SYMPOSIUM: MILK SOLIDS- NOT-FAT

INTRODUCTORY REMARKS

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In pioneer days, our ancestors worked hard to perform endless manual chores, and ate heartily to give their bodies strength and energy. During that generation people were lean and hungry. They counted calories to get more meat on their bones. In later generations, those who grew fat from soft living and overeating shortened their life span.

Today we are fat conscious and count calories to keep fat off our bodies. Partly responsible for this complete reversal of attitude is the fact that we do not walk as much or do as much manual work as our forebears did. Labor-saving devices, new techniques, and machinery now provide a considerable amount of the energy once furnished by the human body.

When the Agricultural Research Service listed items of priority for research this year, human nutrition was first and genetics involved in animal breeding and improvement was second. It should be noted that this includes research on solids-not-fat and protein in milk. Those interested in this field have a sound basis for justifying financial support for their research programs.

Some of you may have noted an advertisement in a recent magazine of national prominence. This advertisement guaranteed a cereal that contained fewer calories per bowl than any other brand. This means the company was selling their product on the basis of what it did not contain as far as calories were concerned. We frequently hear statements such as this from housewives: "When I shop I choose the low-calorie foods and beverages." This is a new pattern, and milk salesmen must recognize this to keep milk in its rightful place in the human diet. Thus there should be much more emphasis on the protein and solids-not-fat content of milk. If this is done, the peculiar trend we experience today can be of a great advantage for milk protein constituents so essential in the human diet. These ingredients become of increasing importance in partially restricted food intakes.

It is generally recognized that the dairy production people are just a trifle late in getting their program under way. For example, in Holland where the calorie counters are far less numerous than in America, milk is now solid on the basis of both protein and fat content. They are equipped to test more than 5,000 samples of milk for protein content in one day by a staff of seven persons. The laboratory has a capacity of 15,000 samples a day.

The topics to be presented on the symposium by Dr. B. L. Herrington, Cornell University; Dr. J. E. Legates, North Carolina State College; Dr. S. N. Gaunt, University of Massachusetts; and Dr. R. E. Erb, State College of Washington should provide us with the opportunity to modernize our appreciation of this field. The achievements and background evaluation summarized for each man participating on the symposium will not be repeated. It is of special value to have these papers published in the Journal of Dairy Science.

TESTING METHODS AND MARKETING ASPECTS OF PROTEIN VS. SOLIDS-NOT-FAT

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CHANGING TIMES

Students are sometimes told that changes are natural and inevitable—that we should not consider change as a calamity but as an opportunity. Changes may become calamities for those who oppose them, but they present opportunities for those who look ahead and prepare for them. All this can be illustrated with examples.

The Dairy Industry has experienced many changes. Let us examine one change which is occurring now, and consider what adjustments should be made to profit by the opportunity it offers. What should we do when people put skim milk instead of cream on the dining table? The per capita consumption of cream has decreased 30% in the last 15 yr. The consumption of skim is increasing rapidly. Everybody does not yet have a chance to buy skim milk but, in the women's dormitories at Cornell University, the future housewives can choose between half-pint cartons of white milk, chocolate milk, or skim milk. This was their choice during May of 1960: white milk...
67%, chocolate milk 3.9%, skim milk 29.1%.

Our grandparents prized milk chiefly for its fat content. Milk was converted to cream or butter before it went to market. In those days, skim milk had no commercial value. It was good only for pigs and chickens. Fat was king of the market place.

This fact was generally accepted that it became part of our language. We are all familiar with such expressions as The cream of the crop, The fat of the land. We know that rich foods are high in fat content and in calories. To skim a book means to select only the best parts and skip the rest. Skim milk became a term of contempt.

But times have changed. People are on reducing diets. Ice milk is displacing ice cream. The per capita consumption of butter has decreased by half. Skim milk has become respectable and is on the front row in display cases. It commands a price only a little lower than that of whole milk. In fact, its price per pound of food solids may be higher than that of whole milk. Huge amounts of dried skim milk are now used for human food. Cottage Cheese is one of our most important products. Even the producers of Golden Guernsey Milk are becoming apologetic. Some of them remove part of the fat, reducing the test to 2%, and sell it as Golden Gold Milk.

Changes are here to stay, at least during the near future, which is of greatest concern to us. We must not ignore these changes; we should study them to see what changes we can make which will be most profitable under these new conditions.

One of the most obvious needs is to change the goal of our breeding program. Why strive to produce more milk fat when the public does not want more fat, and it is unwilling to pay the cost of its production? Let us strive instead to increase production of those milk constituents which the consumer does want.

Paying for Milk

In practice, this means that we must change the basis of payment for milk products. The commercial value of milk products is no longer determined by their fat content. This fact is most clear in the case of bottled skim milk. It is also clear in the case of Cottage Cheese and milk powder. It is emphasized by the low demand for cream and butter. A realistic basis for payment must recognize the value of the nonfat milk constituents. We need a measurement which can be applied to all dairy products, to skim milk as well as to cream and whole milk.

Two different plans have been proposed for measuring the value of skim milk. One would base the price upon total solids content. This plan does not seem so good to the cheese maker. He would prefer to pay on the basis of casein content, or protein content, because they are more directly related to yield of cheese.

Payment for protein instead of solids would ignore the lactose content of milk, but lactose is of limited commercial value at present. There is very little market for it. Many cheese factories discard large quantities of lactose in the whey. It may be a liability instead of an asset, because it can create a very serious waste disposal problem. At the present time, there is no good reason to encourage the production of more lactose. We can not use the value of lactose to support an argument favoring payment for total solids over payment for protein. We must look elsewhere for arguments in support of one plan over the other.

Both plans have been used for payment on a limited scale. We might use both methods in the future, but this could cause much confusion and dissatisfaction which would be avoided if we could all agree to use the same method.

Each method of payment, for protein and for total solids, has its own advantages. We should study all aspects of the problem before choosing one method over the other. We should recognize, for example, that the choice of method will influence the relative market values of milk of different breeds, and the herd associations will be concerned about this. We know in general the Guernsey milk is richer than Holstein milk, but how much richer? That is an important question when you are buying or selling milk.

According to the data of Overman et al. (15), Guernsey milk is 18% richer in terms of protein, but only 8% richer in terms of total solids. If we sold skim milk powder according to protein content, Guernsey powder would be more valuable by 9%. These are the facts of life. Should we demand a higher price for a product containing 9% more protein, or should we sell both at the same price per pound? What does the farmer do when he buys feeds of different protein content?

We might inquire what effect each plan would have upon the success of our breeding programs. It is obvious, of course, that in one case we would select for increased solids and in the other for increased protein. I suspect that the second might yield quicker results, because the goal would be more sharply defined and progress could be more accurately measured. The results of analyses for total solids might confuse the breeder, because a significant increase in one component of milk could be masked by a decrease in another. In effect, under a solids-not-fat program, the breeder would be working partially in the dark and progress might be slower than if he were selecting for protein alone.
EMPHASIZE PROTEIN

We all have one big goal, to sell as much milk as possible to all consumers. May their numbers increase and their appetites, also. Is it possible that the method of payment may affect the sales of milk? At present, we think and talk in terms of fat content, but fat does not have the sales appeal that it used to have. Let's stop talking about fat and talk about protein. The word protein has magical properties today. Home economists, nutrition experts, and ads in our newspapers and magazines all stress the importance of protein in the diet. Let us take advantage of all this free advertising. The meat packing industry has promoted the sale of meat by telling of the high quality of its protein. Cereal manufacturers are promoting special high-protein cereals. Bakers sell high-protein bread. Let us take advantage of this situation and stress the fact that dairy products are excellent sources of high quality protein. We can emphasize this fact by pricing according to protein content. At the same time we can take advantage of the fact that the customer is willing to pay a higher price for protein than for any other class of foodstuff. If you compare the price of steak with the price of bread and potatoes on one hand, or with lard and margarine on the other, you will see the advantages of classifying dairy products as protein foods in the mind of the consumer.

Many people are buying skim milk for table use. They believe it is rich in vitamins, minerals, and proteins. We could tell them it is rich in nonfat dry milk solids, but I doubt if that would be a good sales argument. Let's not mention nonfat dry milk solids at all. No salesman can get enthusiastic about such a mouthful of syllables. No housewife would stop to listen. No radio announcer can speak the words nonfat dry milk solids with the same caressing accents he uses to say protein.

ECONOMICS OF ANALYSIS

Before deciding whether to pay on the basis of solids or protein, we should investigate the practical problem of analysis from the standpoint of cost, speed, and accuracy. First, we should recognize that we can not abandon the fat test as a factor in payment. A new test will add to present costs, not reduce them, but the cost of testing would be small and should have no effect upon the retail price of milk.

Secondly, we do have a variety of methods available for both tests. They differ in speed and accuracy, in the initial cost of equipment, and in the cost of operation, but it is possible to use either method of testing. I have heard a few reports of manufacturing plants in this country which used solids as a basis for payment. It is well known that, in Holland, payments have been based on protein tests since 1957 (16). One central laboratory is able to make 10,000 protein tests per day (18).

I would like to review some of the methods which might be used for testing, and point out some of the problems involved. These problems need not be insurmountable, but they do deserve attention.

PROBLEMS OF ANALYSIS

Drying, with or without vacuum, is the most obvious way to determine total solids. It seems simple, but is is well known that different laboratories have difficulty in checking each other. The time and temperature, the size of sample, and size of dish must be standardized if reproducible results are to be obtained. The technique of weighing is important because evaporation from the dishes, and creaming in the pipette, can cause errors.

Assuming that the details of technique can be standardized so that reproducible results are obtained, we have a more difficult question to answer. Are these results right? Are they too high or too low? In one sense, the answers are unimportant. If we all agree to buy and sell on the basis of one standard test, it does not matter whether the test is right or wrong, so long as the results are reproducible. If we do not agree upon a single test, if we use two or more different methods, then we must face the question of which one is right.

This may be impossible to determine. It requires a definition of the term total solids. I might define total solids as the sum of the weights of the individual components of milk, but this is not enough. Should the lactose be weighed as anhydrous beta lactose, as hydrated alpha lactose, or as something else? This is an important point, because it can change the solids content of milk by more than 0.2%. Which value is correct?

In practice, it is not easy to determine what we are measuring. Sometimes the lactose may not crystallize during drying. It can remain as a glassy material which gives up most of its water rather quickly (5, 9). Sometimes the lactose does crystallize and it is possible to get either alpha hydrate or beta anhydride. In practice, you are likely to get a mixture. The alpha hydrate crystals are very difficult to dry (5). We must learn how to control the physical state of the lactose before we can determine the solids of milk with accuracy.

There is another source of error in drying methods which is hard to evaluate. When lactose is heated with protein, a reaction takes place between them. The product is colored, it is nearly insoluble, and it weighs less than the starting materials. This loss in weight in a Mojonier solids determination may lower the solids value by 0.25%. At present, I do not know how to prevent this reaction or how to correct for it. It can be reduced by drying at a lower temperature, but that raises other complications.

There are other methods of determining total solids, but these other methods are calibrated
by a drying test of some kind. They inherit all of the errors of the drying methods and they have some new errors of their own.

For example, many people have tried to calculate solids-not-fat from the lactometer reading and the fat test. Dozens of equations have been developed, giving dozens of different answers (10). Since only one answer can be correct, we must look for sources of error. Some were inherited from the drying test, but the lactometer test has errors of its own. The calibration of the instrument may be in error. The temperature may be wrong. The fat may be liquid when it should be solid, it may be solid when it should be liquid. These factors are under the control of the operator, but some sources of error are not.

For example, surface tension tends to pull the stem of the lactometer down into the milk. This force is variable. In ranid samples the surface tension may be lowered by 10 dynes. This can change the Quevenne reading by 0.3°. When using very sensitive lactometers having a stem of small diameter and a large bulb, variations in surface tension have less effect upon the reading.

Secondly, the lactometer equations assume that the density of the fat and the density of the solids-not-fat are the same in all milks. Unfortunately, this is not true. When lactometer readings are made at 60° F., the density of the fat in the same sample of milk can change as much as 2%, depending upon the time allowed for crystallization of the fat. Modern procedures avoid this by using a higher temperature to insure that the fat will be liquid. If that is done, the density of milk fat at a given temperature is reasonably uniform in different milks. This is not true of the solids-not-fat. In particular, variations in the ratio of protein to lactose cause trouble because the density of lactose is about 20% greater than that of protein (25, 26). What is much more important is this: The difference in density between lactose and water is 80% greater than the difference in density between protein and water. For this reason, variations in the ratio of protein to lactose have relatively great effects on the Quevenne reading. This source of error is particularly serious when tests are made on the milk of individual cows where the variation in ratio may be rather large.

The density of milk may be measured by other instruments, but they are subject to all these errors except those due to surface tension. The development of plastic balls of different density, but with the same thermal expansion as water, is an ingenious solution to the problem of temperature control (7). These balls differ in density by 1° Quevenne. In spite of this, it is reported that solids-not-fat determined with the balls is practically as accurate as values determined with a lactometer (6). We may judge from this that variations in density of the solids are so great that we gain no accuracy by reading fractions of a degree Quevenne. Since 1° Q. represents about 0.25% of solids-not-fat, this may be the limit of accuracy of such measurements.

It has been proposed that the density of milk be determined by the rate of fall of drops of milk through a liquid of known density (3). Such a method might be very rapid, but it introduces new sources of error without eliminating any of the old ones.

It has been proposed that solids might be determined by titration with an oxidizing agent (12). Some are skeptical about the possibilities of this method; I am one of them, but I do reserve the right to change my mind.

Lactometry methods have been studied widely because they offer promise of greater speed than the drying methods. More samples can be tested per man-hour. But this is not necessarily true when large numbers of samples must be tested. A number of efforts have been made to speed up the drying tests. For example, Swedish workers have mechanized the whole drying operation so that one operator can run 700 samples per day (4). This is much faster than any lactometer method, and mechanization should result in greater reproducibility of results. In this respect, the Swedish method is said to be better than the procedure of the Association of Official Agricultural Chemists.

If we choose to determine protein instead of solids-not-fat, we have many methods to choose from. By general agreement, the Kjeldahl method is considered the standard. It is capable of a high degree of accuracy but that accuracy is not always realized. In particular, the complete digestion of casein requires a number of hours of boiling with sulfuric acid and this is sometimes cut short. Furthermore, we should recognize that the Kjeldahl test is really a test for nitrogen, not a test for protein. In the case of milk, about 5% of the nitrogen is present in nonprotein form. Some analysts correct for this but all do not.

The reliability of the Kjeldahl procedure is based upon two facts. First, we can determine nitrogen with accuracy; secondly, each of the major proteins of milk has almost the same nitrogen content. Normal changes in the relative amounts of the different proteins in milk do not seriously affect the accuracy of the Kjeldahl determination.

Because the standard Kjeldahl procedure is slow, people have tried to develop faster modifications of it. For example, the final distillation and titration of ammonia can be replaced by a color test with some loss of accuracy but a considerable saving of time (19).

Of all these quick Kjeldahl methods, the Kořanyi method is today the most important (11). It eliminates the initial digestion with sulfuric acid entirely. The sample is distilled with alkali plus enough barium chloride to prevent foaming. Only a fraction of the nitrogen is recovered but, under carefully standardized
proposed. We can separate the casein from payment (17).

Many other methods have been proposed to determine protein, ranging from very simple to complex. For example, in the presence of excess ammonia milk becomes viscous, and we can estimate protein from the increase in viscosity of the mixture (1).

We can estimate casein from measurements of refractive index. Two procedures have been proposed. We can separate the casein from the milk and measure the refractive index of the purified casein solution (2) or, we can measure the refractive index of the milk before and after the casein is precipitated (8). We must remove the fat by centrifuging, in order to get distinct readings, but the method has promise. However, the differences in refractive index to be measured are small. A sensitive instrument is required and temperature control is important.

Most proteins absorb ultraviolet light near a wave length of 280 nm. This fact can be used to measure protein with a spectrophotometer. Of course, quartz cells and optics must be used at this wave length. The absorption is actually due to the ring structures in the amino acids, tyrosin, phenyl alanin, and tryptophane. Unfortunately, the different proteins of milk differ a great deal in composition, their absorbing power for ultraviolet light varies over a 3 to 1 ratio and, for this reason, the method does not seem suitable for the mixed proteins of milk.

It is well known that proteins are stained yellow by treatment with concentrated nitric acid. It has been proposed that this reaction might be used as the basis for a colorimetric test using visible light. However, the yellow color is formed by reaction of nitric acid with the same amino acids which absorb in the ultraviolet. The method has the same disadvantages as the direct measurement of 280 mm

In alkaline solution, proteins yield a violet color with copper, the so-called Biuret reaction. This has been proposed as a test for protein, but the test can not be applied directly to milk, because lactose interferes. Because the lactose must be removed by dialysis, or the protein must be separated by precipitation, washing, etc., the test is not as quick and simple as we would like.

Protein may be estimated by means of the formaldehyde titration. Many modifications of this procedure have been proposed and many names are associated with these modifications: Sorensen, Walker, Pyne, Steinegger. In its simplest form, the milk is first adjusted to a pH near 8.3. Neutral formaldehyde is added. The mixture becomes acid as the formaldehyde reacts with the amino groups of protein. The number of free amino groups can be estimated by titrating back to the original pH. This titration can be used as a measure of total protein, but the conversion factor depends upon the relative amounts of casein and noncasein protein in the milk. This ratio is not constant. In particular, it varies with the stage of lactation (20). Fairly good results can be obtained when testing mixed milk, though some advise that the conversion factor be adjusted for seasonal changes. The method is much less satisfactory for testing the milk of individual cows because of the much greater variation in ratio of casein to whey protein (22). The method has other disadvantages. It is based upon a small titration between two end points which are not very sharp. The uncertainties in the two end points are rather large in comparison with the total measurement.

The most promising of the new tests are based upon methods proposed almost simultaneously by Schober and Hetzel (21) and by Udy (23). In dilute solution, milk proteins are soluble in acid solution forming polyvalent cations. Some acid dyes can react with these cations to form an insoluble precipitate. The quantity of protein can be estimated from the amount of dye precipitated and this can be measured colorimetrically. Schober and Hetzel used the dye Amido Black 10B (Merck, Germany). Udy used Orange G, which is readily available in this country. More recently, Buffalo Black has been recommended for the determination of milk protein (24). These methods have attracted much attention. They are new. We may expect improvements in them, but even in their present form the standard deviation from the Kjeldahl is very low, approximately .05%, and this is satisfactory for many purposes. A new laboratory was opened recently in Holland using the Amido Black method (13). They began testing 5,000 samples per day with 12 persons. The laboratory was planned to have a capacity of 15,000 samples per day.

We may expect improvements in these methods. At present, it is necessary to add a rather large excess of dye to insure complete precipitation. This excess makes precise color measurements more difficult. We must measure small differences in color in the presence of a large excess of color. Perhaps we can find dyes forming compounds of greater insolubility, so that a smaller excess of dye may be used.

At present, the dyes on the market are far from pure. In general, we do not know the nature of the impurities, or how they affect the test. Before we can use these methods as a basis

3 Amido Black 10B and Buffalo Black appear to be trade names for naphthol blue black.
for payment, it will be necessary to have some control of the purity of the dyes, or else assurance that the impurities have no effect upon the results of the test.

If we undertake to guide our breeding programs by means of protein tests, enormous numbers of samples will be involved. So far as possible, this testing must be mechanized to cut down operating costs. The details of this will depend upon the method chosen for testing, but the Technicon instrument developed in this country shows what can be done along the lines of mechanization (14). That instrument can be adapted to many analytical procedures. It is entirely automatic, and it is capable of making from 20 to 60 analyses per hour, depending upon the method.

In closing, I would like to make one suggestion. Before we adopt any test to be used as a basis for payment, we must be sure that it is highly reproducible in different laboratories. It is not enough that the test be reproducible in the same laboratory. I can make the same mistake not once but many times. Others can do as well. To discover all of the pitfalls in a method, it is essential that different laboratories work independently, using the same samples. In my opinion, no conclusions about the reproducibility of a method are valid unless this is done. If such a project is undertaken, I would be glad to share in the work.

REFERENCES


