PRACTICAL METHODS OF ESTIMATING THE PROPORTIONS OF FAT AND BONE IN CATTLE SLAUGHTERED IN COMMERCIAL PACKING PLANTS

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INTRODUCTION

This paper presents the results of an investigation which had for its object the finding of more exact practical indicators of the percentage of fat in live steers or in their dressed carcasses. The investigation was restricted to indicators which can be expressed quantitatively and are so simple and so practical that they can be applied in commercial packing plants without much trouble. Similar indicators of the percentage of bone in the dressed sides of beef would also be desirable. Data bearing upon the reliability of one such indicator are presented.

An indicator of fatness, which could be expressed quantitatively and which would be free from the personal opinion of the men who judge the live cattle and the dressed meat, would be very helpful in interpreting the results of feeding trials. As far as fatness is concerned, the usual practice in publishing the results of a cattle-feeding trial or series of trials is merely to give the prices for which the live cattle were sold and perhaps also their dressing percentages and a few comments by the men who bought them. Sometimes the investigator goes so far as to analyze a wholesale cut or a few slices of beef, \( (6, 10) \), but the procedure is far from standardized.

A quantitative measure of the difference in the fatness of two lots is especially desirable in feeding trials designed to test out the productive value of different rations. This is due to the fact that a pound of true fat gained by the animal requires for its production several times as much net energy from the ration as does a pound of nonfat live weight. If the investigator does not have any estimate of the proportion of true fat included in the live-weight gain made by different lots he is handicapped in his interpretation of the results.

There probably does not exist any quantitative indicator or combination of indicators of fatness so accurate as to enable investigators to discard all personal opinions from the experimental data. Nevertheless, the investigator who uses a good quantitative indicator to supplement his own judgment and that of the cattle buyer, even though the indicator is not perfect, is less liable to draw erroneous conclusions from his feeding trials than if he relies upon human judgment alone. A definite knowledge of the degree of fatness of the dressed meat would add much to the knowledge of its value for human food, although it may be true, as maintained by Moulton and his coworkers \( (15) \), and by Mackenzie and Marshall \( (10) \), that the desirability of fatness has been overemphasized in much of the literature on the subject.

\[1 \] Received for publication Aug. 28, 1925; issued March, 1926.

\[2 \] Reference is made by number (italic) to "Literature cited," p. 754.
A knowledge of the percentage of bone in dressed beef would be of value chiefly in tests of different ages, types, or breeds of cattle. It might have some value in feeding trials where minerals were used. It would also occupy a prominent position in all studies of the quality and food value of the meat. This knowledge can be obtained by boning the meat, but this method is expensive.

Information for this study was collected from all sources which had published data pertinent to this problem.

**DATA STUDIED**

By the very nature of the problem, data which could be used were restricted to those experiments in which cattle were so carefully slaughtered that the weight of each part was accounted for, and in which the composition of each part (at least with respect to fat) was determined by chemical analysis. Four groups of published data which could be used were found. They were the analyses of 30 steers and 3 cows made at the Missouri Agricultural Experiment Station (11, 12, 13), the analyses of 4 steers made at the Maine Agricultural Experiment Station (8), the analyses of 3 steers made at the Illinois Agricultural Experiment Station (4), and the well-known analyses of 2 oxen and a calf made by Lawes and Gilbert (9) in England nearly 70 years ago. The extensive analyses of steers made at the Minnesota station (5) could not be used because the individual organs were not weighed and analyzed separately. It was thought possible that combining data from two or more different investigators might lead to erroneous conclusions on account of differences in the technique of slaughter and analysis. Therefore, wherever a plotting of the data showed a possibility of disagreement two calculations were made, one including all the cattle analyzed and the other including only the largest single group, the 30 steers of beef type analyzed at the Missouri station. It is for this reason that the source of each analysis is indicated by the symbols used in the graphs. It was also thought possible that the relations which are true for cattle of one age might not be true for cattle of another age. Therefore the 30 steers analyzed at the Missouri station are shown in the graphs by one or the other of two different symbols, according to whether they were over or under 1 year of age when slaughtered. Parenthetically, it should be observed that the data reveal no difference between the older and younger cattle from the point of view taken in this study, except the well-known fact that younger cattle contain a smaller percentage of true fat than older cattle, and possibly a difference in the slope of the regression equations for fatness and dressing per cent, and in the slope of the regression equations involving percentage of bone in the dressed meat.

It was necessary to calculate some of the percentages which were not calculated in the original publications and to recalculate others which were not presented in a comparable form in the material from all four sources. Thus it was necessary to calculate the percentage of bone in the dressed carcasses of the steers slaughtered at the Maine station, and there were two methods of doing this which did not give exactly identical results. Those results were used which seemed, from the context of the article in which they were presented, to have been obtained in a manner most nearly comparable to that
Estimating Proportions of Fat and Bone in Cattle

used at the Missouri station. Also, the basis for figuring percentages was the live weight of the animal instead of the "warm empty weight" used in presenting the data taken at the Missouri station. This was done because the "warm empty weight" can not be determined on the floor of a commercial packing house. Therefore "warm empty weight," in spite of the advantages of using it in some studies, is practicable only in experimental abattoirs, where very few cattle are killed at a time and where there is no pressing need for haste. The warm weights of the carcasses were used instead of the chilled weights, since it is the warm weights which are actually obtained in the commercial packing plants as a basis for further figures. The "chilled weight" of ordinary commercial practice is not an actual weight at all, but is some arbitrary fraction of the warm weight, usually 97.5 or 98 per cent. The percentage of fat in the entire live animal in the Maine data had to be calculated on the assumption that there was no fat in the skin or in the contents of the digestive tract, an assumption which is not absolutely accurate, but is so nearly so that it has very little effect upon the results. The percentage of fat in the entire live animal was not given in the Illinois data, but was calculated from the percentage of fat in the boneless meat from the dressed sides. The high correlation which seems to justify this calculation is discussed later in the section on "Relation of true fat in entire animal to true fat in lean and fat flesh." The figures actually used are presented in Table I. It is believed that they are accurate and comparable to a high degree. However, there may be several other very minor discrepancies, such as the length of time feed was withheld from the animals before slaughter. This was not stated for the Maine data, but would influence the live weight and all percentages derived from it. The time between the last feeding and slaughtering was longer in the case of the Lawes and Gilbert steers than in the case of the Missouri cows and steers.

RELATION OF TRUE FAT IN ENTIRE ANIMAL TO TRUE FAT IN LEAN AND FAT FLESH

From the standpoint of studying the quality of meat and its usefulness for food, the percentage of fat in the lean and fat flesh (i.e., in that part of the dressed carcass which would be left after a butcher had cut all the bones out of it) is more important than the percentage of fat in the entire live animal. From the standpoint of interpreting the results of feeding experiments, it is the percentage of fat in the entire live animal which is the more important. Therefore the first step in the search for indicators of fatness was to compare the percentage of fat in the entire live animal with the percentage of fat in the lean and fat flesh of the same animal, to see whether these two percentages were so highly correlated that the same indicator would serve for both purposes. A fairly high degree of correlation between these two percentages is to be expected, because they are to a large extent determined by common factors. Thus, the percentage of fat in lean and fat flesh is \( \frac{M}{M + A} \), and the percentage of fat in the entire live animal is \( \frac{M + N}{M + A + N + B} \) where
$M$ equals weight of fat in lean and fat flesh, $A$ equals weight of nonfat material in lean and fat flesh, $B$ equals weight of nonfat material in bones and noncarcass parts, $N$ equals weight of fat in bones and noncarcass parts.

$M$ is much larger than $N$; and in many cattle, particularly in fat cattle, $M + A$ is larger than $N + B$. Therefore variations in $\frac{M}{M + N}$ would be accompanied by corresponding variations in $\frac{M + A}{M + A + N + B}$, even if $N$ and $B$ were not correlated at all with $M$ and with $A$, respectively. If, as is much more likely to be the case, $M$ is highly correlated with $N$ and $A$ is highly correlated with $B$, then the correlation between the two percentages which are formed from $A$, $B$, $M$, and $N$ would be high indeed.

**Table I.—Percentages of fat and bone in individual animals**

<table>
<thead>
<tr>
<th>Animal No.</th>
<th>Percentage of true fat in entire live animal</th>
<th>Percentage of true fat in lean and fat flesh</th>
<th>Percentage of offal fat to live weight</th>
<th>Dressed per cent</th>
<th>Percentage of true fat in offal fat</th>
<th>Percentage of fat in carcass</th>
<th>Percentage of bone in dressed carcass</th>
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* Under 1 year of age.  
* Intestinal.  
* Estimated.
The actual relation between the two percentages is shown graphically in Figure 1. The relations are linear and the coefficient of correlation is $+0.9950 \pm 0.0012$ when only the 30 steers of beef type slaughtered at the Missouri station are considered, and the coefficient is $+0.9944 \pm 0.0012$ when the 3 Jersey cows slaughtered at the Missouri station and the 4 Shorthorn steers slaughtered at the Maine station are included. When it is borne in mind that such errors as occurred in the technique of analysis more probably lowered rather than raised the coefficient of correlation from its true value (on account of its already extremely high value), it is quite reasonable to conclude that $M$ is correlated with $N$ and that $A$ is correlated with $B$ to an extraordinarily high degree, and that we are here dealing with two measurements of what is essentially a single characteristic, the fatness of the animal. This simplifies the search for a reliable indicator of fatness, since the same indicator will serve in investigating the fatness of the meat and in interpreting the results of the feeding experiment. Because these two percentages are so perfectly correlated it will be unnecessary to consider both of them further, and therefore only the percentage of fat in the entire body will be used further in this paper as a criterion with which to test the accuracy of possible indicators of fatness.

Before leaving this subject, however, it may be well to give the regression equations by which one of these percentages may be predicted when the other is known. These equations, based upon all 37 animals, are as follows:

1. Per cent of fat in entire body, $0.7197$ times the per cent of fat in lean and fat flesh + $1.58$ per cent.

2. Per cent of fat in lean and fat flesh, $1.3740$ times the per cent of fat in entire body $- 1.92$ per cent.

Equation No. 1 was used in calculating the percentage of fat in the entire live animal in the case of the 3 Illinois steers.
PER CENT OF TRUE FAT IN FATTY TISSUE AS AN INDICATOR OF THE FATNESS OF THE ENTIRE ANIMAL

It is a matter of common knowledge that the material which the butcher calls fat is not all fat in the chemical sense of the word, but contains a varying amount of moisture and small amounts of protein and ash, and that the per cent of true fat in fatty tissue increases as the animal becomes fatter, and that percentages of the other constituents of the fatty tissue decrease. Especially is this true of the percentage of water in fatty tissue. Such common trade terms as "washy" and "lacking in substance," which are frequently applied to immature grass-fed cattle marketed early in the season, are a practical recognition of this condition.

It was thought possible that this increase in the percentage of fat in fatty tissue might be sufficiently regular with the progression of the fattening process to be useful as an indicator of the fatness of the entire animal. If this were so it would be a very easy matter to get a measure of fatness by taking samples of offal fat or kidney fat from each animal on the killing floor of the packing plant and analyzing those samples for fat later.

The relation between the percentage of true fat in offal fat and the percentage of fat in the entire animal is shown in Figure 2. The similar relation between the percentage of true fat in kidney fat and the percentage of fat in the entire animal is shown in Figure 3. There is a very definite and close relationship between each of these two possible indicators and the percentage of fat in the entire animal, but the relationship is not at all a straight line, and therefore the ordinary methods of correlation are not applicable. It is evident that these indicators have little value as such for either extremely thin or extremely fat cattle, since in the extreme ranges of fatness one of the variables changes but slightly with a large change in the other.

![Figure 2](image-url)

**FIG. 2.**—The relation between percentage of fat in entire live animal and percentage of true fat in offal fat. The curve is the equation, $xy - 100y = -272.5$, and is based on all the data shown.
In order to express these relationships as definitely as possible, an attempt was made to find the equation of the curve which most nearly fits the data in Figure 2 and in Figure 3. Figure 2 is very closely fitted by the rectangular hyperbola \( xy - 100y = -272.5 \), which is shown in the figure. Figure 3 is only fairly well fitted by its rectangular hyperbola \( xy - 100y = -146.4 \), which is also shown. The chief discrepancy between the equation and the data is that the percentage of fat in kidney fat seems to approach as a limit, not 100 per cent, but about 95 or 96 per cent. This discrepancy indicates a continued increase in the nonfat part of fatty tissue, even in extremely fat animals. Perhaps this can be more clearly presented by the following formula:

If \( P \) equals the weight of fat in kidney fat, and \( C \) equals the weight of nonfat in kidney fat, then

\[
\frac{P}{P + C} \text{ equals per cent of fat in kidney fat.}
\]

In the early stages of fattening the percentage increases in \( P \) are relatively enormous compared to the percentage increases in \( C \), and therefore the value of \( \frac{P}{P + C} \) rises very rapidly. If \( C \) did not increase at all, \( \frac{P}{P + C} \) would approach 1.00 as a limit, but if \( C \) continues to increase also, even though very slowly, \( \frac{P}{P + C} \) will approach as a limit a value somewhat less than 1.00. The exact limit will be reached when \( \frac{P}{C} \) equals \( \frac{\Delta P}{\Delta C} \), and one least-squares solution of the present data for a rectangular hyperbola gives that limit as \( \frac{100P}{P + C} \).
equals 94.8, but inspection of the data would seem to indicate that the true physiological limit of fatness of fatty tissue is slightly higher than that.

These figures and equations show that in the early stages of fattening the fatty tissue changes in composition more than in quantity, but that as fattening progresses the composition tends to reach its physiological limit of fatness, and thereafter fatty tissue increases in quantity but remains fairly constant in composition. No difference in this behavior is shown by cattle of different ages and breeds. In the same animal kidney fat contains a higher proportion of true fat than offal fat does.

While these relations have a great deal of interest for physiology and nutrition, the shape of the curves is such that the percentages of fat in offal fat or in kidney fat can not be used as indicators of the per cent of fat in the entire live animal except within wide limits, and therefore they will not be considered further in this paper.

DRESSING PER CENT AS AN INDICATOR OF THE PER CENT OF FAT IN THE ENTIRE LIVE ANIMAL

Dressing per cent as an indicator of fatness in a general way has been widely used. The report of a feeding experiment is considered hardly complete without a statement of the dressing per cents of the various lots. However, dressing per cent has other significance than merely as an indicator of fatness, for upon it depends very largely the margin which the packer must receive between the price of live cattle and the price of dressed beef before he can show a profit. It is in this significance that dressing per cent is most commonly used, especially by men who work in the terminal stockyards and packing plants. However, it is nearly always inferred in such usage that the higher dressing per cent is associated with the fatter animal, and that is undoubtedly true where large enough numbers of cattle are compared unless the cattle differ in sex, breed, or general type. However, so many things other than fatness are thought to affect dressing per cent that, so far as the writer is aware, it has not been used in the interpretation of feeding experiments except in a most general way. Indeed, the practice of figuring dressing per cent is not uniform with respect to whether it is figured on the basis of final feed-lot weights (so as to be more comparable with other experimental results) or on the basis of market live weights (so as to be more comparable with commercial cattle). Dressing per cent is usually figured on the basis of warm dressed weights, from which a certain percentage (usually 2.5 per cent) is deducted to allow for the loss in weight during chilling.

The data upon which this paper is based were figured from the warm dressed weight of the carcass and the live weight of the animal just before slaughter. The animals were slaughtered close to where they had been fed, and there was no shrinkage in transit to be accounted for. The relation between dressing per cent and the per cent of fat in the entire body is shown in Figure 4. Differences in the length of time food was withheld before slaughter may account for the unusually high dressing per cent of the Lawes and Gilbert steers. The unusually low dressing per cent of the two fat Jersey cows may be evidence of a breed or sex difference.
It will be seen from inspection of Figure 4 that in a general way fatness and high dressing per cent are correlated, but that there is a great deal of variation, and when one considers only animals within a narrow range of fatness dressing per cent is not a very reliable indicator of fatness. The correlation between dressing per cent and per cent of fat in entire live animals is $+0.760 \pm 0.043$ when all 43 animals are considered, and is $+0.842 \pm 0.036$ when only the 30 beef steers slaughtered at the Missouri station are considered.

This latter figure excludes the effects of differences in slaughter technique and also of breed differences, and therefore probably expresses the maximum degree of correlation between these two variables under all the most favorable conditions (except uniformity in age) to show a high correlation. Using it as the more nearly correct of the two, the standard error of estimate $^{3}$ becomes only 53.9 per cent as large as the standard deviation, and the regression equation for predicting the amount of fat in the entire live animal from the dressing per cent is:

$$\text{Per cent of fat in entire live animal} = 1.782 \times \text{dressing per cent} - 86.40 \text{ per cent}.$$ 

In applying this equation to other experimental cattle the conditions should as closely as possible duplicate those of the Missouri experiments, i.e., dressing per cent should be figured on the basis of final feed-lot weights and warm-carcass weights. The difference between final feed-lot weights and stockyards weights, commonly known as shrink, is probably mostly due to losses in the contents of the digestive tract. If it were entirely due to this the use of final feed-lot weights would be exactly comparable to the Missouri conditions. However,
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a small part of the shrink may be due to losses in actual flesh, and to the extent that this is so the use of final feed-lot weights for figuring percentages will give lower values than if the animals had been slaughtered under exactly similar conditions to those in the Missouri experiments. The losses in actual flesh are probably small because the daily maintenance requirement for a 1,000-pound steer is equivalent in energy to only about 1 1/2 pounds of true fat, and few experimental cattle are longer than two days in transit. Even if the maintenance requirement is multiplied several times to allow for the work and nervous excitement of the cattle during shipment, the amount of actual flesh lost would still be a relatively small proportion of the shrink. Therefore final feed-lot weights seem to be more nearly accurate for this purpose than stockyard weights, although it should be kept in mind that the use of final feed-lot weights will probably result in percentages slightly too low. In cases where cattle are kept in the stockyards long enough to completely recover their normal feeding habits the use of stockyard weights would probably be more accurate. In actual practice, however, this would be confined to show cattle which had been kept fully supplied with feed for at least four or five days after arrival in the stockyards.

There is also an indication in these figures that with older steers small differences in dressing per cent mean larger differences in fatness than with younger steers. Figure 4 shows this graphically, and raises the question as to whether the use of this equation would not give values too low for the fatness of older steers which were in good condition.

Murray (14) estimates that animals which the practical expert would describe as "fair," "half fat," "moderately fat," and "fat" all come within the range of containing from 15 per cent to 35 per cent of true fat in their live weight. If all animals outside those limits were excluded from Figure 4 the correlation would be much lower than it is for the entire group. In other words, dressing per cent is not nearly so reliable an indicator of fatness as the above figures would indicate when the range of fatness is restricted. And yet a range of from "fair" to "fat" is a wider range than would be encountered in any ordinary group of experimental cattle.

It seems clear, then, that dressing per cent is a good general indicator of fatness, but is affected by too many other things to be very trustworthy, particularly if the range of fatness in the group of animals to be studied is small. This conclusion is in agreement with the results of such other investigations of the question as have come to the writer's attention. Thus Hammond (5) summarizes the work of Mackenzie and Marshall (10) in regard to this point as follows:

Mackenzie and Marshall found, however, that while generally speaking a high carcass percentage is correlated with high fat content and with a low percentage of cartilage, bone, and lean meat, yet there were many and marked individual variations from this rule. Mackenzie and Marshall (10) did not analyze for fat the entire steers with which they worked. Instead they analyzed the seventh rib cut, and did not include in their figures (for per cent of fat) the fat which was scattered about within the muscles, i.e., the marbling fat. From their table the writer has calculated the coefficient of correlation between dressing per cent and per cent of fat in the seventh rib cut. This coefficient is $+0.63 \pm 0.04$ for the group of
84 steers with which they worked. From this rather low correlation it would seem that the untrustworthiness of dressing per cent as an indicator of fatness, especially within narrow ranges of fatness, has not been exaggerated in the preceding statements.

PER CENT OF OFFAL FAT TO LIVE WEIGHT AS A MEASURE OF FATNESS

The per cent of offal fat to live weight is very easily obtained for a group of cattle, but the obtaining of this percentage for each animal individually would interfere very considerably with the routine of packing-house operation. The packers themselves obtain it for each group of cattle which they slaughter, merely as a matter of interdepartmental bookkeeping in order to figure the beef cost of each lot. The two largest pieces of the offal fat are the caul and the ruffle (mesentery), but these two together constitute less than half of the total offal fat, which includes many small bits of fat from the viscera. The caul can be weighed separately for each animal without much extra trouble, but the weighing of the other offal fat for individual animals involves the stripping of the intestines separately and is hardly practicable. Even weighing the ruffle for individual animals is considerable trouble, since it involves tagging each set of intestines and following them to another part of the packing plant to get the weights. Hence the per cent of offal fat to live weight is easy to get for groups, but if indicators for individual animals are desired about all that can be obtained is the weight of the caul and the ruffle.

It is, or was until recently, the commercial practice among many packing plants not to weigh all the offal fat from each lot separately, but rather to weigh the caul fat and the ruffle fat from each lot separately and to figure the total edible noncarcass fat for each lot by some such formula as the following:

Total edible noncarcass fat = 2.5 (caul plus ruffle) 2 pounds for each animal. This formula is said to have checked up well with the actual weights of fat obtained in each day's kill in a commercial packing plant with which the writer is quite familiar, and to have been abandoned only because the actual weights of the different classes of fats lent themselves much better to the requirements of interdepartmental bookkeeping. It is also said, however, that neither the caul nor the ruffle could be used alone in any formula, because the proportion in which these two stood to each other was so much affected by sex, age, condition, and type of the animals.

The Institute of American Meat Packers was asked how generally the formula quoted above was used in American packing plants. The following is quoted by the institute as a representative reply to the inquiries which it made of the different companies as to how they figured the fat yield of a lot of cattle:

We can identify the caul fat and ruffle fat by lots, but we can not identify the gut fat, or, as some packers term it, bulk fat, so we get the actual weight of the caul and ruffle fat and from this determine the weight of the gut fat.

Different packers have various methods of arriving at the weight of the gut fat. We consider the percentage basis the best method, as it gives us a chance to check our estimates and by so doing we can not get very far out of line. Our method is as follows: On good cattle, with caul and ruffle fat weighing 40 pounds or over per head, we estimate the gut fat as equal to 100 per cent of the combined weight of the caul and ruffle fat, and as the weight of the caul and ruffle
decreases per head we increase the per cent of gut fat. This is on the basis that
the poorer grades of cattle would not have as heavy gut fat as the good cattle,
but the gut fat would be heavier in proportion to the caul and ruffle fat.

At the end of the day's business an actual weight of the gut fat is obtained in
total, and this weight compared with the total estimated weight that was used
on the tests tells how close the percentage scale is running to the actual. If the
estimated weight is running under the actual weight of the gut fat, then the
percentage scale should be raised. If the estimated weight is running heavier
than the actual weight, then the percentage scale should be lowered. In this
way the estimated weight will keep fairly well in line with the actual weight, and
would never get out of line to any great extent.

Since these methods of estimating the total offal fat are all empirical
and vary at different plants and with different grades of cattle, it
would seem that the best practice for the investigator to follow (in
experiments in which he does not attempt any further analysis of
the dressed meat) would be to use the empirical formula actually
used in that particular plant for that particular grade of cattle.

![Diagram](image_url)

**Fig. 5.—The relation between percentage of fat in entire live animal and percentage of offal fat to live

However, if he will also state the exact weight of the caul and ruffle
fat from his cattle his results can be more accurately compared with
other results obtained at other packing plants and in other years.

The relation between the percentage of offal fat and the percentage
of fat in the entire live animal is shown in Figure 5. It will be seen
that the correlation is extremely high, except for the fat Jersey cows
(which have a very heavy offal fat) and for a slight tendency among the
extremely fat steers for the offal fat not to continue to increase quite
as fast as the fat in the entire body. The Illinois steers (which were of
three different breeds) also differ somewhat from the other steers.
This is especially true of the Aberdeen Angus steer, and perhaps
emphasizes the need of caution in using this indicator of differences in
fatness between cattle of different breeding.
The coefficient of correlation when the entire 43 head are considered is \(+0.838 \pm 0.031\), and is \(+0.938 \pm 0.015\) when only the 30 beef-bred steers from the Missouri station are considered. Since the latter figure largely excludes breed differences and differences in slaughter technique, it probably represents more correctly the facts as they exist in an ordinary feeding experiment where there is no breed difference and the animals are supposed to differ only in age or in the ration which they receive. Using the figures for the 30 Missouri steers, the standard error of estimate becomes only 35 per cent as large as the standard deviation, and the equation for estimating fatness becomes: Per cent of fat in entire live animal = \(0.30 + 6.304 \times \text{percentage of offal fat to live weight}\).

The constant in this equation (0.30) is so small that it can almost be neglected, and for most purposes it is sufficiently accurate to say that the offal fat varies directly with the percentage of fat in the entire animal.

Thus the percentage of offal fat to live weight is a much more reliable measure of fatness than is dressing percentage alone, having reduced the standard deviation 65 per cent as compared with a reduction of 46 per cent which is accomplished when dressing per cent is used as an indicator. Again, however, it is necessary to use caution in interpreting the results. For instance, in comparing heifers with steers there may be a sex difference in percentage of offal fat which does not parallel differences in fatness. Thus Hammond (5), who studied the records of the Smithfield contests, writing of “suet fat” says: “The results confirm the generally well-known fact that heifers have more internal fat than steers.” However, speaking later of “gut fat” he says: “With gut fat, conditions are reversed and the steer carries a slightly larger proportion than the heifer.” Since the entire animals were not analyzed at Smithfield, it would perhaps be premature to say whether heifers really do have a higher percentage of internal fat than steers of the same degree of fatness, or whether the heifers may not actually contain a larger percentage of fat in their entire bodies than steers which appear to the stock judge to be of about the same degree of fatness. Or Hammond may be speaking here of exactly the same thing to which the practical packing-plant men referred when they said that neither caul fat nor ruffle fat alone could be used to estimate total offal fat when different kinds of cattle were compared, but that a combination of the two could be used, because each neutralized the defects of the other. At any rate it is necessary to use caution in applying any of these indicators to cases where the experimental cattle are known to differ in anything except age or the feeding treatment they received previous to slaughter.

**PER CENT OF CAUL FAT TO LIVE WEIGHT AS AN INDICATOR OF FATNESS**

Aside from the warm-carcass weight (from which an individual dressing per cent may be calculated), the only promising data on fatness which can be obtained without much trouble for individual animals killed in a commercial packing plant are the weight of the caul fat and (with a little more trouble), the weight of the ruffle fat. It seemed worth while to inquire into the reliability of the weight of the caul fat as an indicator of fatness, because in some feeding experiments, particularly those in which correlation studies are made of
body measurements with rates of gain and fatness, it is highly desirable to have a reliable measure of the fatness of each individual animal and not to be restricted to a knowledge of the average fatness of the whole lot.

The relation between the percentage of caul fat and the percentage of true fat in the entire live animal is shown in Figure 6. There is a very close relation, except for the fat Jersey cows from Missouri and the Angus steer from Illinois. Also, the extremely fat animals show more variation than the thin ones. The distribution is in every way similar to that of the percentage of total offal fat, except that the percentage of caul fat is not quite so regular in its relation to the percentage of fat in the entire animal. The weight of caul fat was not given for 4 of the Missouri steers or for the Maine steers. The coefficient of correlation for the entire 35 animals shown in Figure 6 is $+0.845 \pm 0.033$, and for the 26 Missouri steers it is $+0.892 \pm 0.027$. It is thus evident that the percentage of caul fat is almost but not quite as good an indicator of the fatness of an animal as is the percentage of total offal fat.

The figures for ruffle fat by itself or combined with caul fat were not given in the data used in this study, and hence the figures can not be given to test the accuracy of the statement by the practical packing-plant men that the combined weight of caul and ruffle are more accurate indicators of total offal fat than is caul alone. However, unpublished data of the Texas station on groups of steers of similar breeding and feeding show a high degree of correlation between the weights of caul fat and ruffle fat, and since the two together make up a very large part of the total offal fat, it is scarcely possible that the correlation of the combined weights of caul and ruffle with total offal fat could be as small as the correlation of the weights of caul fat alone with total offal fat.
Using the figures for the 26 Missouri steers as being the most comparable to conditions ordinarily encountered in a feeding experiment, the equation for estimating fatness from the percentage of caul fat to live weight is:

\[
\text{Percentage of fat in entire live animal} = 5.19 \text{ per cent} + 14.55 \times \text{percentage of caul fat to live weight.}
\]

The fact that the constant in this equation (5.19 per cent) is of considerable size agrees well with that practical formula of the packing plant in which 2 pounds per animal was allowed for edible non-carcass fat in addition to whatever was calculated from the weights of the caul and ruffle.

**USE OF A COMBINATION OF DRESSING PER CENT AND PER CENT OF OFFAL FAT AS AN INDICATOR OF FATNESS**

Of the indicators considered so far it has been shown that for groups of cattle the per cent of offal fat to live weight is the most reliable indicator of fatness, and dressing per cent is also valuable although not nearly so reliable. A combination of the two should prove more reliable than either one alone. Using all 43 animals, the correlation between dressing per cent and per cent of offal fat is \( +0.472 \pm 0.080 \), and the coefficient of multiple correlation of per cent of fat in the entire body with dressing per cent and per cent of offal fat is \( +0.934 \), which shows that a combination of the two indicators is a very distinct improvement over either one alone. Using only the 30 beef-bred Missouri steers, the coefficient of correlation between dressing per cent and per cent of offal fat is \( +0.728 \pm 0.058 \), and the coefficient of multiple correlation of per cent of fat in the entire body with dressing per cent and per cent of offal fat is \( +0.966 \), which is only a slightly higher coefficient than the simple correlation coefficient between per cent of fat in the entire animal and the per cent of offal fat. Since the addition of dressing per cent to per cent of offal fat improved the accuracy of the indicator so much in the case of the entire 43 head, but only slightly in the case of the 30 head of fairly uniform breeding which were slaughtered under uniform conditions, it seems probable that one or both indicators are affected very much by differences in breed, sex, and differences in slaughter technique. Therefore dressing per cent should always be included when the comparison is between cattle slaughtered at different places or at different times, but is not so necessary when the cattle being compared have all had the same shipment conditions and the same treatment in slaughtering. However, the inclusion of dressing per cent adds a little to the accuracy even under the most uniform conditions, and for the sake of completeness it should always be given, even though it may not be used as an indicator of fatness.

Using Wright's \((17)\) path coefficients to form a score card having as its object the most accurate prediction of fatness from a knowledge of dressing per cent and per cent of offal fat, the score card where all 43 animals are considered is:

<table>
<thead>
<tr>
<th>Per cent</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dressing per cent</td>
<td>43.2</td>
</tr>
<tr>
<td>Per cent of offal fat</td>
<td>56.8</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>
and the standard error of estimate is only 35.7 per cent as large as the original standard deviation. The multiple regression equation is:

\[
\text{Per cent of fat in entire animal} = 3.130 \times \text{(per cent of offal fat)} + 0.940 \times \text{(dressing per cent)} - 46.52 \times \text{per cent.}
\]

Where only the 30 beef-bred Missouri steers are used the score card is:

<table>
<thead>
<tr>
<th>Per cent</th>
<th>Dressing per cent</th>
<th>Per cent of offal fat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32.9</td>
<td>67.1</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

and the standard error of estimate is only 25.8 per cent as large as the original standard deviation. The multiple regression equation is:

\[
\text{Per cent of fat in entire animal} = 4.65 \times \text{(per cent of offal fat)} + 0.716 \times \text{(dressing per cent)} - 36.82.\]

These score cards and prediction equations show vividly the lesser importance of dressing per cent as an indicator of fatness under uniform conditions, and its greater importance in comparing results obtained in different places or in different years or with different classes of animals.

One very evident reason why dressing per cent and per cent of offal fat combine to make a better indicator of fatness than either does alone is that, except in so far as they both indicate fatness, they are mutually antagonistic. That is, a high percentage of offal fat would mean a low dressing per cent if all other conditions were equal. This is apparent from the following formula:

\[
\text{Dressing per cent} = \frac{A}{A+B+C} \quad \text{and per cent of offal fat} = \frac{B}{A+B+C},
\]

where

- \(A\) = weight of dressed carcass,
- \(B\) = weight of offal fat,
- \(C\) = weight of noncarcass parts other than offal fat.

An increase in \(B\) unaccompanied by a proportionate increase in \(A\) and \(C\) will mean a lower dressing per cent and a higher per cent of offal fat. Likewise, an increase in \(A\) unaccompanied by proportionate increase in \(B\) and \(C\) will mean a higher dressing per cent and a lower per cent of offal fat. Knowing this relation one would expect to find a negative correlation between dressing per cent and per cent of offal fat, unless there is some common cause which makes \(A\) vary somewhat in proportion to \(B\). That fatness is this common cause is shown by the fact that the partial correlation coefficient between dressing per cent and per cent of offal fat (for a constant per cent of fat in the entire animal) is negative, being \(-0.33\) when only the 30 beef steers from Missouri are considered and \(-0.46\) when all 43 animals are included.

Before leaving this subject it may be well to consider the limits of accuracy of estimations of fatness made by using these equations. For the entire 43 head the standard deviation of per cent of fat in the entire body is 9.08 per cent and the probable error for any one animal at random is 6.12 per cent. The use of the prediction equation will reduce the standard error of estimate to only 35.7 per cent of the original standard deviation (as shown by the multiple correlation coefficient of +0.934). The probable error of the estimated value of the fatness of a single animal will be 35.7 per cent of 6.12 per cent,
or 2.18 per cent. For groups of cattle the probable error of the estimated fatness will vary inversely as the square root of the number of animals in the group. This means that the probable error of the estimated value would equal the above figure (2.18 per cent), divided by the square root of the number of animals considered. Thus, for the ordinary experimental lot of 10 animals the probable error of the estimated percentage of fat in the entire live animals would be 0.69 per cent. For a group of steers of similar breeding slaughtered under the same conditions (using the data for the 30 beef-bred steers from Missouri) the standard deviation is 9.93 per cent and the probable error for a single individual is 6.70 per cent. The use of the prediction equation will reduce the standard error of estimate to 25.9 per cent as large as the original standard deviation (as shown by the multiple correlation coefficient of +0.966), and therefore the probable error of the estimated fatness of a single animal will be 1.74 per cent and the probable error for the average of a group of 10 will be 0.55 per cent. It will be seen from the size of these probable errors that carrying the figures for percentage of fat in the entire animal to the second decimal place is a useless procedure, and that many of the figures given in this paper are carried out to more decimal places than are significant. They are left in this extended form, however, in order to show the derivation of the equations and to make it easier to add any future data which may be obtained. It is the writer’s suggestion that the prediction equations should be used as given and that the figure thus obtained for percentage of fat in the entire animal should be used only to the first decimal place.

USE OF A COMBINATION OF DRESSING PER CENT AND PER CENT OF CAUL FAT TO PREDICT THE PER CENT OF FAT IN AN INDIVIDUAL ANIMAL

It is sometimes desirable to study the fatness of individual animals within a lot. For this purpose dressing per cent (based on the feed-lot weights and warm-dressed weights) is very easily obtained. Also, it is not much trouble to weigh the caul fat for each steer separately (if the investigator will get the weights himself), and without a very great deal of trouble it is possible to weigh the ruffle fat individually. It is hardly practicable to go beyond that with individual weights of offal fat.

The weights of the caul fat were given for most of the animals included in this study, but the ruffle was not given separately. If the opinions expressed by the practical packing men are correct, that the proportion of caul to ruffle varies widely in different classes of cattle, it is probably unsafe to use the per cent of caul for estimating fatness except between animals which are of the same breed, age, and sex. Even under such conditions it is likely that it is not as accurate an indicator as the combined weights of caul and ruffle. However, the writer has no figures on the ruffle fat for these 43 animals, and so can not compare the accuracy of caul and ruffle combined with the accuracy of caul alone. It may be seen, however, how much the accuracy of prediction for an individual animal is increased when both the dressing per cent and the per cent of caul fat are considered as compared to its accuracy when based upon either one alone.

The correlation between dressing per cent and per cent of caul fat is $+0.570 \pm 0.077$ for the entire 35 animals for which caul weights
were given. For the 26 beef-bred Missouri steers this correlation was \( +0.745 \pm 0.059 \). Using the former figures, the coefficient of multiple correlation is \( +0.917 \), which is a decidedly higher correlation than the \( +0.775 \) between fatness and dressing per cent, or the \( +0.845 \) between fatness and per cent of caul to live weight. The prediction equation (multiple regression equation) is as follows:

\[
\text{Per cent of fat in live animal} = 0.861 \times \text{(dressing per cent)} + 7.684 \times \text{(percentage of caul to live weight)} - 40.24\%.
\]

The standard error of estimate is about 39.9 per cent as large as the original standard deviation, thus making the probable error of the estimated fatness for a single animal about 2.60 per cent.

Using only the figures for the 26 Missouri steers (which are probably more applicable to most cases on account of the uniformity of the conditions under which they were taken), the coefficient of multiple correlation is \( +0.941 \), which is somewhat of an improvement over the \( +0.865 \) between fatness and dressing per cent and the \( +0.892 \) between fatness and per cent of caul fat to live weight for these same 26 steers. The prediction equation is as follows:

\[
\text{Per cent of fat in live animal} = 0.936 \times \text{(dressing per cent)} + 9.073 \times \text{(percentage of caul to live weight)} - 44.96\%.
\]

The standard error of estimate is only about 33.8 per cent as large as the original standard deviation, thus making the probable error of the estimated fatness for a single animal about 2.33 per cent.

It is the writer's opinion that the latter equation is the more accurate for use in comparing steers of uniform breeding. Where different sexes or ages or breeds are to be compared it probably will be best to use total offal fat, and to use caution in drawing conclusions even from that. If individual comparisons are to be made between heifers within a lot the latter equation, involving caul fat and dressing per cent, will probably furnish a good relative guide to their fatness, but it may give absolute figures which are too high (on account of the larger proportion of caul fat which heifers are popularly supposed to have) to be used in comparison with a group of steers. A difference in age may also make the absolute figures wrong, although it must be admitted that the data on which this article is based showed no clear evidence of any such effect of age independent of the changes in fatness which normally take place with age.

**PER CENT OF BONE IN THE DRESSED CARCASS**

In many experiments, especially those comparing animals of different types or ages and those in which minerals are fed, it would be helpful in interpreting the results to know what proportion of bone was in the sides of dressed beef. A chemical analysis is not necessary to determine the percentage of bone to meat but it is necessary to determine the fatness of the meat, and Dechambre (2) and Mackenzie and Marshall (10) have shown that fatness has a great deal of influence on the percentage of bone in meat.

The most practical indicator of the percentage of bone in the dressed sides seemed likely to be the weight of the four legs, below the knees and the hocks, as removed by the butchers in the packing plants. This weight includes all of the legs below the knee and hock joints, except the skin and the dewclaws, which are removed before the legs are unjointed. This weight can be obtained without
much trouble in any packing plant. The correlation between the percentage of bone in the dressed sides and the percentage which the legs are of the live animal (as shown in fig. 7) is $+0.898 \pm 0.020$ for the entire 43 head for which the data were obtained, and is $+0.948 \pm 0.012$ for the 30 beef steers from Missouri. These are both high correlations, the standard error of estimate being 44.0 per cent and 31.8 per cent (respectively) as large as the original standard deviations. It is evident, however, that both variables are influenced to a marked extent by fatness, because increases in fatness would lower both of the bone percentages more or less together and decreases in the amount of fat would raise both the bone percentages more or less together. Since the data cover a wide range of fatness, this effect of variations in fatness may account for much of the correla-

Fig. 7.—The relation between percentage of leg bones to live weight and percentage of bone in dressed sides of beef. The straight line is the equation $z=10.22y+0.04$, and is based on only the 24 Missouri steers which do not show the abnormally high percentage of leg bones to live weight.

Figures 8 to 9 show the relation of fatness to percentage of bone in the dressed carcass and to the percentage of leg bones to live weight. Both of these relations are slightly nonlinear, due especially to the six young, thin Missouri steers which have an unusually high percentage of bone and of legs but a very low percentage of fat. That this is an effect of age seems fairly certain from the fact that all three of the calves slaughtered at 3 months of age are in this group of six which have such an extremely high proportion of leg bones. The other three are the two most poorly nourished of the three which were slaughtered when a little older than 5 months, and the most poorly nourished one of the three which were slaughtered at a little over 8 months of age.
Due to the nonlinearity of the relations shown in Figures 8 and 9 the use of the coefficient of correlation is not completely justified, but on account of the influence of age as well as fatness it was not thought worth while to work out an "index of correlation," and instead four coefficients of correlation were worked out for each of Figures 7, 8, and 9. One included all individuals, one included all individuals except the six young Missouri steers which showed such high percentages of bone, one included all Missouri steers, and the fourth included only the 24 Missouri steers which did not show the unusually high percentages of bone. The last probably most nearly shows conditions as they would exist in an ordinary feeding trial, but even it is not completely free from the influences of age (Table II).

![Figure 8](image)

**Figure 8.—The relation between percentage of fat in entire live animal and percentage of bone in dressed sides of beef**

<table>
<thead>
<tr>
<th>Group</th>
<th>$r_{Bone . Leg bone}$</th>
<th>$r_{Bone . Fatness}$</th>
<th>$r_{Fatness . Leg bones}$</th>
<th>$Fatness r_{Bone, Leg bones}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>43 head</td>
<td>+0.898±0.020</td>
<td>-0.860±0.027</td>
<td>-0.827±0.020</td>
<td>+0.651</td>
</tr>
<tr>
<td>43 less 6</td>
<td>+0.774±0.044</td>
<td>-0.834±0.034</td>
<td>-0.833±0.034</td>
<td>+0.290</td>
</tr>
<tr>
<td>30 steers</td>
<td>+0.946±0.012</td>
<td>-0.916±0.021</td>
<td>-0.845±0.030</td>
<td>+0.811</td>
</tr>
<tr>
<td>30 less 6</td>
<td>+0.914±0.023</td>
<td>-0.927±0.019</td>
<td>-0.906±0.025</td>
<td>+0.467</td>
</tr>
</tbody>
</table>

The exclusion of the six young, thin steers slightly lowers the primary correlation coefficient between per cent of bone in dressed sides and per cent of leg bones to live weight. The exclusion of these six steers markedly lowers the partial correlation coefficient between these same two variables, with fatness constant. The lower values of the partial coefficients show that much of the primary correlation was due to fatness. The effect of excluding the six young, thin steers shows
that much of the primary correlation coefficient between percentage of bone in the dressed sides and percentage of leg bones to live weight was due to the changes of growth. That is, in the very young, thin steers the skeleton is at a more advanced stage of development than the muscles or fat. Probably some influences of age and growth still appear, even in the smallest of the partial correlation coefficients.

It seems safe to conclude that the weight of the leg bones is a good indicator of the proportion of bone in the dressed sides of beef, but that this is largely a secondary effect of the primary factors of age and fatness. If animals uniform in age and fatness are being compared the indicator will not be nearly so accurate, but there will still be a significant positive correlation between percentage of bone in the dressed sides and percentage of leg bones to live weight. Whether breed and sex differences would affect the accuracy of the indicator is not known.

Probably the most reliable prediction equation would be that based upon the 24 Missouri steers, since steers as thin as the other 6 Missouri steers are not often slaughtered commercially. That equation is as follows:

$$\text{Per cent of bone in dressed sides} = 0.04 + 10.22 \times \text{percentage of leg bones to live weight}$$

The probable error of the estimated value for a single individual would be about 1.01 per cent. On account of the wide range in the fatness of the animals from which this equation was derived caution should be used in applying it to other cattle. Figure 7 shows the line representing this equation, and it will be seen that the line does not fit equally well the younger and the older steers. The steers under 1 year of age show more variation and would seem to be better fitted by a line with a steeper slope. The steers over 1 year of age show very little variation from a straight line which would have less
slope than the one shown. The numbers of the steers are probably too small to justify more detailed calculations in regard to this point, but it should be kept in mind that the use of this equation is apt to result in values for the percentage of bone in dressed beef which will be slightly too high for very fat mature steers and too low for thin mature steers.

**RELATION OF DRESSING PER CENT TO PER CENT OF BONE**

On the basis of general observations it is rather commonly believed by animal husbandmen that cattle with small bones have a higher dressing per cent than big-boned cattle, other things being equal. The relations between dressing percentage and percentage of bone are slightly curvilinear, and therefore the cattle were studied separately in the same four groups used previously in studying the relation between percentage of bone in the dressed meat and the percentage of leg bones to live weight. It is obvious that the degree of fatness will have a great deal of influence upon both of these variables, and therefore that it will be necessary to calculate a partial coefficient of correlation between dressing per cent and per cent of bone in dressed meat, fatness being constant. The necessary correlation coefficients are shown in Table III. From this table it will be seen that the very real tendency for a high dressing per cent to be associated with a low percentage of bone is very largely a result of the effect of fatness upon both of these variables. The partial correlation coefficients show a general tendency to be negative, but are so small that their significance is doubtful. It seems safe to conclude that, aside from their relations with fatness, dressing per cent and per cent of bone have little or no relation to each other. This, of course, does not mean that size of bone may not have a causal relation to fatness, and through that relation to dressing per cent. Thus it might be that fine-boned cattle tend to get fatter than large-boned cattle under the same conditions. The data in this paper tell nothing about that. Also, it is possible that size of bone as measured by cannon circumference may not be perfectly correlated with the weight of the bones in the dressed meat. If it is not, then size of bone studied from the standpoint of cannon circumference might show quite different relations with dressing per cent.

**TABLE III.—Primary correlation coefficients between dressing per cent, percentage of bone in dressed meat, and percentage of fat in entire live animal. Partial correlation coefficients between dressing per cent and percentage of bone in dressed meat, fatness being constant**

<table>
<thead>
<tr>
<th>Group</th>
<th>rBone . Dressing</th>
<th>r Bone . Fat</th>
<th>r Fat . Dressing</th>
<th>Fatness r Bone . Dressing</th>
</tr>
</thead>
<tbody>
<tr>
<td>43 head</td>
<td>-0.706±0.052</td>
<td>-0.860±0.027</td>
<td>+0.760±0.043</td>
<td>-0.158</td>
</tr>
<tr>
<td>43 less 6</td>
<td>-0.686±0.059</td>
<td>-0.834±0.034</td>
<td>+0.722±0.053</td>
<td>-0.220</td>
</tr>
<tr>
<td>30 steers</td>
<td>-0.766±0.051</td>
<td>-0.910±0.021</td>
<td>+0.842±0.036</td>
<td>+0.001</td>
</tr>
<tr>
<td>30 less 6</td>
<td>-0.778±0.054</td>
<td>-0.927±0.019</td>
<td>+0.858±0.043</td>
<td>-0.050</td>
</tr>
</tbody>
</table>

The whole problem of size of bone in its relation to meat value, to the desirability of cattle as feeder cattle, and to the desirability of cattle for range-beef production is a large one and is largely outside the scope of this paper. Perhaps the facts just presented may make some contribution toward its solution.
USE OF FATNESS INDICATORS IN THE INTERPRETATION OF FEEDING EXPERIMENTS

In Part I of Bulletin No. 309 of the Texas Agricultural Experiment Station (7) are given the results of a feeding experiment designed to test out the desirability of adding corn to a ration of cottonseed meal and hulls for fattening steers. As was expected, the lot receiving the corn made greater gains, but more expensive gains, than those which received only meal and hulls, and the question of profit resolved itself very largely into a question of the relative desirability of the two lots from the butcher’s viewpoint after the feeding was completed, and the question of efficiency of the two rations for producing gain in weight depended for its answer very largely upon what proportion of the gain made by each lot was fat and what part was protein or material other than fat. In that bulletin is this statement:

* * * it will be seen that Lot III dressed out 1.14 per cent heavier than Lot IV and possessed over 50 per cent more internal fat than Lot IV. Among partially fat animals of the same breeding and the same treatment previous to fattening the amount of this internal fat may be taken as a fair indication of the total amount of fat which they carry. This difference in the amount of internal fat agrees fairly well with the difference in total gain which they made in the feed lots at Spur, in which Lot III gained about 40 per cent more total weight than Lot IV.

It would have been more satisfactory to have had a more definite knowledge of the amount of fat and the amount of nonfat gained by each lot. An estimate of this can be obtained by using the prediction equation derived from the data for the 30 beef-bred steers from Missouri (since Lots III and IV in Texas bulletin 309 were quite uniform, being almost all half brothers or more closely related and all coming from the same herd). The data are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Lot III</th>
<th>Lot IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm dressing per cent</td>
<td>56.31</td>
<td>54.85</td>
</tr>
<tr>
<td>Per cent of offal fat</td>
<td>5.93</td>
<td>3.91</td>
</tr>
</tbody>
</table>

From the equation the percentage of fat in the entire live animals is 31.07 for Lot III and 20.63 for Lot IV, and the deduction can be made that the average steer in Lot III contained in his body 149 pounds more of true fat than did the average steer in Lot IV. If the equation derived from data from all the 43 head discussed in this paper is used the percentages of fat in the live animals are 25.02 and 17.31, and the average Lot III animal contains in its body 112 pounds more fat than the average Lot IV animal. The use of the equation involving only dressing per cent gives values of 13.94 per cent and 11.34 per cent, which are certainly much too low, while the use of the equation involving only offal fat gives values of 37.68 per cent and 24.95 per cent, which probably are too high. The disagreement among the results of the four equations is due to the varying amount of emphasis placed upon dressing per cent by the different equations. As already noted, there is an indication in the dressing per cent figures that the slope of this equation would be much steeper if it were confined to older steers. If that is true it explains why the use of the dressing per cent equation gives too low values in the case of these steers, which were almost mature. It is also probable that the very bulky nature of their ration caused their
final feed-lot weights to include a rather unusual amount of "fill," which would account for the low dressing per cent. All four equations agree that the Lot III steers were fatter than the Lot IV steers, although the estimates of the additional amount of fat in the average Lot III steer vary from 43 to 181 pounds.

Because of the greater uncertainties about the figures based upon dressing per cent, the writer is inclined to place most confidence in the results obtained by the method which values dressing per cent the least without neglecting it altogether. That is the combination equation based upon the 30 Missouri steers. Moreover, the results of this equation are in closest agreement with the judgment of the practical experts as to the condition of the animals if the figures given by Murray (14) for the percentage of fat in animals of different grades are accepted.

As shown by the live weights the average steer in Lot III gained 386 pounds and the average steer in Lot IV gained 289 pounds, a difference of 97 pounds. If the estimation of 149 pounds more fat at slaughtering time in the average Lot III steer than in the average Lot IV steer is accepted, and it is assumed that they were equally fat at the beginning of the feeding (as they probably were, approximately, because they were divided into two lots with that as one of the main points on which division was based), then it follows that the average Lot III steer gained 149 pounds more of fat and 52 pounds less of nonfat live weight than the average Lot IV steer. Assuming that the equation used was the one best suited to this case, the probable error of the estimated difference in fat in the gains made by the average steer of the two lots would be a little more than 9 pounds. Deviations of this estimate from the true value may account for part of the extra 52 pounds of increase in nonfat live weight attributed to the Lot IV steers. Part of that 52 pounds may be attributed perhaps to the greater bulkiness of the ration fed to the Lot IV steers, this causing them to develop more paunchiness than the Lot III steers and thus to be weighed in the final feed-lot weighings with more feed and water in their digestive tracts than the Lot III steers had. Part of that 52 pounds may actually represent an increased growth of muscle, or bone, stimulated by the nature of the ration, although there is little evidence from studies of nutrition to support such a possibility. Assuming that these figures of 149 pounds more of fat and 52 pounds less of nonfat live weight are correct, the following calculations would be logical:

If the fat-free live weight contains about 28 per cent dry matter (12), and a pound of fat contains about 1.67 times as much energy as a pound of fat-free dry matter, then each pound of increase in fat would have required about six times as much energy from the food as each pound of fat-free increase in live weight. Thus the 52 pounds of extra gain in nonfat live weight made by Lot IV is equivalent, on an energy basis, to about 9 pounds of fat, and the average steer of Lot III can be regarded as having produced 140 pounds more of fat per steer in 120 days on a ration which was calculated to have supplied 807.6 more therms of net energy per steer in that period. Using Armsby's (1) figure of 4.309 therms per pound as the energy content of a pound of fat, the 140 pounds of extra fat gained will account for 603.3 therms of the excess fed to Lot III, leaving only 204.3 therms of excess net energy per steer unaccounted for. This is less than 10
per cent of the estimated net energy content of the total ration fed to the Lot III steers. Whether it is to be ascribed to faulty estimation of the amount of fat in the gain, to a higher maintenance requirement of the Lot III steers after they had become fat, to less perfect digestion by them on account of the much larger quantity of grain in their ration, or whether the net energy values used for cottonseed meal or cottonseed hulls, or both, were lower in comparison to the net energy value used for ground shelled corn than they should have been, can not be determined from these data.

If the estimated figures of 149 pounds more fat and 52 pounds less nonfat live weight are regarded as incorrect, and one prefers to regard the difference in gain made by the two lots (97 pounds per head) as composed entirely of fatty tissue of the maximum degree of fatness (about 95 per cent) and to suppose that the remainder of the gains made by the Lot III steers were identical in composition with the entire gains made by the Lot IV steers, then this extra 97 pounds of fatty tissue would account for about 400 therms of the excess net energy calculated to have been fed to Lot III, and about 400 therms would remain unaccounted for in the rations fed to each Lot III steer. This is about 20 per cent of the entire ration fed to the Lot III steers and may be accounted for by some of the reasons enumerated in the preceding paragraph.

The results of these calculations lack much that is to be desired in the way of exactness, but they seem to be an improvement over the statement in Texas bulletin No. 309 (7) that the steers of Lot III required 3.55 therms per pound of gain and the steers of Lot IV required 1.93 therms per pound of gain, and the necessarily general statement that much of this difference must have been due to the larger proportion of fat which probably characterized the gains of Lot III. These calculations give a better picture of what actually took place in these steers during the feeding process, and therefore they seem quite worth while, although they are estimates based upon the average performance of other steers and they can not be considered quite as exact as things which could be weighed or measured on the Lot III and Lot IV steers themselves.

In the other comparison in Texas bulletin No. 309—i. e., the comparison between steers which were not quite 2 years old (Lot I) and steers which were not quite 3 years old (Lot III), both lots being fed the same ration—the calculations can not be carried quite so far. Here it can not be assumed that the two lots contained the same percentage of fat when they went on feed. Not only did the older steers probably contain a larger percentage of fat, because that is usually the case with older cattle, but the younger cattle were also judged to be thinner at the beginning of the feeding. The dressing per cent of Lot I (basis of final feed-lot weights and warm-carcass weights) was 53.99 per cent and the per cent of offal fat was 4.54. Using the equation derived from the 30 beef-bred Missouri steers, the per cent of fat in the average steer of Lot I is 22.95 per cent, which agrees well with the opinions of the men who saw the cattle and also with the prices paid for them. However, this figure can not be used in testing the uses to which the net energy in the rations was put without making some sort of an assumption about the percentage of fat in the Lot I steers when they went on feed. Probably all that is justified is the conclusion that since the older steers were much fatter at the close of the feeding period their gains contained a higher
proportion of fat than did the gains of the younger steers. It is possible that the apparently greater efficiency of the younger cattle may be entirely explained on this basis.

It would appear that if this relation between dressing per cent, offal fat, and fatness is to be used to the greatest advantage, the comparison must be between two lots which can be assumed to be of the same degree of fatness at the beginning, or, if that is not possible, several steers from each lot must be slaughtered as a sample at the beginning of the feeding test.

COMPOSITION OF THE RIB FLESH AS AN INDICATOR OF THE FATNESS OF THE ENTIRE ANIMAL

In experiments where only a part of the beef animal has been analyzed for fatness (6, 10), the portion most frequently used has been the rib cut. In a letter to the writer C. Robert Moulton, who was responsible for collecting and analyzing much of the Missouri data used in this study, says in reference to the composition of the wholesale rib cut: "When at Missouri Doctor Trowbridge and myself from a survey of our data came to the conclusion that the wholesale rib cut rather adequately represented the carcass."

In the rather extensive plans now being made by a number of research agencies for the study of meat composition and quality, the question of analyzing some part of the dressed carcass is frequently considered. Therefore it may be appropriate to consider here the reliability of the fatness of the flesh of the wholesale rib cut as an indicator of the fatness of the entire animal. Of course the chemical analysis of the rib flesh would require the destruction of that cut as well as an expense for the cost of the chemicals and labor used in the analysis. Therefore such procedure would not

Fig. 10.—The relation between percentage of fat in the entire animal and the percentage of fat in the flesh of the wholesale rib cut. The straight line is the prediction equation, \( y = 0.603x + 3.92 \) per cent, and is based on all animals shown.
ordinarily be practicable with cattle sold to commercial packing plants. However, the experimenter might arrange in advance for the purchase of the wholesale rib cuts from the packing plant for analytical purposes. Certainly many more investigators could do this than could undertake to analyze entire steers.

Figure 10 shows the relation between the percentage of fat in the entire live animal and the percentage of fat in the flesh of the wholesale rib cut. The 30 Missouri steers, the 3 Missouri Jerseys, and the 3 Illinois steers are included. The relation seems to be linear, and the coefficient of correlation is \( +0.987 \pm 0.003 \).

The standard error of estimate is only 16 per cent as large as the original standard deviation, and the probable error of the estimated fatness for a single steer is about 1.04 per cent. The equation for predicting fatness is:

\[
\text{Percentage of fat in live animal} = 0.603 \times \text{(percentage of fat in rib flesh)} + 3.92 \text{ per cent.}
\]

This indicator is more reliable than any one of those already discussed or any combination of them. Moreover, differences in sex and breed of the cattle slaughtered and differences in slaughter technique seem to have less influence upon this indicator than upon the others already discussed. It would seem, therefore, that the analysis of the flesh from the wholesale rib cut might be well worth while in experiments in which it is important to determine exactly the degree of fatness of the entire animal. For the worker who has the means of making these analyses the use of the other indicators of fatness would probably be of interest only for checking the results of the analysis of the rib flesh. For the very large number of animal husbandry workers, however, who are not in a position to buy and analyze the ribs of the cattle they have fed, the use of the indicators previously discussed should prove helpful.

SUMMARY

The object of this study was to find whether there were any reliable quantitative indicators of the percentage of fat in the bodies of cattle and of the percentage of bone in the dressed sides of beef which could be obtained easily in commercial packing plants. This study is based upon the published records of the slaughtering of 30 steers and 3 cows at the Missouri station, 4 steers at the Maine station, 3 steers at the Illinois station, and 3 steers slaughtered by Lawes and Gilbert in England.

The percentage of true fat in the lean and fat flesh and the percentage of true fat in the entire live animal were almost perfectly correlated.

The percentage of true fat in offal fat and in kidney fat bears a very definite relation to the fatness of the animal, but that relation is curvilinear and not adopted for use as an indicator.

The percentage of offal fat to live weight was found to be the most reliable single indicator of fatness.

The percentage of caul fat to live weight was found to be the most reliable, but it would lose much of its reliability if used in comparing different breeds or sexes.

Dressing per cent was found quite reliable where wide ranges of fatness were compared, but not very reliable within narrow limits of fatness.
A combination of dressing per cent and percentage of offal fat to live weight is recommended as the most reliable indicator of fatness for groups of cattle.

A combination of dressing per cent and percentage of caul and ruffle fat to live weight is recommended as the most reliable indicator of fatness for individual animals.

The percentage of leg bones to live weight is shown to be a very good indicator of the percentage of bone in the dressed sides of beef, but this is largely a secondary correlation resulting from extreme differences in fatness and age among the animals studied.

The percentage of bone in dressed meat is negatively correlated with dressing per cent to a very high degree. This correlation is largely a secondary result of the high correlation between the degree of fatness and each of these two percentages. There is little or no evidence of any relation between dressing per cent and percentage of bone in dressed meat when the degree of fatness is constant.

Prediction equations are given for the use of these indicators, and their limits of accuracy are discussed. The most reliable and useful prediction equations found are as follows (final feed-lot weight being used as the live weight in all formulas where live weight is involved):

(a) Fatness of groups of cattle:

\[
\text{Per cent of fat in entire live animal} = 4.65 \text{ (per cent of offal fat to live weight)} + 0.716 \text{ (dressing per cent)} - 36.82 \text{ per cent.}
\]

(b) Fatness of individual animals of the same sex:

\[
\text{Per cent of fat in entire live animal} = 9.073 \text{ (per cent of caul fat to live weight)} + 0.936 \text{ (dressing per cent)} - 44.96 \text{ per cent.}
\]

(c) Percentage of bone in dressed carcass = 10.22 (percentage of leg bones to live weight) + 0.04 per cent.

The use of such estimations in interpreting feeding experiments is illustrated by an example, using data from Texas bulletin No. 309.

The percentage of fat in the flesh of the wholesale rib cut is a more accurate indicator of the degree of fatness of the entire animal than any of the other indicators studied. Where the chemical analysis necessary for this determination is practicable its use is recommended. Its prediction equation is:

\[
\text{Per cent of fat in entire animal} = 0.603 \text{ (per cent of fat in rib flesh)} + 3.92 \text{ per cent.}
\]

LITERATURE CITED


