The Conservation of Food Energy

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For many years investigators in this and other countries have been engaged in studying the values of foods and feeding stuffs as sources of energy. The following pages are submitted in the belief that the accumulated results of the researches in this and other laboratories are capable of useful application and should if possible be made of service in the present food situation.

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INTRODUCTORY

Within the past year the United States has been rudely awakened from its dreams of plenty to be faced with the urgent problem of maintaining the food supply for itself and for its allies in the face of all the difficulties incident to a state of war. A National Food Administration has been created and entrusted with large powers to deal with all phases of the complex situation. Questions of the labor supply, marketing, price control and transportation are being dealt with in a large way, while nation-wide propaganda have been launched for an increased food production by the farmer and for greater economy on the part of the consumer.

Crude Products Inedible.—But however bountiful the farmer's crops, in their crude state they are not human food. Some of them, like hay or the straw of his grain crops, can be utilized only indirectly by feeding them to live stock. Others, like wheat and corn, while they can also be used as animal feeds, are commonly thought of as being directly available to man. This, however, is only partially true. While wheat may be fed to live stock, man does not eat wheat but wheat flour and a bushel (sixty pounds) of wheat yields only about forty-three and one-half pounds of white flour along with sixteen and one-half pounds of milling offals useful only as stock feed.

Two Methods of Utilization.—Two alternatives, then, are open for the conversion of farm crops into human food:

First, they may be fed directly to animals to produce beef, mutton, pork or milk.

Second, such of them as admit of it may be subjected to various manufacturing processes—milling, starch and glucose manufacture, oil extraction, brewing, distilling—by which a greater or less proportion of them is converted into forms acceptable for man's use, and the by-products of these operations may be utilized in the production of meat or milk.

Their Relative Efficiency.—In any scheme of food conservation it is clearly of vital importance to know the relative efficiency of the various methods just indicated. How can we get the greatest human food value out of a bushel of wheat or of corn? Shall we feed it to live stock and if so, shall we use the beef steer, the mutton sheep, the hog or the dairy cow as the mechanism for converting it into edible products? Or shall we manufacture it into flour or table meal or use it as a source of starch or glucose or alcoholic beverages, and feed only the residues of these processes to live stock, and if the latter alternative is adopted, to what kind of live stock can they best be fed?

This publication is an attempt to contribute certain data toward the solution of this problem as regards some of the more important farm products. Sections I to XIII show in some detail the methods employed while Section XIV attempts to summarize the broader teachings of the inquiry. In addition to such published data as could be found the author is under obligation to the following correspondents for information regarding the commercial yields of foods and by-products in the various manufacturing operations considered.

Milling:—

Prof. Harry Snyder, The Russell-Miller Milling Co., Minneapolis, Minn.

Mr. B. W. Dedrick, Instructor in Milling Engineering, The Pennsylvania State College.

Director W. R. Dodson, Louisiana Experiment Station.

Glucose Manufacture:—

Mr. G. W. Moffett, Vice-President, Corn Products Refining Co., New York.

Brewing and Distilling:—

Dr. H. W. Wiley, Washington, D. C.

Dr. Robert Wahl, American Brewers' Review, Chicago, Ill.

Mr. Louis Rosenfield, Sunny Brook Distillery Co., Louisville, Ky.

Mr. A. M. Breckler, The Eflorose Sugar Co., Cincinnati, Ohio.

Oil Production:—

Mr. H. S. Bailey, Bureau of Chemistry, U. S. Dept. of Agriculture.

Mr. Cecil O. Philips, Sec'y, Union Seed and Fertilizer Co., New York.

I

THE MEASURE OF FOOD VALUES

A beefsteak, a slice of bread and a glass of milk cannot well be compared directly as to their nutritive values. Before comparisons such as those indicated in the introduction can be made there must be some common standard by which to measure the food values of a great variety of diverse materials. As a preliminary to the choice of such a standard a brief consideration of the three main purposes which the food serves appears necessary.

What Food Supplies.—First, food supplies building material for the growth of the various tissues and organs in the young animal and for their maintenance and repair in the mature one. In general these building materials are of two kinds: the mineral substances, which are required for the bones and in less degree for all the organs, and the proteins out of which the muscles and other working parts of the body are built up.

Second, it supplies energy for the various activities of the internal organs which are necessary to sustain life, and for the performance of work. The food is in a very real sense the fuel of the body, much as gasoline is the fuel of the auto or aëroplane, supplying the power to drive it and incidentally yielding heat to keep it warm.

Third, all food contains minute amounts of substances called vitamines, of which there appear to be two groups, the fat-soluble and the water-soluble. These vitamines furnish no appreciable amounts of building material nor of energy but their presence is essential to the various operations of the bodily machinery, especially in growth. In a very crude way they may be said to be somewhat like the oil which neither serves as fuel nor repair material for the engine and yet is essential to its smooth running.

Food Energy.—All food is produced primarily from the constituents of the soil and the air by the higher (chlorophyl-bearing) plants. The motive power for the transformation is supplied by the sun's rays and the sun energy thus absorbed is stored up in the proteins, starches, fats and other ingredients of the plant. It may be estimated that a 50-bushel corn crop would contain in grain and fodder nearly ten thousand therms of energy per acre, sufficient, if it were all converted into heat, to raise the temperature of one hundred tons of water from the freezing to the boiling point or equal to more than fifteen thousand horse-power hours of work. It is this stored-up matter and energy in agricultural products on which both men and animals depend to supply their daily needs.

Of these needs the principal one is that for energy. A man eats, or should eat, in order that he may work and work is simply the expenditure of energy. Along with energy his food also supplies the mineral matters and proteins necessary to keep his body in repair and the vitamines required to ensure its normal functioning, but a large share of his food is of value simply as body fuel.

Availability.—To answer the question raised in the introduction, therefore, how we can get the greatest human food value out of wheat, corn or other products, what we need to know primarily is how much of the energy stored up in them it is possible to render available for running the human machine. While it is true that a due supply of mineral matter, proteins and vitamines in the food is equally *essential*, it is not, from the present point of view, equally *important*, since comparatively slight modifications in a diet supplying sufficient energy can ordinarily remedy deficiencies in this respect. For this reason modern studies of human dietaries give prominence to the energy relations and the problem here raised will be discussed on that basis, i. e., we shall consider how much energy in forms available for human nutrition can be obtained from agricultural products in the various ways indicated in the introduction.

Other Factors.—It is true that the problem of food conservation or of rationing an army or a people is very far from being so simple a thing as merely supplying a certain number of calories of energy or grams of protein. Questions of palatability, of dietary habits, of market facilities, and of costs of fuel, labor, transportation and marketing, both in agricultural and manufacturing industries, all have to be considered. To illustrate, it is shown in subsequent pages that the energy of corn may be most completely utilized by milling it and using only the corn bran for stock feed, and that considerable energy is lost when corn is fed directly to animals. It does not follow, however, that we should ship corn meal to our European allies, even if spoiling in transportation could be prevented, since neither their dietary habits nor their domestic economy render the general use of corn bread practicable. Neither does it necessarily follow that no corn should be fed to live stock, even were the supply less abundant than it is. The energy of grain is carried largely by the starchy materials (carbohydrates). Fats, however, are important constituents of a dietary, both as affecting its palatability and satisfying quality and also for another reason not so often appreciated. Fat is a much more concentrated fuel than carbohydrates. If the attempt were made to sustain a man doing severe physical work, for example, one of our soldiers at the front, on wheat bread alone it may be estimated that he would have to eat about three and three-fourths pounds, an almost impossible quantity. But if three-quarters of a pound daily of fat salt pork and two ounces of butter were furnished, this with the addition of only one pound of bread would fully supply the necessary protein and energy.[1] Considerations of this

[1] It scarcely need be said that this is not suggested as a model ration. It is intended simply to illustrate one reason for the importance of a due amount of fat in the diet.

sort might fully justify the sacrifice of energy incident to the production of pork from corn for the sake of the smaller weight and bulk of the ration and the lessened tonnage required for its overseas transportation, but this can be determined with certainty only when the extent of the sacrifice is known.

The foregoing considerations serve to illustrate the way in which conclusions which might be drawn from energy data alone are subject to important modifications in the actual administration of food control. Nevertheless, the ultimate object of all food control measures is the recovery of the greatest practicable amount of food value from the products of the soil and a fundamental requirement for intelligently combining all the diverse factors under changing conditions is a quantitative knowledge of the efficiency of different methods of procedure in conserving the food supply. The studies of human and animal nutrition during the last twenty years afford data for an approximate computation of this efficiency and the results for some of the more important farm crops are recorded in the following pages.

II

ENERGY IN HUMAN FOODS

How Determined.—The recognized method of estimating the energy supplied in human foods consists in determining first, the amounts of protein, fat and carbohydrates contained in the material and second, the proportions of them which escape utilization when the material is eaten.[1] For example, the average of a large number of analyses shows one hundred pounds of wheat flour to contain 11.4 pounds of protein, 1.0 pound of fat, and 75.1 pounds of carbohydrates, of which 85 per cent., 90 per cent. and 98 per cent. respectively are digestible when the flour is made into bread, so that one hundred pounds of wheat flour supply 9.7 pounds of protein, 0.9 pound of fat and 73.6 pounds of carbohydrates in available form. But each pound of digestible protein or carbohydrates has been shown to supply 1.82 therms[2] of available energy and one pound of di-

[1] While this method takes no account of the mineral ingredients nor of the vitamines it is, nevertheless, sufficiently accurate for practical purposes under ordinary conditions of diet.

[2] For the present purpose a therm is to be looked upon simply as a unit of energy—the yard-stick used in measuring it. Technically, it is defined as the energy equivalent to the heat required to raise the temperature of 1000 kilograms of water one degree centigrade or 3962 pounds of water one degree Fahrenheit.

gestible fat 4.04 therms, and it is thus easily computed that one hundred pounds of wheat flour supply 165 therms of energy for man's use. Since fat and carbohydrates are simply carriers of energy the foregoing statements may be simplified by saying that 100 pounds of wheat supply 9.7 pounds of protein and 165 therms of energy.

Energy Values.—In the following table are given the energy values as thus computed of the food products considered on subsequent pages:

AVAILABLE ENERGY PER 100 POUNDS[1]

	Therms
Wheat flour:	
"Straight" or "standard patent"	165.0
Whole wheat	156.1
Graham	150.5
Corn meal	165.5
Hominy	165.0
Glucose	167.4
Corn oil	422.0
Barley flour	164.0
Beer	21.0
Rye flour	163.0
Oatmeal	185.0
Polished rice	168.5
Buckwheat flour	162.0
Cottonseed oil	422.0
Cottonseed flour	153.0
Peanuts	256.0
Peanut oil	422.0
Milk, 4% fat	28.8
Butter	361.0
Cheese	195.0

[1] Chiefly from Atwater and Bryant, U. S. Dept. of Agr., Office Expt. Stas., Bul. 28 revised.

III

THE EFFICIENCY OF THE ANIMAL

Recovery of Energy.—In its relation to the conservation of the food supply, the animal is a transformer. The grazing steer converts the crude, inedible substances of grass into flesh and fat; the stall-fed dairy cow manufactures from her hay, silage and grain the totally different product milk.

Only a part, however, of the energy and protein contained in the feed of the animal is recovered in the meat, milk or other animal products secured. In order, then, to measure the contribution made by the steer or the cow to the conservation of the food supply it is necessary to know its efficiency as a converter—that is, what proportion of the protein and energy given it in the various feeding stuffs is recovered in the meat or milk produced.

As regards the recovery of energy, extensive investigations by rigid scientific methods, both abroad and in the United States, during the past two decades have yielded results which seem to the writer sufficiently well established to afford a foundation on which to base at least a first approximation to the efficiency of the animal as a conserver of the food supply. As regards protein, the data are, unfortunately, far less satisfactory, while the actual recovery in practice is dependent to a large extent on the proportion of protein in the ration.

Net Energy Values.—The facts concerning energy are conveniently expressed in what have been called net energy values. For example, one hundred pounds of corn contain about 178 therms of energy. When this corn is fed to a steer, however, about 43 therms escape unused in the various excreta and about 50 therms more are lost in the extra heat production which always follows the eating of feed. The remaining 85 therms, equal to 47.75 per cent. of the entire 178 therms, is the portion that is utilized and is the net energy of the corn. It may be used to support the vital activities of the animal or, if he is already receiving a ration sufficient for this purpose, it may be utilized for growth or fattening and be stored up in the increase which later serves as human food. Similarly, one hundred pounds of average timothy hay contain about 43 therms of net energy and one hundred pounds of oat straw about 35 therms, that is, they contribute these amounts to the nutrition of cattle. Similar although less well established factors are also available regarding the utilization of feed by the milch cow, the sheep and the pig. The following are the net energy values of the farm products considered on subsequent pages.

NET ENERGY VALUES PER 100 POUNDS[1]

	For cattle and sheep	For swine	For dairy cows
	Therms	Therms	Therms
Wheat	91.8	108.9	116.4
Corn	85.5	118.8	108.4
Barley	89.9	106.1	114.0
Rye	93.7	123.7	118.8
Oats	67.6	79.7	85.7
Rice (rough)	77.3	111.0	98.1
Buckwheat	59.7	70.5	75.7
Cottonseed	78.3	97.7	99.3
Peanuts	109.0	136.0	138.3
Skim milk	14.3	14.7	....
Buttermilk	13.3	13.3	....

Value of Forage.—When materials like pasturage, hay or straw are used to produce meat or milk it is apparent that they are indirectly contributing to the food supply to the extent of their net energy values and the same thing is true of the inedible by-products of the various manufacturing processes referred to in the introduction. Whatever animal products may be secured in this way are a direct addition to man's food supply. With grains and the like, on the other hand, a considerable part may be used directly as human food, leaving only the by-products to be used for animal production. The purpose of this discussion, as already explained, is to compare these two methods of utilization.

[1] Armsby: The Pennsylvania Experiment Station, Bulletin No. 142, July, 1916.

We must not, however, jump to the conclusion that this may be accomplished by a comparison of the energy values of the foregoing table with those of the one on p. 17; that because, for example, corn meal has an energy value of 165.5 therms for human consumption and corn one of 85.5 therms for cattle, half as much food value is utilized in the latter case as in the former. Aside from the fact that one hundred pounds of corn yield only about 85 pounds of table meal, two very important considerations have to be taken into the account, as is shown in the two following sections.

IV

FOOD VALUE OF INCREASE BY ANIMAL

Not All Edible.—The first of the two considerations just mentioned is that not all the increase made by the growing or fattening animal is edible. Part of it is contained in the bones, which have practically no nutritive value. Still another portion is found in the hide, hair, hoofs, horns, etc., and still another in the entrails. The dressed carcass amounts to from 55 to 65 per cent. of the live weight in cattle and sheep and 75 to 85 per cent. in hogs and still contains the bones and more or less other waste. While, then, a steer may store up 85 therms of energy in his body (p. 19) as a result of eating one hundred pounds of corn, by no means all of this is available for human food. What proportion is so available will depend upon the ratio of dressed to live weight and upon the amount of waste in the dressed carcass.

Cattle.—Thus, on the basis of analyses of the entire bodies of medium fat cattle by Lawes and Gilbert and by Jordan the body of a thousand-pound steer contains about 1392 therms of energy. Such cattle will dress about 58 per cent., i. e., a one thousand-pound animal yields about 580 pounds of carcass of which about 17½ per cent. or 101 pounds is inedible waste.

The remaining 479 pounds of edible substance contain about 678 therms of energy. Finally, when the edible portions of the carcass are consumed there is a further loss of about 10½ per cent. due to the fact that the meat is not wholly digestible, so that out of the total of 1392 therms of energy contained in the body of the steer only 606 therms, or 43½ per cent. of the whole, is actually utilized for human nutrition.

In a precisely similar although somewhat more complicated manner it may be computed that a pound of increase in live weight in a fairly mature fattening steer contains about 2.1 therms of energy of which about 1.11 therms, or 53 per cent., is available as food for man. The higher percentage arises from the fact that less inedible matter is produced in fattening than in growth.

Sheep.—The sheep makes a somewhat better showing. On the average one pound of live weight of a medium fat sheep contains 1.517 therms of energy of which 0.747 therm, or 49.2 per cent., is available.

Pigs.—The pig stands above either the steer or the sheep in this respect, partly because he stores up more energy in a pound of live weight but chiefly because of a much higher ratio of dressed to live weight, ranging from 75 to 85 per cent. as compared with about 58 per cent. for cattle and 60 per cent. for sheep. One pound of live weight of a medium hog may be estimated to contain 2.186 therms of total energy of which 1.975 therms, or 90.4 per cent., is available to man.

Dairy Cows.—Finally the list is headed by the dairy cow. A daily yield of twenty-five pounds of milk with 4 per cent. of fat will contain about 8.4 therms of total energy, of which 94 per cent., or 7.9 therms, is available for man's support, as compared with 2.2 therms in a daily gain of two pounds by a fattening steer or with 3 therms in a daily gain of one and one-half pounds by a two-hundred pound pig.

V

THE OVERHEAD FEED COST

Maintenance.—The second consideration which must be borne in mind in any estimate of the food conservation through the animal is that a certain amount of his feed is consumed to keep the animal machinery running, much as a factory must first be supplied with enough power to keep in motion the shafting, belting and machinery in general before any product can be turned out. This, which we may call the overhead feed cost, is commonly spoken of as the maintenance requirement.

Thus, if a thousand-pound steer is given fourteen pounds of timothy hay daily the six therms of net energy which it contains will be found to be just about sufficient to support him without gain or loss and he will neither add to nor subtract from the food supply. His economic efficiency is zero. It is only when his feed is increased beyond this lower limit that he begins to store up food material for man.

Moreover, his usefulness as a food producer will depend upon how much feed he can consume beyond the minimum. If he eats twenty pounds of the hay daily, he will be getting in excess of his maintenance requirement 2.6 therms of net energy to be stored up in his body, while if he can eat twenty-five pounds of hay he will have 4.75 therms to store up. In the one case his gain will be about 0.13 therm for each pound of hay fed and in the other case about 0.19 therm, or 46 per cent. more.

What is true of a simple hay ration is also true of the mixed rations of forage and grain used in practical productive feeding. A considerable fraction of the feed goes simply to maintain the animal and the profits of the feeding are largely dependent upon how much can be consumed beyond this limit, i. e., upon the relation of the total volume of business transacted to the overhead cost.

This is why the intensive production of meat or milk usually involves the use of grain or other concentrated feeding stuffs. Only on very good pasture can an animal consume enough forage in excess of maintenance to support rapid production and so ensure the minimum overhead cost per unit. Hay, straw and the like contain so much innutritious ballast that the greatest amount which can be eaten will support only a relatively small production with a correspondingly high feed expenditure per unit.

Maintenance by Forage Crops.—The overhead cost cannot be materially reduced, since the internal organization of an animal is not accessible to improvement. The best we can do is to meet it as cheaply as possible. This can be done under ordinary conditions by the free use of the ordinary home-grown forage crops, which are usually much cheaper sources of nutritive material than the grains or their manufacturing by-products. Aside from the milk requirements of the very young animal, it has been demonstrated to be entirely feasible to produce good yields of milk or well fattened carcasses not only of cattle and sheep but of swine as well, on a ration containing ample roughage to meet the requirements for maintenance, leaving the concentrates to be applied directly to the production of human food.

With the overhead feed cost thus provided for, it is a comparatively simple matter, with the data at hand, to estimate with a good degree of accuracy how much human food in the form of beef, mutton, pork or milk can be obtained from a pound of corn or wheat, for example, or of their various by-products, and thus to secure an approximate answer to the question proposed at the outset.

Of course the maintenance of the animal by means of forage crops still has to be paid for. The point is that he does not have to draw on the supply of human food. What we are considering here is not how animal foods can be produced most cheaply, but how the food supply as a whole can be most fully conserved, and while the two are intimately related it is the second question and not the first with which food administration is primarily concerned. Assuming that the animal receives at least enough forage to supply his maintenance requirements, the attempt will be made in the following sections to compute what amounts of human food can be realized from some of the more important food crops of the farm when handled in various ways.

Forage Crops for Production.—Of course herbivorous animals may readily eat *more* roughage than is required for maintenance and it is most desirable, both from the standpoint of economy of production and from that of food conservation, that they should do so. In particular the use of excessive amounts of grain in the fattening of cattle and hogs, as has been the practice in many sections, involves the destruction of vast amounts of potential human food. As already pointed out, whatever animal products are obtained from forage crops are just so much added to the food supply. This, however, need not interfere with the proposed comparisons. Even if a considerable fraction of the production is at the expense of roughage, whatever concentrate is added to such a ration, within reasonable and economic limits, may be expected to produce its proportional quota of meat and milk just as if added to a simple maintenance ration.

The exact methods of computation will be illustrated as we proceed.

VI

WHEAT

Wheat is preëminently the bread grain of the western world. It is subjected on a large scale to only one manufacturing process, viz., milling. It therefore offers a convenient starting point for our comparisons. In one hundred pounds of average wheat there are contained about 183 therms of total energy. How much of this can be recovered for human nutrition?

Feeding Directly.—Wheat is not ordinarily fed to domestic animals, yet it may be and was to a somewhat considerable extent in the middle west not so very many years ago. If one hundred pounds of it were consumed by animals whose maintenance requirement was already provided for, the available data as to net energy value (p. 20) show that out of its 183 therms of total energy there would be retained in the body or in the milk 91.8 therms by beef cattle and sheep, 116.4 therms by dairy cows and 108.9 therms by swine.

But by no means all of these amounts are available for human food. It was pointed out under IV that much of the energy in the increase of cattle, sheep and swine is contained in the offal and in the inedible portion of the carcass while there is also a further small loss of energy when the edible portion or the milk of the cow is eaten by man. For example, in the case of beef cattle it was computed that only 43½ per cent. of the energy contained in the body of the animal is actually available for human nutrition. Out of the 91.8 therms of energy stored up in the body of the steer as the result of feeding one hundred pounds of wheat, then, only 40.0 therms would contribute to the food supply. Precisely similar computations for the other common animals give the results which follow. It might be repeated that these figures show the recovery by the animal after the power required to keep its bodily machinery running has been provided by other materials:

	Recovered in animal products	Percentage recovery
Wheat fed to	Therms	
Cattle	40.0	22
Sheep	45.2	25
Pigs	98.4	54
Dairy cows	109.5	60

Milling.—Taking, now, the other alternative, let us see how much of the wheat energy can be recovered by milling the wheat and using only the offal for stock feed. The ordinary commercial milling yields about 73 per cent. of white or "straight" flour (including a little "second clear" flour), about 2 per cent. of "red dog" flour, and 25 per cent. of shorts and bran, all of which are ordinarily used for feed although part of the red dog flour can also be used as an admixture with the higher grades of flour. A pound of "straight" flour supplies (p. 17) 1.65 therms of energy available to man. The 73 pounds obtained from one hundred pounds of wheat would therefore yield 120.5 therms, or considerably more than the greatest total amount recoverable in animal products, while in addition the offal may be fed to stock.

The 27 pounds of mixed shorts, bran and red dog flour would contain about 49.9 therms of total energy, of which there would be recovered in animal products by cattle and sheep 15.5 therms, by dairy cows 19.6 therms and by swine 24.2 therms. But, as is the case when entire wheat is fed, only part of these amounts is actually available for man's nutrition. Making the same relative deductions as before for the inedible and indigestible portions of this energy, and adding to the remaining available energy the 120.5 therms supplied by the 73 pounds of wheat flour, we find there would be recovered for human food the following amounts:

	Recovered in animal products	Recovered in "straight" flour	Total recovered	Percentage recovery
Offal fed to	Therms	Therms	Therms	
Cattle.......	6.8	120.5	127.3	70
Sheep.......	7.6	120.5	128.1	70
Pigs........	21.9	120.5	142.4	78
Dairy cows...	18.5	120.5	139.0	76

Evidently wheat makes a much greater contribution to human nutrition when it is converted into flour and only the by-products used for stock feed than when it is consumed directly by animals, the difference being very large in the case of beef and mutton production and considerable even in pork and milk production.

Whole Wheat Flour.—Wheat, however, may be milled to yield a much larger percentage of flour and less offal than in the usual commercial process and such milling has been strongly urged as a matter of food economy as well as for other reasons. Some idea of the extent of the economy which may thus be effected can be obtained by a comparison with two familiar products, viz., whole wheat flour and graham flour.[1]

In the production of whole wheat flour about one-half of the coarse bran is removed while in the manufacture of graham flour the entire wheat grain, including the bran, enters into the flour. The resulting flours contain somewhat less energy per pound than "straight" flour, viz., whole wheat flour 1.561 therms and graham flour 1.505 therms.

One hundred pounds of wheat, therefore, when manufactured into graham flour would yield 151 therms of energy, or 82.5 per cent. of its total content, for man's nutrition as compared with 127 to 142 therms recovered when "straight" flour is produced. For the whole wheat

[1] The computations are based upon the data reported by Snyder in U. S. Dept. of Agr., Office Expt. Stas. Bulletins 101 and 126.

flour, assuming the bran to have the same value as a stock feed as that produced in the manufacture of "straight" flour, the figures would be as follows:

	Recovered in animal products	Recovered in whole wheat flour	Total recovered	Percentage recovery
Offal fed to	Therms	Therms	Therms	
Cattle........	3.4	135.0	138.4	76
Sheep........	3.8	135.0	138.8	76
Pigs..........	11.0	135.0	146.0	80
Dairy cows...	9.3	135.0	144.3	79

These figures make it appear that there is a slight advantage in milling to 86 or 87 per cent. and a greater advantage still in leaving all the bran in the flour as in the manufacture of graham flour.

VII

CORN

Unlike wheat, corn, although used to a considerable extent as food for man, is popularly regarded in the United States and still more in Europe as a stock feed, and in fact only a small percentage of the corn crop of the United States is utilized for human consumption.

Besides its use as feed, however, corn serves as the raw material in other manufacturing processes than milling, such as the manufacture of hominy or of starch and glucose and of malt and distilled liquors. These various processes yield by-products useful as feeding stuffs so that there are a variety of possibilities open regarding the utilization of corn for human nutrition.

Feeding Directly.—Taking first its utilization directly as a stock feed, one hundred pounds of average corn contain about 180.3 therms of gross energy. Of this total there may be retained in the body or the milk of an animal whose maintenance is otherwise provided for 85.5 therms by beef cattle and sheep, 108.4 therms by dairy cows and 118.8 therms by swine. Substantially the same proportions of these amounts as in the case of wheat would be lost in the offal and the inedible portions of the carcass and expended in the digestion of the edible part of the products. Computed just as in the case of wheat, the final recovery would be as follows:

	Recovered in animal products	Percentage recovery
Corn fed to	Therms	
Cattle	37.2	21
Sheep	42.1	23
Pigs	107.4	60
Dairy cows	102.0	57

Milling.—When corn is milled for the production of table meal there is obtained about 85 per cent. of bolted meal and 15 per cent. of corn bran. A pound of the meal supplies 1.655 therms of energy available to man, so that the 85 pounds obtained from 100 pounds of corn would contain 140.7 therms or, as in the case of wheat, considerably more than can be recovered in animal products when the corn is fed to live stock.

The 15 pounds of corn bran would contain about 28 therms of total energy. When used as feed it may be estimated that there would be utilized by cattle and sheep 10.7 therms, by dairy cows 13.5 therms, and by swine 15.0 therms. The relative losses in the inedible and indigestible material of the meat or milk would be the same as in previous cases. Deducting these and adding the available energy of the 85 pounds of meal, the total recovery of energy for human nutrition in this case would be as follows:

	Recovered in animal products	Recovered in meal	Total recovered	Percentage recovery
Bran fed to	Therms	Therms	Therms	
Cattle.......	4.6	140.7	145.3	81
Sheep........	5.2	140.7	145.9	81
Pigs.........	13.6	140.7	154.3	86
Dairy cows...	12.7	140.7	153.4	85

Corn is also milled for the production of hominy, about 68 pounds being obtained from one hundred pounds of corn. The by-products (hulls, germs and scourings) constitute hominy feed.

A pound of hominy contains 1.65 therms of energy available for human nutrition, or practically the same amount as corn meal, so that the 68 pounds obtained from one hundred pounds of corn would furnish 112.2 therms.

The 32 pounds of hominy feed would contain about 59.2 therms of total energy, of which it may be estimated that there could be utilized under average conditions by cattle and sheep 28.4 therms, by pigs 39.5 therms and by dairy cows 36.0 therms. Making the same percentage deductions as before for the inedible and indigestible portions, the net amount contributed to human nutrition would be by cattle 12.2 therms, by sheep 14.0 therms, by pigs 35.7 therms and by dairy cows 33.9 therms, and the total recovery in this method of utilizing corn would be as follows:

	Recovered in animal products	Recovered in hominy	Total recovered	Percentage recovery
By-products fed to	Therms	Therms	Therms	
Cattle..........	12.2	112.2	124.4	69
Sheep..........	14.0	112.2	126.2	70
Pigs............	35.7	112.2	147.9	82
Dairy cows....	33.9	112.2	146.1	81

Starch and Glucose.—In the manufacture of glucose from corn the starch of the latter is separated as completely as practicable by mechanical means (grinding, sifting and washing) and subsequently converted into glucose. The residues are the gluten and hulls of the corn and the materials dissolved in the steep water, together constituting gluten feed, and the germs from which the corn oil is pressed leaving as a residue germ oil cake. From one hundred pounds of corn there are obtained 24.5 pounds of gluten feed, 3.5 pounds of germ oil cake, 3 pounds of corn oil and 65 pounds of starch, equivalent to 72.2 pounds of glucose. Of these the starch or the glucose and the corn oil are at least potentially available for human food while the gluten feed and the germ oil cake are useful only for animals. Starch supplies 1.86 therms of available energy per pound, equivalent to 1.67 therms per pound of glucose, and the corn oil may be reckoned at 4.22 therms per pound. The edible products from 100 pounds of corn thus treated would therefore supply a total of 133.6 therms, assuming the oil to be used as food, or 120.9 therms omitting the oil.

From the by-products when fed to stock there may be recovered in the body or the milk in the case of gluten feed 19.8 therms by cattle or sheep, 25.1 therms by dairy cows and 27.5 therms by hogs. For the germ oil cake the corresponding figures would be 2.9 therms by cattle and sheep, 3.7 therms by dairy cows and 3.7 therms by pigs. Making the same percentage deductions as before for the inedible and indigestible portions of the animal products, we get as a final result per 100 pounds the following:

	Recovered in animal products	Recovered in glucose and oil	Total recovered	Percentage recovery
By-products fed to	Therms	Therms	Therms	
Cattle..........	9.9	133.6	143.5	80
Sheep..........	11.2	133.6	144.8	80
Pigs............	28.2	133.6	161.8	90
Dairy cows....	27.1	133.6	160.7	89

Distilling.—Still another method of utilizing corn is as the raw material for the production of malt and distilled liquors or of alcohol.

Of the seventy and one-half million bushels of grain reported to have been used in brewing in the United States in 1916, corn made up a little over twenty-two per cent., the remainder being chiefly barley with a little rice. The recovery of food value in brewing may therefore be more advantageously discussed in connection with barley.

On the other hand, corn is an important source of distilled liquors and of commercial alcohol. Based on the experience of distillers, there may be computed from the composition of corn a commercial yield of 17.9 pounds of pure alcohol per bushel, or 32 pounds per hundred. Distillers generally use mixed grains (corn, rye and malted barley) and obtain an average yield of 17.2 pounds per bushel (56 pounds) of mixed grain, equivalent to 30.7 pounds per hundred pounds of grain, a result confirming the figure given above for corn. The by-product of distillation is distillers' grains, the yield of which, in the dried state, may probably be estimated to be about the same as that of brewers' grains in the production of beer, viz., 28 pounds per hundred of grain.

The 28 pounds of dried distillers' grains would contain in the neighborhood of 56 therms of total energy, of which there could be recovered in the bodies or milk of animals to which it was fed, on the same assumptions as in previous cases, 23.8 therms by cattle and sheep, 33.2 therms by pigs and 30.2 therms by dairy cows. Deducting the loss in the inedible and indigestible materials, there would be recovered as human food, 10.4 therms in the case of cattle, 11.7 therms in the case of sheep, 30.0 therms in the case of pigs and 28.4 therms in the case of dairy cows.

Food Value of Alcohol.—The final conclusions as to the proportion of the total energy of the corn which is recovered for human nutrition will depend upon whether the alcohol is regarded as a food. This question, in the judgment of the writer, should be answered in the negative so far as food conservation is concerned.

It is true that it has been established beyond controversy that dilute alcohol in moderate amounts may not only be burned in the human organism but may replace an equivalent amount of such materials as carbohydrates and fats which are universally recognized as foods. On this basis one pound of pure alcohol would yield 3.14 therms of available energy. This, however, by no means warrants placing this energy on the credit side of the account.

First, a considerable proportion of the alcohol produced is used for commercial and manufacturing purposes and does not enter in any way into the food supply.

Second, distilled liquors are not consumed for the sake of their food value but as beverages for the sake of their flavor or as a result of habit. To attempt to supply any considerable part of the daily food requirement in this way would almost certainly produce more or less of the deleterious effects noted in the next paragraph.

Third, the physiological effects, other than nutritive, must be reckoned with. Quite aside from the familiar results of excessive drinking, and the dangers of alcohol as a habit-forming drug, it appears well established that its effect as a narcotic on the nervous system and on both physical and mental efficiency goes far to offset its nutritive value. Alcohol can doubtless be utilized to a limited extent as a source of energy for the human machine but its use deposits grit in the bearings and slows down the machine so that it is very questionable whether it adds to the *effective* food supply.

In the following comparison, however, to be perfectly impartial, the percentage recovery of the energy of the corn has been computed both excluding and including the possible food value of the alcohol.

	Recovered in animal products	Recovered in alcohol	Percentage recovery	
			Excluding alcohol	Including alcohol
Distillers' grains fed to	Therms	Therms		
Cattle	10.4	100.5	6	62
Sheep	11.7	100.5	6	62
Pigs	30.0	100.5	17	72
Dairy cows	28.4	100.5	16	72

VIII

BARLEY

Barley is used chiefly as a feed grain and in the manufacture of beer, comparatively little barley flour having been produced until recently.

Feeding Directly.—Average barley contains about 184 therms of gross energy per one hundred pounds. When fed directly to live stock it may be estimated, in precisely the same way as in the case of wheat or corn, that the following amounts would be recovered for man's use in the meat or milk produced.

	Recovered in animal products	Percentage recovery
Barley fed to	Therms	
Cattle	39.1	21
Sheep	44.3	24
Pigs	95.9	52
Dairy cows	107.3	58

Milling.—Barley may be milled to produce about 80 per cent. of flour. Kellogg and Taylor,[1] however, state that for admixture with wheat flour a 60 per cent. milling gives the best results. Assuming that

[1] The Food Problem, p. 207. The Macmillan Co., New York, 1917.

the 40 per cent. of barley feed remaining is fed and making the same comparisons as with wheat and corn, the following results are obtained, showing, as before, a much greater recovery than when the entire grain is used as feed.

	Recovered in animal products	Recovered in flour	Total recovered	Percentage recovered
Barley feed used for	Therms	Therms	Therms	
Cattle	12.7	98.4	111.1	60
Sheep	14.4	98.4	112.8	61
Pigs	37.4	98.4	135.8	74
Dairy cows	34.9	98.4	133.3	72

Brewing.—In 1916 about fifty-two and one-half million bushels of barley, or about twenty-nine per cent. of the total crop, were used in the United States for the production of beer. According to competent authorities, one hundred pounds of barley yield in good average practice:

Beer	421 lbs.
Dried brewers' grains	28 "
Malt sprouts	4 "
Dried yeast	2 "

The beer will contain about 0.5 per cent. of protein, 5.0 per cent. of carbohydrates (chiefly dextrin-like substances) and 3.5 per cent. of alcohol. Including the alcohol, the 421 pounds of beer would contain 88.3 therms of energy available to man, while excluding the alcohol reduces the amount to 42.0 therms.

The brewers' grains, malt sprouts, and spent yeast are available as stock feeds and the recovery of food energy from each may be computed as in previous cases, with the following results:

	Energy recovered in animal products			
	By cattle	By sheep	By pigs	By dairy cows
	Therms	Therms	Therms	Therms
From 28 pounds dried brewers' grains....	6.5	7.4	15.9	17.8
From 4 pounds malt sprouts...........	1.3	1.4	3.1	3.3
From 2 pounds dried yeast.............	0.6	0.7	1.7	1.8
	8.4	9.5	20.7	22.9

The total recovery of energy in the beer and indirectly by the feeding of the by-products is therefore

	Recovered in animal products	Recovered in beer		Percentage recovery	
		Including alcohol	Excluding alcohol	Including alcohol	Excluding alcohol
By-products fed to	Therms	Therms	Therms		
Cattle..........	8.4	88.3	42.0	53	27
Sheep..........	9.5	88.3	42.0	53	28
Pigs...........	20.7	88.3	42.0	59	34
Dairy cows.....	22.9	88.3	42.0	60	35

Even if the alcohol be included, the recovery of energy is notably less in brewing than in milling although somewhat greater than that secured when the barley is used directly as feed. If the alcohol be not included, the recovery in brewing is much less than that obtained by feeding the barley to pigs or cows and little if at all greater than that secured by feeding it to cattle or sheep.

IX

RYE

Rye, like wheat, may be fed directly to live stock or may be milled for the production of rye flour, while in the past considerable amounts have been consumed in the manufacture of distilled liquors.

Feeding Directly.—One hundred pounds of rye contain about 184 therms of gross energy. When fed to live stock the recovery, computed as before, is:

	Recovered in animal products	Percentage recovery
Rye fed to	Therms	
Cattle	40.8	22
Sheep	46.1	25
Pigs	111.8	61
Dairy cows	111.8	61

Milling.—With average milling, rye yields about 64 per cent. of flour and 36 per cent. of bran and shorts. One pound of rye flour contains 1.63 therms of energy available to man or 104.3 therms in the 64 pounds secured from one hundred pounds of rye. The energy recovered by feeding the 36 pounds of milling offal to stock and the total recovery in flour and offal are therefore as follows:

	Recovered in animal products	Recovered in flour	Total recovered	Percentage recovery
Bran fed to	Therms	Therms	Therms	
Cattle	12.4	104.3	116.7	63
Sheep	14.1	104.3	134.4	64
Pigs	34.5	104.3	138.8	75
Dairy cows	34.1	104.3	138.4	75

Distilling.—When used for the production of distilled liquor, rye is stated to yield some five per cent. less alcohol than corn, or about 30.4 pounds per hundred pounds of rye. Computed, as in the case of corn, both with and without the alcohol, the recovery of energy in the edible products is:

	Recovered in animal products	Recovered in alcohol	Percentage recovery	
			Excluding alcohol	Including alcohol
Distillers' grains fed to	Therms	Therms		
Cattle	6.8	95.5	4	56
Sheep	7.7	95.5	4	56
Pigs	19.8	95.5	11	63
Dairy cows	18.7	95.5	10	62

X

OATS. RICE. BUCKWHEAT

Feeding or Milling.—Aside from the relatively small amount of rice used in brewing, these grains are either used directly as stock feeds or milled for the production of table meal or breakfast foods. The estimation of the energy recovery by the two methods is made precisely as in previous cases and as before shows a much higher utilization when as large a proportion of the grain as possible is consumed directly by man. It hardly seems necessary to give the details of the calculations. The final results are as follows:

	Percentage recovery of energy			
	Cattle Per cent.	Sheep Per cent.	Hogs Per cent.	Dairy cows Per cent.
Oats				
Fed direct	15	17	38	42
Milled	58	58	64	64
Rice				
Fed direct	18	20	53	48
Milled	57	58	62	62
Buckwheat				
Fed direct	14	16	34	38
Milled	56	57	40	60

XI

COTTONSEED

Cottonseed is not directly available as food for man but yields an edible oil which is coming into use to an increasing extent, while from the press residue (cottonseed meal) there is manufactured a cottonseed flour which promises to be of value as human food.

Feeding Directly.—Cottonseed contains about 242 therms of total energy per one hundred pounds. When it is fed to live stock the recovery of energy in edible products, computed as in previous instances, may be estimated as follows. No figures have been computed for swine since cottonseed is not regarded as a safe feed for this species.

	Recovered in animal products	Percentage recovery
Cottonseed fed to	Therms	
Cattle	31.1	13
Sheep	38.5	16
Dairy cows	93.5	39

Oil Extraction.—In the cottonseed oil mills one hundred pounds of seed yield about 15.7 pounds of oil and 49.7 pounds of cake or meal, the remainder being linters and hulls whose feeding value is for the present purpose negligible. From the 49.7 pounds of cottonseed meal there may be recovered in edible and digestible form in the carcass or milk of the animal to which it is fed the amounts shown below, while the oil, if used directly as human food, may be reckoned at 4.22 therms per pound, or a total of 66.3 therms, so that the total utilization would be as follows:

	Recovered in animal products	Recovered in oil	Total recovered	Percentage recovery
Cottonseed meal fed to	Therms	Therms	Therms	
Cattle	19.4	66.3	85.7	35
Sheep	22.0	66.3	88.3	36
Dairy cows	53.3	66.4	119.6	49

Cottonseed Flour.—Cottonseed flour is made from cottonseed meal by a special treatment which removes the hulls as thoroughly as possible. The writer has been unable to secure any information regarding the yield of cottonseed flour, but the data regarding its composition seem to indicate that at least 60 per cent. of prime cottonseed meal may be recovered in the flour, equivalent to 29.8 pounds from one hundred pounds of cottonseed. On the basis of digestion experiments it may be estimated that a pound of the flour contains 1.53 therms of energy available for human nutrition. The 29.8 pounds estimated to be obtained from 100 pounds of cottonseed would accordingly be equivalent to 45.6 therms, which added to the 66.3 therms recovered in the oil makes a total recovered of 111.9 therms, or 46 per cent., in addition to whatever could be recovered by feeding the residue from the preparation of the flour to live stock.

XII

PEANUTS

While the peanut, either as the roasted nut or in the form of peanut butter, is usually regarded as a condiment rather than as a food, it is capable of contributing materially to human nutrition. There is also now being offered in the market a peanut flour, prepared from the press cake left in the manufacture of peanut oil, while the oil itself if properly made is a valuable food.

The writer has been unable to secure any data regarding the yield of peanut flour from a unit of raw material. The following comparisons therefore are between the nuts used exclusively as human food, exclusively as stock feed, or for the manufacture of oil, the press cake being fed to animals. All the data relate to the hulled nuts.

Feeding Directly.—One hundred pounds of hulled peanuts contain about 276.3 therms of energy. When they are fed directly to stock, the following figures may be computed in the same manner as in previous cases:

	Recovered in animal products	Percentage recovery
Peanuts fed to	Therms	
Cattle	47.4	17
Sheep	54.9	20
Swine	122.9	44
Dairy cows	130.1	47

Oil Extraction.—One hundred pounds of hulled peanuts are stated to yield 60 pounds of peanut cake and 40 pounds of oil. The oil may be estimated to contain 4.22 therms per pound of energy available for man, or a total of 168.8 therms. The value recovered from the cake when fed to stock may be estimated as before and the total recovery computed as follows:

	Recovered in animal products	Recovered in oil	Total recovered	Percentage recovery
Peanut cake fed to	Therms	Therms	Therms	
Cattle	24.4	168.8	193.2	70
Sheep	27.6	168.8	196.4	71
Swine	63.3	168.8	232.1	84
Dairy cows	67.0	168.8	235.8	85

Finally, one hundred pounds of peanuts used directly as human food would supply 256.0 therms of energy or 93 per cent. of their gross energy.

XIII

MILK

In all the foregoing comparisons it has been assumed that the milk produced by dairy cows is consumed directly as human food. Milk itself, however, serves as the raw material for the manufacture of butter or cheese and of small amounts of other food products.

Butter Making.—In the manufacture of butter it is possible also to use the resulting skim milk and buttermilk as human food, in which case the total food value may be considered to be practically the same as that of the fresh milk. As a matter of fact most of them are fed to animals.

One hundred pounds of 4 per cent. milk contain 30.6 therms of total energy of which 28.8 therms, or 94 per cent., is available to man. It will yield about four pounds of butter containing per pound 3.61 therms of available energy, or a total of 14.42 therms, 12 pounds of buttermilk and 84 pounds of skim milk. When the by-products are fed to calves or pigs, the amounts of energy recovered in the edible and digestible forms would be:

	In 84 lbs. skim milk	In 12 lbs. buttermilk	Total
Fed to	Therms	Therms	Therms
Calves	5.23	0.70	5.93
Pigs	11.19	1.45	12.64

Adding the amount available in the butter, the total recovery would be:

	Recovered in animal products	Recovered in butter	Total recovered	Percentage recovery
By-products fed to	Therms	Therms	Therms	
Calves	5.93	14.42	20.35	67
Pigs	12.64	14.42	27.06	89

In other words, the percentage recovery when butter is manufactured and the by-products fed to animals is about 70 to 90 per cent. as compared with 94 per cent. when the milk is consumed as such. The estimates of the recovery of the energy of various materials made in previous pages must evidently be reduced in this proportion when butter instead of milk is the main object of the feeding.

Cheese Making.—In the manufacture of cheese, the whey is practically available only as stock feed.

One hundred pounds of milk will yield about 10 pounds of cheese and 90 pounds of whey. Ten pounds of cheese have an energy value of 19.5 therms as human food, while 90 pounds of whey would yield 4.1 therms in animal products when fed to calves and 8.5 therms when fed to pigs and the total recovery can be tabulated as follows:

	Recovered in animal products	Recovered in cheese	Total recovered	Percentage recovery
Whey fed to	Therms	Therms	Therms	
Calves	4.1	19.5	23.6	77
Pigs	8.5	19.5	28.0	92

XIV

SUMMARY

In the foregoing pages the attempt has been made to compare the efficiency of the various methods by which some of the more important farm products may be made to contribute to the food supply. The comparisons are based solely upon the proportion of the total energy of these products which can be recovered for man's use and take no account of the relative utilization of the protein and mineral ingredients nor of the presence or absence of accessory ingredients (vitamines). While all these are essential requirements for nutrition, quantitatively the principal function of food is to supply energy and a knowledge of the relative amounts of energy which can be recovered in various methods of utilization is a factor of prime importance in food conservation.

The results obtained are approximate averages only. Such calculations must necessarily be based on average figures and refer to average conditions. Moreover, some of the factors employed in the computations are by no means so exactly established as is desirable. Consequently, while the mathematical computations are believed to be correct, the reader should beware of laying too much stress on small differences. On the other hand certain broad teachings are evident.

Loss in Feeding.—The most obvious of these is the great loss of energy involved in the conversion of vegetable into animal products, that is, in the feeding of live stock. It is here assumed that the maintenance of the animal is provided for by a sufficient supply of forage of one sort or another, so that the body resembles a factory already supplied with sufficient power to run the empty machinery. Even under these conditions, however, with none of the energy of the added grain expended in supporting the overhead cost, it appears that from thirty-nine to as much as eighty-six per cent. of the energy of grains consumed by animals is lost in one way or another and only from fourteen to sixty-one per cent. is recovered for man's use. Obviously, the diversion to stock feeding of any material edible by man is from this standpoint a very wasteful proceeding.

Comparison of Animals.—Another fact which appears clearly is that the percentage recovery of energy in animal products differs widely with the nature of the animals fed. In this respect cattle and sheep form one distinct group and pigs and dairy cows another, the differences within each group being relatively small. In the production of beef and mutton the loss is very large, ranging from seventy-five to eighty-six per cent. This is due in part to the extensive fermentation which occurs in the stomach of cattle and sheep and in part to the relatively large proportion of inedible material contained in their bodies. In pork and milk production the losses are notably smaller, ranging from thirty-nine to sixty-six per cent. The body of the pig contains much less inedible matter than that of the steer or the sheep and his feed is subject to fermentation to a far less degree than in ruminants. In milk production the conversion appears to be decidedly more efficient than in meat production while there is no inedible waste.

Inedible Products Saved.—On the other hand, the animal performs a most important function in the utilization of products inedible by man. The various forage crops and the inedible by-products of manufacturing can, through the medium of the animal, be made tributary to man's support. It is true that there may be an even greater loss in the conversion than obtains with the grains but whatever is thus recovered is so much added to the food supply and the importance of utilizing these materials to the greatest practicable extent can hardly be overemphasized.

Milling vs. Feeding.—It is clear, then, that the endeavor should be to utilize as large a proportion of vegetable products as is possible directly as human food, leaving only the by-products to be fed to stock. In the case of the cereals this is accomplished chiefly by some form of milling. The total recovery of energy effected in this way is relatively high, ranging from fifty-six to eighty-one per cent. when the offals are used for beef and mutton production and from sixty to eighty-five per cent. when they are used for pork and milk production, as appears from the following comparison of the percentage recovery in this way with that secured by feeding the same materials directly to animals.

	Average percentage recovery of energy			
	With cattle and sheep		With pigs and dairy cows	
	Fed directly	Milled and offals fed	Fed directly	Milled and offals fed
Wheat	23	70[1]	57	77[1]
Corn	22	81[2] / 70[3]	58	85[2] / 82[3]
Barley	23	61	55	73
Rye	24	64	61	75
Oats	16	58	40	64
Rice	19	57	50	62
Buckwheat	15	56	36	60

Vegetable Oils.—In the case of the oil-bearing seeds a high percentage recovery may also be computed on the assumption that the resulting vegetable oils are used for food purposes, an assumption which appears to be far from corresponding with present facts. Similarly, a high recovery is estimated in the manufacture of starch and glucose only on the assumption that these products are all utilized as food.

Brewing and Distilling.—The brewing and distilling

[1] Usual 73 per cent. milling. [2] Milled for table meal.
[3] Milled for hominy.

industries, on the contrary, show a very low utilization of the energy of their raw materials unless the full theoretical food value is assigned to the alcohol produced. Only some twenty-eight to thirty-five per cent. is recovered in other products in brewing and only from four to sixteen per cent. in distilling. Even if the alcohol be included in the computation the recovery is still notably lower than that obtained by milling the same materials, as appears from the following tabulation:

	Percentage recovery of energy			
	Offals fed to cattle or sheep		Offals fed to pigs or dairy cows	
	Including alcohol	Excluding alcohol	Including alcohol	Excluding alcohol
In brewing				
Barley	53	28	60	35
In distilling				
Corn	62	6	72	16
Rye	56	4	62	11

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