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INTENSIVE BEEF PRODUCTION; ACCOMPLISHMENTS AND PROBLEMS

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The utlization of cattle in the production of food for human consumption takes place primarily in those areas that have either an excess of roughage or an excess of grain. Although cattle and sheep are the major economic ruminant animals that can utilize roughage, it is misleading to say that cattle production can only take place where there is an overproduction of roughage in a world that is short of food. In those areas where grain production exceeds the demand for human food, grains are used to produce beef. Garst (1963) has said that the real function of livestock is to burn off the carbohydrates and to concentrate protein. Thus if carbohydrate is produced in excess, whether it is cellulose or starch, livestock serve a positive role in human nutrition. In my opinion, we are nowhere near the world's capacity to produce grain. This paper will review certain aspects of intensive beef production utilizing grain as practiced in the United States. A comprehensive review of intensive beef production has been provided by T.R. Preston & M.B. Willis (1970).

Intensive, means to cause an increase in degree or amount, to increase the yield per unit of input. In livestock production, there is probably no better example of this than the cattle feedlot industry in the United States (U.S.). Other areas in the world have intensified livestock enterprises, but these represent primarily an intensification of labour. The feedlot industry in the U.S. represents an intensification of capital input in order to minimize labour input. Most of the practices which characterize this industry can be so described, and the degree of intensive feedlot production and its geographical location can be largely related to the willingness of financial systems to invest in this intensive system of production and to the willingness of feedlot operators to undertake a large financial obligation to achieve the scale of operation that makes many of the things to be described here a reality. Agricultural production is characterized by diversity, habit and tradition, rather than being based on sound records and business judgements. The latter is what characterizes the large cattle feedlot operations in the U.S.

The major centres of large units in the U.S. are in the panhandle area of Texas and Oklahoma, the Southwest area of Arizona and Southern California, and in the plains area of Nebraska, Kansas and Colorado. The traditional Corn Belt area of the United States (Iowa, Illinois, Indiana, Missouri, Minnesota, and Ohio) is still a major cattle feeding area but practices are more conventional, traditional and generally on a smaller scale than in the abovementioned areas.

In 1973, there were 146,420 feedlots in the U.S.; recently, there has been a decline in the total number of feedlots (5% decrease in 1973). However, the number of lots with a capacity of greater than 8000 head increased by 7% in 1973. These larger lots made up less than 1% of the total, but marketed 48% of the fed cattle in the United States. There were 206 lots with capacities over 16,000 head, which accounted for 35% of the fed cattle (U.S.D.A., 1974). It has been projected that by 1975, the panhandle area of Texas-Oklahoma, Kansas and Nebraska will finish two-thirds of the cattle in the U.S.; Iowa and Illinois will account for one-sixth of the total (Dietrich, 1971).

In the large feedlot areas, most of the operations can feed between 5,000 and 50,000 head of cattle at one time; some feedlots are even larger with capacities up to 200,000 head. Since the typical feeding period is 120–150 days, it is possible to feed annually up to two and one-half times the capacity of any given lot. More typically, approximately 80% of capacity is realized; therefore two times the capacity of the lot is fed annually.

As already mentioned, such lots require a large capital investment not only in physical facilities, but also in cattle to stock these lots. Many lots have feed mills which are used almost solely to feed the cattle. Typical costs for physical facilities range between $50–150 per head capacity and cattle costs range between $175–250 per head. Thus an initial investment, not considering feed, for a 20,000 head lot would be near $6 million.

Few feedlots therefore represent a typical farmer owned enterprise. Generally they are financed by financial institutions (e.g., commercial banks) and managed by professional persons familiar with procurement, nutrition, veterinary medicine and marketing. In many cases, the cattle are owned by persons interested only in investing money and are fed in feedlots on contracts, based generally on feed and yardage costs.

Because of the heavy outside financial interest, complete records are maintained which are essential for the financial transactions involved. These records, however, serve to evaluate practices thus enabling small improvements in overall efficiency to be measured, something that has never been possible in traditional agricultural enterprises. While many advantages are claimed for the location, etc. of these large feedlots, the evaluation of meaningful records is, in my opinion, the chief advantage that large feedlots have over traditional systems of feeding cattle.

Typically, these feedlots utilize weanling calves and some yearlings, both steers and heifers. Initial weights range between 160–300 kg. Overall, the ration fed consists of 30% roughage and 70% concentrate, and is fed *ad lib.* Initially, the ration contains a lower level of concentrate, with the level of concentrate increasing during the feeding period up to as high as 90 or even 100%. The amount of feed dry matter required to produce a unit of liveweight gain generally ranges between 5 and 8. Upon reaching a final condition that is typical of U.S.D.A. grade Good and Choice, these cattle are generally sold direct to packing companies for slaughter. Slaughter weights range between 360–540 kg (Dietrich, 1968).

Other points that further characterize the feedlot industry will be developed in subsequent discussion. The industry as it has developed has made some outstanding accomplishments and it has been plagued by some problems. A discussion of these will serve to further describe this industry.

The major reason for the scale and extent of the feedlot industry has been the surplus grain production in the U.S. between 1950 and 1970. This obviously meant cheap grain, which lead to nutrition and management systems that permitted the feeding of high grain rations. Research showed that roughage was not a requirement for ruminants, although most studies indicate some benefit in performance when low levels (e.g. 5%) of roughage are included in the ration.

Grain processing methods have been a major research area, which has been recently reviewed (Waldo, 1973; Hale, 1973, Natl. Res. Council, 1973). Benefits with certain grains are especially notable. Milo (grain sorghum) is not well utilized by cattle without prior processing. Grinding and rolling greatly improves its utilization but steaming followed by flaking results in maximum utilization. Some benefits are derived from processing barley; dry rolling, however, appears to result in maximum utilization with only inconsistent further improvements with steaming and flaking. Improvements in the utilization of corn (maize) are not nearly as large and are less consistent. Our research (Vance, Preston, Klosterman & Cahill, 1972) has shown that unprocessed whole dry corn will actually give better performance in finishing cattle than rolled dry corn, depending on the level of roughage that is concurrently fed. With roughage levels less than 15–20% of the ration, whole corn will result in better performance than rolled corn, whereas the reverse is true when roughage levels exceed 20% of the ration.

Small but consistent improvements in grain utilization especially in feed efficiency (5–10%), are seen when grains are stored in restricted air containers (e.g., silos) following harvest with higher-moisture levels (25–32%) than is possible for storage as dry grain (10–15%). "Reconstitution" of grain gives a similar result. Water is added to dry grain prior to placing in a silo to effect the "reconstitution" process, followed by storage and partial ensiling for at least 3 weeks.

Another major accomplishment is the mechanization of feeding, greatly reducing labour. This has happened partially because of the use of high grain rations that are more easily mechanized than rations containing high levels of roughage. Feed wagons or trucks are used with side deliveries into fence line feed bunks. Feed ingredients are weighed into these trucks followed by mixing prior to placing into the feed bunk; most of these feed delivery systems have built-in scales enabling feed records to be kept on each pen of cattle. The other common method of mechanized feeding uses augers or belts that blend feed ingredients and deliver the mixed feed along feed bunks. This system is more common to those areas of higher rainfall, since mud in drives adjacent to feed bunks can become a problem and because coverage of the bunk to shield the feed from rain and snow is more easily accomplished.

Since rations are prepared daily from a standardized combination of feed ingredients, computer formulation of rations is practiced by many lots to achieve specified nutrient levels and other ration requirements which are known or found to be desirable for a particular set of circumstances. These specifications generally include energy concentration (net energy), protein, calcium, phosphorus, potassium, salt (NaCl), vitamin A, antibiotics, etc. Feeds may be given an arbitrary roughage value and a minimum roughage value is specified for the total ration. Many other nutrient and feed specifications are included depending on feed sources available and the particular preferences of the nutritionist in control of ration formulation. Where choices are possible for various ingredients, computer formulation using least cost computations results in minimizing the cost of the total ration. It has been emphasized, however, that least cost formulas are not necessarily maximum profit formulas, since ration specifications do not consider changes in profit potential with changing specifications (Preston, 1972). It can be generalized, however, that costs are minimized by feeding nutrients at levels that will allow maximum rates of gain.

More efficient utilization of physical facilities is another accomplishment of large feedlots, thus enabling higher cost facilities (e.g., feed mills, covered slotted floor feeding barns) to be part of the feedlot. As mentioned above, more traditional systems of cattle feeding generally feed one group of cattle annually thus greatly increasing capital costs per head of cattle fed.

Because of the numbers of cattle involved and the detailed records maintained by large feedlots, small alterations in nutrition and management can be evaluated and standard procedures altered to incorporate those found to give beneficial results. Thus small changes can be measured, something that is not possible under many typical experiment station conditions, because of small experimental numbers and the large experimental error associated with cattle research.

Probably the biggest and most obvious accomplishment has been the volume production of a standardized product for an unbelievably expanding market for beef. U.S. Choice beef is by far the most popular grade of beef. Massive volumes are marketed on the basis of carcass weight, grade and retail yield specifications, something that probably would never have developed without the large volume and standardized practices of large feedlots. All enterprises have problems, however, and the feedlot industry partially because of its rapid growth has had its share.

Grain and protein feeds have been increasing in price, especially during the past 18 months. Thus the basis for the establishment and growth of the feedlot industry, namely cheap grain, is rapidly disappearing. Furthermore a shortage of non-protein nitrogen (urea) and phosphorus sources has disrupted application of computer formulation because while prices for these ingredients are still quoted, they simply are not available in some cases for use in rations. This situation is renewing interest in roughage utilization for finishing cattle (Oltjen, Rumsey & Putnam, 1971) and in the value of by-product feeds (Preston, Vance & Cahill, 1973). Backgrounding, a term applied to a system of production where calves are grown on high roughage rations until they weigh 250–350 kg prior to finishing on high concentrate diets, is gaining in popularity.

Varying degrees of success are experienced when cattle are fed high concentrate rations. There is an adaptation period during which cattle adjust from roughage to concentrate rations. Founder, laminitis or lactic acidosis, is the most common problem observed in starting cattle on high concentrate rations. This is apparently due to the rapid proliferation of micro-organisms in the rumen that produce lactic acid and the relatively slow growth of those organisms that utilize lactic acid. The symptomology is probably due to D(-) lactate which may not be metabolized systemically (Dunlop & Hammond, 1965; Telle & Preston, 1971; Morrow, Tumbleson, Kintner, Pfander & Preston, 1973). Decreased feed intake, poor performance, diarrhoea, lethargy, founder and death are the symptoms of this problem.

High concentrate rations also result in changes in the rumen wall that may increase the incidence of liver abscesses. Thus clumping of the papilae, accumulation of hair-and sloughing of the rumen wall are commonly observed in cattle fed high concentrate rations. Performance of cattle affected with liver abscesses is generally reduced (Powell, Durham & Gann, 1968). Penetration of the rumen epithelium by hair accumulated between the papillae has been suggested as the source of bacteria involved in liver abscesses (Fell, Kay, Whilelaw & Boyne, 1968; Fell, Kay, Orskov & Boyne, 1972). The use of broad spectrum antibiotics markedly reduces the incidence of liver abscesses, as does the use of low levels of roughage (e.g., 5% of the ration).

It has been suggested that the use of high concentrate rations leads to excessive quantities of fat in the carcass. However, data to support this view is very limited. To the contrary, most published reports indicate that plane of nutrition does not affect carcass composition (Preston, 1971), at least when cattle are slaughtered at weights and degrees of fatness that are typical of the U.S. grades of Good and Choice (e.g., 25–35% fat in the carcass). However, prior to this point (e.g., less than 18–20% fat), plane of nutrition may affect carcass composition (Fox, Johnson, Preston, Dockerty & Klosterman, 1972). The grading system used in the U.S. is highly related to the degree of fatness because of its dependence on intramuscular fat (marbling). With current methods of growing and finishing cattle in the U.S., the importance of marbling as a quality indicator is very questionable (Parrish, Olson, Minor & Rust, 1973), whereas the role of maturity (age) is of significance (Goll, Carlin, Anderson, Kline & Walter, 1965). There is no doubt, in my opinion, that the present system of grading in the U.S. is seriously confusing the picture as to what it required genetically and nutritionally to produce a high proportion of lean meat that has a high consumer acceptance. Feeding steers instead of bulls is a good example, where practically all factors favour bulls except perhaps the degree of marbling.

Concentration of cattle in large feedlots has accentuated a common farm chore, namely the disposal of manure. The current environmental emphasis has greatly accentuated this problem and many of the requirements of the U.S. Environmental Protection Agency are posing impossible demands on some existing feedlots. Presently there does not appear to be a more practical solution than the one practiced for centuries, namely spreading on land. Run-off from both feedlots and land on which manure is spread may cause pollution of surface waters and perhaps sub-surface water. Odours from feedlots can become very offensive, especially to residential areas. Like many environmental problems, complete elimination of the problem often means extreme costs which would probably eliminate the product from the market place. Slotted floor facilities with pits beneath allow storage and containment of feedlot wastes for later distribution on land. Since anaerobic fermentation takes place in these pits, the material at the time of removal has a very offensive odour. Various aeration systems have been tried with varying success; most of these are costly in terms of power to operate the aeration equipment. Many feedlots are using lagoons to collect and oxidize feedlot wastes, using the water for irrigation or for reflusing manure into the lagoon.

More ingenious ideas are being tried (Winter, 1974) and one or more of these may offer a practical solution. An enormous composting operation at a large feedlot in Ohio produces a stearile compost in seven days for the gardner and organic food enthusiast at a price that is equal to the feed fed to the cattle originally. Alternately, a low level of this compost can be incorporated back into cattle rations to supply a source of "roughage". "Wastelage" is a term used for feed resulting from the ensiling of manure with other feed materials (Anthony, 1971). Use of manure to produce methane is now being proposed as a source of energy. With the shortages of fertilizer materials due to insufficient energy and increasing fertilizer costs, manure may again be used as a source of plant nutrients, a recycling procedure that is hard to surpass.

One of the biggest problems of the feedlot industry in the U.S. is the supply of cattle to place on feed. Expansion of the feedlot industry and the demand for beef has exceeded the expansion potential of brood stock producers. Simply stated, there are insufficient cows to produce the calves required to keep the feedlot industry at full capacity. As a result, prices of replacement cattle for the feedlot have increased. Cattle are assembled from all over the U.S. and shipped perhaps 1800 km to the feedlot. Additionally, lighter weight calves are being purchased (e.g., 100 kg). Both of these practices have markedly increased the problem of "shipping fever", a syndrome that is respiratory in nature but also involves, founder and death in getting the cattle started on feed following a long shipment under semi-starvation conditions. Many calves will be sold through one or more auction barns prior to arriving in the feedlot, thus exposing them to a full range of respiratory and other diseases. Death losses of 1–3% are common in these cattle and losses up to 10–30% are possible.

Despite considerable research and many claims, there is no known procedure that will prevent the uncertainty of this problem. The feeding of relatively high levels of antibiotics and sulpha drugs will greatly lessen but not eliminate the problem. Many vaccines are available which under certain circumstances may be quite effective; they do not offer sufficient protection, however, to be considered reliable. Preconditioning is terminology applied to cattle that have been weaned, dehorned, castrated, taught to eat from a bunk, drink water from a water tank and properly vaccinated, all sufficiently ahead of shipment to minimize the stress of shipment. While all of these practices are no doubt desirable, no one seems to be willing to pay sufficient premium to the producer to make it worthwhile. Thus many calves are weaned and shipped, and the above procedures are applied at various points thereafter. It is not uncommon for cattle arriving at a feedlot to be given a worming treatment, vaccinated for several bacterial and viral diseases, injected with a massive dose of vitamins A, D and E, treated for grubs, dipped for lice and mange and given a hormone implant, all on the day of arrival at the feedlot.

I would like now to discuss what might be desribed as research needs and probabilities of new findings that will prove useful to intensified beef production. Compared to other classes of livestock, beef cattle have greater potential for improved efficiency simply because they have the lowest feed efficiency of any class of livestock, measured by almost any input-output relationship.

One of the major factors limiting the efficiency of growing-finishing cattle is their low voluntary feed intake (Preston, 1968). Thus efficiencies for the production of edible protein and corresponding voluntary feed intakes are approximately as follows:

Animal	*Protein efficiency*	*Voluntary intake*
Lactating dairy cows	27%	3–5 times maintenance
Growing-finishing pigs	16%	3 times maintenance
Growing-finishing cattle	6%	2.2 times maintenance

Feed intake in growing-finishing cattle on rations that exceed 67% dry matter digestibility (e.g., greater than 50% concentrate) declines resulting in a rather constant energy intake and, therefore, a constant rate of gain with increasing concentrate level. There is some tendency to think that higher levels of concentrate result in higher rates of gain. This may be true in certain circumstances but generally speaking, rate of gain plateaus with concentrate levels above 50% of the total ration. Feed efficiency, as would be expected, continues to improve with increasing concentrate level. This of course has some practical value since less feed needs to be handled and less manure is produced.

If feed intake remained the same (e.g., 100 gm dry matter/$W_{kg}^{0.75}$) with increasing concentrate level, it can be projected that growing-finishing cattle could be as efficient as swine on all-concentrate rations (Preston, 1972). This is where there is greatest potential for improved efficiency in cattle. Various reasons can be postulated for this limitation, e.g., volatile fatty acid (VFA) end products from the rumen, heat production, and growth versus lactation. All of these, however, have points which negate them as explanations, Lactating cows produce VFA's and produce large quantities of heat; both lactating cows and growing pigs eat more feed than growing-finishing cattle. Factors affecting feed intake have been reviewed recently (Baile and Forbes, 1974).

The use of hormones is one production technique that can markedly improve the performance of feedlot cattle. Unfortunately, the use of hormones has become a political rather than a scientific question in the U.S. Exogenously administered hormones, primarily those with oestrogenic activity, will improve rate of gain in steers approximately 12–15% and feed efficiency 8–10%. A vast body of literature has accumulated in the 24 years following this discovery and is too voluminous to review here. Unfortunately, the mode of action of these compounds is stimulating growth is still unknown. Several have been postulated but all have failings that eliminate them as the sole explanation. As mentioned previously, castration eliminates one of the best sources of hormone for enhanced production in cattle. The use of bulls in intensive systems of beef production is an ideal combination since the decreasing tenderness observed in bulls generally does not begin to take place until they are 18–20 months of age. With intensive practices, bulls can be finished for slaughter by this time. It is of interest to note that bulls and hormone treated steers tend to perform equally (Preston, Klosterman & Cahill, 1971). The use of entire male animals in meat production has been recently reviewed (Rhodes, 1969).

One of the greatest needs for research relates to carcass composition as it influences the yield of edible meat and its quality attributes. Breed types, mature body size, slaughter weight and perhaps plane of nutrition may all play a role in carcass composition (Hedrick, 1972). In the U.S., the present measures of carcass grade present a real paradox to the producer. Since marbling, the major factor involved in grading, is highly related to total fat concentration in the carcass, to improve grade generally means to decrease yield of edible meat. Since current systems of intensive beef production greatly diminish or even eliminate marbling as a good indicator of quality, it seems that to continue with this system of grading can do nothing more than to greatly confuse the issue regarding those breeding and production systems that will improve efficiency and still result in highly acceptable beef.

It is well known that the concentration of fat increases in the carcass with increasing weight and conversely the concentration of protein decreases. Therefore, studies on the influence of plane of nutrition on carcass composition must be evaluated at equal body or carcass weight. Cattle fed on higher planes of nutrition generally gain faster and therefore will be heavier after an equal time on feed resulting in carcasses with a higher fat concentration.

The proportion of mature body weight at which cattle are slaughtered is probably the main factor governing the concentration of fat in the carcass (Preston, 1971). Thus, beef trading should be oriented towards the percent of fat required in the carcass for a given consumer clientele and the size of carcass desired. Since maturity (age) is a major factor in tenderness, production systems that will yield carcasses with the required maturity can then be developed. Breed type or mature body size and slaughter weight can then be more logically manipulated to achieve the desired result.

Carcass fat concentration can be quite easily estimated with acceptable accuracy by measuring the specific gravity of the carcass (Preston, Vance, Cahill & Kock, 1974; Garrett & Hinman, 1969). This technique could be easily added to the slaughtering procedure for cattle. Such a practice would greatly enhance the ability of packing companies to sell beef carcasses with known composition.

More research emphasis is needed in the area of live animal evaluation of carcass composition. Several techniques have been studied but most are either too costly or too time consuming to be used either to evaluate breeding stock or to study the growth curves of experimental cattle. Measuring urea space in live cattle is rapid and inexpensive and predicts carcass composition with reasonable accuracy (Preston & Kock, 1973). Further research on this technique may provide sufficient experience to determine if it has promise as a research tool and for the selection of breeding bulls.

The major thrust of this paper has been the intensification of beef production primarily by increasing the proportion of grain in the ration and the resulting advantages and problems that result. Initially, the point was made that roughage utilization is a unique capability of ruminants such as cattle. This is also an aspect of beef production that can be intensified. This is especially needed in the intensification of beef cow management for the production of calves. Unfortunately, most published research in this area deals with basic studies on cellulose utilization and forage evaluation. One of the major limitations in the utilization of roughage has been the large labour input required for its harvest, storage and feeding. Recent developments in the design of farm machinery may alter this picture in the future.

Harvesting and storage of fresh forage as silage is a practice of long standing and is easily mechanized to minimize labor. Corn is no doubt the easiest crop to ensile and results in a high quality feed with minimum risk. Harvesting the entire corn plant as silage can result in 50% more beef produced per hectare than will result from feeding the grain only (Preston, 1972).

"Big package" forage handling machines for harvesting and storing hay and crop residues appear promising, especially where cattle can be fed outdoors for the entire year. Various hay making equipment has been evaluated at Ohio (Van Keuren, Parker & Gill, 1973). Hay quality and feeding value is maintained in these large packages. Thus beef cows can feed from these packages at or near where the hay is harvested thus minimizing labor. Small round bales weighing 20–30 kg, left in the field at harvest time for later grazing by cattle have been used for some time. Newer equipment can package hay in 100–1000 kg packages. Of equal interest is the use of harvesting and packaging equipment for crop residues, such as corn stalks (Butts, 1973). Such crop residues, with proper supplementation, are ideal for beef cows since they are low in energy which keeps cows in a more thrifty breeding condition.

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