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Calorie Intake and Industrial Output

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IN THE FIELD OF THE PHYSIOLOGY of nutrition the energetic side of metabolism had the primacy for many years. M. Rubner, R. Tigerstedt, F. G. Benedict, and others studied thoroughly the calorie consumption of man in various kinds of activity. Afterwards, the interest in the energetic problems dropped, since it was not difficult to produce enough calories for the majority of men. Heavy work was reduced more and more by technical devices, and the progress of world economy and world trade made famines uncommon. Since in most parts of the world there was no calorie problem, interest was directed to other fields of the physiology of nutrition, especially vitamins.

This situation was entirely changed with the beginning of war, which induced a nutrition experiment of the widest range. It generally was possible to prevent the occurrence of avitaminoses with the help of scientific knowledge. The requirements for calories, however, could not be satisfied in many parts of the world. At the beginning of the war rations were graduated in order to economize as much as possible, this graduation becoming more and more elaborate as want increased. In the summer of 1943 rations in Germany had to be decreased far below the actual requirements. A man without supplements could do little to adapt himself to the decreased rations. The worker with his extra allowance, however, could lower his calorie consumption by lowering his output and restore the balance between intake and output. This situation in Germany provided an opportunity to study in many cases the connection between calorie intake and industrial output.

In the description of our observations the calories contained in food are separated into two groups according to their role in metabolism. The first group includes calories necessary for the metabolism of the body during strict rest and those required for digestion, which together amount to 1,600–1,800 calories per day according to size, weight, and food intake. The second group consists of work calories, needed for muscular activity of every kind.

In 1942, 20 workmen, fed entirely by their factory, were occupied with the erection of an embankment inside the works. Their task was composed of dumping debris out of railway cars and changing the rails to advance the points of dumping. A measure of the work done was given by the number of tons of debris dumped per hour and man. At the beginning the workmen did not receive the rations for heavy workers. They had, besides their calories for resting metabolism, 820 work calories per day and dumped 1.5 tons per hour. Our observations, results of which are given in Fig. 1, started after several months of work of this kind. Neither the workmen nor the personnel charged with the supervision and inspection of the workers were informed about our investigations. Three weeks later the workmen received the rations for heavy workers except when difficulties in transport made this impossible. This resulted in unequal nutrition. The output of the workmen changed parallel to these enforced variations in available work calories. After one year 2.2 tons per man and hour were dumped with an average of 1,300 work calories. The body weight of the workers increased about 4 kg. during that year, proving that the capacity for work, given in the rations for heavy work, was not fully utilized. Since the termination of the embankment was urgent, the workers were promised cigarettes for greater production. At first, 2.5 tons per hour was the minimum production for which this premium was awarded; after several weeks the premium was graduated, the maximum being given for 3 tons and later on even for 4 tons. This induced a considerable in-

This paper came to us from the hands of Dr. David B. Dill, professor of industrial physiology, Harvard Graduate School of Business Administration. Dr. Dill met the authors in September 1945, while in Germany on a technical mission for the Quartermaster Corps, U. S. Army. The authors then had reecived permission from the British authorities to reopen their laboratory at Dortmund. The laboratory had functioned at Bad Ems and Dietz during the last year of the war.

crease of output, 3 tons soon being attained by nearly every man; after the last increase of the premium limit the average output reached 3.4 tons. The premium system lasted for the last half year of the embankment construction, during which time the 20 workers lost, on the average, 3.5 kg. of weight.

The result of these observations is clear. In the time without premiums production varied directly with available calories, yet the actual production differed enough from the energy equivalent of the rations to allow an increase in body weight. With the awarding of cigarette premiums the proportionality between output and available calories was lost at once. Output surpassed so much the range of calorie possibilities that the deficit had to be made up continuously from the very substance of the body.

A second investigation was undertaken in 1943 with a group of 31 miners. These miners were 20–30 years of age when they started working as miners, and at the time of the study they had just finished their training as "cutters." During the training period a total of 2,800 calories, allowing 1,200 work calories per day, was given, securing a daily output of 7.0 tons of coal per man. They used, therefore, 170 work calories per ton. At our suggestion these workers received 400 extra calories per day and thereby increased their daily output to 9.6 tons per man. Expending now 155 work calories per ton, they lost in six weeks, on the average, 1.2 kg. of body weight. The number of extra calories was then raised to 800. In consequence, the output increased a little (to 10 tons), and the body weight slowly returned to its original value. The actual requirement is, therefore, to be found between 155 and 200 calories per ton.

Further experiments were conducted in steelworks in 1944. On our advice 400 extra calories per day were given to the workers living in a camp. Workmen occupied on a steam hammer thereby increased their output 22 per cent, simultaneously increasing their body weight slightly. Sixteen other workers were occupied on a 1,500-ton press, already being used at its capacity; hence, the production of these workers could not increase, and in three months the body weight increased from 67 kg. to 72.5 kg. on the average.

The best example of the connection between nutrition and output is given by the coal production of the Ruhr district during the war. In Fig. 2 are plotted the calories of the rations during the war and the output of the workers in the pits of the Ruhr coal mines from September 1939 to September 1944. The total calorie consumption of the miners working in the pits before the war, depending on the job, varied from 3,600 to 4,800. In agreement with these figures the output of the first year of war was but little lower, the ration then being 4,200 calories. From 1,150 to 1,200 work calories were needed per ton of coal mined. These needs cover the whole number of miners employed underground and not merely cutters, as in our investigation of 1943. When in the course of the second year of war rations were cut somewhat, the output went down exactly as expected from the fall in available work calories. The first major cut in rations, which occurred in April 1942, was not followed immediately by a decreased output, as shown in the two upper curves of Fig. 2. Instead, the workers, in trying to keep up production, contributed calories out of their body substance. The lower curve, which

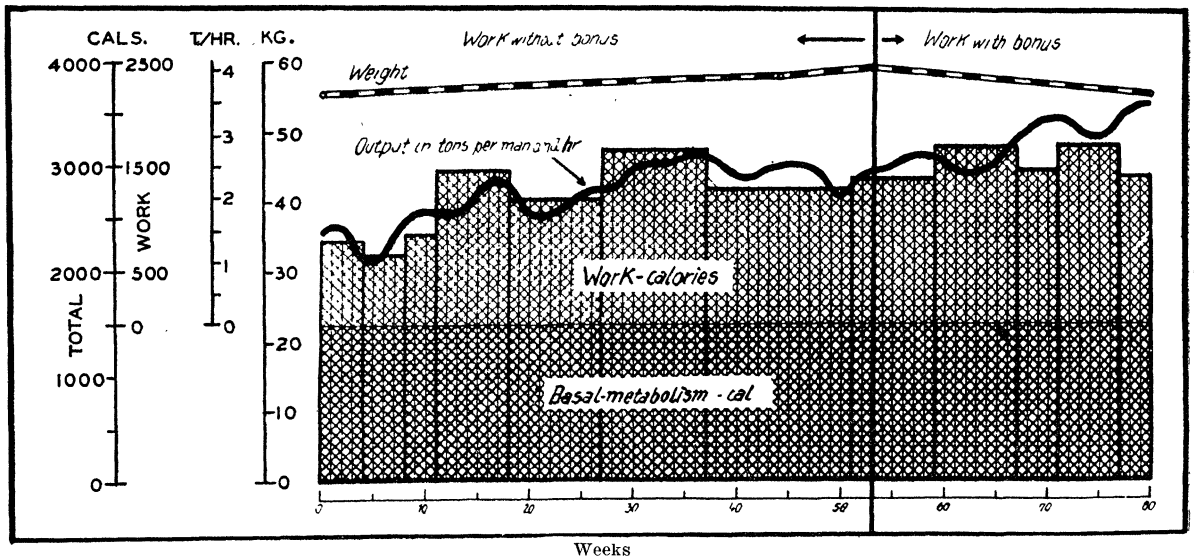

FIG. 1

shows the calories available per ton of coal mined, fell rapidly from April 1942 down to 900 calories per ton. Very soon, however, the curve rose and by autumn of 1942 again exceeded 1,100 calories per ton. From the summer of 1943 to the end of the observations in the autumn of 1944 it was always between 1,150 and 1,200 calories, its original height. The production of a single plant did not always show the connection with the calorie supply because of the numerous troubles caused by war. However, our review of the whole production of the Ruhr district demonstrates quite clearly that the fall of coal output during the war was primarily due to the cuts in rations.

masters, and engineers, all of whom are short about 500 work calories per day. Still more difficult is the situation of housewives, fed the basic ration but needing 800 work calories per day.

As a result of our observations it is clear that every professional activity requires a fixed amount of calories. No activity can be continuously greater than in accordance with the caloric intake; otherwise, loss of weight is induced, and this lowers the capacity, finally stopping work entirely. A regular control of body weight in industrial workers is, therefore, a good measure of their calorie supply. The output on varying rations is unthinkingly adapted to the available

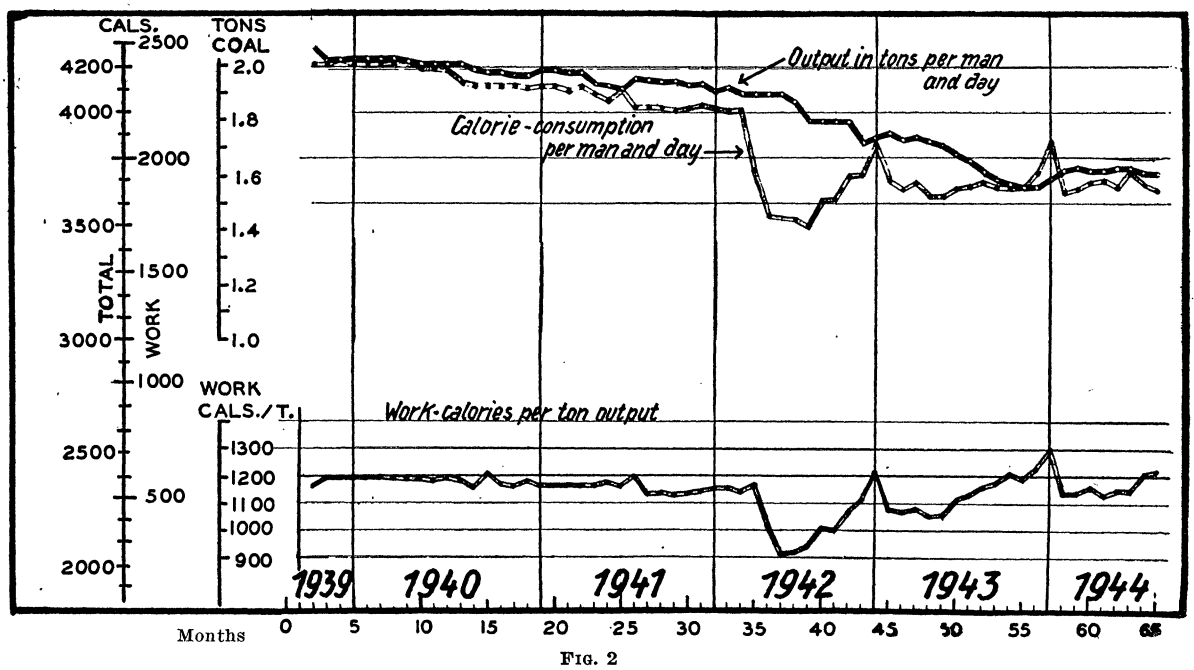

FIG. 2

Exactly the same observations have been made after the war, during the resumption of work. Investigations of the calorie consumption of workers in bridge-building works in Dortmund in the autumn of 1945 demonstrated that the work done was in accordance with the rations provided. The allowances of 2,200 calories for men doing heavy work and 2,700 calories for those doing the heaviest work permitted about half the amount of peacetime work. Bad as this result is from the point of view of production, it really touches the workman's health only slightly. With his rations and extras he first satisfies his resting metabolism and the needs of his leisure hours. He does as much work with the rest as is actually possible. The consumer of the basic ration of 1,500 calories, however, can barely keep up his resting metabolism. For his leisure and professional work he is bound to use his body substance or secure illegal food. These conditions apply to clerks, assistant chemists, designers, work calories by the worker himself, the body weight being kept constant.

Our results prove that rationing of food also means rationing of industrial production of a country. Control of production is diverted from management to those responsible for food administration, who often cannot see the consequences of their decisions. Under existing conditions the job of one man often has to be done by two or three men with a higher total wage cost.

There is a lack of knowledge about the work a man is able to do with the calories available. Engineers appointed to fix the times for piece work and for job performance have calculated these times and the resulting flow of the manufacturing process under the assumption of unlimited food supply. Rationing makes these calculations as worthless as efficiency tables of an airplane motor with insufficient fuel. Today's situation is, therefore, rightly paraphrased by the sentence: Reconstruction is a problem of calories.