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THE USE OF ENERGY BY THE RED-MEAT INDUSTRY IN A ENERGY-CONSCIOUS ENVIRONMENT

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The first type of energy saving in meat technology can be readily achieved by the application of good housekeeping procedures. The next step involves proper installation of heat exchangers at strategic points in the plant. New directions in meat processing as hat meat processing, electrical stimulation, can give some energy savings.

"Food is the most critical form of energy. Agriculture is essentially an energy conversion process-the transformation of solar energy to food energy for mankind" [1]. However, further energy inputs are required at every step of the food chain, from tilling and fertilizing the soil to food preparation in the home. The four major steps in this chain are shown in Table 1. In 1980 11.3% of the total energy consumed in Canada was used in the agri-food system, from planting to table. It is interesting to note that primary production, and storage and preparation at home consume similar amounts of energy, and are well ahead of the two intermediate steps, namely processing and packaging and transportation and retailing. These figures were published by Sidaway-Wolf [2].

Table 1. Energy consumed by the Canadian agri-food system (1980)*)

	Energy consumed 10^9 MJ	% of Canada's total energy	% of food system energy
Primary production	244	3.4	30
Processing and packaging	170	2.4	21
Transportation and retailing	143	2.0	18
Storage and preparation	247	3.5	31
Total	804	11.3	100

*) As adapted from Sidaway-Wolf [2].

The figures given by Sidaway-Wolf differ considerably from some others which have appeared in the literature. Thus, Voisey [1] states that 15% of the total energy consumed in Canada is used by the agri-food industry. Hulse [3] gives a figure of 16%. It should be borne in mind that these estimates were made at different time periods, and that the food industry in Canada has been particularly successful in reducing energy usage. Also, the agri-food industry is huge and complex, and in estimating energy consumption one must make many assumptions. Sidaway-Wolf as gone back to the original statistical source material, amd we must accept her figures as the best available to date for Canada.

The situation in developing countries will not be dealt with here. It is a subject which deserves careful and separate consideration.

No matter how calculated, the agri-food system consumes a substantial portion of the energy supply of the modern state. On the other hand, we might also argue that food satisfies the most basic of human needs, and to provide our population with an abundant, nutritious, varied, and safe food supply is well worth the expenditure of 11.3% of our total energy usage. This is not to argue that sensible steps should not be taken to save energy, provided that the very special requirements of food manufacturing and handling are given adequate consideration.

Perhaps a general statement about energy costs would be in order here. The cost of oil is very low now and sales have been made at close to $ 10 per barrel. I hope that this does not lead anyone to the naive conclusion that we should no longer worry about the cost of energy. Petroleum is a non-renewable resource, and prices will undoubtedly rise again. It should also be noted that the slaughtering and meat-processing industry is a very heavy user of natural gas, 48% of total energy in 1980 [2]. Heavy oil amounted to 14.8%, and electricity to 19.2%. Natural gas has only cecently begun to come down in price on our continent and electricity has, in fact, gone up. Heavy oil may indeed have gone dow in cost, but the effect on the energy economy of the meat industry would be small. There is certainly no room for complacency here about energy costs.

It is interesting to note that the energy consumption of the food-manufacturing industry represents 0.78-3.59% of the cost of production, depending on sector. Meat processing is at the bottom of this range and distilleries at the top. Data for five industry sectors are given in Table 2. The Canadian Food and Beverage Industry under the leadership of the Energy Management Task Force has set itself the ambitious goal of improving energy performance for the period 1975 to 1985 by 23.5%. Performance fell somewhat short of this goal, only 22.0%. However, this is still a very laudable effort.

Of the 108.5×10^9 MJ of processing energy consumed by the Canadian Food and Beverage Industry in 1980, the meat industry accounted

Table 2. Energy data by some industry sectors*)

	Value	Cost of	Energy cost value of good %
Meat processing	6,944	54.3	0.78
Poultry processing	989	12.6	1.27
Fish production	1,465	33.2	2.27
Dairy production	4,309	64.1	1.49
Distillieries	679	24.4	3.59

*) As adapted from Sidway-Wolf [2].

for 13.46 $\times$ 10^9 MJ, or 12.4%. However, as already noted, the cost of processing energy in this industry is only 0.78% of the total cost. Raw materials, largely animals, represent 75% of costs, wages and salaries 11%, packaging materials and maintenance making up the rest. In spite of this rather small percentage which the energy cost represents, the absolute sum is large, 54.3 million dollars (Table 2). Important savings have already been achieved by the Canadian meat industry, as will be shown later.

An effective energy conservation programme should be preceded by an historical audit, which requires no great technical expertise. The results can prove to be very useful since they can point towards those processes, and individual elements of these processes, which are heavy energy consumers. Such an historical audit can make use of existing accounting and production figures, and should be carried back in time over some years. With this as a foundation for an energy conservation program, we can start by utilizing The Meat Energy Conservation Guidelines as produced by the American Meat Institute and reproduced in the Research Bulletin of the Canadian Meat Council [4].

The advantage of keeping an energy inventory is shown in the excellent report by Nutt and Kissell [5]. It gives a summary of the energy consumption per kilogram of product for various meat-packing operations (Table 3). The heavy energy consumers are smoking and cooking, with

Table 3. Energy usage by the meat packing industry (United States)*)

	Processing energy MJ/kg of product
Slaughter only	4.4
Fresh of frozen	7.3
Canned	10.3
Smoked and/or cooked	27.9
Cured and/or finished	8.1
Cooked	23.1

*) As adapted from Nutt and Kissel [9].

canning being a rather poor third. It points the way as to where we might look for energy savings. These are US figures, but the Canadian ones would be similar.

In Table 4 we list some of the auxilliary operations required in connection with hog processing, and give the energy requirements as a percent of the total. It should be noted that inedible rendering is a heavy consumer of energy, most of it escaping as steam from the rendering kettles. A practical approach to the utilization of this energy is given below.

Table 4. Daily energy demands for selected hog processing operation*)

	Daily energy consumption % of total
Scalding	3.8
Dehairing	9.5
Inedible rendering	23.0
Edible rendering	12.8
Blood drying	12.8
Clean up	9.7
Refrigeration and freezing	28.4
Total	100.0

*) As adapted from Nutt and Kissel [9].

It should be noted that scalding, dehairing, singeing, and polishing are in total substantial consumers of energy. In beef-processing operations the hide along with the hair is simply mechanically removed. In Table 5 the hair-removal operations listed above for the hog carcass are compared with skinning. The energy requirements are strikingly different, being in favour of skinning by a ratio of 50 : 1. Why is skinning of hog carcasses not practiced more widely on the American continent? The skin is in any case largely removed from the individual cuts during

Table 5. Energy requirements-dehairing*) vs. skinning**)

	MJ per hog	
	dehairing	skinning
Steam	5.42	0.11
Electricity	1.01	0.29
Gas	14.50	0.0
Total	20.93	0.40
Ratio of energy usage	50:1 (about)	

*) Dehairing includes scalding, dehairing, singeing, and polishing.
**) As adapted from Nutt and Kissel [9].

further processing. Perhaps the technique of skinning has not as yet been perfected so that pieces of fat are removed along with the skin. Special grading regulations may also have a bearing on this. However, in reality we do not know the answer to this question.

We have arbitrarily divided the approach to energy savings into three types, and we shall from now on deal only with the meat-processing industry.

THE GOOD HOUSEKEEPING APPROACH

The first type of saving can be readily achieved by the application of good housekeeping procedures. These include the adjustment of steam traps, reduced lighting, replacement of incandescent lights by fluorescent fixtures, and use of pipe insulation. In a seminar as reported in the National Provisioner [6] many hints are given as to how energy can be saved in the packinghouse. Most of these steps involve little capital or technical input. Nevertheless, these "quick-fix" methods can lead to substantial savings.

THE IMAGINATIVE ENGINEERING APPROACH

The next step in achieving better energy utilization involves a more sophisticated approach and requires a modest capital input. The installation of heat exchangers at strategic points in the plant is a step which would readily occur to a competent engineer. The monitoring of oxygen, carbon monoxide, carbon dioxide, and temperature in the stack of a steam boiler house is helpful in making burner adjustments, thus minimizing steam costs.

Based on the experience of Canada Packers Inc., let us now give some other concrete examples of the application of sound engineering principles and common sense to packinghouse operations. Canada Packers is a diversified Canadian corporation, and the largest producer of food products in Canada.

Meat and poultry processing plants consume large volumes of hot water for plant and equipment cleaning. By using high-pressure hot-water rising systems (35 to 175 kg/sq cm), the hot water flowrate can be reduced from 90 to about 23 L/min. To achieve further energy savings the only alternative now seems to be to reduce the temperature of the hot water used for cleaning. It is now between 71 °C and 82 °C. To achieve this, low-temperature alkali-based, foaming-liquid cleaners were developed suitable for meat and poultry processing plants. They are effective at 43 ± 3 °C. In actual plant tests in the cookroom these low-temperature cleaners were as good as, if not somewhat better, than the standard cleaners used at 71 ± 3 °C. This has resulted in an energy saving of 35.6%. These developments were desccibed in a report by Scriven to Agriculture Canada, so far unpublished [7].

Some of the largest and most cost effective savings were found in the steam distribution system. However, finding the problems could be difficult and time-consuming because a steam distribution system may contain hundreds of potential failure points distributed over several kilometres of pipeline. Over a period of several years, a technique was developed which is referred to as Base Load Analysis. This enables accurate estimates of the total amount of distribution losses and aids in locating the major failure points in the system.

Base Load Analysis is based on the fact that distribution losses occur at a fixed rate and will manifest themselves as a minimum or "base" load that is present whenever the boilers are in operation. Most of the time this load is masked by process and building-heating loads. However, when the plant is notin operation and the building is not heated, the base load can be measured directly on the steam flow meter. In a well designed and maintained distribution system the losses (base load) should not exceed about 5% of the average steam load during production periods. Among some of the older facilities base loads were found in the 30 ro 50% range.

Base Load Analysis is also used to assist in the location of the major faults in the distribution system. This involves systematically shutting down and re-opening the valves to each branch of the distribution system and noting any changes in the base load. In this way the major problem areas can be identified.

This program has resulted in some very significant savings. In one plant the cost reduction was $ 112.000 per annum for an investment of less than $ 10.000.

Boiler flue gas heat recovery has been practised for many years. However. the amount of heat that could be recovered has been limited by the requirement that the flue gas not be cooled below its acid dew-point in order to prevent cold-end corrosion of the heat exchanger. As a result, flue gas was not cooled below about 150 °C, and only a small fraction of the sensible heat and none of the latent heat could be recovered, limiting the total heat recovery to about 25% of the total available heat.

In 1982, Canada Packers installed a condensing flue gas heat-recovery system at its plant in Winnipeg. The system is called a Direct Contact Heat Recuperator, and is manufactured by John Thursley Limited, of Harrogate, England. It recovers heat by bringing the flue gas into direct contact with cold-water sprays. The heated spray water is passed through a plate heat exchanger, and is used to heat potable water for processing and sanitation. The spray water is then recirculated to the heat recovery system.

The recuperator produces water at a temperature of approximately 54 °C. Flue gases leave the recuperator at a temperature of 38 °C or less, which effectively raises the overall combustion efficiency to more than 96%. The annual natural gas savings have been estimated to be about 41.000 GJ, for a net cost reduction of $ 141.000. The total installed cost was $ 400.275, of which $ 160.192 was contributed by the Manitoba) Canada Conservation and Renewable Energy Demonstration Agreement.

Two of Canada Packers' beef slaughtering facilities operate batch-type inedible rendering systems. Rendering takes place in steam-jacketed cookers which evaporate the moisture from the raw material and melt the fat. The moisture evaporated by the cookers is exhausted as saturated vapour at 100 °C which contains about 95% of the latent heat derived from the steam supply. Prior to the installation of the present heat-recovery system, the vapour was condensed in barometric condensers and discharged to the sever.

A 1980 study revealed that there was a very good match between the rendering waste-heat flow and the heat required for hot water for processing and sanitation. As a result, a waste-heat recovery system was designed which employs a spiral-type heat exchanger to condense the vapour and heat potable water. The first installation was at the Moose Jaw, Saskatchewan plant in 1982, followed by one in Lethbridge, Alberta in 1984.

The Moose Jaw installation resulted in a estimated annual saving of 17.800 GJ of natural gas and a net cost reduction of $ 53.000. The cost of the installation was $ 140.745 of which $ 26.190 was contributed by the Saskatchewan/Canada Conservation and Renewable Energy Demonstration Agreement.

NEW SCIENTIFIC AND TECHNOLOGICAL APPROACHES

MICROWAVE ENERGY

Microwave energy is by no means new but has not been applied to any great extent to meat processing. A recent review by Mandigo and Janssen is a useful source of information [8]. These authors pointed out that there were 78 processing systems already in existence in the USA in 1976. These included processors for precooking chicken and bacon, the tempering of meat, and the coagulation of extruded reformed meat.

Microwave installations are available for defrosting meats, sometimes called tempering. Microwave energy is carefully applied to raise the temperature of product to -4 to -2 °C. Energy is applied intermittently and the product is allowed to "temper" out between pulses. This is done so as not to allow pockets of water to form. This would soon lead to local overheating. Afted the tempering period thawing is allowed to proceed normally. It is claimed that this reduces the time and energy required to defrost meats.

In reading the paper by Mandigo and Janssen [8] we must come to the conclusion that the major application of microwave cooking has been in the food-service industry and in the home. Millions of homes on the American continent now have microwave ovens. The food-service industry uses many precooked and preseared meat items which can be readily finished in the microwave oven. Table 6 gives a comparison of energy requirements when cooking in a conventional electric oven and in a microwave oven. Mandigo and Janssen conclude that mircowave cookig requires about one-third of the energy of conventional cooking.

Table 6. Energy requirements for cooking in a conventional electric oven and a microwave oven*)

	Energy used (Kw-hr)	
	conventional	microwave
Breaded chicken	0.93	0.36
Tuna casserole	0.83	0.16
Rib roast, 1.8 kg	0.92/kg	0.41/kg
Baked chicken	1.33	0.37
Beef stew	0.57	0.91
Turkey, 5 kg	3.29	1.60

*) As adapted from Mandigo and Janssen [10].

However, they also caution that the microwave-cooked product may be different in appearance and flavour from what the consumer expects. This is certainly a factor which must be kept well in mind.

We cannot help but wonder whether the meat industry is not missing an opportunity in the use of microwave energy. By way of example, a large commercial bakery in the Toronto area uses 67 m conveyorized ovens to bake, say, cheese crackers. This is done in 6 to 7 minutes and the moisture content is reduced to 4-5%. However, the proper appearance and taste of the cracker is developed in three minutes, the rest of the time being taken to remove moisture to achieve the desired crispness. A microwave oven at the end of conventional gas-fired oven will reduce the moisture to 3 to 4% in a few seconds. Production can thus be increased by 30-50%, depending on product. In crispness, appearance, and taste the cracker is indistinguishable from the conventionally processed product. Can we think of such applications in the meat-processing industry? Here the object is not usually the removal of moisture. Can a combination of conventional and microwave processing produce a product of the desired sensory properties in a shorter time and with a saving in energy?

NEW DIRECTIONS IN MEAT PROCESSING

From the point of view of management, the third and most difficult step in energy conservation involves major redirection and large capital investment. Plant facilities may have to be consolidated and old and inefficient plants abandoned and replaced by new ones. From the point of view of the food scientists and technologists, the most important step is the adoption of entirely new processing methods. One that immediately comes to mind is hot processing, or hot boning, perhaps preceded by electrical stimulation. Thus, about 70% of the hog carcass goes out processed in one form or another. Why chill the carcass down when the next step is the processing of individual cuts by curing and heating? How much easier would it be to chill individual beef cuts, rather than carcasses, either before or immediately after packaging? The savings in refrigeration cost and space would certainly be substantial.

The subject of hot processing was extensively discussed at a recent symposium on Meat Science and Technology, and the proceedings have been published [9]. In this symposium C. L. Kastner gave a valuable overview, and the situation in five countries was covered by other authors.

According to R. L. Henrickson there appears to be very little direct industry application of hot processing of primal cuts in the United States [9]. This is also true of Canada. Hot processing is used in the production of pork sausage. The process is very simple. Lean meat and fat are separated from the hot carcass, chopped, partially cooled, seasoned, and ground and stuffed. This makes the product available to the consumer in less than ninety minutes after bleeding. This is apparently widely practiced in the United States.

The situation for pork primal cuts is much different. The curing of hot-processed pork cuts is hardly practiced in the United States and Canada. The literature was reviewed in some detail by Kastner [9] and it would seem that a satisfactory product can be produced. This view is supported by Hendrickson [9].

In summary, logical as it may seem from a time- and energy-saving point of view, the hot processing of pork primal cuts is not being practiced. Henrickson [9] attributes it to conservatism. This is certainly an important factor. However, there may be another reason. There is a tendency on the American continent towards single-purpose plants that either kill and dress, or process meat products, but do not do both. This would make it impossible to move the hot product from slaughtering to processing. The two must be side by side in an integrated operation.

There is a very lively interest in the hot-processing of beef. By this we mean the subdividing of the beef carcass shortly after slaughter into primal and sub-primal cuts, followed by packaging and chilling. The objectives would be do to reduce shrink, to save on refrigeration capacity and space, to reduce the cost of transportation and, generally, to shorten considerably the time between slaughter and sale. However, not all of these objectives are compatible with one another.

It is now well-known that rapid chilling may have a detrimental effect on the texture of meat which is still in the pre-rigor state. This phenomenon is referred to as cold shortening. This whole field has been extensively reviewed on many occasions, and for an overivew the reader is referred to the proceedings of the symposium already mentioned above [9]. A very useful monograph has recently appeared called "Electrical Stimulation". It is volume 1 of a series on Advances in Meat Research [10].

As a general guide cold shortening occurs when the pH is above about 6.2 and the temperature falls below 11 °C Bendall [11]. Hot-boned cuts are particularly susceptible to cold shortening because they chill down faster and are no longer supported by the skeleton. Using Bendall's guidelines, schemes have been developed for handling hot-boned beef cuts in order to avoid cold shortening. Buchter [9] describes a commercial operation in Denmark where hot-processed prepackaged beef cuts are chilled at 12 °C for 5 hours, then at 7 °C for 17 hours, and finally at 2 °C for another 20-24 hours. It should be carefully noted that no electrical stimulation is used.

Electrical stimulation is, however, a very useful tool when applied to beef and sheep carcasses shortly after slaughter J. Savell [9]. It causes a rapid contraction-relaxation cycle which drains the ATP content of the muscle, thus, causing a relatively rapid fall in pH to about 6. On rapid chilling cold shortening can no longer occur. It may be interesting to note that electrical stimulation may be inappropriate for pork carcasses due to the danger of increasing the incidence of PSE pork Kastner [9]. For a thorough treatment of this subject the monograph already referred to should be consulted [10].

Electrical stimulation is being extensively used in the meat industry, apparently world-wide. The reasons for using it are discussed in detail by G. C. Smith [10]. According to R. L. West [9], there are 500 plants in the United States that are now using this process. New Zealand, of course, pioneered in this are and a good account is given by B. B. Chrystall and C. E. Devine [9]. It is also used in many countries in Europe.

Electrical stimulation should make the hot boning of beef readily possible. The two techniques are complementary. The economics are favourable as shown in a very comprehensive report by Fergusson and Henrickson [12]. The two authors reported separately on this subject at a later date Fergusson [13] and Hendrickson [9]. Fergusson [13] claims that hot boning gives a 2% higher yield of total meat, an 80% reduction in cooler space, and a 68% decrease in the heat energy required to cool the meat. This results in an increase in the retail value per side of $ 17.00. These are indeed startling figures which require careful consideration.

In spite of these advantages hot boning is in fact not being used to any great extent. In the United States 70 to 80% of the beef is already shipped as boxed beef, that is as vacuum-packaged primal and sub-primal cuts. This eliminates some of the savings in transportation which could accrue from shipping hot-boned beef. However, there are other important savings which could well be realized by hot boning. Perhaps reluctance to change is one of the reasons. Thus, a technology worts to be realized.

CONCLUDING REMARKS

The food industry is a substantial user of energy but, considering the very basic function which it performs, not unduly so. However, certainly in Canada, it has been diligent in bringing about energy savings, 22.0% in the decade 1975 to 1985. This is a record of which one can be proud. The meat industry has participated fully, as indicated above. However, I should like to end up with a quotation from J. F. Kefford [14], the Secretary — General of IUFoST — "Finally I would make the point that in the food industry, more than in most industries, it is not wise to optimize processes on the basis of energy economy alone; the safety and quality of the product must be prime considerations, and they may conflict with energy economy".

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ZUŻYCIE ENERGII W PRZEMYŚLE MIĘSNYM W WARUNKACH OGRANICZEŃ ENERGETYCZNYCH

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Streszczenie

Zużycie energii do wyprodukowania żywności oraz przechowywania i przygotowywania do spożycia w domu jest podobne i o wiele wyższe niż w dwu pośrednich ogniwach: w przetwórstwie i pakowaniu oraz transporcie i dystrybucji (tab. 1). Zużycie energii w przemyśle mięsnym jest bardzo zróżnicowane w poszczególnych operacjach jednostkowych oraz zależne od przetwarzanego mięsa (tab. 3). Ponadto zużycie energii można obniżyć przez gospodarność dzięki poprawnym instalacjom elektrycznym oraz przez wykorzystanie nowych, naukowych i technicznych osiągnięć (tab. 6).

W latach 1975-85 nastąpiło w Kanadzie zmniejszenie zużycia energii w przemyśle spożywczym o 22%, w czym nie mały udział ma przemysł mięsny.