. The ash especially because it was determined in a porcelain dish for this sample and it was impossible to get all the carbon burned off. The last two samples were the first and last ones from the separation experiment, and the difference is thus accounted for. The samples 512 and 514 tested high and brought up the average quite a little. The samples came from a Jersey cow so the
high per cents are not astonishing.

Comparing the milk of the two towns it is easily noticed that the milk from the Urbana men is quite a little higher, but now deducting the two highest from Urbana, that is the two Jerseys samples and the two lowest from Champaign, that is the two Holstein samples, the average would be about equal. The milk on the whole is very good especially when compared with Chicago milk. All correspond very close to the average and not having any such variation as Chicago. The results are a little lower than the analysis of the milk from some of the towns of New Jersey, as shown in their Experiment Station Bulletin. It would seem from the above that small towns do have a good milk supply and at a reasonable price, and it would seem advisable to recommend the more extensive use of milk in such towns for it is a reasonable cheap food. The milk price averages below six cents which is very cheap and ought to stimulate a large consumption. The composition is such that a person need not fear adulteration and can well be satisfied with the product. In nearly every case the composition is above the general standard, meaning that it is as good milk as can be secured under ordinary circumstances.

The nutritive value based upon the composition is quite a little above the average. The milk also seems to be very wholesome for it appears nice and clean. The milk is delivered once a day in most cases, namely in the morning. In a few cases however it is delivered twice a day. In only one case of the
entire collection was there any dirt found in the vessel and there was seldom any odor detected. That is odor of the barn. In no case did the milk taste bitter or unnatural. The dairy wagons were clean both on the inside and outside.

In large cities the milk is not usually delivered fresh, because the milk has to come in by rail and often great distances; and often the milk can not be delivered until the following morning making it 36 to 48 hours old, and it is then not a wonder that it is sour. But if this milk is carefully handled and shipped in refrigerator cars it is fresher than that produced close by but carelessly handled. As a rule, however, milk produced far away is not as fresh as that produced close by. The producer of such milk is generally more careless and the milk gets warm taking it to the station and often it is not kept on ice in the car, so it is not astonishing to get sour milk once in a while. We can see that the small town has the advantage over the large one, and it is brought out still more when we compare the above results with the results obtained from Chicago milk.

CONDENSED MILK.

In large cities the supply of ordinary milk is often replaced by condensed milk. Condensed milk is at a disadvantage in many respects, first because it has to be put up in small cans thus greatly increasing the cost, and another is that it often has to be transported a long way, and then requires large sums
of freight to be paid. Now let us look at the advantages of condensed milk, and we see that it keeps indefinitely as long as the can is not opened and keeping longer than other milk after it is opened for it is thoroughly sterilized at the time of opening. The milk is in a concentrated form, because it is condensed before placing in the can. You will nearly always get what you pay for, that is you will not get skim milk or watered milk. The variations that exist are practically those due to variations in milk as it comes from the cow; there may be slight differences in the amount of condensation. So we will expect to see variations in condensed milk as well as in normal milk, not only in different brands but in the same brand and from day to day. Again it has the advantage of being in first class condition at all times while whole milk is often sour by the time it reaches the customer, and it is always at hand while the other milk you generally only get at the time of delivering. It was mentioned that the disadvantage was the increased cost due to putting up in small cans and freight; to counterbalance this or to reduce the cost we will see that this milk is always produced where it can be produced cheapest. Now let us look at the composition of condensed milk.
### ANALYSIS OF UNSWEETENED CONDENSED MILK.

<table>
<thead>
<tr>
<th>Number of sample</th>
<th>Price per can (¢)</th>
<th>Total solids (%)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Sugar (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>517</td>
<td>10</td>
<td>31.21</td>
<td>9.19</td>
<td>8.54</td>
<td>12.20</td>
<td>1.56</td>
</tr>
<tr>
<td>518</td>
<td>9</td>
<td>31.08</td>
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<td>8.68</td>
<td>12.69</td>
<td>1.72</td>
</tr>
<tr>
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<td>29.58</td>
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<td>10.82</td>
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</tr>
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<td>8.18</td>
<td>8.13</td>
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<td>7.76</td>
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<td>11.60</td>
<td>1.57</td>
</tr>
</tbody>
</table>

We see that the average of these analysis is nearly two and a half times ordinary milk; the price ranges from 9 to 12¢ per can, that is cans holding about a pint. The average price is 10¢ per can. Reducing this to quarts of whole milk we get 8¢ per quart. This is somewhat higher than the average price of milk in Champaign and Urbana and a trifle higher than that of Chicago. The reason for this increased cost has already been pointed out. The constituents are practically in the same proportion to each other as in the whole milk so one can see that nothing has been changed but simply water has been evaporated. The nutritive value is not interfered with any more than it is in boiling or heating ordinary milk.

There is another kind of condensed milk to which some time will be devoted and a kind of milk which is probably used to a greater extent than the kind that has just been under discussion and that is sugared condensed milk. In the manufacture
of this large amounts of sugar are added to preserve it.

**ANALYSIS OF SUGARED CONDENSED MILK.**

<table>
<thead>
<tr>
<th>Number of sample</th>
<th>Cost per can.</th>
<th>Total solids</th>
<th>Fat</th>
<th>Protein</th>
<th>Ash</th>
<th>Milk sugar</th>
<th>Cane sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>523</td>
<td>8</td>
<td>71.58</td>
<td>9.99</td>
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<td>1.71</td>
<td>14.86</td>
<td>39.75</td>
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<tr>
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<td>71.90</td>
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<td>11.74</td>
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<tr>
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<td>1.51</td>
<td>11.88</td>
<td>45.20</td>
</tr>
<tr>
<td>526</td>
<td>15</td>
<td>71.66</td>
<td>8.81</td>
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<td>1.61</td>
<td>13.00</td>
<td>43.99</td>
</tr>
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<td>1.85</td>
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<td>13.73</td>
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</tbody>
</table>

We see from the average of these analyses that the per cent of fat, protein, ash, and milk sugar is just a trifle higher than in the unsweetened condensed milk. The total solids are much higher, the addition of sugar making this difference as can be seen in the last column of this table. 41.33% of sugar has been used to replace water, this has then greatly increased the nutritive value. The price is only 1 cent per can higher than in the other condensed milk. The manufacturer can better afford to put larger amount of nutritive value into the milk, first because sugar is cheap and the process of preserving is not as expensive because the sugar helps to preserve.

We have seen that sugared milk is cheaper when based upon the nutritive value but a little higher can for can.
The amount of milk constituents is practically the same in the two but it is seen that the manufacturer of the sweetened milk has the advantage.

Now look for a moment at the other side to see if the unsweetened milk has any advantage over the other. We can see that unsweetened milk can be used in any place where whole milk can be used. It is practically normal milk after diluting to two and a half volumes. It can then be used as a beverage or in the same way as other milk. Sugared milk can not be used where no sugar is wanted, as for example in coffee by persons who drink their coffee without sugar. In delicate cooking where only a limited amount of sugar is needed. This may not seem like a very great disadvantage but it is when we think for a moment how extensively milk is used for such purposes.

It now remains for the consumer to decide which he will use, whole milk or condensed milk, sweetened or unsweetened. He will largely have to be guided by the conditions surrounding him, and in many cases it will be well worth his time to make a careful study as to what milk to buy or which dealer to patronize.