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FOREWORD

This paper is one of a series reviewing various forms of traditional agricultural production and related aspects. Preliminary work on this review was carried out within the scope of activities of the Food and Agriculture Program's Task 2 ("Technological Transformations in Agriculture: Resource Limitations and Environmental Consequences"). One of the goals of this task's activities is the review of various alternative technologies available in the world for the production of major crops and animal products. This paper can be seen as a first step towards this final objective providing information backed by concrete data.

Research work on the topics presented has been carried out partly at IIASA and partly at the All-Union Research Institute of Information and Technical-Economic Research in Agriculture.

Kirit S. Parikh
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INTRODUCTION

Industrializing the production of animals has had a substantial impact on livestock management and feeding practices, feed sources, types of livestock feeding and methods of compounding feed rations. However, feed ingredient sources vary in different countries since they are determined to a considerable extent by the soil and climatic conditions of a specific geographic zone and by the economic aspects of feed crop cultivation in individual countries.

In the United States concentrates account for over 40% of the total volume of animal feed; the amount of concentrates as well as other feedstuffs increases steadily. For instance, from 1965 to 1978 the annual consumption of concentrates in the U.S. increased from 146 to 165 million tons, the consumption of hay (1965-77) from 108.4 to 127.0 million tons, the consumpion of other roughage and succulents from 111.8 to 151.2 million tons, the consumption of pasture grasses (1965-75) from 178.7 to 198.1 million tons. Grain accounts for a considerable share in the total bulk of concentrates fed--75-80%.

In European countries roughage and succulents are important in livestock diets (in spite of the high volume of grain production in individual years). Intensive grassland farming makes for considerable amounts of roughage and succulents in diets. Grass, the cheapest kind of feed, is included in diets for all farm animals making it possible to achieve a high milk yield and meat performance during the period with a reduced intake of concentrates. Even in the U.S. and Canada where the feed grain is produced in large amounts, grass is vital for dairy farming and represents

the basic feed for meat animals during the grazing season.

Considerable improvement in livestock performance is a common trend for all the developed countries. This is mainly achieved by feeding complete protein-balanced rations entailing the production of a greater volume of formulated feed, full-ration mixtures and non-protein feedstuffs.

In recent years a trend has been observed in the socialist countries towards regarding feed production as a separate branch. In several countries such as Bulgaria and West Germany specialized feed-producing farms have been set up both on arable land and grassland (in view of establishing big livestock breeding enterprises). Specialization and concentration of feed production within the framework of agro-industrial complexes necessitate all-round mechanization of production processes which results in a lower cost price of feed and, in the long run, in lower cost price of animal products.

1. Field Feed Production

Intensification of livestock husbandry considerably alters the structure of field feed production. Of particular importance is the proper determination of optimum crop ratios in crop rotation systems aimed at the maximization of feed production and continuous supply of green feed for farm animals.

For feed producing farms recommendations have been worked out regarding the disposition of sown areas depending on the climatic conditions and the specialization of farms. For each climatic zone the most profitable crops have been identified.

"Green conveyer" (i.e. a continuous supply of green feed for farm animals during a prolonged period of time by optimal rotation of feed crops) is an integral part of feeding system employed in industrial complexes (especially if livestock is kept in confinement all the year round) (Vinogradova 1980).

Perennial grasses play an important role in the development of feed resources and offer the possibilities of solving the feed protein problem. The sowing of grasses depends largely on seed availability. A high level of the development of seed farming has been achieved in the U.S., Canada, Denmark and Sweden. These countries satisfy their own requirements and grow seeds for export. Some countries propagate home-bred varieties of various grass species in other countries with more favourable soil and climatic conditions. Thus, some leguminous plant varieties of Norwegian, Finnish, West German and Swedish origin are constantly propagated in the U.S., Canada, Greece, Turkey, Portugal, and Spain; these varieties produce high yields ensuring high profits for the seed growing enterprises (Vinogradova 1978).

Along with the increase of feed crop yielding capacity much consideration has been given to higher feed value in recent years. For instance, in Hungary investigations are carried out into the possibilities of breeding alfalfa for lower fiber content and higher content of protein, carotene and xanthophyll.

In Roumania collections of plant material are studied to find ways of using American and Mexican varieties as a stock material for further selection for higher protein content. Work is under way aimed at achieving a lower saponin content in alfalfa (Hungary, Czechoslovakia) and a higher digestibility and better palatability resulting in a greater feed intake (Czechoslovakia, France) (Novoselova and Kuleshov 1978; Mika and Nasinek 1977; Feedstuffs 1977).

Work carried out in the Swaleff Institute, Sweden, aimes at achieving higher feed value of clover. The correlation between feed digestibility and protein content has been established. High digestibility of organic matter is characteristic of high-protein plants (Novoselova and Mikhailichenko 1975).

In East Germany extensive use has been made of intergeneric and interspecific hybridization of Graminea and Cruciferae spp. to improve their feed value. The above research work has resulted in the development of such hybrids as *Festuca pratensis* x *Festuca arundinaceae*, *Lolium multiflorum* x *Festuca arundinacea*, etc.

Hybrids resulting from crossing garden radish and oil radish with Jersey cabbage also proved to be promising for feed purposes. An oil radish variety low in mustard oil has been developed at the Institute of Plant Breeding, USSR. Work is under way to elaborate a method for quantitative determination of thiocyanates in the vegetative mass of Jersey cabbage, which would permit the development of varieties with lower thiocyanate content.

The new fodder rape variety Samo which contains lower amount of glucosinolates has been developed in Sweden. The variety is characterized by a high yield of green mass (422 to 460 quintals per hectare), dry matter content, 13.9 to 14.8%, raw protein content, 14.4 to 14.9% and digestible organic matter, 73.9 to 80.5% (Magyarosi 1978).

Parallel with breeding feed crops for higher protein content, research work is under way in a number of countries aimed at developing varieties which are able to tolerate frequent cutting. The protein yield per hectare would then increase due to cuttings at earlier stages of development. In recent years several such alfalfa varieties have been developed in France ("41-61", "134x51", "128x78", etc.) (Mika and Nasinec 1977:456-458; Guy et al. 1978:142-147; Svirskis and Slesaravitchus 1979:54-55).

Mixed sowings of feed crops with leguminous and other high-protein crops are also sources of increasing the protein yield per hectare. This is a common practice in many countries (e.g. East Germany, Poland, Bulgaria, West Germany) (Halasz 1977:81-89; Johnston and Sanderson 1978:421-426; Husdjur 1979).

There is a continuous trend towards the use of catch-cropping system providing for an additional source of feed with an increased protein content. The above catch-cropping system is widely used in East Germany, Poland, Bulgaria, West Germany (Toth 1977:12; Fischer 1978a:1700-1703; Fischer 1978b:1800-1801; Oliver 1978:12-13; Simon and Herrmann 1978: 125-126; Fatyga 1978:81-88).

2. Grassland Management

Intensification of hayland and pasture use along with converting more natural ranges to productive grassland is a major trend in modern feed production. Grasslands occupy over 2/3 of the world agricultural land (Voyan 1977; FAO Production Yearbook 1979:45-56).

During the last 10-15 years the area of haylands and pastures in the developed countries remained relatively stable. Crop yielding capacity was high. Depending on the soil and climatic conditions and the agronomic practices cultivated pastures yield at least 8000 feed units per hectare. In the Netherlands the maximum yield from pasture land is 14 tons per hectare with the total milk production exceeding 11 million tons in 1979 (Peyrand 1978:49-53; Statistics of cattle and sheep farming in the Netherlands 1979; Van Burg et al. 1980:15-33). In France the average yield of hay from permanent pasture exceeds 3.3 tons/ha, and from highly productive pastures 10 tons/ha (Special prairie Permanente, 1976; Laissus and Jeannin 1978:5.35-5.40; Laissus 1980:97,99,101). In West Germany the average yield of hay amounts to some 6 tons/ha and in Great Britain, 4.4 tons per ha (U.K. National Economic Development Office 1974; Mott 1980: 388-407; Buchner and Sturm 1980:227-256).

Pasture feed is the cheapest in all the countries of the world. Comparative studies carried out in Great Britain demonstrated that the yield per hectare and cost of 1 kg are respectively: barley - 3.9 tons/ha and 5 pence; swede - 6.1 tons/ha and 3.7 pence; turnip - 4.7 tons/ha and 3.7 pence; grass for silage - 7.3 tons/ha and 3.2 pence; corn for silage - 8.9 tons/ha and 3.0 pence; grass for hay - 4.4 tons/ha and 2.0 pence; pasture grass - 7.6 tons/ha and 1.1 pence (U.K. National Economic Development Office 1974).

In view of the high economic effectiveness of keeping cattle on pasture, ongoing research in European countries, the U.S. and Canada focuses on the more efficient use of pastures and higher yields. The effort to increase grass consumption with the aim of saving concentrates and obtaining lower cost price of milk is especially well pronounced in Great Britain (Zazenby 1980:26-37).

At the present stage of the development of grassland management there are three main trends:

- breeding work aimed at genetic improvement of feed crop varieties;
- improvement of agricultural practices with such factors as the intensification and methods of grassland use to be taken into consideration;
- the development of new systems of grassland use aimed at the simplification of the rotational and strip grazing methods.

Application of nitrogen fertilizers is a major agronomic practice in grassland farming.

Given below are data on pasture productivity and the output of animal products as affected by Nitrogen application rates (U.K. National Economic Development Office 1974):

Table 1. Animal production from grass (Common Market countries)

Level of production	N, kg/ha	Herbage[a] yields		Cow[b] grazing days/ha	Beef[c] grazing days/ha	Expected production in 180-day grazing season			
		DM+ kg/ha	DCP++ kg/ha			cows/ ha/	milk per ha	beef cattle per ha	live-weight gain kg/ha
Low	0	5500	600	390	820	2.2	5880	4.6	820
Medium	150	9800	1100	700	1460	3.9	10500	8.1	1460
High	300	11700	1600	835	1750	4.6	12500	9.7	1750
Very high	450	13200	2020	940	1970	5.2	14100	10.9	1970

DM+ = dry matter;

DCP++ = digestible crude protein

a) = estimated 75% DCP

b) = estimated intake of a 500 kg cow yielding 15 kg milk: 14 kg DM per day

c) = estimated intake of a 350 kg beef animal gaining 1 kg/day: 6.7 kg DM per day.

In the Netherlands some farmers apply 400 to 500 kg of nitrogen per hectare of pastureland. Nitrogen application rates vary depending on the soil type. Annual application rates on sandy soils, 150 kg N/ha (Van Burg et al. 1980:15-33; U.K. National Economic Development Office 1974). In France it is recommended to apply 250 kg of nitrogen per hectare of pastureland (Farmers Weekly 1980:91,93; Laissus 1980:97, 99,101; Special Prairie Permanente, 1976). In West Germany some farmers apply 180 to 400 kg of nitrogen per hectare; these high application rates make possible the intensive use of grassland (7 to 8 cycles during a season) and provide for a high feeding value of the green mass (Heymann and Buhlmann 1979:228-245; U.K. National Economic Development Office 1974; Mott 1980:388-407; Buchner and Sturm 1980: 227-256).

During the past decade in France, Great Britain, the U.S. and Canada the energy crisis induced the revaluation and more extensive use of leguminous crops for establishing pastures (Farmers Weekly 1980:91,93). Experiments demonstrated that clover provides for the accumulation of 40 to 200 kg of nitrogen per hectare (139 kg/ha on an average). White clover mixed with grasses provides an average dry mass yield of 70 quintals per hectare of pastureland with an accumulation of 120 kg N/ha (Breese and Davies 1974:11-26; Brockman 1974; Breese and Davies 1976; Hughes 1979:60-74).

In many countries extensive research work is under way to study the rational use of organic fertilizers.

In Great Britain it has been shown that for one hectare of grassland the application of liquid manure produced by 5 cows during winter fully satisfied the requirements in phosphorus and potassium for grass. Manure contains only sufficient nitrogen to meet the requirements of the

first crop of grass, all further cuts need additional application of mineral nitrogen fertilizers. However, the additional profit due to the use of organic fertilizer is estimated at Pound Sterling 10 per cow, or Pound Sterling 50 per hectare (Ministry of Agriculture, Fishery and Food 1974-75; Schechtner et al. 1980:77-93).

Despite the proven advantages of the rotational grazing system over the continuous grazing system, during the recent decade a clearly manifested trend has been observed in the European countries towards the introduction of the continuous grazing system which would simplify considerably the whole pasture management practices. Recent studies carried out in West Germany, Great Britain and some other countries showed a benefit of rotational grazing of only 1.5% and 6% to dairy cows and beef animals correspondingly as compared to continuous grazing. Herbage intake and animal production close to the potential maximum can be achieved on rotationally grazed swards when a stubble of 8 to 10 cm is left after grazing; on continuously grazed swards 7 cm stubble is to be left.

Labor inputs under continuous grazing system can be considerably less than those under rotational grazing; besides that, the denser pastures may be more resilient to weed ingress and sward deterioration. Experiments showed that continuous grazing requires considerable management skill; the "pasture/ animal" system is to be maintained in a state of equilibrium (Hood, 63-69; Le Du 1980:31-43; Ernst et al. 1980:119-126).

Much attention is given to the optimization of the stocking rate. For intensive dairy farms the recommended stocking rate is 5 cows per hectare of the grassland in summertime or 2.5 cows per hectare if the animals are provided with grass feed all the year round. However, these rates may vary depending on the grass stand composition, methods of grazing and other factors (Stevens 1975:3-5; Fisons Fertilizer Leaflet 5-A16/Rev).

Investigations carried out in West European countries have shown that due to the high quallity pasture feed (with dry matter digestibility at not less than 73-78%) it is possible to reduce the consumption of concentrates in rations (Zazenby 1980; Farmers Weekly 1980).

3. Bulk Feed Production

In recent years a highly productive livestock industry has become a major emphasis in many countries. Important problems are the bulk feed (silage and hay) production and the improvement of technological processes of hay-making and silage-making.

Ensiling is the most common method of green feed preservation. In the U.S. the annual production of silage exceeds 100 million tons. The annual production of silage in France amounts to 45-55 million tons (corn silage), in West Germany 30 million tons, in Great Britain 17 million tons (1976). In Norway, Finland and Sweden ensiling is the main method of the production of succulent feed.

Major crops for silage making in the U.S. and Canada are corn and sorghum and in European countries mostly perrenial grasses (Oehring 1972:815-816; Runov 1975; Output and utilization of farm produce in the UK 1972 to 1978).

Ensilage involves a considerable loss of nutrients. According to the data supplied by the Research Center of the U.S. Department of Agriculture the total loss of nutrients in the course of the ensilage amounts to 25%, in West Germany this loss is believed to vary between 21 and 39% (Logan and Hillman, Extension Bull.19; Witting and Filenberger 1974: 592-596).

Therefore the primary emphasis in ensilage is the minimization of the losses of nutrients. In order to achieve this the harvest time must be optimal (corn must be harvested at milk/dough and dough stage, legumes - at stooling and bud stage, grasses - at heading and early flowering stage); furthermore, field wilting increases the dry matter content and facilitates fermentation. In order to improve the quality of silage, chemical conditioners should be added - especially organic acids, such as formic acid, propionic acid, or their mixtures, as well as formaldehyde and in the future, anhydrous ammonia. Besides that, the loading of the silage into hermetically sealed ground silos should take no more than 2 to 3 days; the above silos are to be equipped with the silage handling machinery (Baylor 1976:224-228; Demarguilly and Dulphy 1977:53-61; Donaldson and Edwards 1977:71-81; Arnold 1978:79-88; Chenais 1978).

In addition to the ensiling much emphasis is given to haymaking in a number of countries. The annual volume of hay production in the U.S. amounts to over 100 million tons (including some 70 million tons of alfalfa hay), in France to about 50 million tons, in West Germany to about 30 million tons, and in Great Britain to 9 million tons (Bittermann and Lochmann 1977:255-270; Agricultural Statistics USDA 1978; Schukking 1978:11-118).

The present technology of haymaking involves the reduced period of field drying, further drying to 60-70% dry matter content, and the use of chemical conditioners (organic acids and compounds) (Baylor et al. 1977: 7-29; Cardell 1978:44-47).

Baling is the major method of storing hay in the U.S., Canada, Great Britain and France. In the U.S. approximately 90% of the total hay yield is baled. In West Germany, approximately 40% of the total hay yield is baled with plans for a future increase in baled hay. In Great Britain nearly the total hay yield is baled.

A tendency towards the use of baled hay has started in recent years in West European countries and in the U.S. There are three methods of the preparation of bales: the bales can be made of field dried grass; they can be made of chopped fresh mass; preparation of full-ration bales under stationary conditions.

4. Formula Feed Production

The production of formula feed in the U.S., Japan and 9 Common Market countries keeps increasing. During 1969-76 in the U.S. the production of formula feed increased from 66 million tons to 70.8 million tons, and the total formula feed production in 1978 reached 98.9 million tons. The remaining concentrated feed (nearly 48 million tons) are used in simple mixtures. The total consumption of concentrated feed in 1978 amounted to 146 million tons (Vladimirova 1972; Vladimirova 1980a:37-43).

In 9 Common Market countries formula feed production increased from 47.7 million tons in 1970 to 71.1 million tons in 1978. The increase in formula feed production from 1970 to 1978 in individual countries was as follows: in West Germany from 9.7 to 14.6 million tons; in France from 7.6 to 13.5 million tons; in Italy from 3.6 to 8.6 million tons; in the Netherlands from 7.9 to 12.7 million tons; in Belgium and Luxemburg from 4.3 to 5.1 million tons; in Ireland from 1.0 to 1.6 million tons; in Denmark from 2.6 to 4.1 million tons. In Great Britain formula feed production declined from 11 to 10.9 million tons.

In Japan formula feed production increased from 8.15 in 1965 to 19.6 million tons in 1977 and to 20.4 million tons in 1978/79 (estimated).

An increase in relative amounts of formula feed in farm animal's diet considerably improves livestock performance. It has been shown that formula feed consumption per cow per year in the Netherlands increased from 10.94 to 19.1 quintals from 1970 to 1977 and milk yield per cow per year from 4340 to 4825 kg; in Great Britain from 3.64 to 14.42 quintals and from 3929 to 4580 kg; in West Germany from 4.16 to 8.1 quintals and from 3800 to 4180 kg correspondingly. In the Common Market countries the consumption of formula feed per cow in 1977 averaged 8.29 quintals, the average milk yield being 3840 kg. These figures are forecasted to reach 11.3 quintals of formulated feed consumption and 4250 kg average milk yield, ranging from 3300-3700 kg in Ireland, France, Belgium and Luxemburg to 4800-5100 kg in Great Britain, The Netherlands and Denmark (Vladimirova 1980b:42-51; 1972; 1980a).

In 1977 the average formula feed consumption per 100 kg of pork was 266 kg in the Common Market countries (ranging from 185-189 kg in Denmark and West Germany, to 412-466 kg in the Netherlands and Belgium/Luxemburg). According to the forecasts for 1985 formula feed consumption per 100 kg of pork will reach 300 kg. Relative amounts of formula feed in pig's diets will amount to nearly 100% in the Netherlands, 85-90% in Ireland, Belgium and Luxemburg, 65-70% in Italy and France, 60% in Great Britain and 50% in West Germany and Denmark.

A trend towards lower relative amounts of grain in formula feed still remains in effect in the formula feed industry in European countries. Thus, relative amount of grain in formula feed in all Common Market countries declined from 60.9% to 54.1%, and to as low as 18% in the Netherlands.

The volume of non-grain feed import shipments into the Common Market countries increased from 8.95 million tons in 1973 to 15.4 million tons in 1977. Imported non-grain feed includes soybean oil meal (4.8 million tons in 1973 vs 5.85 million tons in 1977), tapioca (2.65 million tons in 1973 vs 4.2 million tons in 1977 and 5.0 million tons in 1978) and other

non-grain feed, such as milling wastes, maize gluten feed, pulp, etc. (1.7 million tons in 1973 vs 5.5 million tons in 1977).

During the period 1965 to 1977 considerable changes took place in formula feed composition in Japan. Relative amount of corn increased from 34.9% to 36.3%, sorghum from 19.5% to 25.7%, soybean oil meal from 7.6% to 10.9%, fish meal and other high-protein feed of animal origin from 5.1 to 5.2%, granulated alfalfa meal from 0 to 1.7%, other ingredients from 11.7 to 12%. On the other hand, relative amount of bran (excluding soybean bran) declined from 4.6 to 2.1%.

Particular importance is placed worldwide on the use of biologically active additives in formula feed, such as growth regulators. For instance, in the U.S. spendings to purchase these additives increased from $460 million in 1968 to $1.474 billion in 1978, with the following breakdown: for feed additives - $969.5 million; for biopreparations (vaccines, antitoxines) - $105.9 million; for medical drugs - $375.8 million (Vladimirova 1977a:25-33; 1972; 1980a; 1980b).

5. Beef Cattle Feeding

Meat production in many countries (such as U.S., Canada, Australia, New Zealand, France, Great Britain, etc.) is mostly based on the use of available native and cultivated grassland. Therefore, economical systems of grazing based on scientific research have been elaborated, which ensure a high output of animal products per unit area and low requirements for concentrates.

Roughages, bulk and pasture feeds are still important despite the introduction of industrial technology in beef production.

In the U.S. breeding stocks of beef cows and stockers are fed rations which contain 73% of pasture feed, 19 to 20% of roughages and bulk feed (hay, haylage, silage, plant growing wastes) and 7 to 8% of concentrates (grain, protein additives). Similar situation is observed in other countries with developed meat production (Canada, Australia, France, Great Britain and some other countries) (Tulushnikov 1978:78-110).

Experience in livestock farming shows the high economic efficiency of feeding the diets with a high content of hay, haylage, silage, corn residues, processing industry wastes (fresh, einsiled and dried beet pulp, distillery grains, brewer's grains, etc.).

American specialists point out the economic benefits of feeding cattle on corn silage with high energy and dry matter content without using corn grain. This results in the greatest net profit per unit area - $653.9 per ha as compared to $427.3 per ha, $358.1 per ha, $563.1 per ha when 0.5, 1.0 and 1.5 kg of corn grain per head per day are added to the silage diet respectively. The cost of 1 ton of corn silage must not exceed 8 dollars (Wise 1978:1-4).

The use of corn feed for beef production is considered most economical in Great Britain. This system requires 0.1 ha of grain crops and 0.21 ha of corn to feed one animal. The system provides for 1108 kg/ha liveweight gain with the consumption of the dry matter of grain and corn feed amounting to 335 and 1800 kg per animal respectively. The system of beef production with the use of fodder beets makes it possible to achieve

greater liveweight gain (1190 kg/ha); however, it involves greater spendings per 1 kg of weight gain (18 pence as compared to 10 pence per kg of feed under the previous system) (Farmers Weekly 1978:18-19).

Feed grain shortages and high prices in the world market compel scientists and specialists to look for more economical ways of meat production with the use of industrial technology.

Thus, in the U.S. and Canada much attention is given to investigations on feeding beef cattle roughages (hay) and concentrates. The economic efficiency of high-energy rations used in beef production is determined by the ratio of prices for hay and grain. If the value of grain is 40% higher than the value of hay, it is more profitable to feed cattle a diet containing 50% hay. If the value of grain exceeds that of hay by more than 70%, rations including 80 to 98.8% hay should be fed. If the difference between feed grain and hay prices is not very significant it is better to feed rations with 20% hay. Feeder steers have a daily weight gain in the range of 0.9 to 0.95 kg - 1.2 to 1.36 kg; dressing percentages vary from 52.8 to 53.9% (Agriculture Forestry Bulletin 1978:22-25; Beacom 1979: 24-25).

The trend to use concentrate-based rations for commercial feeding of beef cattle is still observed in some countries, such as the U.S., Canada, Great Britain, Australia. Relative amount of grain together with other concentrates at the end of the finishing period makes up as much as 90% of the diet and even more, while all the roughages (hay, field crop production wastes) constitute not more than 10% in the rations. The use of such rations makes it possible to shorten the finishing period considerably (Ermakova 1978:28-32).

6. Sheep Feeding

Sheep farming in Bulgaria, Hungary, East Germany, the U.S. and Australia have also lately tended to shift towards industrial technology. Large specialized farms producing young stock, mutton and wool have been set up.

First of all industrial principles are applied to handling feeder stock (lambs born the current year, wethers and cull ewes) since they ensure the faster payback of capital investments than sheep raised for wool or replacement gimmers. The above payback is facilitated by the elaboration of methods of intensive lamb raising with the use of milk substitutes providing for the possibilities of earlier weaning and the use of commercial feedstuffs (Ermakova 1980).

The industrialization of breeding stock management presents a problem, since a number of production processes (such as servicing, lambing, rearing of lambs at an early age) require considerable inputs for construction, mechanization of feed distribution, water supply, disposal of manure, etc.). In many countries the industrialization of sheep breeding is carried out based on the use of pasture grazing system. In many countries with developed sheep breeding (such as the U.S., Australia, France, New Zealand, etc.) methods of rational use of natural grasslands have been developed, such as rotational grazing systems, additional feeding of concentrates and roughages at critical life periods (usually the second half of pregnancy and first half of lactation period), establishment of dry

and irrigated cultivated pastures and accumulation of feed reserves (hay and concentrates) to be fed in case of drought or severe cold and snow in winter (Ermakova 1980).

In the zones of intensive crop farming the development of commercial sheep husbandry is based on the use of home-produced feed and on keeping sheep in confinement in the winter or the whole year round. This is mostly typical of European countries having limited areas of natural and cultivated pastures. As a rule, confinement diets mainly include hay, haylage, silage, straw or other wastes of field crop production and the processing industry; small amounts of grain or concentrates may be added (Ermakova 1980).

In Bulgaria and East Germany recommendations have lately been developed on feeding sheep full-ration bulk, granulated or baled feed mixtures containing whole plants of corn (in Bulgaria) and straw from grain crops (in East Germany) (Platikanov and Stoyanov 1977:46-49; Ditrich and Hoffman 1978: 368-370).

7. Swine Feeding

New technologies of swine management and feeding as well as of breeding for higher lean meat yield and other factors changed some of the animal requirements for nutrients and biologically active substances. Therefore an extensive research work is under way in the world aimed at specifying swine requirements for energy, protein (aminoacids), vitamins and mineral substances in different periods of their lifetime.

More effective methods of swine feeding are being developed. Thus, in the feeding of pedigree sows a new trend is observed towards limited feeding of pregnant sows (right after the insemination) and towards abundant feeding (at times ad libitum) of milking sows.

In some countries such as the Netherlands, Belgium, a common practice is flushing (intensive feeding) of sows 10 to 15 days prior to the insemination. However, american scientists believe that under conditions of early weaning such a method of raising productivity can be recommended only for young and emaciated adult sows (Vladimirova 1975; 1974a:27-30; 1974b:43-52).

In Czechoslovakia and East Germany pregnant sows receive 2.4 to 2.8 kg of full-ration formula feed per day during the first 90 days of pregnancy. In the U.S. it is recommended to feed 1.8 to 2.2 kg of formula feed during the first 10-11 weeks of pregnancy and raise this amount by some 0.5-0.89 kg during the last 5 weeks. In Great Britain pregnant sows (liveweight 140-220 kg) are fed 2.0-2.6 kg of formula feed containing 87% of dry matter, 14% of raw protein and 3.3 Mcal/kg of digestible energy. Animal scientists in the U.S., East Germany, Czechoslovakia, West Germany and some other countries believe that the sow liveweight gain during the period of pregnancy must not exceed 30-52 kg (Vladimirova 1975; 1974a).

The level of feeding of milking sows depends on their conditions, age, number of littermates, weaning age, etc. In large pig breeding units in Czechoslovakia milking sows (with 8-12 piglets) receive 2.4 kg of full-ration formula feed with 0.4 kg per piglet which makes an average of 5.6-

6.8 kg. In the U.S. sows are fed ad libitum or receive 2.5-4.5 kg of formula feed per 100 kg of liveweight during the first 10 days after farrowing. In Great Britain if pigs are weaned earlier than 3 weeks of age, sows are fed 2.7 to 3.6 kg of formula feed, if piglets are weaned at the age of 5-6 weeks, sows are fed 4.5 to 5.4 kg of formula feed, or, depending on the number of littermates the amount of feed per day varies between 5 to 12 kg (the feed contains 87% dry matter, 18% raw protein and 3.3 Mcal/kg of digestible energy) (Vladimirova 1976a).

If pregnant sows are fed limited diets (mainly low in energy) particular attention is given to feeding adequate supplies of protein and aminoacids, vitamins, macro- and microelements. Investigations carried out at 6 experimental stations in the U.S. have shown that for pregnant sows 15 to 16% protein (300 g per animal per day) is optimal; with the amount of formula feed reduced from 2 to 1.6 kg, 17.5% protein will be optimal. The diets of breeding sows should not only contain the optimal amount of protein, but adequate amounts of certain aminoacids as well (Vladimirova 1973:16-18).

The rations are enriched with vitamins A, D, E, K, riboflavin, pantothenic acid, niacin, vitamin B12 and choline. Under stress conditions it is necessary to add biotin, pyridoxine, folic acid and ascorbic acid. Macro- and microelements are also added. In the rearing of piglets a trend is observed towards early weaning and keeping them in 1-3-tier cages. In the U.S. piglets are weaned at the age of 3 weeks. Starter diets necessarily include dried skimmed milk and dried whey, yeast, sugar, fat, monosodiumglutamate, flavourings and antibiotics (Vladimirova 1976a; 1974b).

Research is under way to find more effective ways of fattening young stock with dry (loose or granulated), wet or slop feed distributed from automatic feeders, from floor or from troughs, rationed or ad libitum.

In commercial hog units in Poland the best growth rates and feed use efficiency are achieved by feeding animals wet or slop feed from troughs.

54 experiments have been carried out in the world to compare feeding swine dry and wet feeds; a greater growth rate was observed in 29 cases and better feed use efficiency, in 25 cases of feeding wet feed.

Investigations carried out in 19 research centres in Great Britain also demonstrated advantages of wet feed (1.5 to 4.1 kg) over the dry feed. Average daily liveweight gain was 0.59-0.61 kg as compared to 0.57 kg, with wet feed consumption per 1 kg of weight gain being 3.34-3.45 kg against 3.59 kg.

The data obtained in 57 experiments carried out to compare the efficiency of dry loose and granulated feed have shown that the use of granulated feed for swine feeding resulted in a faster growth of the test animals in 39 experiments with better feed conversion ratio registered in 48 experiments. However, the use of wet feed provided for better feed conversion ratio than the use of granulated feed (3.3 kg against 3.5 kg).

The following parameters of growth rate and food conversion ratio were obtained on 277 pig breeding specialized farms in Hungary in 1977: for animals fed from automatic feeders: growth rate 0.487 kg per day with food conversion ratio being 3.97 kg; for animals fed from floor: 0.471 and

3.87 kg; for animals fed from troughs (dry mixtures): 0.481 and 4.03 kg; for animals fed from troughs (wet mixtures): 0.504 and 4.03 kg; for animals fed from troughs (slop feed): 0.496 and 3.85 kg correspondingly (Vladimirova 1976:22; 1975).

The best carcass quality is obtained when hogs are fed ad libitum to liveweight of 36 to 45 kg and then up to the slaughter time receive a limited feeding.

Feed additives and growth regulators are widely used in pig feeding. 102 commercial experiments with 4.6 thou young pigs carried out in Yugoslavia have shown that the use of such feed additives as Aureo SP-125 (1 kg of Aureo SP-125 contains 50 g of chlorotetracycline, 50 g of sulfamethazine, 25 g of penicillin), copper, peyzon, flavomycin and mecadox, resulted in the stimulation of growth and saving of feedstuffs (Vladimirova 1976b; 1977b).

In the U.S. the following pig growth regulators were used in 1979: arsanilic acid, sodium arsanilate, bacitracin, bacitracin methylenedisalicylate, Yn-bacitracin, bambermycin, carbadox, chlorotetracycline, erythromycin, oleandomycin, furazolydon, oxytetracycline, penicillin, rocksarson, tylosin and virginiamycin.

Further comprehensive studies of the feeding rates with regard to protein and aminoacid components would provide for more economical use of protein feedstuffs.

In Great Britain feeding swines barley diets (with 9.5% protein) with the addition of lysin (2.0-3.8 g) and threonine (1.0-1.8 g) resulted in 0.60-0.65 kg average daily weight gain as compared to 0.36 g without additives; feed consumption per 1 kg of weight gain was 2.9-3.2 kg vs 5.3 kg correspondingly (Vladimirova 1976b; 1977b).

Possibilities of an extensive use of such rations in future will largely depend on commercial production of the indispensable aminoacids.

8. Poultry Feeding

Intensification of poultry industry accompanied by a considerable increase in poultry productivity resulted in radical changes of methods of feeding and rationing of nutrients; new approaches to the determination of feeding value of feed have been elaborated. The structure of poultry rations has changed as well. However, a tendency is observed towards the reduction of the amounts of grain and fish meal as most deficient components in poultry rations. Work is under way to find various substitutes and to develop new synthetic additives (aminoacids, vitamins, antibiotics, microelements, etc.) (Vladimirova 1978a).

In almost all highly developed countries formula feeds for poultry are thermally treated and granulated which results in the increase of the total feeding value. Method of limited feeding is gaining ground. The use of the above feeding methods is aimed at the higher feed use efficiency and lower feed consumption.

Carbohydrates contained in grain and grain products are the major source of energy in poultry diets. Until recently the feeding value of poultry feeding rations was determined as a sum of non-nitrogenous extractive substances and raw fiber. However, the data accumulated in recent

years show that the above approach fails to provide comprehensive energy characteristics of feed. The new method of feed evaluation includes the identification of reserve carbohydrates (such as monosaccharides, disaccharides, dextrins, starch) and "skeleton" carbohydrates, or cellulose/lignin complex (hemicellulose, pentosans, lignin, etc.).

Pure reserve carbohydrates have very high digestibility coefficient (95-99%), while poultry digest only 10 to 20% of cellulose/lignine complex. The evaluation of feed by the ingredients of carbohydrate complex is especially important if high-fiber feed is used as a substitute for grain. A successful use of high-fiber feeds depends on their quality and method of production (Vladimirova 1977c:25-29; Ezerskaya 1979).

Though the output of formula feed for poultry tends to increase, the relative amount of grain in poultry formula feed is declining worldwide. In the Common Market countries the production of formula feed for poultry increased from 15.86 million tons in 1970 to 18.9 million tons in 1978 with an appreciable decrease of the relative amount of grain in the rations. For instance, in West Germany the relative amount of grain in poultry rations decreased from 40 to 30%. The use of tapioca in formula feed amounted to 1.35 million tons, by-products of grain processing industry, 2.3 million tons, and feed of animal origin, as low as 0.5 million tons or 3.1%. In the Common Market countries due to the introduction of more economical ingredients the efficiency of the use of formula feed keeps increasing since 1960; annual increase of the efficiency of feeding broilers is 1.33%, turkey 1.81%, laying hens 2.05%. The above ingredients include: fodder beans (10-15%), potato meal and tapioca (up to 20%), grass meal of good quality (10-15%), wheat bran and rice screenings (10-30%), cottonseed cake (10%), hydrolytic feather meal (5-10%), meal produced from the wastes of hatchery and meat processing industries (5-10%), molasses (5%), animal fat (5%) (Vladimirova 1972; 1977d:22-25; 1978b:34-39).

Currently, tapioca as grain's substitute receives much attention in the Common Market countries. However, as it has been shown in the U.S. and some other countries, the use of tapioca calls for additional amounts of protein to be included in the feeding rations; however, such sources of protein as oil seed meal and fish meal are as critical as grain which is currently in short supply. Consequently, the use of tapioca in the feeding rations becomes economical only in the countries where sufficient amounts of synthetic aminoacids (such as lysin, methionine) and other high-protein products (such as yeasts, protein of monocelled organisms, etc.) are available. Technological treatments of feedstuffs enhancing their nutritive value is of particular importance for the introduction of low- grain diets. In Canada it has been found that treatment of feed with hot steam at 71-88° C resulted in a higher nutritive value of feed fed to broilers, the increase of liveweight of broilers by 12%, and the reduction of feed consumption from 1.8 to 1.68 kg. This was confirmed by the results of the trials carried out in East Germany, where the use of granulated feed also resulted in the decrease of feed consumption by broilers from 2.6 to 2.3 kg per 1 kg of liveweight gain. Trials carried out in the U.S. have shown that enzymes included in feeding rations (especially cellulolytic enzymes) increased the use of metabolizable energy of wheat bran by 32% (2132 Kcal/kg vs 1612 Kcal/kg). In Argentina a new method

of rice bran fermentation is gaining ground in the commercial production of broilers; the method provides for the reduction of feed consumption (2.6 kg vs 2.5 kg per 1 kg of liveweight) and the increase of the liveweight of broilers (2360 g vs 2020 g per head) (Vladimirova 1969; 1970; 1972; Ezerskaya 1979).

Long-term trials conducted at the Experimental Station in North Louisiana, USA, have shown that the rations with a high content of rice screenings and enriched with lysin and methionine (corn 52.2%, soybean oil meal 17.0%, rice screenings 15.6%, alfalfa meal 4.0%, and Premix) are comparable with the high-concentrate rations (corn 66%, soybean oil meal 14%, fish meal 3.3%, rice screenings 2.2%, alfalfa meal 4.0%). During 336 days of the experiment in the above groups a laying hen produced on an average 247 and 248 eggs correspondingly, with the feed consumption being 2.4 and 2.52 kg per 1 kg of eggs (Vladimirova 1969; 1972).

In the U.S. detailed studies of the nutritive value of dried brewer's grains have been carried out and the consumption rates for different kinds of poultry have been determined; the percentage of dried brewer's grains in the rations of broilers depends on the age of broilers and varies from 5 to 20%; the level of dried brewer's grains in the rations of laying hens varies from 20 to 25%; in the rations of turkeys from 5 to 25%, and in those of ducks from 10 to 15%. The brewer's grains contain 2513 kcal of metabolizable energy per 1 kg of the product, as well as 27% of raw protein; besides that the above product contains agents preventing the occurence of liver fatness syndrome in poultry.

In India poultry rations include up to 30% of sorghum, 20 to 40% peas, rice screenings and wheat bran, up to 20% molasses and 7 to 13% fat and oil of animal origin as corn's substitutes.

One of the major problems the poultry industry is facing now is the development of poultry rations balanced in protein, since the reserves of both fish meal and feed grain are limited. Currently, an intensive research work is under way to develop methods of commercial production of new sources of protein. In this connection the production of synthetic aminoacids has increased in recent years; rations with various additives are tested. In the U.S., Great Britain, France and some other countries various raw materials are used to produce monocelled protein to be used (together with yeast) as fish meal's substitute in poultry rations.

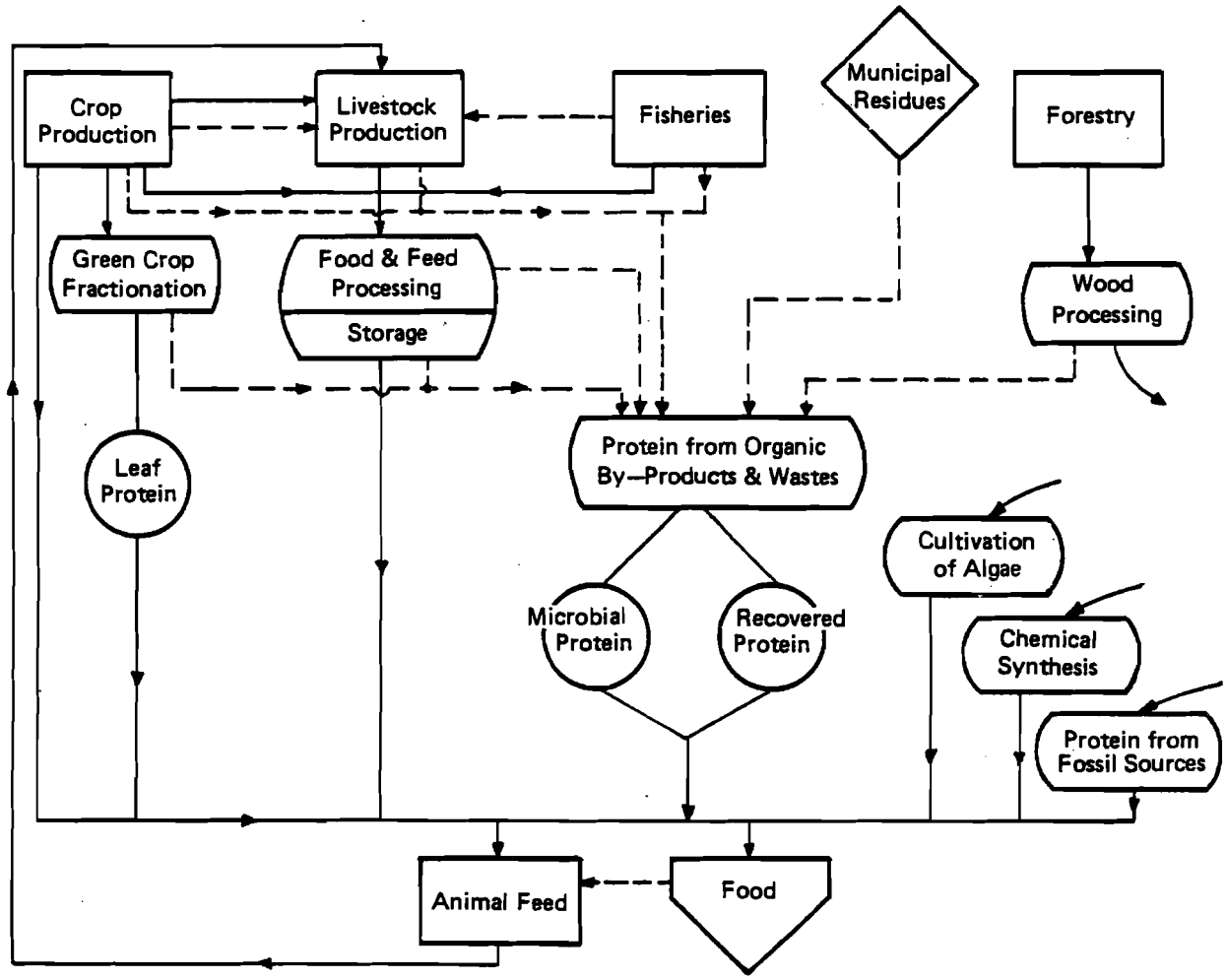
In France the protein problem has been actually solved through the adequate volume of production of lysin and methionine. It has been shown that pure plant rations can be successfully used provided the above aminoacids are available.

Limited feeding is known to increase the efficiency of feed use in poultry industry; this method is gradually gaining ground. Limited feeding is most successfully used in the U.S. despite the fact that actually all kinds of feedstuffs are available there.

In the U.S. many large poultry farms practice limited feeding. Feeds are limited only quantitatively. Feed intake is carefully recorded. Feed is distributed in all the feeders in the amounts to be consumed in 45 minutes. Liveweight serves as an indicator of growth and development of the young stock. Feeding value of poultry rations is determined based on

metabolizable energy and aminoacid levels; this provides for maximum efficiency of the feed use (Vladimirova 1972; 1977c; Ezerskaya 1979).

PRODUCTION OF EDIBLE PROTEINS FROM AGRICULTURAL AND OTHER SOURCES



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