



HGCA RESEARCH REVIEW No. 14

**THE POTENTIAL FOR THE
PRODUCTION AND UTILISATION OF
OATS IN THE UNITED KINGDOM**

Edited

by

RICHARD M. BENNETT

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FOREWORD

One of the most important functions of the Centre for Agricultural Strategy is to provide independent and long-term assessments relating to developments in the agricultural and related industries. The Centre was pleased therefore to be asked by the Ministry of Agriculture, Fisheries and Food and by the Home-Grown Cereals Authority, to carry out this review of the potential for oats production and utilization in the United Kingdom.

For various reasons, the size of the oat crop in the UK has declined over the last 30 years and has become very much a minor crop with a rather 'old fashioned' image. Recently, however, the search for alternative enterprises for agriculture, consumers' awareness of links between health and food, together with technical developments involving oats especially in plant breeding, have led to a renewed interest in oat production and usage. This study has therefore been commissioned at a highly appropriate time, when a reassessment of the current and potential value of oats to producers and users is required.

In carrying out this study, we have been fortunate in having the assistance of the excellent team of consultants referred to later in this report (see Appendix 1.1). Our thanks are also due to a large number of organisations and individuals, including millers, feed compounders, research institutes and trade representatives (see Appendix 1.2), who have contributed to our discussions and responded to enquiries in a helpful and constructive way. The valuable contribution made by Mr Richard Bennett the CAS project co-ordinator, who has brought together and distilled a vast amount of information and opinion in producing this report, must also be acknowledged and appreciated.

It is very much hoped that the information presented, the conclusions reached and the recommendations made in this report will help to direct future research and development into the most potentially beneficial areas and help to stimulate informed discussion.

C R W Spedding

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HGCA RESEARCH REVIEW NO 14

The Potential for the Production and Utilization of Oats in the United Kingdom

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ABSTRACT

The aims of this Review are to identify and assess the limitations and potential for oats in the UK, both at present and in the foreseeable future, and to identify measures needed to improve or realise any potential, including research and development needs.

The approach of the Review was to identify the major determinants of the pattern of the production and utilization of oats in the UK and to examine each of these main areas of consideration and their inter-relationships. The areas identified and subsequently discussed in separate chapters of the Review are; (i) human food, nutrition and health; (ii) livestock feeding; (iii) industrial uses of oats; (iv) plant breeding; (v) agronomy; (vi) farm economics; and (vii) marketing, policy and trade aspects. The final chapter contains conclusions and recommendations. The Review utilized the considerable knowledge and expertise of a core team of nine consultants, each concerned with a particular aspect of oats production or utilization, and also involved discussions, meetings and consultations with a wide variety of individuals and organizations.

The Review identifies a number of areas of likely potential for oats including on the demand side; recorded health benefits of oat consumption, the use of oats in new snack foods, the use of naked oats for livestock feed, particularly for non-ruminants and the industrial food use of oats (a high-value fraction possessing excellent emulsifying properties has been identified). On the supply side there is significant potential for the improvement of oats and naked oats in terms of the needs of producers and current/potential users and significant progress has already been made, with new oat varieties now available to growers which could make a notable impact on average yields. Oats are well-suited to organic production. The return to oat growers, already competitive under certain conditions with spring wheat and winter barley, could be further improved by plant breeding. The instability of the oats market with fluctuating prices and supplies is one important factor limiting the expansion of the oat crop.

In view of these, a number of possibly beneficial areas for research and development are identified such as research into the oat gum fraction, the value of naked oats to the food industry, measurements of the nutritive value of current oat varieties for the main species of livestock, agronomic research on the newer varieties and on oat grain quality, as well as research on oat plant breeding.

This Review, completed in January 1989 and with 238 pages in the full document, was funded jointly by the MINISTRY OF AGRICULTURE, FISHERIES AND FOOD and the HOME-GROWN CEREALS AUTHORITY. Copies may be obtained from the Home-Grown Cereals Authority, Hamlyn House, Highgate Hill, London N19 5PR at a price of £17.50 each (postage and packing included).

ABBREVIATIONS

ADAS	Agricultural Development and Advisory Service
AFRC	Agricultural and Food Research Council
BOBMA	British Oats and Barley Millers Association
BYDV	Barley Yellow Dwarf Virus
CAP	Common Agricultural Policy
CAS	Centre for Agricultural Strategy
CCC	Chlormequat
cif	carriage including freight
DANI	Department of Agriculture for Northern Ireland
DE	digestible energy
DM	dry matter
DOMD	digestible organic matter in the dry matter
EC	European Community
ECLAIR	European Collaborative Linkage of Agriculture and Industry through Research
ECU	European Currency Unit
FEU	Feed Evaluation Unit
GATT	General Agreement on Tariffs and Trade
g	gramme
GB	Great Britain
ha	hectares
HFCS	high-fructose corn syrup
H-GCA	Home-Grown Cereals Authority
hl	hectolitre
IBPGR	International Board for Plant Genetic Resources
kg	kilogramme
ME	metabolisable energy
MAFF	Ministry of Agriculture, Fisheries and Food
m.ha	million hectares
MJ	megajoule
mt	million tonnes
NCD	neutral detergent/cellulase digestibility
NDF	neutral detergent fibre
NIAB	National Institute of Agricultural Botany
NOSCA	North of Scotland College of Agriculture
OM	organic matter
oz	ounce

PBI	Plant Breeding Institute
RDI	Recommended Dietary Intake
SAC	Scottish Agricultural Colleges
SBOMV	soil-borne oat mosaic virus
t.ha	thousand hectares
t	tonnes
UK	United Kingdom
UKASTA	United Kingdom Agricultural Supply Trade Association
um	micro metre
US	United States
USDA	United States Department of Agriculture
USSR	Union of Soviet Socialist Republics
VIL	variable import levy
WPBS	Welsh Plant Breeding Station

CHAPTER 1 INTRODUCTION

Background

- 1.1 In March 1988, the Centre for Agricultural Strategy (CAS) was commissioned by the Ministry of Agriculture, Fisheries and Food (MAFF) and by the Home-Grown Cereals Authority (H-GCA) to carry out a review of the potential for the production and utilization of oats in the UK, with the aim of helping to identify research and development needs.

Objectives

- 1.2 The objectives of this study were to:
- i) Review the past and present situation concerning the production and utilization of oats in the UK, looking at the various determinants of both supply and demand, such as the technology available for producing oats and consumer preferences.
 - ii) Identify and assess the limitations and areas of potential for oats in the UK both at present and in the foreseeable future, where possible trying to evaluate any potential markets for oats.
 - iii) Provide an overall assessment of the potential for oats production and utilization in the UK.
 - (iv) In the light of i), ii) and iii), try to identify those measures needed to improve or realise any potential, including research and development, with some assessment of the extent to which current research meets the needs identified by the study.

Approach and Methodology

- 1.3 The basic approach to this study used by CAS was to first consider the past and present patterns of production and

utilization of oats in the UK and to systematically explore and examine the major determinants of both supply and demand. This approach is represented by Figure 1.1.

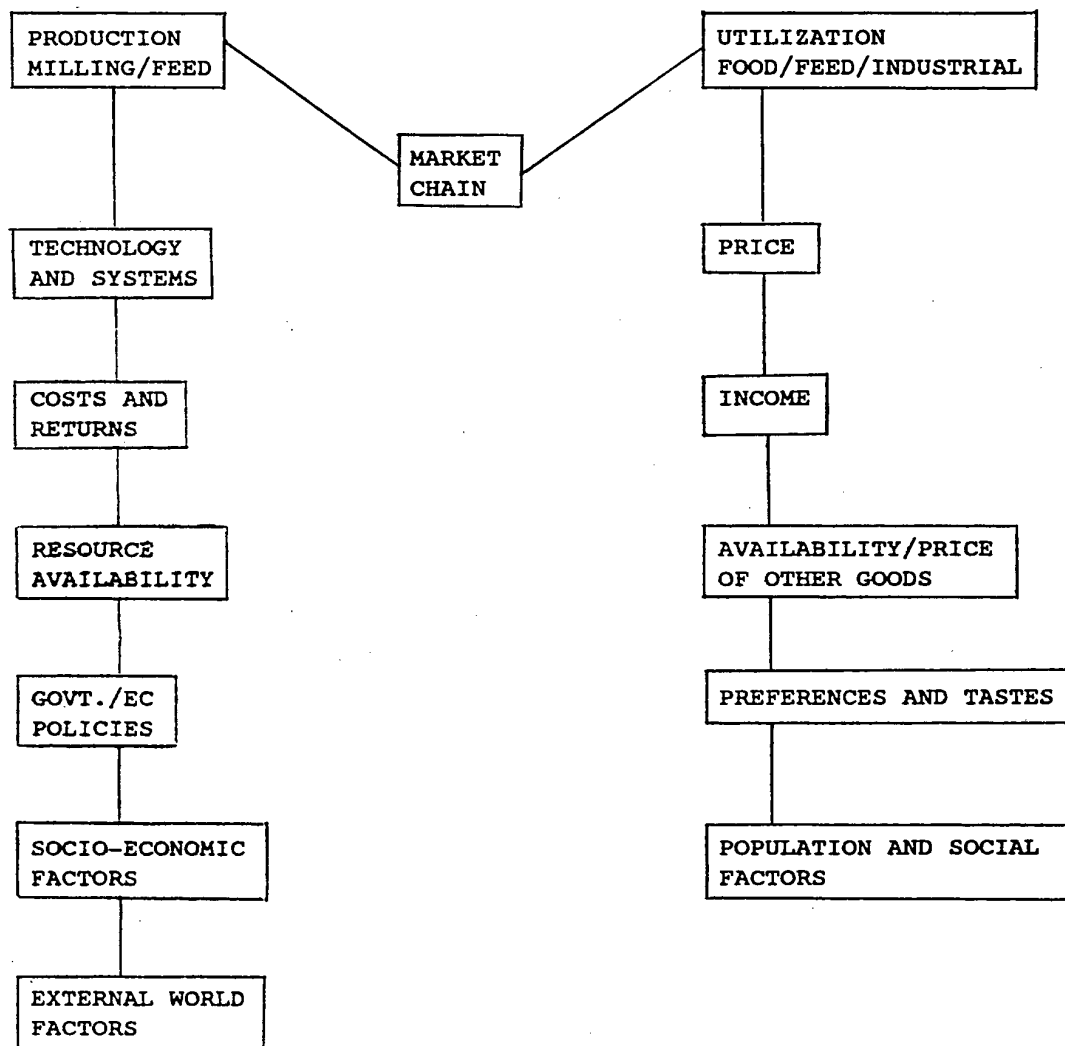
Production of oats results in a largely homogeneous product differing only in its quality, with the exception of the new Naked Oat varieties and organic oats. Utilization can be divided into three separate areas, oats for human food, oats for livestock feed and oats for industrial uses both in food manufacturing and non-food uses.

Production and utilization of oats are linked through the market chain of merchants, millers, feed compounders and so on, with the notable exception of where oats are grown and used on the same farm.

- 1.4 The pattern of both production and utilization is determined by a variety of inter-relating factors, as shown in Figure 1.1. Thus, the pattern of oats production depends on the technologies available, production systems used, the costs and returns to producers, government and EC policies, external world factors and socio-economic factors, all of which are inter-related. Similarly, utilization depends on the price of oats at any one time, the income of consumers, the availability and price of other goods, the preferences and tastes of consumers and population/social factors.

- 1.5 Determinants of production may also affect utilization directly. For example, government/EC policy might affect the availability and price of other goods, such as through price support for wheat and barley. Other complications are added by the market chain, where processors of oats act as both consumers (eg. buying oats from a farm producer) and producers (eg. selling oat products to retail stores, for feeding to livestock etc).

Figure 1.1 Inter-relating factors determining the production and utilization of oats.



- 1.6 The main determinants of the pattern of oat production were considered to be:
- i) Systems of oat production. This involves husbandry and agronomic considerations.
 - ii) Technology available to producers. This is largely the same as for other cereals such as wheat and barley, with the notable exception of varieties of seed available. Hence plant breeding and genetics are important factors for oats production.
 - iii) Costs and returns to producers. This involves the economics of oat growing at the farm level, especially in comparison to other alternative cereal crops.
 - iv) Government and EC policies and intervention. The effect of government and EC support regimes for agricultural products, of set-aside policies, policies toward the countryside and so on.
 - v) External world factors. The international oats market and international trade will have an impact on production.
- 1.7 The pattern of oat utilization depends on the demand for oats for human food, livestock feed and industrial uses. Each of these are very different markets, having determinants of differing importance. For each area of use the main determinants of demand (eg. price, preferences and availability and price of other goods) are examined.
- 1.8 The major part of the methodology of the study was therefore to examine each of these main determinants of the production and utilization of oats. To achieve this, a core team of nine consultants was set up, each of whom has a specialised knowledge of and expertise in a particular aspect of oats production and/or utilization, which had been identified as an important determinant of the pattern of oats supply and demand in the UK. Those aspects covered by each consultant can be broadly divided

into eight different, but related, areas of consideration. These are:

- (1) Agronomy and plant husbandry³.
- (2) Plant breeding and genetics.
- (3) Farm economics.
- (4) Agricultural policy and international trade.
- (5) Human food, nutrition and health.
- (6) Livestock feeding.
- (7) Industrial non-food and food manufacturing.
- (8) Marketing.

A list of consultants working on the project is contained in Appendix 1.1 of this report.

- 1.9 The activities of the consultants were guided, monitored and co-ordinated by the CAS project co-ordinator. The consultants were encouraged to make direct contact with each other where interaction was necessary, and consultants also met for discussions and exchange of ideas at a formal one-day workshop held at CAS.
- 1.10 The project co-ordinator was responsible for holding discussions, meetings and consulting with a variety of individuals and organisations concerned with the production and/or utilization of oats (see Appendix 1.2), such as millers (eg. the British Oats and Barley Millers Association - BOBMA), feed compounders (eg. Dalgety Agriculture), ADAS and research institutes (eg. AFRC).

³ Two consultants were engaged to examine the agronomy and husbandry aspects of oats. One with a particular knowledge of Winter Oats in England, and the other of Spring Oats in Scotland.

Consultants themselves were encouraged to directly contact such individuals and organisations as appropriate.

The project co-ordinator had the final role of synthesising the findings of the project team.

- 1.11 Chapters 2 to 9 of this report cover each of the main areas of oats production and utilization as identified and discussed above. Each of these Chapters also contains a summary and conclusions. Chapter 10 gives an overview of conclusions reached, together with recommendations for research and development.

CHAPTER 2 THE INTERNATIONAL AND UK OATS MARKET - AN OVERVIEW

World Market

- 2.1 Oats production worldwide between 1984 and 1986 averaged 48.6 mt out of a total world grain crop of 1889 mt - making it the sixth most important grain crop in output terms behind wheat, maize, rice, barley, and sorghum. With only a 2.6% share of global grain production, oats is a relatively minor crop. International trade is also relatively less important for oats. Whereas 11.7% of world cereals production is exported, for oats the share is only 3.4%, reflecting the tendency for a greater proportion of the oats crop to be consumed domestically. Oats typically represent less than 1% of world cereals exports.
- 2.2 While world grain production has followed a steady upward path for many years, oats production has tended to decline. Due to large, year-on-year harvest fluctuations the trend is difficult to see. World production steadily increased from the mid 60s to 56 mt in 1971 from when it declined, before recovering in the late 70s to 52 mt. During the early 1980s the oats crop has fluctuated in the range 44 to 50 mt.
- 2.3 The majority of oats is grown in the Northern hemisphere - principally in the cooler and wetter regions of Europe and North America between latitudes 35 and 50 degrees North. The current structure of world oats production by country is shown below.

Together, the nine countries listed account for over 80% of world output. By far the largest producer is the Soviet Union followed by the United States. The United States' share, though relatively large compared to other countries, has fallen steeply from around 30% at the beginning of the 1960s to around 16% in the mid 1980s. Both production and consumption in the United States have halved over this period - from approximately 16 mt to 8 mt. In contrast, the share and absolute size of the Soviet Union crop has grown rapidly and, as a result, overtaken the United States as the major producer (and consumer) of oats.

World Oats Production

(annual averages, 1984-86; in million tonnes)

World total	48.6	100.0%
of which:		
Canada	3.3	6.6%
United States	6.7	13.7%
Finland	1.2	2.5%
France	1.6	3.3%
West Germany	2.0	4.2%
Poland	2.5	5.2%
Sweden	1.7	3.5%
USSR	20.4	41.9%
Australia	1.4	2.9%

Source: FAO Production Yearbook.

The opposing trends in the Soviet Union and the US partly reflect climatic differences - oats are more closely suited to the cooler, humid climate of the northern parts of the Soviet Union than to the other grain crops, preferred in the US for their greater profitability and soil characteristics.

- 2.3 The pattern of oats consumption closely reflects that of production with only 3-4% of production traded internationally. The majority of the oats crop, currently around 75% of output, is utilized as animal feed with food and seed use absorbing close to 22%. There has been a small increase in the relative importance of the food use category over time - rising from 17% in the early 1960s (or 2 mt).

The volume of trade in oats has shown no persistent upward or downward tendency since the beginning of the 1960s. It has consistently been in the range of 1 to 2 mt. Given the rapid growth in overall cereals trade, in the 1970s in particular, this has effectively implied a declining relative position for oats. The low bushel weight characteristics (high bulk to weight ratio), implying relatively greater transport costs per tonne delivered, is likely to be a contributing factor here.

- 2.4 The five main exporters of oats, collectively accounting for over 85% of world exports are listed below.

World Oats Exports

(annual averages, 1984-86; in '000 tonnes)

World total	1,648	100.0%
of which:		
Finland	295	17.9%
France	259	15.7%
Sweden	409	24.8%
Canada	147	9.0%
Australia	288	17.5%

Unusually, for cereals, the United States does not enter the list of major exporters. However, in earlier years the US was a leading exporter and continued to be a net exporter until 1981. In 1973, for example, its share of world exports was over 40% - reflecting heavy Soviet purchases in a period when feedgrains in general were in short supply. Over the last 25 years or so, the countries showing most rapid export growth have been Sweden (+0.32 mt or 380%), France (+0.24 mt or 1000%) and Finland (+0.41 mt or 9700%). Countries which have seen exports decline are the US, the USSR (despite rapid output growth) and Canada.

- 2.5 From 1982, the United States has been the major importer of oats followed by the USSR - together accounting for 50% of oats traded. Other countries importing substantial quantities of oats include Japan, Switzerland, Italy, and West Germany.

World Oats Imports

(annual averages, 1984-86; in thousand tonnes)

World total	1,491	100.0%
of which:		
United States	431	28.9%
Japan	118	7.9%
West Germany	98	6.6%
Italy	94	6.3%
Switzerland	103	6.9%
Netherlands	70	4.7%
United Kingdom	22	1.5%
USSR	289	19.4%

Import demand has grown most strongly in the US and the Soviet Union, while imports have tended to fall most rapidly and by the most significant amounts in 'traditional' importers in the European Community : West Germany, Italy and the Netherlands.

The increase in demand for imported oats in the US (mainly from Sweden but also from Canada and Finland) has been partly attributed to the superior quality of imported supplies (high bushel weight and colour) needed to meet the increased demand for quality oats. This is linked to the dietary changes in US households (eg. towards muesli and other high fibre products) and the growth in demand for premium horse rations containing oats. Import demand by developed countries in general is likely to be stimulated as more people adopt 'high fibre diets' where oats have advantages over other cereals.

A recent paper on international oats trade concludes 'with increasing awareness of the nutritional value of oats for human consumption across a broad band of fibre-based foods, opportunities exist for more quality oats to enter into international trade' (Baker, 1988).

The European Community

- 2.6 The area planted to oats in the European Community (EC) steadily contracted in both absolute and relative terms throughout the 1950s, 60s and 70s. In the mid-1950s over 5 m.ha of oats were harvested - over 20% of the cereals area. In the first half of the 1980s, the oats area had fallen to 1.7 m.ha - only 6% of the cereals area. The accession of Spain and Portugal has increased the oats area in the Community (to around 1.9 m.ha) but has not arrested the relative decline (now only 4% of Community cereals area).

Production of oats in the EC has also fallen, from 12 mt in the mid 1950s to 6/7 mt currently, but not as sharply as the area of oats due to improved yields. Despite significant improvements in yield, oats continue to fall behind the yield levels of barley and wheat except on more marginal cereal land. The divergence in

yield performance appears less acute in the UK - more suited to oats cultivation - than in most other Member States.

- 2.7 Supply/demand balance sheets for the EC and UK oats market (Tables 2.1 and 2.2 of Appendix 2.1) summarize their make-up and how they have developed since the early 1970s.

Oats constitute only a small part the UK and EC cereals market in terms of output, utilization and trade and is appropriately labelled a minor crop. In 1987 oats made up 4.3% of the Community grain harvest and only 2% of the UK crop. The five largest producers and users of oats in the Community are West Germany, France, Spain, the United Kingdom and Italy in descending order of magnitude (1983-86).

EC-12 Oats Production and Consumption - by Member State
(annual averages, 1983/84 to 1986/87; in '000 tonnes)

	Production		Consumption	
EC-12 Total	6915	100.0%	7064	100.0%
of which:				
West Germany	2857	41.3%	3054	43.2%
France	1916	27.7%	1676	23.7%
Spain	591	8.5%	589	8.3%
United Kingdom	557	8.1%	580	8.2%
Italy	381	5.5%	461	6.5%

- 2.8 The bulk of EC oats production is utilized as feed (88% in 1984-86), either directly on the farm where grown or as purchased feed through merchants and compounders. The split between 'on-farm where grown' and 'bought-in' varies between Member States and over time. For West Germany the split is 83% on-farm/17% bought-in, for France 85%/15%, for Italy 42%/58%, for Spain 58%/42%, and the United Kingdom 47%/53% (1984-86 averages).

Human consumption of oats in the EC-12 is about 350-400,000 t/annum; 5% of total oats utilization. Roughly the same amount is used for seed. As expected, there are marked differences in human consumption levels per caput between Member States. In

West Germany, the UK and Ireland per caput consumption levels are very similar - around 1.6 kg/annum. Denmark has by far the highest level - around 4.1 kg/annum. Apart from the Benelux countries (0.3 kg/caput/annum), consumption in other Member States is negligible. The Denmark figure is perhaps a useful pointer for assessing the potential for expansion of oats consumption in other EC countries. Assuming per caput consumption rose throughout the EC to the Denmark level (probably unrealistic), total human consumption would rise to 2.2 mt.

The United Kingdom

- 2.9 The UK area devoted to oats has fallen from over 1 m.ha in the mid-1950s, to less than 0.1 m.ha in 1987. Over the same period output has declined from over 2.7 mt to 0.45 mt. In 1988, an estimated 121 t.ha were devoted to oats, an increase of 22% over the 1987 level, with indications that output might be around 0.7 mt, nearly 0.25 mt (56%) higher than the 1987 level.
- 2.10 In contrast to oats, Table 2.3 of Appendix 2.1 shows that the area devoted to wheat and the output of wheat has grown dramatically. Wheat output by the mid-1980s was four to five times higher than that in the mid 1950s and double that even of the 1970s. Barley production has also increased, but not as dramatically as wheat, with output not really having increased since the latter 1970s.
- 2.11 The supply and demand balance for the UK oats market over the last decade is shown in Table 2.2 of Appendix 2.1. Percentage self-sufficiency rates over the period are typically in the high nineties, with trade playing a very minor role in volume terms.

There has been a relatively stable market of around 145,000 t for human food uses of oats, and figures over the last 3 years suggest a slight rise in this use to 165,000 t in 1987/88.

The other main outlet for oats in the UK is the animal feed market. Overall feed use has declined from around 1 mt in the

early 1970s to only 0.25 mt in 1987/88. Significant fluctuations in the level of animal feed use from year to year can be seen.

- 2.12 Regional figures from the June 1987 Census show that England has the largest area sown to oats (63251 ha), followed by Scotland (28052 ha), Wales (4485 ha) and then Northern Ireland.

In England, the South East Region has the highest oats hectareage, although individual counties in England with highest areas of oats are Hereford and Worcester, Shropshire and Devon (which are all counties where cattle and sheep production are important). In Scotland, the Grampian Region in the North East has the highest oats hectareage.

Conclusions to Chapter 2

1. World oats production accounts for only 2.6% of total global grain production. Oats production worldwide has tended to decline over the last 10-15 years.
2. The USSR followed by the United States are the largest producers, and against the general world trend, production and utilization of oats in the USSR has grown rapidly. Around 75% of the world oat crop is used for livestock feed. The United States has been the main importer of oats, followed by the USSR. The main exporters are Sweden, Finland, Australia and France.
3. Production of oats in the EC has also fallen from 12 mt in the mid 1950s to 6/7 mt and represents around 4.3% of the Community grain harvest. The largest producers and consumers of oats in the EC are West Germany followed by France. Around 88% of oats in the EC are used as feed.
4. In the UK, the area devoted to oats has fallen from over 1 m.ha in the mid-1950s, to less than 0.1 m.ha in 1987, with output declining from over 2.7 mt to 0.45 mt over the same period. Utilization of oats has declined for livestock feed and remained fairly static for human food uses.

CHAPTER 3 OATS FOR HUMAN FOOD

Oat consumption in the UK

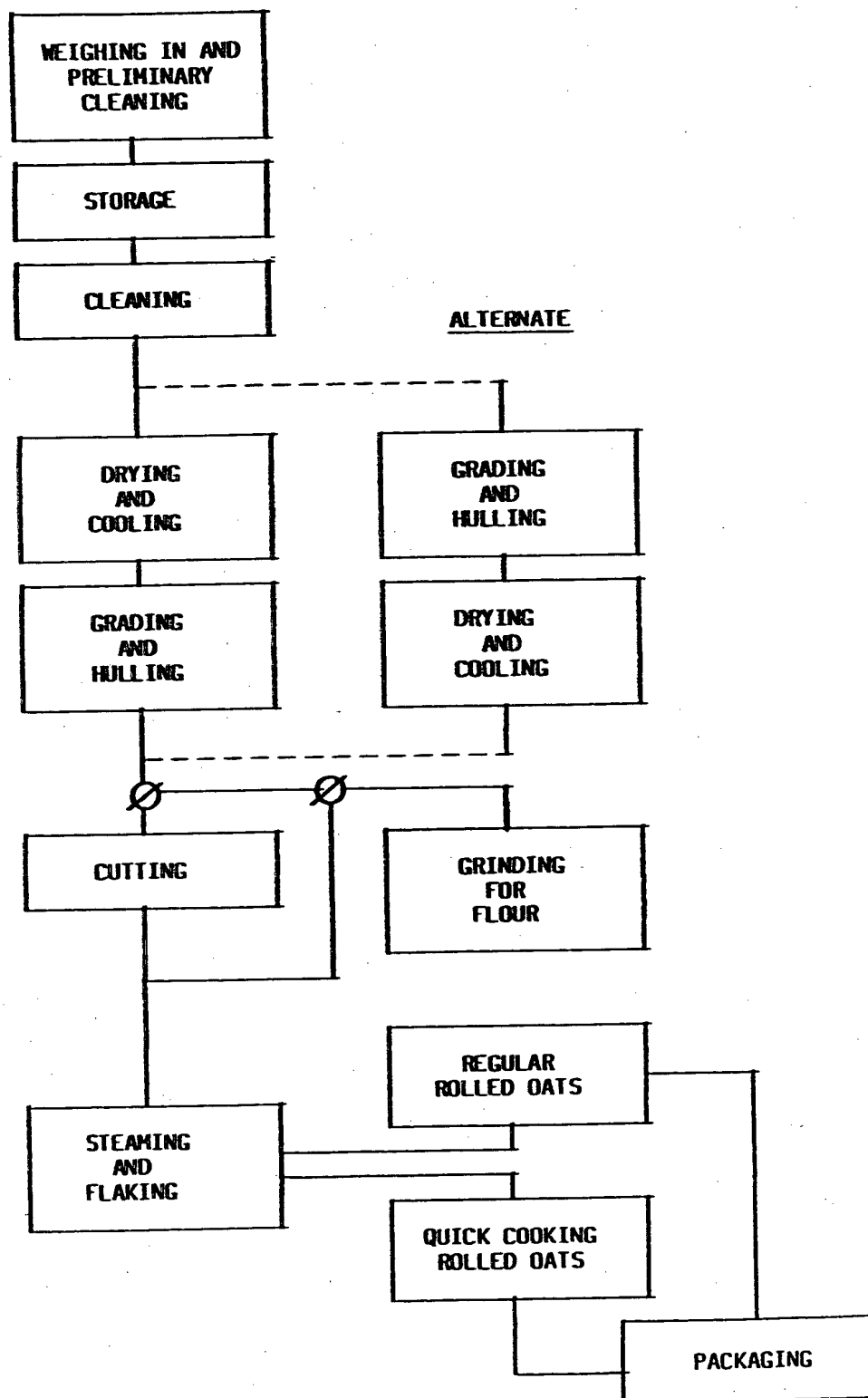
Form consumed

- 3.1 For human consumption, the fibrous husk or hull which encloses the oat groat or kernel is removed by milling. The milling process is in fact a relatively complex one for oats and accomplishes more than merely removing the husk. The process consists of six general steps as shown in Figure 3.1; cleaning, heating and drying, hulling and grading, cutting, steaming, flaking.
- 3.2 Cleaning involves the removal of dust, chaff, weed seeds, coarse grains and any other impurities. The oats then undergo a heating and drying process (toasting), which inactivates the enzymes lipase and tyrosinase and is necessary to ensure good keeping properties, whilst also improving the taste. Drying also enables the hull to be more easily removed. In the hulling step, the oats are graded by size and the hulls are abraded or knocked off the oats (by the oats being thrown against discs rotating at high speed). The oat groats are then cut into two to four pieces, steamed (to soften and condition the groats for flaking) and then passed to the flaking roll and rolled into flakes. The cut groats are rolled into relatively thin flakes for instant or quick-cooking oatmeal, whilst uncut groats are flaked about 50-75% thicker for regular oatmeal.

The milling process is described and discussed in some detail in Webster (1986).

- 3.3 There are several possible variations to the general process described above. First, oatflakes are not prepared in the same way by all manufacturers. The main difference lies in whether toasting takes place before or after hulling, and when the oats are cut, whether steaming takes place before or after cutting. Although the major end product is regular rolled oats or quick-

FIGURE 3.1 STEPS INVOLVED IN OAT MILLING/PROCESSING



Source: Webster (1986)

cooking (instant) oats for preparation of oatmeal, some processors also manufacture oat flour (see Figure 3.1).

- 3.4 The typical product breakdown resulting from milling oats is: rolled oats (flakes), 45-60%; oat hulls, 24-27%; feed oats¹, 10-20%; mixed grains and seeds, 2-3%; and fines², 2-5%. The precise percentage breakdown depends on the quality of oats being milled and the efficiency of the milling process. The yield of oat flour would be comparable to that for oat flakes, where flour rather than flakes is the end-product.

Quantities consumed

- 3.5 In the 1986/87 marketing year, 160,000 t of oats were processed for human food use. Of this approximately 151,500 t were produced by 'conventional' methods, and an estimated 4,500 t were produced by 'conservation grade' methods and 4,000 t were produced 'organically'. The 151,500 t of conventional oats gave a milling yield of approximately 90,000 t of oats and oat products, with the remainder being by-products and wastage as described above. The data in Table 3.1 (which has been obtained from a UK oat miller) gives an estimated breakdown of the consumption of oat products both by form and by usage.

It can be seen that porridge oats remains the largest single market for human food use of oats, accounting for around 44% of the total. However, a significant proportion of oats sold as porridge oats may be used in home cooking. Clearly rolled oats is the major oatmill product, accounting for two-thirds of usage.

¹ Feed oats are light, double, and thin oats removed during the cleaning process as are the other mixed grains and seeds, which are also usually sold for feed.

² Oat fines are slivers of oat produced from cutting and flaking and are used either for animal feed or blended into the oat flour milling system.

Table 3.1 Usage of milled oat products in the UK

	'000 Tonnes				
	Rolled	Flour	Other	Total	%
Porridge, instant	5.3	1.1	4.2	10.6	12
Porridge, traditional	28.6	-	-	28.6	32
Total porridge	33.9	1.1	4.2	39.2	44
Granola	6.3	-	-	6.3	7
Muesli	8.2	-	-	8.2	9
Total	14.5	-	-	14.5	16
Bars	3.3	-	-	3.3	3
Other baking	7.4	1.1	24.5	33.0	37
Total	10.7	1.1	24.5	36.3	40
Overall total	59.1	2.2	28.7	90.0	100
As % of total	66	2	32	100	

The 'Other baking' uses of oats are primarily for biscuits, with a small amount used in speciality breads and other products. Oatmeal flour is a major constituent of many baby foods and is also used as a thickener in foods.

Oat bran, which is produced in the USA (and has achieved prominence in therapeutic diets), is not at present marketed in the UK. However, one oat miller produces an 'Oat Bran and Oat Germ' product.

- 3.6 Calculation of consumption from Table 3.1 and gross population figures indicates that around 30g (about 1 oz) of oats are consumed per head per week. Data from Household Food Consumption and Expenditure statistics, give oats consumption as only 13 g (0.45 oz) per head per week. However this figure appears to represent only porridge oat breakfast cereal. Recalculation to allow for this gives a total consumption of 29 g/head/week which is close to the first estimate.

At this level of consumption oats make only a very small contribution to the nation's diet. Calculations using data for 1986 show that oats provide only 0.8% of dietary energy. This compares with 33.1% of dietary energy from all cereal products

and 14.7% from bread. Oats account for only 2.4% of total cereal dietary energy.

Trends in cereal and oat consumption

- 3.7 The relatively constant oat consumption since 1960 has been achieved against a more than 20% decline in total cereal consumption. This is shown in Table 3.2 which also shows that this decline is almost entirely accounted for by reduced bread consumption.

Table 3.2 Cereal consumption in the UK since 1960 (oz per head per week)

	1960	1970	1980	1986
Total cereals	70	62	55	55
Breads	45	38	31	31
Other cereal products	25	24	24	24

However despite this decline there are other interesting changes. Table 3.3 shows that, although there has been over a 50% fall in white bread consumption, brown bread consumption has doubled and that of wholemeal has increased five-fold, with a particularly marked rise in the most recent years.

Table 3.3 Bread consumption in the UK since 1960 (oz per head per week)

	1960	1970	1980	1986
White	39	32	22	17
Brown	2	2	4	4
Wholemeal	1	1	2	5
Rolls etc	na	na	4	5

na = data not available.

The most obvious explanation for this is the response of the public and the food industry to recently published guidelines linking nutrition and health which encourage the consumption of diets higher in fibre. A further factor may be an increased public awareness of the prevalence of food additives coupled with the perception of wholemeal products as being more 'natural' or

'wholesome'. Overall this data clearly indicates that patterns of cereal consumption are liable to rapid and significant change.

- 3.8 Trends in the consumption of oats and oat products show overall consumption relatively stable since as far back as 1960. A decrease in consumption of traditional oat products such as porridge with a move to convenience breakfast cereals, has been offset by increases in consumption of mueslis and cereal bars (with a relatively small proportion of oats in them) and by the use of oats in biscuit manufacture. Several oat millers saw the oat market for human consumption as increasing by around 5% per annum at present, with future growth areas such as cereal bars and biscuits, and use of oats in bread being mentioned. Statistics in Table 2.2 of Appendix 2.1 show a 4-5% per annum increase in food use of oats from 1984/85 to 1987/88, some 20,000 t. A substantial proportion of this increase is probably due to an increased usage for cereal bars and biscuits. For example, one manufacturer of these products quoted an increase of 6-7,000 t of oats from 1985 to 1987.

Oat consumption in other countries

- 3.9 Estimates have been made using gross population statistics and data on the usage of oats for human consumption from EC sources and these are shown in Table 3.4. Oat consumption in the UK is close to previous estimates given above. Consumption in other countries shows very wide variations with negligible amounts being eaten in the Mediterranean countries. Of particular interest is the very much higher consumption in Denmark than other countries. Consumption data for Finland and to a lesser extent Sweden also show relatively high levels of oat consumption. Data on the form in which oats are consumed for all countries where consumption is equal to or greater than the UK would be useful as a guide to possible areas of increased usage in this country.

Table 3.4 Consumption of oats in EC countries (g/head/week)

Greece, Italy	Nil
Spain	1
France	2
Netherlands	5
Belgium	7
W Germany	24
UK	26
Ireland	33
Denmark	56

Human nutritive value of oats

Nutrient composition

- 3.10 Cereals are often considered primarily as sources of dietary energy. However they also contain substantial quantities of other nutrients. There are no data available which compare the composition of the various UK oatmill products. However, any differences between oatmeal and rolled oats will be very small.

Table 3.5 compares the chemical composition of oatmeal and three other cereals: wholemeal flour which, unlike white flour, is unfortified and whose consumption is associated with a prudent diet; brown rice (another wholegrain cereal); and cornflakes, a popular staple breakfast cereal that is fortified with minerals and vitamins. Oats have the highest concentration of energy. This is due mainly to the higher oil content. The nutritional significance of oat protein, oil, fibre and other constituents is discussed below. With the exception of Niacin and Vitamin B₆, the nutrient content of oats is similar to or higher than the other two unprocessed cereals. The Vitamins D, B₁₂ and C are absent from unfortified cereal products.

Table 3.5 Nutrient composition of oats and other cereals

	Oatmeal	Wholemeal flour	Brown rice	Cornflakes
Dry matter (g/100g)	91.1	86.0	86.1	97.0
Energy (MJ/100g)	1.70	1.32	1.52	1.52
Oil (g/100g)	8.7	2.2	2.8	0.6
Starch (g/100g)	72.8	65.8	80.0	77.7
High protein (g/100g)	12.4	12.7	6.7	7.9
High dietary fibre	8.3	9.3	2.0	0.9
Sodium (mg/100g)	33	3	3	1110
Potassium (mg/100g)	370	340	250	100
Calcium (mg/100g)	55	38	10	15
Magnesium (mg/100g)	110	120	110	14
Phosphorus (mg/100g)	380	320	310	38
Iron (mg/100g)	4.1	3.9	1.4	6.7
Copper (mg/100g)	0.23	0.45	0.85	0.03
Zinc (mg/100g)	3.3	2.9	1.8	0.3
Sulphur (mg/100g)	160	N	90	N
Chloride (mg/100g)	73	38	230	1820
Manganese (mg/100g)	3.70	3.14	2.30	0.08
Selenium (mg/100g)	3	53	2	2
Iodine (mg/100g)	N	N	N	10
Vitamin D (mg/100g)	0	0	0	2.8
Vitamin E (mg/100g)	1.7	1.4	0.8	0.4
Thiamin (mg/100g)	0.50	0.47	0.59	1.0
Riboflavin (mg/100g)	0.10	0.09	0.07	1.5
Niacin (mg/100g) ¹	3.8	8.2	6.8	16.9
Vitamin B ⁶ (mg/100g)	0.12	0.5	N	1.8
Vitamin B ¹² (mg/100g)	0	0	0	2
Total folate (mg/100g)	60	57	49	250
Pantothenate (mg/100g)	1.0	0.8	N	0.3
Biotin (mg/100g)	20	7	N	2
Vitamin C (mg/100g)	0	0	0	0

¹ includes the potential contribution from tryptophan; N, nutrient present, but data unreliable; 0, none of the nutrient present.
Data from Holland, et al (1988).

Nutrient density

- 3.11 Calculation of nutrient densities enables the evaluation and comparison of the individual nutrients provided by a food. Nutrient density relates the content of individual nutrients to the food's energy content and to the Recommended Dietary Intakes (RDI) for nutrients and energy. It is calculated as follows -

$$\frac{(\text{Nutrient per 100g})}{(\text{Energy per 100g})}$$

$$\frac{(\text{RDI of nutrient})}{(\text{RDI of energy})}$$

A nutrient density of 1 indicates that the food provides a marginally adequate amount of the nutrient. Values below 1 indicate a deficiency, while those in excess of 1 indicate that the food is a good source of that nutrient. The nutrient densities have been calculated (Table 3.6) for oatmeal and the

Table 3.6 Nutrient densities of oats and other cereals

	Oatmeal	Wholemeal flour	Brown rice	Cornflakes
Protein	1.4	1.8	0.8	1.0
Phosphorus	2.4	2.5	2.1	0.3
Magnesium	1.8	2.6	2.0	0.3
Calcium	0.3	0.3	0.1	0.1
Iron	1.1	1.4	0.4	2.1
Zinc	1.1	1.2	0.7	0.1
Thiamin	2.5	3.0	3.3	5.5
Niacin	1.5	4.0	2.9	7.2
Vitamin E	1.1	1.1	0.6	0.3
Vitamin B ₆	0.3	1.6	-	5.0
Riboflavin	0.4	0.5	0.3	6.9
Folate	0.7	0.9	0.7	3.5
Dietary fibre	1.4	2.0	0.4	0.2

cereals in Table 3.5 using RDI's from the United States since these cover a wider range of nutrients than those from the UK. The RDI's used were for women aged 23-50. There is no RDI for fibre, but this has been taken as 30 g/day and dietary fibre has been calculated as Englyst fibre plus lignin.

With the exception of Vitamin B₆, the nutrient density of oats is comparable to the other unfortified cereals. Vitamin B₆ deficiency is extremely rare and has never been reported in adults.

Protein

- 3.12 Oat protein is of higher quality, having a better balance of essential amino acids than other cereals. Furthermore, unlike other cereals, the protein quality of oats does not decline significantly if the protein content is raised by agronomic

practices or plant breeding. Lysine is the first limiting dietary essential amino acid in oat protein. However, this deficiency is unlikely to be of significance, even if oats were the sole source of protein, since as shown in Table 3.6 oats contribute a more than adequate amount of protein to the diet.

Oil

- 3.13 Oats have a higher oil content than other cereals. The main constituent fatty acids of oat oil are polyunsaturated linoleic acid (about 40% of total) and monounsaturated oleic acid (about 30% of the total). Although the oil content of oats makes only a small dietary contribution, it will provide essential linoleic acid and also contribute to intake of unsaturated fat which current dietary guidelines indicate to be preferable to saturated fat. Associated with the oil are the tocopherols, the main component of which is fat-soluble Vitamin E.

Fibre

- 3.14 Oats are a good source of dietary fibre. About half of the total dietary fibre in oats is water-soluble fibre. Consequently oats contain about 4% of soluble fibre compared with only around 2% in wholemeal flour. The soluble fibre of oats is also unusual in that it consists primarily of B-glucan. This B-linked glucose polymer dissolves to form very viscous solutions. It is chiefly responsible for the smooth mouthfeel of porridge. A number of dietary soluble fibre constituents have been found to exert effects on carbohydrate and lipid metabolism and it appears that oat B-glucan is the main component responsible for the therapeutic physiological effects of diets high in oats. This role for oat fibre and its possible anti-nutrient effects are described more fully below. Barley is the only other cereal which contains significant amounts of B-glucan. However, barley B-glucan appears to be less readily soluble than that of oats.

Antioxidants

- 3.15 Oat flour was used as a food antioxidant prior to the introduction of synthetic antioxidants. Earlier work has shown that oats contain a range of antioxidant compounds which are esters of phenolic acids. In addition phytate, which is present in oats in significant quantities, has recently been shown to possess antioxidant properties in food systems. Tocopherols (Vitamin E) also act as antioxidants in vitro and in vivo. The nutritional significance of these antioxidants is at present unclear. However, in vivo oxidant processes can result in damage at a molecular level which may be important in the initiation and progression of a number of disease states including cancer and ischaemic heart disease. Further research is needed to evaluate oat antioxidants in food systems and from a nutritional standpoint.

Free fatty acids

- 3.16 Oats contain varying amounts of free fatty acids. These may be present in the oat grain at harvest and amount to 3-14% of the total oil. Additional free fatty acids can be generated by the breakdown of the oil under the action of the enzyme lipase, which is present in the pericarp and released during milling. However, this enzyme is normally inactivated in the milling process by a stabilisation step involving steam treatment. High free fatty acid contents may be found if the original oats have a high level or if the stabilisation procedure is inadequate. High levels of free fatty acids may lead to a rancid off-flavour. The free fatty acids can also bind minerals, principally calcium and magnesium, and render them unavailable for absorption. Some food manufacturers, particularly those of infant foods stipulate a maximum level for free fatty acids in the oats which they purchase from the millers. Staying within this specification is a problem in some years when, for reasons which are not understood, the home-grown oat crop has yielded a large proportion of oats harvested with an already high free fatty acid level. However, not all oat millers regard high free fatty acids as a problem. Thus, further investigation into the significance

of oat free fatty acids in nutrition and its importance to the food industry is needed.

Bitter substances

- 3.17 In some circumstances oats and oat products may possess an unacceptable bitter off-taste. This can be the result of the utilization of oats which have become spoiled before milling or may develop during processing or storage. Its onset during processing or storage appears to be chiefly due to enzymic action and it is normally prevented by the enzyme inactivation which occurs during stabilisation. However, if bitter substances are present in oats before milling they cannot be eliminated and the resulting oat products will be unsuitable for consumption. This problem may be associated with pre-harvest sprouting or with heat damage arising from post-harvest drying. It has been found to occur in both home-grown and imported crops and probably requires further investigation.

Phytate

- 3.18 Phytate (phytic acid or inositol hexaphosphate) is found in a number of seed crops. It does not appear to be extensively broken down in the digestive tract and thus the phosphorus which it contains is unavailable for absorption. About 70% of the phosphorus in oats is present as phytate and therefore must be considered unavailable. A similar proportion of the phosphorus of wheat and rice is also present as phytate. Phytate also has the ability to sequester calcium, magnesium, zinc and iron and render them unavailable for absorption. This is unlikely to be important unless the diet is particularly high in phytate and low in these minerals. The ability of phytate to bind iron has been implicated in its antioxidant activity in vitro, and its use as a food antioxidant has been proposed. It is not clear whether phytate plays a role in the antioxidant activity of oat flour. Oats, in common with wheat and rice contain less than 1% phytate, but maize contains over 2%. Although classed as an anti-nutrient, phytate may play a role in some of the observed beneficial physiological effects of oats. Phytate can for

instance reduce the rate at which starch is digested and may be important in the reduced Glycemic Index of oats (see below).

Trypsin inhibitors

- 3.19 Inhibitors of the digestive enzyme trypsin are found in significant quantities in certain legume seeds. They have been detected in cereals including oats. However, they are present only in small amounts and are heat labile, being destroyed on heating during processing or cooking. Thus, trypsin inhibitors are unlikely to be of any nutritional significance in oats.

Oat bran composition

- 3.20 Oat bran is a coarse milling fraction of oats that is higher in protein and dietary fibre than rolled oats. Although referred to as bran, it is much less coarse than wheat bran. Table 3.7 compares the composition of oatmeal, oat bran and wheat bran and shows that, although oat bran is much lower in total dietary fibre than wheat bran, it is higher in soluble fibre.

Table 3.7 The composition of oatmeal, oat bran and wheat bran (g/100g)

	Oatmeal	Oat bran	Wheat bran
Dry matter	91	92	92
Oil	8	8	6
Protein	12	21	14
Total fibre	8	22	40
Soluble fibre	4	11	3

Evaluation of oats in human feeding

- 3.21 In a human feeding experiment where oats were the sole item of diet for 11-12 days, the major nutrients were well digested. The only problem encountered on this diet was a negative calcium balance, which was attributed both to the low calcium level and the presence of phytate. Such difficulties would not be anticipated in a normal mixed diet.

- 3.22 The data reviewed above show that oats have a nutrient profile which compares well with other cereals and indicates that oats can make a valuable contribution to the diet. However, there are a number of constituents of oats whose significance in food and nutrition is only poorly understood.

Health and therapeutic effects of oats

- 3.23 The therapeutic effects of dietary oats have been ascribed primarily to the dietary fibre fraction. Dietary fibre is featuring prominently in current dietary guidelines and food manufacturers are keen to market their products with a high fibre label where appropriate. There is great interest among nutritionists, food manufacturers and concerned members of the public in the reported therapeutic effects of oats. The first section below outlines the basis of the current interest in dietary fibre.

The dietary fibre hypothesis

- 3.24 Dietary fibre is receiving increasing attention from human nutritionists. It is becoming increasingly clear that it can no longer be regarded as inert roughage in the diet, but that it may play a role in the alleviation of a number of diseases and conditions prevalent in western developed countries. This link has been established primarily from epidemiological data. A number of mechanisms have been postulated to explain these effects but their significance is as yet unclear. Dietary fibre is not a single chemical entity, and it is now common to differentiate between insoluble fibre, which appears to chiefly improve gastrointestinal function, and soluble fibre which appears to exert its effects on lipid and carbohydrate metabolism. However the role of dietary fibre is incompletely understood and the dietary fibre hypothesis remains unproved. Its chief tenet is that diets high in fibre protect against certain western diseases. It is possible, if improbable, that other food components associated with high fibre diets are responsible for this effect or that it is due to a combination of food components in high fibre diets.

Fibre as an anti-nutrient

- 3.25 Fibre is, by definition, not digested in the human gastrointestinal tract. A varying amount of it may be broken down by hind gut bacteria to yield short chain fatty acids that can enter the pathways of energy metabolism, but the energy yield will be much less than that of an equivalent amount of digestible carbohydrate. Soluble fibre constituents have also been shown to reduce the rate of uptake of other nutrients from the gastrointestinal tract and recent reports have suggested that high soluble fibre intakes may be associated with an increased risk of cancers of the small intestine. Thus dietary fibre may act as an anti-nutrient. However this is likely to be of little significance in normal mixed diets.

Physiological effects of oat diets

- 3.26 In addition to their generally good nutrient profile, diets containing oats have also been found to be effective at alleviating conditions which are associated with a number of diseases. These conditions are prevalent in western developed societies and include hypercholesterolaemia and diabetes. Hypercholesterolaemia or elevated plasma cholesterol levels are considered to be a major risk factor in heart disease and a number of drug and dietary treatments have been proposed to reduce plasma cholesterol. Oats have featured in a number of these diets and the results of the reported human experiments are summarised in Table 3.8. From this it can be seen that diets containing both rolled oats and oat bran have been successful in reducing plasma cholesterol. However oat bran was more generally effective than rolled oats. Oat bran is higher in total and soluble fibre and it is this latter which appears to be chiefly responsible for its hypocholesterolaemic effects, although the protein fraction may also contribute.

Table 3.8 Summary of therapeutic effects of dietary oats in human studies

Rolled oats

Quantity fed (g/day)	Main effects	Year	Country
140	CL-	1963	Netherlands
43	CL=	1978	Ireland
42	CL=	1980	USA
125	CL=	1981	UK
35	CL-	1986	USA
150	CL-	1987	UK

Oat bran

29 or 57	FW+	1977	USA
100	CL-	1980	USA
94	CL-	1981	USA
100	CL-;FW+	1984	USA
39	CL=	1986	USA

CL, plasma cholesterol; FW, faecal weight;
+, increase; -, decrease; =, no effect.

Many of these studies incorporated oats into the diets while maintaining the overall nutrient balance. In others the oat diet was combined with modifications in fat intake which were also likely to be beneficial. In the Irish study, porridge oats were substituted for cornflakes but this simple dietary intervention was without significant effect on plasma cholesterol. To obtain a significant effect 90-100 g (3-3.5 oz)/day of oat bran or 140-150 g (5-5.3 oz) of rolled oats were needed. Total UK bread consumption currently averages only about 4.4 oz/day. Thus the above results indicate that substantial dietary changes are needed to achieve the intakes of oats or oat bran that produce significant cholesterol reductions. Nevertheless in view of the clearly demonstrated potential of oats to decrease plasma cholesterol a general increase in oat consumption, even if small, will tend to reduce hypercholesterolaemia in the population.

- 3.27 Dietary oats have also been shown to improve gastrointestinal function, reducing transit time and increasing faecal bulk. Both these effects are considered beneficial and may help to alleviate or prevent conditions such as haemorrhoids, diverticulitis and colorectal cancer. Although data is available from only one experiment the intakes required to achieve these effects appear

to be less than those required to influence lipid metabolism (Table 3.8).

- 3.28 In short term experiments oats fed at equivalent carbohydrate levels to other cereals have been found to give a significantly lower rise in blood glucose levels. This observation has been developed into the concept of the Glycemic Index which is a comparative measure of the integrated blood glucose rise observed with different foodstuffs. The Glycemic Index of oats is lower than that of most other commonly eaten cereals. This effect is also mainly attributed to the soluble fibre fraction, though the phytate and the nature of the oat starch may also play a role. Diets high in fibre and complex carbohydrate are being increasingly accepted as a means of diabetic control. Oat bran diets have been shown to be beneficial to diabetics and in one American study patients were able to reduce or eliminate insulin administration.

Oats and coeliac patients

- 3.29 Coeliac disease is an intestinal malabsorption syndrome which arises in certain individuals as a reaction to the presence in the diet of gliadin, one of the components of the cereal protein, gluten. Its prevalence is 1 in 2000 and there are about 25,000 patients in the UK. If untreated death or severe disability follow in the majority of cases. Treatment rests in the exclusion of gluten, which is found in wheat, rye and barley in significant amounts, from the diet. The position of oats is as yet unclear. Sensitive tests indicate that the gliadin fraction responsible for the disease is present and some physicians believe oats should be avoided. However a large number of coeliac patients include substantial quantities of oats in their diet without problems.

Oat husk

- 3.30 Oat husk is around 90% fibre when determined as cell wall material. This consists of 30-40% of both cellulose and hemicellulose fractions and lignin contents are high (7-9%).

Soluble fibre content is negligible. Oat husk is of similar composition to very poor quality straw. However its high fibre content and ready availability has lead to production of an oat fibre product by the fine milling of oat husk. Initially the palatability of products including this fibre source was poor but these problems have been resolved and oat husk fibre has been successfully incorporated in baked cereal products at levels up to 30%. Although this substance will analyse as total dietary fibre its composition is very different from that of oat groat fibre and its physiological effects will not be comparable. A potential hazard also exists with this product since oat husk contains significant amounts of silica, present as spicules, which have been shown to cause gastrointestinal irritation in animal experiments. In view of the increasing public awareness of the potential benefits of increasing both fibre and oat consumption it may be felt necessary to lobby for improvements in food labelling so that fibre additives derived from oat husk are not confused with oat groat fibre.

Other reported nutritional benefits of oats

- 3.31 Livestock producers sometimes report that animals appear healthier and more productive when on oat diets. A few comparisons have been made and this hearsay advocacy has not been substantiated in controlled experiments. There are similar unsubstantiated reports from humans where oats have been claimed to improve endurance performance, alleviate gastric disorders in infants and to produce behavioural improvement in adolescents. However it is difficult to test such claims in humans. Oats contain a vast array of chemical constituents and it is possible that one or more of these remains to be identified as an essential or ameliorating nutrient.

Value of oats for food products

- 3.32 Although significant amounts of oats are utilized in other products, the current main food use of oats is for breakfast cereals. Compared to other cereals there is a relative lack of information of food applications of oats. However in addition to

its nutritional attributes oats have a unique flavour and texture and excellent moisture retention properties and they can increase the viscosity and stability of food systems. Oats form a major component of many infant foods which attests to its value as a safe and bland nutrient and as a food component. Its qualities include hypoallergenicity, flavour compatibility and good keeping qualities.

Oats lack gluten and for this reason cannot be made into leavened products. However oats may be incorporated into a wide range of baked products and can successfully replace up to 30% of the wheat flour in breads. The good moisture retention of oats results in increased shelf life for these products. Oats can also be incorporated into biscuits at up to 15% and have been shown to improve fat stability, which is probably due to the antioxidants present. Recent work indicates that oat bran can also be used successfully in baked goods. Clearly it is feasible to incorporate oats in a wide range of specialty breads, cakes and biscuits which could be marketed using the current healthy eating image of oats.

- 3.33 Rolled oats are used as a thickener in soups, gravies and sauces and can be used as a meat extender in meat loaf and meat pasties as well as in a variety of home-cooked baked goods. Oats are also used as a topping or dusting on a variety of foods (eg. as an oat 'batter' on fish) because of their rich, whole grain appearance. Indeed, the unique flavour and texture characteristics of oats are cited by many food manufacturers as their most important attributes for inclusion into a wide range of food products.

Oat flour has been used as an antioxidant in food manufacturing and with an increasing pressure on the use of synthetic antioxidants, has potential for further use.

Some food manufacturers, that were contacted in the course of this study, saw the potential for developing a range of new snack foods based on oats or using oats as a major ingredient. There are many interesting possibilities for the production and

marketing of hitherto unavailable oat products. These include the revival and commercial modification of traditional oat foods such as sowans or shot which were formerly eaten in Ireland, Scotland and Wales. The fuller availability of oat bran in the UK might enable the commercial production of the oat bran muffins which have been used in many of the therapeutic diets tested in the USA. These could be marketed as a speciality bread. Oats may achieve greater prominence in the diet, if there are products available whose main constituent is oats, rather than merely incorporating a percentage of oats into other foodstuffs.

- 3.34 One novel food use of oats found on further investigation of potential uses for oat fractions in food products carried out by a commercial food manufacturer, is that of an emulsifying agent. The emulsifier in question, identified and isolated from oats, was found to have emulsifying properties very important to the chocolate/confectionery industry (amongst possible others). The emulsifier would play an important role in covering and creating confectionery bars, where the flow and setting characteristics of chocolate are important. The emulsifier has the potential to fill a necessary gap for an emulsifier in the industry, being derived from a natural plant product with a healthy image, having no flavour problems but with excellent emulsifying properties.

The experimental extraction process for the emulsifier involves solvent extraction which removes the oil fraction of the oat groat. Further extraction can then be carried out to isolate a purer form of the emulsifier. Two different emulsifying products with different emulsifying qualities and characteristics can be produced, the oil or the purer emulsifying agent. There is a patent on the emulsifier at present and others have been applied for in relation to various uses of the emulsifier in the food industry.

The processing of oats (crushed) to produce the emulsifying fraction results in three main products; defatted oat flour (residue), an oil fraction and the emulsifier. The economic viability of large-scale industrial use of the emulsifier depends on the value of these three products. The economic viability of

the process is dependent on the value of and market for the flour fraction in particular. If such a market can be found, the usage in terms of dehulled oats for processing could be considerable (for the UK market alone, a tonnage in excess of 50,000 t. has been mentioned by a commercial source). Possible 'high value' markets for defatted oat flour include its use in snack foods.

This example highlights the potential benefits from basic research into the chemistry of oats and oat fractions.

The use of oats for food aid

- 3.34 The good nutritional characteristics of oats, their bland taste, good storage stability and suitability for both infant and adult diets indicates that they could be valuable in food aid programmes. Oats could be offered as oatmeal or as ready prepared oatcakes which are of low bulk and thus easily transported. However people are very conservative about the foods that they will eat and a drawback may be the unfamiliarity of oats to the recipients. In such cases instruction in the value and preparation of oat foods may be needed. Oatflakes have been used for food aid and this is documented by the Federation of Associations of Oat and Barley Millers in the EC.

The use of food for aid other than for famine relief is controversial, although the role of food aid for famine relief is generally well agreed.

Naked oats

- 3.35 Naked oat cultivars have recently been developed and released for use in the UK. The principal difference between the usual husked oats and naked oats is that in the latter the groat threshes free from the husk during harvesting. Consequently naked oats are very similar to oat groats in composition. The utilization of naked oats as a raw material for the oat milling industry appears to present no major difficulties. Furthermore the use of naked oats could result in substantial improvements (eg. 30%) in milling yields and enable the elimination of some of the stages

in the milling process which would reduce both equipment and energy costs. However, such modifications to existing oatmilling plants may only prove feasible if there is a good supply of naked oats of milling quality. Furthermore, significantly lower yields per hectare are obtained from naked oats and it would be necessary to offer the grower a premium for this crop. On the other hand the use of naked oats may enable growers to produce milled oat products from their own crops without the need for costly dehusking equipment, although other equipment for steaming and flaking for example would probably still be required.

Conclusions to Chapter 3

1. Oats currently make only a very small contribution to the UK diet. An average of around 30g of oats is consumed per head per week, supplying only 2.4% of total cereal dietary energy.
2. There is currently a relatively narrow range of oat food products available and only limited use of oats in other products such as in bread and other baking.
3. Oats have a number of nutritional benefits:
 - (i) oats have protein of a higher quality with a better balance of essential amino acids than other cereals;
 - (ii) oats have a higher oil content than other cereals giving a higher energy value, with a high proportion of unsaturated fat;
 - (iii) oats are a good source of dietary fibre;
 - (iv) oats generally have a good and balanced nutrient composition.
4. A number of health benefits of oats have been recorded, largely ascribed to the soluble dietary fibre fraction (mainly B-glucan). Possible health benefits include helping to lower blood cholesterol levels (important in reducing heart disease), and

alleviation of conditions such as haemorrhoids, diverticulitis, colorectal cancer (by increasing faecal bulk), and diabetes.

5. Food manufacturers see the potential for developing a range of new snack foods based on oats or using oats as a major ingredient, and there are possibilities for the production and marketing of hitherto unavailable oat products. There is a potential for increased use of oat fractions in food processing such as oat flour as an antioxidant and thickener, and oat gum as an emulsifying agent.
6. Consumer attitudes to oats are favourable, with oats having important taste and texture characteristics, and a generally natural and healthy image.
7. Naked oats could be of value to the milling industry and might enable growers to produce some oat products themselves.
8. There is a number of constituents of oats whose significance in food and nutrition is only poorly understood.

CHAPTER 4 OATS FOR LIVESTOCK FEED

Introduction

4.1 The major consumers of oat grain within the livestock species are cattle, sheep, pigs, poultry, horses and goats. Table 4.1 shows the numbers of livestock in the UK between 1983 and 1987. It is apparent that there has been a steady decrease over this period in total numbers of cattle, an overall but fluctuating decrease in pig numbers, but a steady increase in the total sheep and poultry populations. Horse numbers, estimated from 2 censuses carried out in 1986 by the British Horse Society, are believed to be about 500,000 and increasing.

Table 4.1 Numbers of livestock in the UK ($\times 10^3$ head)

Species	1983	1984	1985	1986	1987	% change 1983-87
Cattle ¹	13,290	13,213	12,911	12,507	12,182	- 8
Sheep ¹	34,069	34,802	35,682	37,021	38,788	+14
Pigs ¹	8,174	7,689	7,865	7,981	7,906	- 3
Poultry ¹	117,854	118,846	119,456	120,350	124,253	+ 5
Horses ²	?	?	?	500	?	+ ?

1 UKASTA data.

2 British Horse Society (pers. comm.).

4.2 The use of oats for livestock feed has declined significantly over the last few decades. Over the 1976/77 to 1987/88 period, the use of oats for livestock feed declined by 60% (see Table 2.2, Appendix 2.1), from 621,000 t to 250,000 t. In 1987/88 therefore, livestock feed use of oats accounted for 55% of total oats utilization in the UK. However, only two years previously (1985/86) some 435,000 t, 70% of total oats utilization, was fed to livestock, due to the greater availability and relatively low price of oats for livestock feed in that year. Feed use tends to

fluctuate depending on the availability, and hence the price of oats, relative to other feeds.

- 4.3 A relatively high proportion of oats grown is retained on the farm for livestock feed. In the 1986/87 marketing year, some 235,000 t were retained on farm for this purpose, representing nearly 47% of farm production of oats and 71% of total livestock feed use.

An estimated 95,000 t of oats were sold for feed in 1986/87 in addition to the oats retained and fed on farm.

- 4.4 The quantity of oats used in compound livestock feeds has fluctuated considerably over the last few years (see Table 4.2).

Table 4.2 Cereals used in manufacture of compound feedingstuffs in GB ($\times 10^3$ tonnes)

Cereal	1983	1984	1985	1986	1987	% change 1983-87
Wheat	2,543	2,973	2,918	3,240	2,971	+ 17
Barley	1,539	892	584	558	621	- 60
Maize	710	193	146	184	201	- 72
Oats	64	45	55	73	37	- 42

Source: MAFF Statistics

The increased usage in 1986 reflects the greater availability of oats from the 1985 harvest. The use of oat grain within the compound feed industry is highly dependent on the availability and price of oats.

In 1987, around 37,000 t of oats were used in the manufacture of compound feedingstuffs. Compound feed manufacturers also deliver approximately 14,000 t/annum of unprocessed oats to farmers for use in home mixes, and this has remained constant since 1983 (H-GCA pers. comm.). Thus the total oats accounted for by

compounders in 1987 (51,000 t) and by on-farm feeding (235,000 t) leaves 44,000 t unaccounted for. This presumably is accounted for by local contracts for racehorses and breeding establishments, and horse feed generally, as well as by compound manufacture statistics relating to Great Britain, whilst statistics for oat supply/demand balances relate to the UK market.

No breakdown of feed use according to species of livestock is available.

- 4.5 Oat grains may be fed to livestock whole or lightly processed (eg rolled or crushed), forming almost all of the concentrate part of the diet, or as a component of a manufactured compound feed either pelleted or as a coarse mix, or as an ingredient in a 'home-mix' prepared on the farm.

Non-ruminant animals, such as calves, pigs and poultry, obtain much of their energy from cereals, whereas for ruminants the total contribution is lower, though cereals provide the bulk of the energy in the concentrate portion of the ration.

- 4.6 Apart from the oat grain, which may be chemically treated or physically processed, other parts of the crop available for feeding to livestock include hay, straw, stubble, greenfeed oats, hulls, byproducts (oatmeal etc) and whole crop silage.

Limited quantities of oat straw are fed as a poor quality forage to some classes of livestock, notably ruminants. The amounts available from 1983 to 1986 estimated by MAFF are shown in Table 4.3 and compared with those for wheat and barley.

Table 4.3 Estimated production of cereal straw in England, Wales and Northern Ireland for use or sale ($\times 10^3$ tonnes)

Cereal	1983	1984	1985	1986	% change 1983-86
Wheat straw	3,065	3,308	3,398	3,770	+ 23
Barley straw	4,191	4,586	4,252	4,265	+ 2
Oat straw	418	519	605	398	- 5

Source: MAFF Statistics

Nutritive value of the oat crop

Oat grain

- 4.7 According to the review of Wainman *et al* (1975), there has been little if any systematic change in the chemical composition of oat grains over the past 100 years, yet their nutritional value is recognised as being variable. This has been attributed to variations in protein, fibre and bulk density of the grain.

The mean chemical composition of oat grains, comprised of values reported in the literature during the past 14 years is given in Table 4.4 together with recently reported values for a range of barley and wheat grains.

- 4.8 As harvested, oat grain carries a husk or hull formed from the inner and outer paleae, unlike wheat, barley, maize or naked oats. The proportion of groat or kernel to hull which largely determines the nutritive value of the oat grain, is dependent on variety, environment and season and can vary from 20-30% (WPBS Information Sheet). The crude fibre content of oat grain is significantly higher than that for barley or wheat, and the cell wall content represented by the NDF fraction is also much higher as are the levels of cellulose and lignin. The lignin content affects the degree to which the cell walls are able to be

Table 4.4 Chemical composition of cereal grains, (all as g/kg DM unless stated otherwise)

Chemical fractions	Wheat ¹	Barley ¹	Oats ²		
			Mean	SD	n
Dry matter (g/kg)	834	851	881	14.3	16
Crude protein	125	128	116	13.2	21
Crude fibre	21	46	105	11.6	34
Ether extract	16	20	43	14.0	35
Total ash	16	22	29	5.7	35
Starch	680	599	480	36.0	25
Gross energy (MJ/kg DM)	18.5	18.5	19.5	0.22	30
Neutral detergent fibre					
Acid detergent fibre	102	165	283	26.5	10
Cellulose	26	54	147	13.8	26
Lignin	20	47	105	12.7	7
	8	12	36	9.3	27
Calcium	0.8	0.8	0.8	0.17	24
Magnesium	1.0	1.2	1.5	2.20	23
Phosphorus	3.1	3.7	3.4	0.56	24
Potassium	4.6	4.6	5.3	0.97	23
Sodium	0.1	0.2	0.2	0.10	23
Sulphur	1.6	1.6	2.1	0.28	2
Copper (mg/kg)	3.7	4.4	3.3	0.94	18
Iodine (mg/kg)	0.1	0.1	-	-	-
Iron (mg/mg)	105	67	171	87.7	2
Manganese (mg/kg)	32	19	39	10.5	18
Selenium (mg/kg)	<0.1	<0.1	-	-	-
Zinc (mg/kg)	24	35	27	3.6	18
Chloride	1.0	1.0	0.9	0.14	2
Vitamin B6 (mg/kg)			3.0	-	1
B12 "			2.0	-	1
E "			16.0	-	1
Choline "			467	-	1
Folic acid "			0.4	-	1
Niacin "			8.0	-	1
Pantothenic acid (mg/kg)			6.8	-	1
Riboflavin "			0.5	-	1
Thiamine "			6.8	-	1
Amino Acids (g/16 g N)					
Arginine	4.7	4.5	6.9	0.17	4
Histidine	3.0	2.7	2.5	0.39	4
Isoleucine	3.6	3.6	3.8	0.24	4
Leucine	6.9	7.0	7.7	0.28	3
Lysine	3.0	3.7	4.2	0.21	4
Methionine	1.4	1.5	1.9	0.26	4
Cystine	2.4	2.2	2.6	0.83	4
P-alanine	4.7	5.1	5.3	0.21	4
Threonine	3.0	3.5	3.6	0.21	4

Table 4.4 continued

Chemical fraction	Wheat ¹	Barley ¹	Oats ²		
			Mean	SD	n
Valine	4.6	4.9	5.3	0.22	4
Alanine	3.9	4.2	5.0	0.36	4
Aspartate	5.1	5.5	8.8	0.23	4
Glutamine	28.0	24.1	20.4	0.81	4
Glycine	4.0	4.2	5.2	0.21	4
Serine	4.6	4.2	4.9	0.54	4
Tyrosine	3.0	3.4	3.5	0.44	4
Fatty acids					
16:0 Palmitic	2.4	3.6	9.5	2.70	2
18:0 Stearic	0.1	0.2	0.6	0.17	2
18:1 Oleic	1.7	2.2	23.2	6.83	2
18:2 Linoleic	8.8	9.8	22.7	4.12	2
18:3 Linolenic	1.0	1.6	1.0	0.30	2
NCD ³	929	888	755	-	1
In vitro digestibility	858	801	662	0.2	30

Source: 1 ADAS National Feed Composition Survey 1988

2 Various sources

3 Neutral detergent/cellulase digestibility

degraded, the more lignification the lower the degradability, and there is evidence of variation in hull lignin content with variety (Crosbie *et al.*, 1984). In other words it may be possible to select oats for a low lignin content and hence higher nutritive value.

- 4.9 From the data presented here, the mean protein content of oats is lower than that of wheat and barley though not significantly so. Standard textbooks (eg McDonald *et al.*, 1988) record all cereals as being deficient in certain essential amino-acids, for example lysine and methionine, but note that oats have a higher lysine content than the others. However, in the results quoted in Table 4.4, the lysine content of oat protein is not very different from that of the other cereals. The same authors also suggest that oat proteins are of poor quality and are deficient in histidine and tryptophan. Oat proteins may be more soluble than those of barley, as the former are higher in globulins, but lower in

prolamines and glutelins, thus the rumen degradability of the oat protein may be higher (Sanne, 1988).

- 4.10 Oats have the highest oil content of all the cereals. The oil consists largely of unsaturated fatty acids, mostly oleic (18:1) and linoleic (18:2). These oils tend to produce a soft body fat in pigs (Enser 1984), and may oxidize fairly quickly (Gurr 1984).

The increased oil or ether extract content of oats accounts for a gross energy content that is higher (19.5 MJ/kg DM) than that for wheat (18.5 MJ/kg DM) or barley (18.5 MJ/kg DM). As will be explained later, the higher energy is not all available to the animal; hence it does not lead to a higher metabolisable energy (ME) content.

- 4.11 Starch content is lower in oat grain (408g/kg DM) compared with wheat (680 g/kg DM) and barley (599 g/kg DM). The mineral profile is similar for all cereals. All cereals are low in calcium, but there appears to be some evidence that in oats, calcium may be less available since the phytate phosphorous present is more effective at immobilising calcium than that in other cereals (McDonald et al, 1988). Phytate phosphorus levels are slightly lower for oats than for other cereals (Hopkins et al, 1987).

Measures of digestibility in vitro both using rumen fluid (IVD) and neutral detergent cellulase (NCD) show that oat grains are less digestible than wheat and barley. This is due to the higher fibre content of oat grains.

Nutritive value of oat grain for ruminants

- 4.12 Digestibility and energy values of oat grain used for ruminants until 1983, (MAFF et al, 1975) were based on very old data, possibly originating from the work of Kellner in the early 1900s. The literature indicates that little systematic work was carried out until that of Wainman et al (1975), who examined 16 oat samples by energy balance trials using sheep as a model ruminant. The results of these trials were incorporated into later feed

composition tables (MAFF, 1986). More recently the ADAS Feed Evaluation Unit (FEU) (Everington unpublished) has examined 5 samples of rolled winter oats using a similar method. Table 4.5 shows digestibility and energy values for oat grain from these 3 sources and for comparison those for barley and wheat also.

Table 4.5 Digestibility and energy values of cereals for ruminants

	Wheat ²	Barley ²	Oats		
			1	2	3
DOMD (g/kg DM)	884	823	680	700	740
ME (MJ/kg DM)	13.6	12.8	11.5	12.0	12.4

Source: 1 MAFF et al 1975, 2 MAFF 1986, 3 FEU data unpublished
DOMD: Digestible organic matter in the dry matter.

- 4.13 The metabolisable energy content of oats for ruminants is lower than that for the other cereals but more recent measurements attribute a higher ME to this cereal than previous work. This is most likely due to the selection of samples tested in each case. For example, of the 16 oats examined by Wainman et al (1975) many were spring varieties having a lower than average oil content, whereas those samples tested at the ADAS FEU (unpublished) were all winter oats which appear to have a higher ME content. The variability between samples within all 3 cereals is similar, the standard deviation being 0.7, 0.7 and 0.5 for wheat, barley and oats respectively (MAFF, 1986).

While only small numbers of samples can be evaluated, there will always be criticism as to the range of samples studied. However, from the limited information available our best estimate of the ME content of oats is that it lies between 12-12.4 MJ/kg DM. There is an indication of a possible relationship with season of sowing.

Sheep

- 4.14 Most feed evaluation studies are carried out using sheep for practical reasons, and the results are applied universally to all ruminants. Recent work has already been mentioned above and individual data are shown in Table 4.6.

Table 4.6 Published values for the nutritive value of oats.

Reference	Method	Animal	OM dig	GE dig	ME (MJ/kg DM)
Hoffman <u>et al</u> (1963) ¹	Diff	Sheep	0.746	0.738	12.64
Wainman and Smith (1972) ¹	Sole	Sheep	0.725	0.698	12.55
Wainman and Smith (1972) ¹	Sole	Sheep	0.678	0.641	11.26
Wainman and Smith (1973) ¹	Sole	Sheep	0.714	0.695	12.62
Wainman <u>et al</u> (1973) ¹	Sole	Sheep	-	0.732	12.57
Orskov <u>et al</u> (1974) ¹	Diff	Lambs	0.699	-	-
Wainman <u>et al</u> (1975) ¹	Diff	Sheep	-	0.698	12.00
Margan <u>et al</u> (1987)	Sole	Sheep	-	-	13.50
Everington <u>et al</u> (1988)	Diff	Sheep	0.761	0.749	12.44

Diff - fed in combination with a forage. Values for oats calculated by difference.

Sole - fed as sole feed.

¹ Source: Wainman et al (1975).

This includes some very high ME values, up to 13.5 MJ/kg DM (Margan et al, 1987) but the method of evaluation using oats as a sole feed is not typical of a UK feeding situation. Wainman et al (1975) commented that this may predispose to digestive upsets and unstable rumen fermentation patterns, so these values are best treated with some reservation.

- 4.15 Most recent work specifically related to sheep, has examined the effects of processing on feed utilization. Orskov et al (1974) compared the utilization by lambs of barley, maize, wheat and oats, fed either whole or coarsely ground and pelleted. They reported that oats gave the poorest feed conversion ratio and was

the least digestible of the four cereals. Apparent digestibilities of the organic matter of the cereals in the order given above were .811, .843, .827 and .699 for the whole and .772, .821, .866 and .675 for the ground and pelleted grains. There was no significant effect of processing, although whereas there was no incidence of rumenitis with either of the oat rations, feeding whole grains prevented rumenitis occurring with the other cereals. Orskov et al (1974) concluded that the poorer utilization of oats was due to lower intakes which presumably were a result of the high levels of oat fibre.

In the study of Vipond et al (1985), pregnant ewes were found to void fewer grains of oats than they did of barley when fed similar levels of whole grains. As the basal diet was changed from silage to hay or roots the excretion of whole grains decreased. Vipond et al (1985) observed that regurgitation of grains would be more difficult with a long fibrous silage and this may be the major cause of the observation.

The conclusion that may be drawn is that there is no benefit to be gained in nutritional terms by processing oat grains for sheep.

Cattle

- 4.16 Most work with cattle has been related to examining the effects of processing on feed utilization and attempts to manipulate milk quality. The nutritive value as measured in vivo in sheep is assumed to be the same for all ruminants. There are indications from production studies that the efficiency of utilization of the ME in oats is greater than that for other cereals (Moran 1986), but little calorimetric evidence is available to support this.

Oats have been included at up to 30% in commercial dairy and beef compound feeds, when the economics of doing so were favourable, and at up to 10% of calf rations, mainly in coarse mixes.

In a trial using cattle aged 6 months and upwards, Morgan and Campling (1978) compared the cereal sources barley and oats,

feeding each either whole or rolled. They examined starch digestibility as an indicator of the animals' ability to digest whole grains and concluded that digestibility declined with age of the animal. The starch of whole oats was digested better than that of whole barley and the authors concluded that barley but not oats were worth rolling prior to feeding. McDonald and Hamilton (1980) also found that there was little benefit to be gained from crushing oats. They suggested that feeding more than 50-60% of oats in the diet of steers may be detrimental to animal performance, but that this aspect required further investigation. Rolled barley, wheat and oats each comprised 60% of the DM of complete diets offered to lactating cows by Moran (1986). There was no difference in voluntary DM intake, and OM digestibilities were in decreasing order 0.735, 0.689 and 0.610 for wheat-, barley- and oats-containing diets respectively. Digested OM was utilized most efficiently by cows given oats. Cows fed oats produced most milk and milk fat, due in part to higher levels of dietary fibre and oil. Moran (1986) also investigated the effect of replacing rolled oats in the diet with whole oats soaked in sodium hydroxide. Cows on these diets had slightly higher DM intakes (18.02 kg DM/head/day) than on rolled oats (17.78 kg DM/head/day) and produced more milk, milk fat and protein though none of these differences were significant.

- 4.17 Rumen degradability of the dry matter of rolled barley, wheat and oats was examined by Moran (1986) and the data fitted to the equation of Orskov and McDonald (1979) viz, $P = a + b(1 - e^{-ct})$ where P = DM digested in the rumen at time t , a is the immediately soluble fraction, b is the insoluble but potentially digestible fraction, and c is the rate of digestion of b . The results are shown in Table 4.7.

Table 4.7 Degradability characteristics of barley, wheat and oats dry matter, incubated in the rumen of cows (g/kg incubated or as stated).

	Barley	Wheat	Oats	SE
Potentially digestible (a+b)	928 ^a	917 ^a	761 ^b	20
Insoluble but potentially digestible (b)	732 ^a	598 ^b	373 ^c	25
Soluble in rumen (a)	196 ^a	319 ^b	389 ^b	25
Rate of digestion (%/h)	44.4 ^a	85.4 ^b	85.8 ^b	7.2

a,b,c - Within each line, values with different (after Moran, 1986) superscripts are significantly different ($P < 0.05$).

Oats had the lowest proportion of potentially digestible dry matter of the 3 cereals.

- 4.18 Martin and Thomas (1988a) investigated manipulating the saturated fatty acid content of cows milk fat by using oats instead of barley as the dietary cereal source. The cereals were given rolled, with and without formalin treatment to give some degree of rumen protection, and were fed together with hay and soya bean meal. Mean daily milk yields were significantly higher ($P < 0.05$) with oats (17.1 kg/d) than with barley (15.9 kg/d), with the formalin treated grains highest overall (oats 19.2, barley 16.9 kg/d). There were no significant differences in fat or protein yields but the oats diets led to significant reductions ($P < 0.001$) in the saturated fatty acid content of the milk and hence an increase in unsaturated acids, mostly mono-unsaturates. Changes in milk fatty acid composition are shown in Table 4.8.

The mechanism for these changes, according to Martin and Thomas (1988a) would appear to be a reduction of mammary synthesis of 6:0-16:0 fatty acids due to the influence of supplementary fat on rumen fermentation. Additional unsaturated fatty acids from the diet are hydrogenated in the rumen and the 18:0 subsequently desaturated in the mammary gland.

Table 4.8 Milk fatty acid composition (g/kg total fatty acids) for animals given diets containing barley, formalin treated barley, oats and formalin treated oats.

Fatty acid	Barley	Treated barley	Oats	Treated oats	SED
6:0	20	17	14	16	2
8:0	14	14	10	10	1***
10:0	35	37	20	21	2***
12:0	43	45	25	23	3***
14:0	146	151	104	106	4***
16:0	395	390	281	275	14***
16:1	31	29	30	27	2
18:0	101	94	166	161	11***
18:1 cis	171	174	289	301	10***
18:1 trans	10	9	25	22	3***
18:2	26	30	24	26	1**
18:3	9	9	13	12	2

** $P < 0.01$; *** $P < 0.001$ (after Martin and Thomas 1988a)

Recently, Finnish workers (Heikkilä *et al.*, 1988) found very similar results when comparing Ayrshire cows fed oats or barley as a cereal source. It is noteworthy that Banks *et al.* (1987) found that milk from Jersey cows was less susceptible to manipulation in this way. These latter workers reported that an added benefit of increased mono-unsaturated fatty acids was to enhance the spreadability of butter made from this milk.

- 4.19 Thus oats would seem to be a good energy source for dairy cows. Though not of such high energy value as other cereals they have the advantage that they may be fed successfully without processing, hence reducing costs, and they may be used to manipulate milk fat composition in such a way as to encourage health-conscious consumers to increase their intake of milk. Suggested links between the consumption of saturated fatty acids and the development of coronary heart disease and other disorders in man, has led to recommendations that their consumption be reduced (Martin and Thomas, 1988a) and hence a decline in the consumption of milk and milk fats in human foods generally. It would appear that milk and milk products from oat-fed cows would assist in meeting these recommendations.

Pigs

- 4.20 The results of recent evaluation trials with oats for pigs are shown in Table 4.9. Little experimental data on feed evaluation are available in the literature.

Table 4.9 Published values for DE and ME content of oats (MJ/kg DM) for pigs.

Reference	DE	ME
De Goey and Ewan (1975) ¹	11.90	11.41
Morgan et al (1975) ¹	13.26	12.93
Salo and Alaviuhkola (1980)	-	13.51
Wiseman et al (1982)	12.74	12.38
Wiseman et al (1982)	12.48	11.97

¹ Source: Wiseman et al (1982).

In the work of Wiseman et al (1982) the mean digestible energy (DE) content ($\pm$ SD) of oat grain for pigs was 12.6 ($\pm$ 0.6) MJ/kg DM, while that for wheat and barley was 16.02 ($\pm$ 0.43) and 15.52 ($\pm$ 0.17) MJ/kg DM respectively. The lower and more variable energy value for oats is likely to be due to the higher fibre content of whole oat grains which non-ruminants are unable to digest fully. Lin et al (1980)¹ fed oat groats (dehulled oat grains) to pigs and reported that when compared with maize, sorghum, wheat and barley grains, the apparent digestibility of nitrogen, amino acids and gross energy of oat groats was greater than any of the other cereals. The measured DE of the groats was 17.2 MJ/kg DM thus indicating that the fibre of the oat grain depresses its energy value for the non-ruminant.

Though its high fibre content limits the use of oats in creep or starter rations, oat groats or flakes have been used in baby pig diets. Oats have also been used to supplement low fibre feeds such as separated milk and whey products (ADAS data sheet No NC/PG 4). The maximum inclusion (% as fed) is likely to be about 40, 10 and 25% for sow, weaner and grower diets respectively (Dalgety, pers. comm.).

- 4.21 One of the factors contributing to the variability of the nutritive value of oats is its bulk density. Some Finnish workers (Salo and Alaviuhkola, 1980) studied the relationship between bulk density and energy value using growing pigs and two groups of oats, light (<40 kg/hl) and medium (51-56 kg/hl). As expected the light oats contained less starch and hence NFE digestibility was reduced; pigs digested oat starch totally but only about 30% of the hemicellulose fraction. Despite this finding, Salo and Alaviuhkola (1980) found that bulk density could not be correlated accurately with energy value, whereas starch, crude fibre and protein content could. They also found a correlation between colour and energy value, as crop damage at harvesting appeared to cause the grain to darken and have reduced palatability. It would seem unlikely however, that colour would be a reliable guide to nutritive value.
- 4.22 In conclusion, oat grains are not a good energy source for pigs compared with wheat and barley, but oat groats have a higher energy value than other cereals.

Poultry

- 4.23 Few energy values for oats are available in the literature from recent studies with poultry, but those that have been reported are given in Table 4.10.

Table 4.10 Published energy values of oats for poultry.

Reference	Type of bird	Apparent ME (MJ/kg DM) ⁿ	True ME (MJ/kg DM)
McNab and Shannon (1974)	Hen	12.5	
Sibbald and Price (1976) ¹	Cockere1	12.7	15.2
Davidson et al (1978)	Chick	11.9	
Gallimore (pers. comm.)	Cockere1	-	13.0
	Hen	14.7	-
	Chick	13.9	
Hopkins (1988) ²	Cockere1	14.5	14.7
McNab (pers. comm.)	Cockere1	-	15.1

n: Corrected to zero nitrogen balance

1 Source: Davidson et al (1978).

2 Source: ADAS National Feed Composition Survey 1988.

Again considerable variation is evident for both apparent (AME) and true (TME) metabolisable energy contents for oat grains. Compared with wheat (15.3 MJ/kg DM) and barley (14.2 MJ/kg DM, J R Hopkins, pers. comm.) the AME of oats is low due to the high level of fibre which is unavailable to poultry.

- 4.24 Poultry rations may include a small proportion of ground oats, up to about 10% in a layers ration of a total cereal inclusion of up to 75%. Using oat groats, Hulan et al (1981) fed up to 60% in starter diets and 80% in finisher diets with no adverse effects. This showed that it is the limitation of the high fibre content, which is diluting the energy density of whole oat grain, and so preventing too high an inclusion.

McNab and Shannon (1974) compared the nutritive value of barley, maize, oats and wheat for laying hens. They suggested that part of the starch of oats may be unavailable to the birds and that very little of the other carbohydrates of any of the cereals are digestible. Wallis et al (1985) found that combining oats with wheat enhanced the utilization of dietary energy and amino-acids in broiler diets above calculated levels. This synergistic effect was also noted by the same workers with oat hulls in the ration.

It would appear that turkeys can digest fibre to a greater extent than chicks (Leeson et al, 1974). Of a range of raw materials tested, comparing the ME content for both species, the ME value obtained with turkeys (12.8 MJ/kg DM) was 8% higher than that found with chicks (11.9 MJ/kg DM), leading to the conclusion that either a correction factor, perhaps based on fibre, needs to be applied before using values determined in chicks for turkey ration formulation, or that values should be determined separately for turkeys.

Horses

- 4.25 There are few values reported in the literature for energy content of oat grain for horses, and in the case of published tables of values it is unclear as to whether these are measured

in horses or calculated from ruminant values. However, those values available are given in Table 4.11.

Table 4.11 Published values for the digestible energy content of oats for horses.

References	DE (MJ/kg DM)
NRC (1978)	14.0*
Kigin <i>et al</i> (1982)	16.8
Thompson <i>et al</i> (1984)	14.5
Frape (1986)	12.4-13.8*

* Taken from published tables of recommended values; not known whether measurements were made with horses in vivo.

Horses are not ruminants though they are often fed as though they were. They require better and more easily digestible feeds, and for rationing purposes the use of DE is recommended (Cuddeford, 1986). Energy losses as methane from extensive hind gut fermentation are probably lower than those for ruminants though no published measurements have been found.

4.26 Most European horses, especially thoroughbreds, are fed on concentrates, hay and grass. Traditionally, oats are the concentrate of choice, containing energy and fibre in proportion well suited to the equine digestive system (MacCarthy *et al*, 1976). For example, yearlings and foals may be fed 75-85% of the concentrate portion of their diet as oats. These may be rolled or cracked before feeding. Commercial horse feeds will also contain oats, a typical coarse mix containing between 15-30%. Table 4.12 gives an indication of the amounts used in compound feeds for various classes of horse. Oatfeed, comprising oat hulls and milling losses, may be a useful fibre source as may be oat straw.

4.27 Tradition still plays a large part in horse feeding. It is considered safer to feed oats that have been stored for a little while, rather than freshly harvested oats (MacCarthy *et al*, 1976). The authors suggest this may be because the latter have a

higher NFE content, mostly starch, which has been associated with digestive upsets.

Kigin, Fick and Schurg (1982) examined the effect of processing on digestibility of oats by feeding them to mares, either whole rolled, whole water-soaked or steam processed and flaked. There was no apparent effect on either digestibility or acceptability, thus these workers recommended the feeding of unprocessed whole oats to mature horses to reduce processing costs.

Table 4.12 Examples of compound formulations for various classes of horse (% fresh weight).

Ingredient	Foal Creep	Weaned Foals	Yearling	Race Horse	Mare Gestat-ion	Mare Lact-ation
Naked oats	15	-	-	-	-	-
Rolled oats	20	25	15	35	30	15
Rolled barley	35.75	45.8	52	23.25	22.25	36
Soya bean meal	15	15	12	15	11	13
Dried skimmed milk	5	-	-	-	-	-
Molasses	5	5	5	7	7	7
Wheat bran	-	-	-	7	10	7
Dried lucerne/grass	-	5	7	8	10	7
Linseed meal	-	-	5	-	4	4
Dicalcium phosphate	2	2	1	2	2	1.25
Limestone	0.75	0.5	-	0.75	0.75	0.75
Salt/trace elements	1	1	1	1	1	1
Vitamin supplement	0.5	0.7	1	1	2	1

Source: (T Harrington, pers. comm.)

4.28 In conclusion, whole oats have been strongly recommended for feeding to mature horses often as the sole concentrate feed, though when considering the quantities fed and the importance oats have in this area, very little published data are available to either confirm the traditional views or to compare oats with alternative energy sources.

Alkali-treated oat grain

- 4.29 Alkali treatment, using either sodium hydroxide (NaOH) or ammonia (NH_3) has become increasingly common as a method of trying to upgrade the nutritive value of materials containing large proportions of cell wall, such as straw. Cereal grains have also been treated in this way.

Orskov et al (1981) reported improved feed conversion, digestibility and rate of growth for lambs receiving NaOH-treated oat grain, when compared with untreated grain. The performance of lambs fed NaOH-treated grain was also superior to those fed physically processed oats. Cows fed diets containing whole oats soaked in NaOH ate slightly more than those on untreated rolled oats and produced more milk, milk fat and protein, though none of these improvements were significant (Moran, 1986). However, the disadvantages of NaOH treatment, such as the problems of handling the caustic liquid and the high sodium content of the treated material which leads to increased water consumption by the animals, may outweigh the advantages.

Ammonia treatment has nutritional and practical advantages, the most important of which is the supplementary nitrogen supplied by the ammonia. Treatment of whole oat grain with levels of 7.5, 15.0 and 30.0 g/kg NH_3 significantly improved apparent dry and organic matter digestibilities from .681 to .696, .722 and .765, and from .691 to .714, .738 and .780 respectively, when fed to adult wethers (Brand et al, 1985). Apparent digestibilities of NDF, hemicellulose and protein were also significantly ($P < 0.1$) increased.

Oat straw

- 4.30 The chemical composition and nutritive value of oat straw are shown in Table 4.13 together with wheat and barley straws for comparison.

Table 4.13 Chemical composition and nutritive value for ruminants of cereal straws (all as g/kg DM unless stated otherwise).

	Wheat	Barley	Oats
Dry matter (g/kg)	869	867	833
Crude protein	38	42	45
Crude fibre	423	433	417
Ether extract	13	14	14
Total ash	74	52	69
Gross energy (MJ/kg DM)	18.2	18.6	18.1
NDF	806	814	732
Acid detergent fibre	499	522	486
Cellulose	406	413	426
Lignin	97	97	92
DOMD <u>in vivo</u>	413	447	483
ME (MJ/kg DM)	6.2	6.6	7.2

Source: FEU Technical Bulletin 85/8

Though most of the chemical analyses are similar for all 3 cereal straws, the content of NDF (cell wall) material was lower in oat straw. In general oat straw was found to be softer and more palatable than that of wheat or barley, and its nutritive value in terms of both DOMD and ME was superior to that of wheat or barley. There was a large variation between the limited numbers of samples studied so none of these differences was significant (FEU Technical Bulletin 85/8). The quantities of oat straw available are given in Table 4.3 and are quite limited. Its major use will be as bedding though some may be offered as a forage especially to young stock.

- 4.31 There has been considerable interest in upgrading cereal straw using NaOH and NH_3 treatments. Given the variability in the untreated straws within variety it has proved difficult to establish significant improvements in nutritive value because of the large numbers of samples that would need to be examined.

A joint study between IGAP (Hurley) and ADAS FEU examined the effect of ammonia treatment on cereal straws using an An-Straw-

Verter oven. Four samples of oat straw were treated, and the treated and untreated material fed to wether sheep in a standard energy balance trial. Samples of 9 wheat and 9 barley straws were studied in the same way. The major conclusion was that the better the quality of the straw prior to treatment, the smaller the extent of improvement in nutritive value. Hence the ME of wheat and barley straws was upgraded by, on average, 1.4 MJ/kg DM whereas for oat straws the improvement was only 0.6 MJ/kg DM (Givens et al, 1988). Given the variability between samples, the economics of such treatment are probably not favourable for oat straw.

Sodium hydroxide treatment of straw appears to upgrade all straws by a similar amount, regardless of the initial feeding value (Moss et al, in press). Although ME was not measured in this work, treatment of 5 wheat and barley straws and 2 oat straws gave improvements in DE of 2.85, 2.48 and 2.00 MJ/kg DM respectively.

Greenfeed oats

- 4.32 McDonald and Wilson (1980) examined the feeding quality of autumn sown oats as a grazing crop in New Zealand. They concluded that its greatest potential is in the vegetative stage (IVD >800 g/kg) and up to approximately ear emergence after which quality decreased markedly. This is one of the major New Zealand grazing crops. In the UK early spring grazing of oats may be useful for sheep, and if not overgrazed, a good grain yield will still be achieved.

Whole crop oats

- 4.33 Orskov et al (1983) prepared samples of whole crop oats harvested about 7 days before ripeness, in large plastic bags, either untreated, or treated with either NH_3 or NaOH. The untreated control deteriorated during storage and was discarded. Food intakes were low with NH_3 treated oats and the authors concluded that further work was required.

Oat by-products - hulls

- 4.34 The utilization of low cost fibre in pig diets as an alternative to cereals is of interest, especially for the sow, allowing increased feed intake by reducing energy density and thus reducing behavioural problems associated with low gut fill. Hence, Mroz et al (1986) incorporated oat hulls at up to 50% into the ration of sows. They calculated that oat hulls had an ME of about 6 MJ/kg. Improvements were seen in litter size, birth weight and sow milk fat content with increasing fibre. Plasma cholesterol content was lowered and sow behaviour improved presumably due to an increased degree of satiety.¹

Oat hulls contain varying amounts of lignin ranging from 9-61 g/kg. Lignification of cell walls prevents their digestion by ruminants. Crosbie et al (1984) identified a strong correlation between acid detergent lignin (ADL) and pepsin-cellulase digestibility (PCD) of oat hulls, and indicated that considerable scope exists to select for low-lignin character in oat breeding. If a market can be found for oat hulls, then the economics of dehulling oat grains and feeding the groats and hulls separately may be worth investigating.

High fat and high protein oat grains

- 4.35 There are few references to the evaluation of new oat cultivars in terms of livestock feeding; however, two that have been reported are outlined briefly below. Digestible energy, protein quantity and quality are lacking in oat grains. The work reported here attempts to improve the economic value of oats by increasing the levels of these attributes.

A cultivar developed in Canada (Letonia x Fulwen), containing a high level of oil within the kernel (90-100 g/kg) was fed to growing dairy calves, beef calves and yearling steers and compared with regular oats (Devlin et al, 1977). No digestive

¹ Whole oats would have the same effect - these authors were finding applications for oat hulls as a waste by-product.

problems occurred as a result of the higher oil intake and the authors concluded that high fat oats were well utilized by growing calves. No values were calculated for the individual components of the ration but the apparent digestibilities of nutrients in the whole ration were not significantly affected by the high fat oats.

The oat groats (dehulled) of high protein cultivars, Dal (180 g/kg CP) and Goodland (205 g/kg CP) were fed to chicks and rats by Maruyama et al (1975). Lysine, an essential amino acid, is limiting in most cereal grains, and as protein content is increased by the efforts of the plant geneticist, lysine content increases only slightly. Oats however, retain a good amino-acid balance as protein content increases, so that protein and lysine increase concomitantly. Amino-acid analyses and chick growth experiments indicated that the genetic increase in protein content of oats was achieved without any reduction in protein quality (Maruyama et al, 1975).

Although the work reported here is at least 10 years old it does indicate some of the potential recognised to improve oats quality.

Naked oats

- 4.36 Naked oats offer improvements in nutritive value by virtue of having a thin non-lignified husk from which the grain threshes free.

The chemical composition and in vivo nutritive values for 2 naked oats varieties, Rhiannon and Kynon, which have been studied at the ADAS FEU, are given in Table 4.14, together with the results of similar trials on traditional winter oats.

Table 4.14 Chemical composition, digestibility and energy value of naked oats and winter oats (as g/kg DM except where stated otherwise).

	Naked oats		Winter oats n=5
	Rhiannon (Spring) n=5	Kynon (Winter) n=2	
Dry matter (g/kg as fed)	854	884	878
Crude protein	119	149	105
Crude fibre	45	28	105
Ether extract	97	83	62
Total ash	23	23	29
Gross energy (MJ/kg DM)	20.1	19.8	19.6
Neutral det fibre	141	NA	290
Acid det fibre	51	NA	144
Cellulose	36	NA	98
Lignin	18	NA	41
DOMD	835	887	740
DE Ruminant (MJ/kg DM)	17.1	17.7	14.7
ME Ruminant (MJ/kg DM)	14.7	14.8	12.4
TME _n Poultry (MJ/kg DM) ¹	16.8 (n=1)	16.5	15.1

Source: Everington and Givens (unpublished) except for 1: J McNab (pers. comm.)

NA Not yet available.

n Number of samples analysed.

Naked oats (especially Kynon) have a higher protein content than traditional oats, and the good quality has been maintained because lysine increases with protein content unlike other cereals. Fibre levels have decreased as would be expected with the loss of the hull. Ether extract content is elevated, particularly for Rhiannon, and concomitantly, the gross energy content is increased. All measures of nutritive value are higher for naked oats and are similar for winter and spring varieties. It is worth noting that the energy values reported here for winter oats are in general higher than values for oats shown earlier.

- 4.37 Naked oats have been used in the same way as husked oats by Martin and Thomas (1988b) to attempt to reduce the saturated fatty acid content of cows milk, but at a lower inclusion level of oats in the diet. To date the high levels of rolled naked

oats used have led to a depression of silage intake but similar effects on the fatty acid profile (decreased 16:0-18:0, increased 18:1, 18:2) as found with husked oats have been seen. Further work feeding unprocessed naked oats is in progress to try to overcome the problems encountered with rolled material.

Naked oats appear to have none of the disadvantages of traditional husked oats, in terms of livestock feeding, and seem to be superior in metabolisable energy content to other cereals, possibly including maize.

No research is known to be carried out assessing the value of naked oats for feeding horses.

- 4.38 There has been some interest (eg. Doyle and Valentine, in press²) in the potential for naked oats, which might be bred with high protein levels, to substitute for imported protein sources such as soya. In nutritive terms, oats may replace:

- (a) for ruminants - all other cereals and 'energy' feeds such as cassava, citrus pulp, maize by-products (not maize gluten meal), rice bran, sorghum and wheat by-products;
- (b) for pigs and poultry - all cereals, in practical terms mainly wheat.

This substitution will depend on relative prices.

The substitution of imported soya for naked oats, given the very much higher protein levels of the former (some four times the level of naked oats), is likely to be insignificant (depending on relative prices and the ability to increase naked oat protein levels).

² see Plant Breeding References.

Conclusions to Chapter 4

1. The use of oats for livestock feed has tended to decline over time. The major factor limiting the use of oats in livestock feeds from a nutritional point of view is the high fibre content, especially for non-ruminants.
2. The evidence available suggests that oats have a lower metabolisable energy value for all species of farm animals, with the energy value on average being 11% lower than barley and 15% lower than wheat.
3. Feed compounders have tended not to use oats as part of their least-cost feed formulations due to (i) high fibre/low metabolisable energy (ii) price (iii) availability.
4. However, oats do form an important and necessary part of feed formulations and diets of several species of livestock, particularly for 'active' horses.
5. Beneficial effects of feeding oats to various species have been found, for example the reduction in the level of saturated fatty acids in milk and the increased 'spreadability' of butter fat when dairy cows are fed oats.
6. Naked oats appear to have significant potential for livestock feeding. From a nutritional point of view there are few limitations to their use and they appear to be superior to wheat and barley. Realised potential however, is likely to depend largely on availability and cost. Other varieties of oats with known high protein and oil levels would also have a high value to feed compounders.
7. There is little information on the livestock feed value of oats other than the grain. For example, grazing of oats and oat silage.

CHAPTER 5 INDUSTRIAL USES OF OATS

Introduction

5.1 The agricultural products processing industry generates bulk materials for food, feed and use as chemical intermediates. The major outputs from such activities are sugar, starch and derivatives, vegetable oil and various protein feeds. In general specific plant species have been selected by the agricultural processing industry as raw material for production of these materials - for instance sugar (sucrose) is produced only from sugar beet and sugar cane. There is no plant grown specifically for protein content. However, wheat is processed for gluten for human consumption with starch as a by-product, and soya protein is purified as a by-product of oil production. The widest range of plants is used for vegetable oil production, ranging from palm to maize, soya and rape. Starch is produced from maize, wheat, potatoes and rice in Europe, with manioc and sago palm being used in the tropics.

Industries involved in such separations and/or using the separated fractions exist worldwide on a very large scale using raw materials which include oil seeds, roots and tubers, palm stems and cereals to generate starches, modified starches, sugar syrups, vegetable oils, fatty acids, proteins, amino acids and a wide range of lower volume specialty products. From these primary fractions a much wider range of materials is generated for use in feed, food, beverage, fuel, chemical, medical and speciality markets.

The range of plant raw materials available to the agroprocessing industry is extensive. Most contain the basic components of starch, oils, proteins and insoluble fibre but differ in respect to the proportions in which they occur as well as the amount of water present in the material as harvested. Selection of raw material by a given industrial sector reflects both the composition, the ease of separation and the resistance the harvested material has to hydrolysis, as well as storage life which in turn reflects water content of the harvested material.

Such considerations have led to a starch processing industry dominated by wet milling of maize, a vegetable oil industry in which the major products are derived from palm and soya, and a protein industry (mainly generating animal feed) based on the sale of the residues from the vegetable oil industries. This is discussed in more detail, with reference to oats, later in this Chapter.

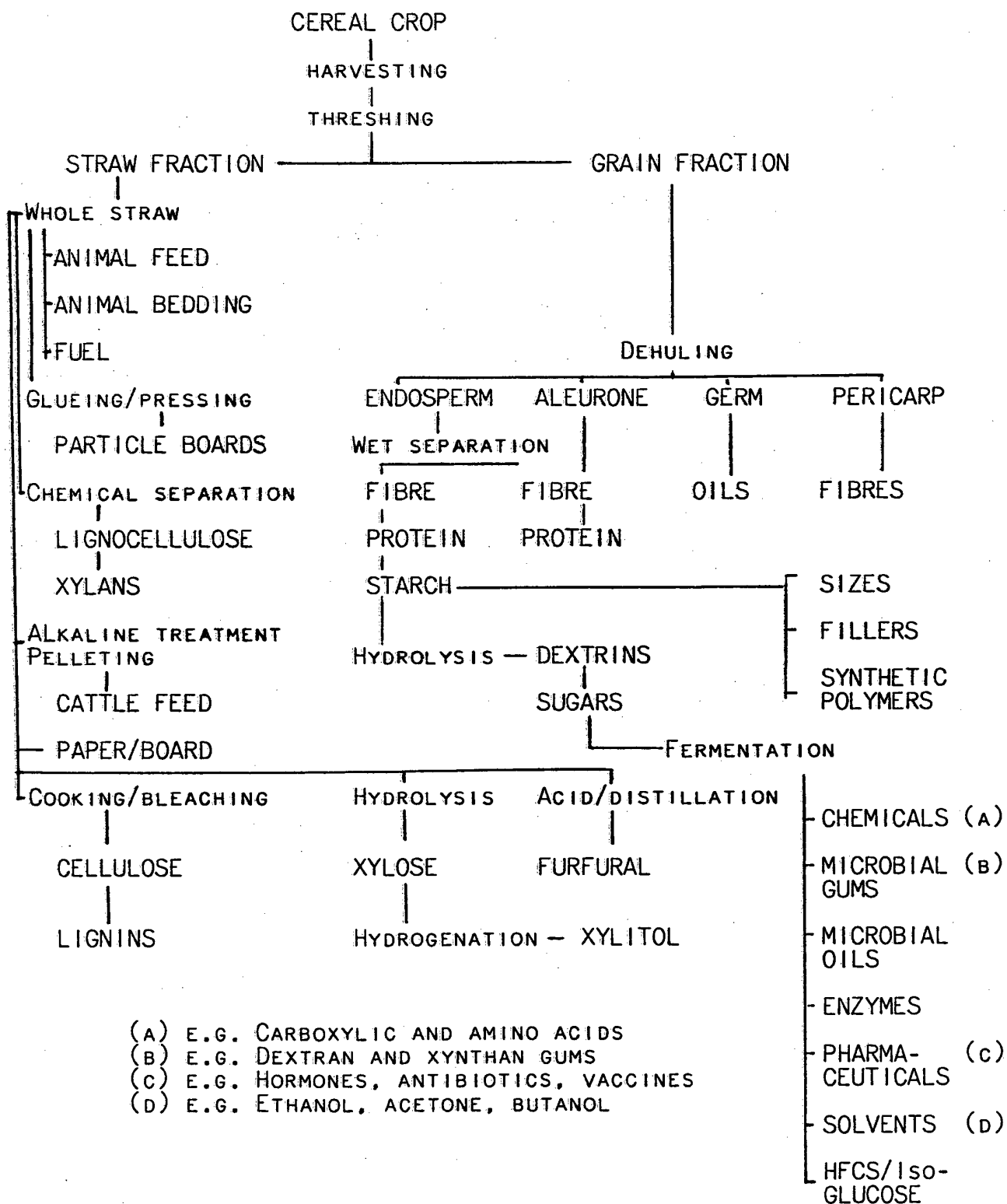
- 5.2 The 'biomass energy concept' developed in the 1970s, and the concept of the agrorefinery in the 1980s suggested that agricultural produce, possibly gathered in its entirety through whole crop harvesting rather than being fractionated in the field, would form the raw material into a factory dedicated to generating a wide range of fuel and/or chemical products of various types in a way which conceptually parallels the activities of a petrochemical refinery. This concept has been discussed in some detail on behalf of the EC by Rexen and Monk (1984).

Figure 5.1 shows a general outline of cereal fractionation possible with an agro-refinery based on whole-crop harvesting.

This approach has contributed to some of the thinking behind the ECLAIR programme currently being debated for funding within the aegis of the new framework programme of the EC following ratification of the Single Act in 1987. ECLAIR has a proposed budget of over 100 million ECUs. However, in spite of the comprehensive nature of the Rexen and Munk report and the spirited response to preliminary calls for proposals in this area, oats is hardly mentioned if at all.

The paucity of interest expressed in oats probably reflects a number of factors including that as far as the EC farming community is considered as a whole, it is a crop of regional interest. Second the existing industries associated with the processing of plants use a rather limited range of raw materials, as discussed above, amongst which oats do not appear to any significant extent.

FIGURE 5.1 GENERAL SCHEME OF CEREAL FRACTIONATION WHICH COULD TAKE PLACE WITHIN AN AGROREFINERY BASED ON WHOLECROP HARVESTING



The industrial use of oats, particularly non-food industrial use, is very little world-wide, and is of even less significance in the UK. No commercial non-food industrial utilization of oats in the UK is known.

- 5.3 The industrial use of oats, by definition, covers aspects of utilization where oats or oats derived products are used within a manufacturing process. For convenience in this Chapter such use is considered in relation to the three sections of (i) human food, (ii) animal feed and (iii) chemicals. In order to avoid repetition with material presented in other Chapters, discussion is restricted to those processes in which the material under consideration (groat, husks, straw, etc) is treated in such a way that it is changed in chemical nature or chemical composition. Direct use of oats which have simply been crushed, milled, flaked or otherwise treated so as just to modify the size or texture are not considered.

Emphasis is placed on industrial use of the groat itself where it has been subject to some separation in order to produce fractions enriched in respect of the major constituents including starch, protein, lipids, glucans and other minor constituents as well as lignocellulosic materials (non-soluble fibre).

Oats - composition and processing

- 5.4 The ability to obtain separated fractions of oats, enhanced for a particular component or constituent, reflects chemical composition, the structure of the entire grain and the distribution of the various chemical constituents within the structure. This section deals with the gross composition of the oat grain and presents general information on the chemical composition and distribution between various morphological parts of the material as harvested. Further information covers current processing of oats for the food market, indicating the type of products generated and their gross composition and how this can lead to some enrichment or specific classes of chemical compounds.

The oat produces an inflorescence consisting of several spikes bearing up to three kernels, each surrounded by a two-part hull. Removal of the hull leaves the groat. The parts of the groat can be equated with fractions produced during separation, which in turn become enriched for the particular components found in a particular morphological structure. The major structural components are the seed coat, aleurone layer, endosperm and embryo. Starch is located in the endosperm which also contains a considerable proportion of the lipid content. Most of the protein is in the groat, with the highest concentration in the embryo - but the largest quantity is in the endosperm and aleurone layer. In comparison with wheat, oats have a higher protein content in the bran fraction obtained by sieving coarse ground oat flour.

Oat composition

- 5.5. There are problems in attempting to summarize briefly the chemical composition of oats since the data obtained through analysis of a particular sample will reflect the variety used, the fractionation techniques, the analytical methods used and the maturity of the oat when harvested, the climatic conditions during the growing period and the storage conditions and time since harvest. Laboratory analysis of carefully separated or dissected material may differ from analyses obtained with commercial fractions, whilst simple protein determinations based on Kjeldahl analysis ($N \times 6.25$) will differ from those obtained by summation of amino acid spectra determined by amino acid analysis. Hence, the material presented here should not be taken as definitive. Rather, typical results have been selected from the literature to be used as illustrative material in discussion of the use of oat components in competition with those derived from other cereals in order to highlight advantages and disadvantages.

An indication of the weight fractionation of the oat is shown in Table 5.2. The actual hull to groat ratio may vary resulting in

the groat accounting for between 68-75% of the total for A.sativa.

Table 5.2 Fractionation of oats on a weight basis.

Whole Oats 100 kg			
Hull	30 kg	Groat	70 kg
Pentosans	9 kg	Protein	12 kg
		Glucan	9 kg
		Starch	49 kg

In particular lipid and protein content vary with variety. Typically oat lipids may account for 4.2-11.8% of the weight of the groat with protein at between 5-9%, although some cultivars may have up to 24%. Normally the hull contains less than 2% protein. The bran fraction may be enriched to around protein 24-25%.

Starch content has been reported by Paton (1977) as 43.7 - 61%, with an average 52.8%, and by MacArthur and D'Appolonia (1979) as between 42.7-55.6%. Amylose concentration ranges between 19 and 28%.

Crude fibre content of the hull is around 11-12% of which around 17% is lignin and 30% alpha cellulose and the rest hemicellulose (pentosans). This results in whole oats containing about 14% pentosans (mainly araban and xylan). These occur in a higher concentration in the hull (29%) as compared with 4% in the groat. Similarly the dehulled oat contains only around 3% lignin.

The groat contains a characteristic beta-D-glucan at a concentration of 2-12% as well as low amounts of free sugars, phenolic compounds, phytin, vitamins and minerals.

- 5.6 The process of conventional oat milling has been described in Chapter 3. The major chemical components of oats and of the oat products produced from milling are given in Table 5.3 below.

Table 5.3 Average composition of oats and oat products with respect to major components (%).

	Water	Protein	Oil	Starch Carbohydrate	Fibre	Ash
Groat	7-9.6	15-16	6-7	63-67	1.5-2.8	1.9-2.2
Kernel	13	12.3	7.7	63.5	11.3	1.9
Grain	7-14	9-12	4.6-5.3	58-60	8.9-11.2	2.7-4.0
Hull	6-7	2-4	1.2-1.7	49-50	33	3.9-6.0
Oat flour	7-8	10-16	5.5-7.0	65-78	1-3.6	1.3-2.1
Rolled Oats	7-8	14-15	4.2-7.8	67-71	0.7-2.1	1.5-1.8
Bran	7	5	2	50	28	6

The oat groat contains three morphologically and chemically distinct components as shown in Figure 5.2; the bran, germ, and starchy endosperm. With mechanical disruption, the groat tends to naturally fragment into these three fractions. However, in practice, the high lipid content and soft texture of the groat make it difficult to separate cleanly into the three fractions by commercial methods. It is not within the scope of this Review to give a detailed description of the chemistry of oats and its fractions. A full account of the chemistry and functional properties of oat fractions (as far as is known), is given in Webster (1986). In summary of this account, the bran consists of several distinct tissues and contains protein bodies, neutral lipids, ferulic acid, and significant concentrations of niacin, phytin, and aromatic amines. The starch endosperm, which contributes in excess of 80% of the dry weight of the oat groat, is the primary source of starch, protein and β -glucans. The germ is chemically similar to the bran, but does not appear to contain niacin or aromatic amines.

As discussed in more detail later, due to the complex nature of the endosperm, it is difficult to get additional oat fractions enriched in protein or lipid for further processing.

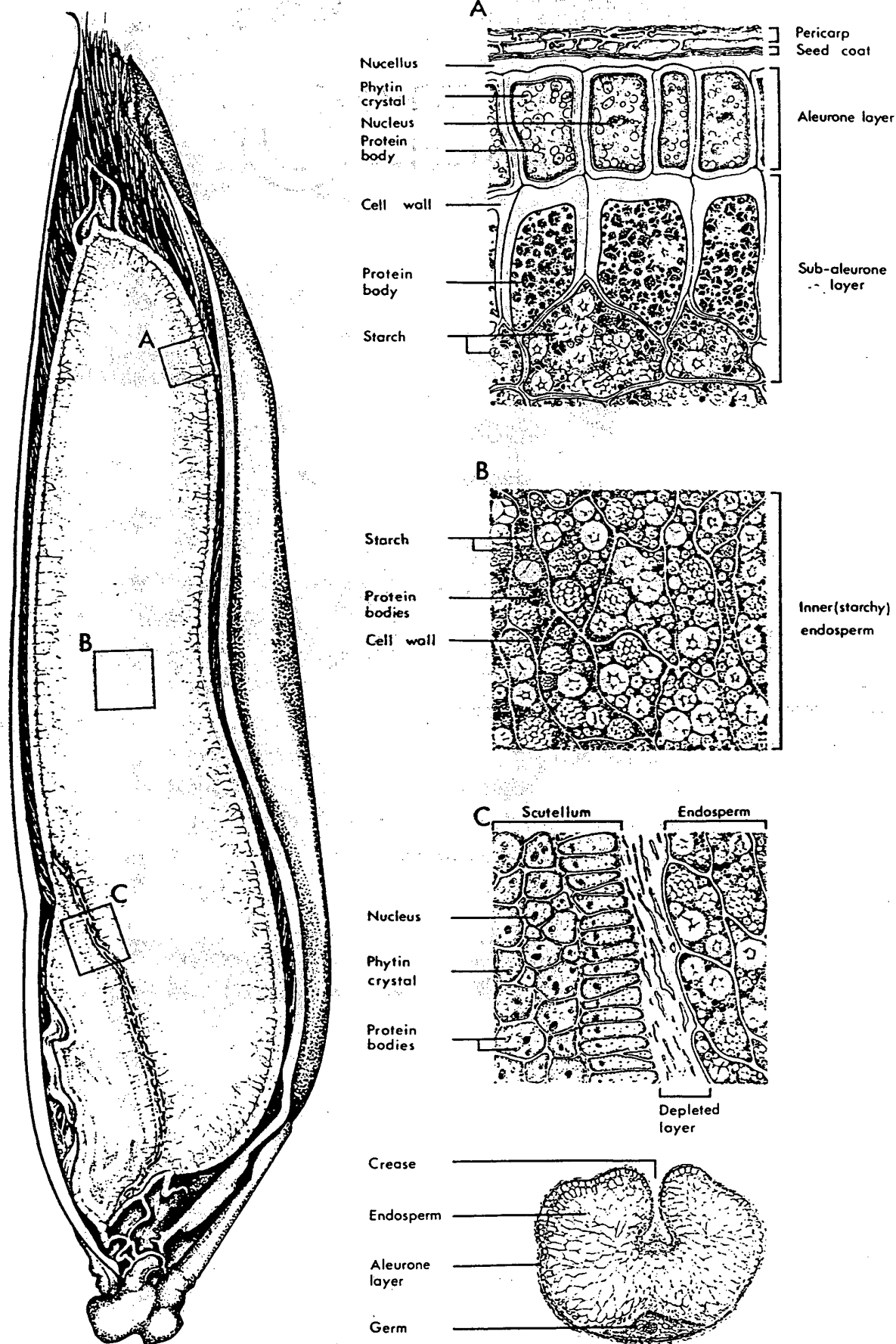


FIG. 5.2 Major structural features of the oat kernel. On the left is a kernel (with hulls on) that has been split longitudinally to reveal the approximate size and location of the major tissues. At the lower right is a view of a cross section of the groat. (A), (B), and (C) are higher magnifications of portions of the bran, starchy endosperm, and germ. Source: Webster (1986)

Oat fractions

5.7 The previous section has indicated the general composition of various milling fractions of oats. This section considers the chemical composition of the various constituents in more detail, outlining chemical and physical properties as well as indicating where these might be of sufficient value to justify the expense of using more complex separation processes to obtain specific enriched fractions for use in food formulations and/or chemical manufacturing processes.

Starch

5.8 Starch is a polymer of glucose linked through alpha 1-4 glycosidic bonds which appears in two forms - amylose, an unbranched polymer of lower molecular weight, and a higher molecular weight fraction, amylopectin. The ratio of amylose to amylopectin, as well as the degree of polymerization of both components varies from one plant species to another. In the plant, native starch occurs as microscopic granules, the general properties of which (shape, appearance, size range) are sufficiently characteristic to enable the source to be identified using a light microscope.

The physical and functional properties of oat starch are summarized in Table 5.4 which also compares these properties with those of some of the more common cereal starches currently produced commercially. A number of significant differences occur.

Table 5.4 Comparison of properties of oat starch with those of other cereal starches.

	Diameter (μm)	(Purity of commercial product %)					
		Starch	Ash	Protein	Fat	Fibre	Sugar
Oats	5	80	1	5	3-11	2	2
Maize	15	87	1	4	1	2	6
Wheat "A"	10	85	1	1	1	-	-
Wheat "B"	10	86	7	6	2	2	1
Potato	30	83	4	2	2	-	-

Within the cell, native oat starch granules exist as individual clusters associated with neighbouring discrete protein bodies, in contrast to wheat or barley where the grains are embedded in a homogenous matrix. This makes it more difficult to recover fractions of high starch (or protein) purity.

- 5.9 Oat starch has a relatively smaller average granule size which is similar to that of rice. Granules range from 3 to 12 μm but may form conglomerates of up to 60 μm diameter. On heating, the granules swell without appreciable change in shape. Wet milling produces yields of 30-40% of whole oats (dry basis) with an average granule size of 5 μm . The granules vary greatly in shape, often polyhedral, but spindle and pointed oval granules also occur. Birefringence is weak with a polarization cross located centrally in most cases. These characteristics are of value in identifying or distinguishing oat starch or flour from that derived from other sources.

The density of moist starch as separated is around 1.5 rising to around 1.6 on drying.

The amylose content of oat starch (variously reported at between 16-27%) is similar to that of wheat and maize. The absolute density, water binding capacity, and intrinsic viscosity of amylopectin of oat starch resemble those of wheat starch, whilst the viscosity of oat amylose is higher. Oat starch is distinguished by a much higher lipid content than other cereal starches. These lipids are embedded, in part, within the starch helix which results in pasting properties which differ from those of other cereal starches. Table 5.5 compares some of these properties.

Oats starch has a high water absorption (70%) in baking tests and has a relatively low gelatinization temperature as compared to the other major starches.

Table 5.5 Properties of Starch Pastes.

	Gelatinisation Characteristics (Temperature of Paste, degrees C)	Paste Viscosity	Rate of retrogradation
Oats	55-60	high	low
Maize	75-80	medium	high
Wheat	80-85	medium low	high
Potato	60-65	very high	medium low

- 5.10 The characteristic gelatinous form of cooked oats, such as in porridge, reflects the specific characteristics of the oat starch as well as the presence of other constituents, such as glucans as discussed below. Compared with most other cereal starches gels based on oat starch are more elastic, adhesive, and translucent. In addition oat based gels have good storage properties due to the fact that the starch lipids (which are over 50% lysolecithin) resist oxidation since they are included in the amylose helix.

Acetylation or hydroxylation of oat starches result in a lowering of the gelatinization temperature and an increase in viscosity of gels.

Lipids

- 5.11 Oat groats have the highest lipid concentration among the cereal grains, from around 3% to over 12% of the grain weight. The lipids are highly unsaturated and contain considerable amounts of linoleic acid. Detailed analysis, however, is highly dependent on the method (solvent) used to extract the starting material. There is some evidence that there is a negative correlation between the lipid level and the protein level in the groat and in general oil content of spring oats is lower than that of winter oats.

The oil is not bound and it is easily extracted using solvents. Since in oats the oil is located in the endosperm not the germ, as in maize for example, this does not enable an oil-rich starch-free germ fraction to be produced. However, solvent extraction

of oat flour before flaking, or solvent extraction of rolled oats, may not affect the starch products significantly.

The distribution of oil in various parts of the oat is shown in Table 5.6.

Table 5.6 Distribution of lipids in various substructures of oat kernels.

	% dry basis	Fraction total lipid
Grain	5.4	100
Hull	0.6	3.3
Groat	7.6	98.7
Germ-free groat	6.8	65.7
Germ	11.2	14.4
Endosperm	6.5	83.3

5.12 The fatty acid composition of oat lipids is shown in Table 5.7. About 95% of the fatty acids in the extractable (oil) lipids are palmitic (16:0), oleic (18:1) and linoleic (18:2). The levels of oleic and linoleic are usually similar in contrast to lipids from wheat and maize in which the concentration of linoleic normally exceeds that of oleic.

Table 5.7 Fatty acid composition of oat lipids.

Myristic	trace
Palmitic	15-26
Stearic	1-4
Oleic	25-46
Linoleic	24-48
Linolenic	1-4

The average linoleic acid content of oat oil is similar to that of wheat germ oil. Freshly extracted oil is generally neutral. However, free fatty acids may be generated by enzyme hydrolysis of triglycerides by the active lipases contained in the endosperm. The various parameters used to describe physical and chemical properties of vegetable oils for commercial purposes are listed in Table 5.8. Levels of sterols are low resulting in a high degree of saponification.

Table 5.8 Physical and chemical properties of oat oil.

Iodine value	107
Acid number	30 - 90
Saponification value	105 - 116
Unsaponifiable	1.3 - 2.2
Refractive index	1.464 - 1.470
Specific gravity	0.919 - 0.921

Proteins

5.13 The quality, digestibility and amino acid spectrum of oat protein has been extensively investigated (Shukla, 1975). Oat protein differs from most other cereal proteins in that around 80% is a salt-soluble globulin (Table 5.10). This protein has a relatively high lysine content resulting in greater nutritional value, although it may be deficient in methionine. The functional properties of the oat proteins are similar to those of soybean proteins. Oat protein concentrates and isolates have potential as nutritive, bland and functional protein additives comparable to those derived from soybeans.

The actual composition and proportion of various types of protein differ between various parts of the oat (Table 5.9) and hence variations occur in the nature of the protein and amino acid spectrum between various parts of the processed oat as shown in Table 5.12 and the amino acid spectrum of oat protein is compared with that of soybean in Table 5.11.

Table 5.9 Percent protein in morphological parts and commercial fractions of oats.

Parts of the oat	
Embryo axis	44.3
Scutellum	32.4
Bran	18.8
Endosperm	9.6
Commercial fractions	
Oats	13.4
Flakes	17.6
Hulls	5.7
Groats	17.1

Table 5.10 Types of proteins found in groats.

	Globulins	Albumins	Prolamines	Acid Sol.
Weight % in groats	13	1	2	1
Weight % total protein	80	5	10	5

Table 5.11 Amino acid spectrum of oat protein (globulin) compared with that of soybean.

	Oat	Soybean
Lysine	4.2	6.0
Histidine	2.6	2.3
Arginine	9.3	7.5
Aspartate	9.4	10.4
Threonine	3.5	3.7
Serine	4.9	4.6
Glutamate	21.1	18.4
Proline	4.2	5.3
Half cysteine	1.2	1.3
Glycine	4.5	3.4
Alanine	4.4	3.6
Valine	5.2	4.6
Methionine	0.7	1.4
Isoleucine	4.4	4.5
Leucine	7.5	6.7
Tyrosine	4.2	3.5
Phenylalanine	5.8	4.5

Table 5.12 Percentage composition of oat proteins from various parts or fractions of the grain.

	Hull	Groat	Bran	Endosperm	Embryo
Protein (%)	4.2	13.8	18.8	9.6	44.3
Lysine	5.6	4.5	4.1	3.7	8.2
Histidine	2.1	2.4	2.2	2.2	3.9
Arginine	4.1	6.8	6.8	6.6	8.3
Aspartate	15.6	8.7	8.6	8.5	10.2
Threonine	4.8	3.4	3.4	3.3	5.0
Serine	4.6	4.6	4.8	4.6	4.8
Glutamate	14.5	21.7	21.1	23.6	14.2
Proline	4.8	5.5	6.2	4.6	3.2
Half cysteine	0.2	2.1	2.4	2.2	0.5
Glycine	5.8	5.2	5.4	4.7	6.3
Alanine	7.0	5.0	5.1	4.5	7.2
Valine	6.4	5.5	5.5	5.5	6.0
Methionine	2.3	2.2	2.21	2.4	2.2
Isoleucine	3.9	3.9	3.8	4.2	3.9
Leucine	7.2	7.6	7.4	7.8	7.1
Tyrosine	2.3	3.0	3.5	3.3	2.1
Phenylalanine	4.3	5.2	5.1	5.6	4.2

Fibre, gums and pentosans (hemicelluloses)

- 5.14 Oats contain a number of glucans and pentosans which are constituents of the cell walls. These include pentosans characterised by the presence of L-arabinofuranose residues linked as single unit side chains to a backbone of beta-1, 4-D-xylopyranose residues. These represent about 65% of the wheat flour non-starchy fraction but only 10% and 5% of the endosperm and bran respectively.

Oat beta-glucans are mixed beta (1,3 and 1,4) linked, unbranched, polymers of glucose with gum-like properties which occur as a major cell wall polysaccharide in the endosperm cells. The chemical composition is similar to that of lichenin. These gums are probably responsible for the characteristic form of oats when dissolved in hot water (porridge). However, they do not form gums in cold water where a more creamy product is formed.

These gums may be obtained using aqueous extraction from oat flour. However, extracted gums are not pure, but usually contain over 70% and up to 90% glucan depending on the extraction procedure.

Exact concentrations reported vary quite widely with varieties and no doubt also reflect extraction procedures, since reported values vary from less than 1% to over 10%.

The greatest concentrations are found in the outer layers of the thick sub-aleurone layer and hence occur at a higher level in the oat bran which is enriched for this cellular fraction. Reported concentrations vary, according to methods used to obtain the gum fraction, from around 3-5% at one extreme and from 12-15% of groats at the other. The oat gum is essentially stable to sugar and salt and retains high viscosity at low concentrations.

Oats also contain arabinoxylans which may be co-extracted to varying extent in gum preparations. The concentration of pentosans is particularly high in the hulls (28-34%) giving an average percentage on whole grain weight of around 14%. The

pentosans of both the hulls and oat straw contain high levels of xylan. Unlike the glucans these polymers are insoluble in water, but can be removed using alkali.

Oat antioxidants

- 5.15 Over 24 different phenolic compounds that have antioxidant activity have been isolated from oats. The major components are all derivatives of hydroxycinnamic acid with the antioxidant activity attributed to the caffeic and ferulic acid contents. Their activity on a weight basis is comparable to propyl gallate and butylated hydroxytoluene. In the past, fine ground oat flour has been used to stop rancidity in milk products, fish oil, etc, whilst a number of commercial antioxidants based on oat flour or solvent extracts have been marketed. Addition of oat flour to composite flours and blends offer improved keeping quality.

Minor constituents

Sugars and oligosaccharides

The levels of free sugars and oligosaccharides found in oats are somewhat lower than those found in other common cereals as shown in Table 5.13.

Table 5.13 Free sugar and oligosaccharide levels in cereals (g/kg).

	Oats	Barley	Wheat	Maize
Fructosans	0.89	7.80	10.30	-
Raffinose	1.92	4.50	3.31	1.86
Glucose difructose	0.38	2.50	4.06	-
Maltose	-	0.90	-	-
Sucrose	6.39	9.08	8.36	7.83
Glucose	0.52	1.07	0.92	0.5
Fructose	0.91	0.26	0.57	0.55
Total	11.01	26.11	27.52	10.74

The relative proportion of these sugars between the oat flour fraction and the oat bran fraction has been reported by MacArthur and D'Appolonia (1979) as shown in Table 5.14.

Table 5.14 Percentage of minor sugars found in oat bran and oat flour.

	Oat flour	Oat bran	Oat kernel
Sucrose	0.40-0.63	1.70-2.66	0.77-0.87
Raffinose	0.16-0.26	0.29-0.48	0.17-0.18
Maltose	0.01-0.03	0.01-0.05	
Stachyose	0.07-0.08	0.20-0.24	
Verbascose	-	0.30-0.05	
Fructose	0.02-0.03	0.03-0.07	0.03-0.06
Glucose	0.06-0.07	0.07-0.10	0.03-0.05

Mineral content of oats has been reported as shown in Table 5.15 (Youngs et al, 1973).

Table 5.15 Mineral content of oats.

	Groat	Bran	Endosperm
Phosphorous (%)	0.54	0.94	0.27
Potassium (%)	0.44	0.98	0.18
Magnesium (%)	0.18	0.35	0.07
Calcium (%)	0.05	0.1	0.02
Iron ppm	47.2	96.0	20.4
Zinc ppm	35.8	54.4	36.1
Manganese ppm	46.0	81.7	31.6
Copper ppm	4.8	5.67	2.99
Boron ppm	1.1	2.72	-
Barium ppm	0.6	2.4	0.34

Industrial use of starch, oils and proteins and the potential role for industrial use of oats

- 5.16 The major products produced by the present agricultural products processing industry are sugar, starch and derivatives, oil and protein.

The choice of raw material used within a specific sector is based on the interaction of a number of different factors, the most important of which are:

1. Raw material price, end product value and market demand.

2. Price support, tariffs, preferential trade agreements, manufacturers discounts, etc.
3. Seasonal and geographical availability.
4. Chemical composition and quality of raw material.
5. Technical aspects related to processing and separation.

The major factors therefore are a combination of price of raw material, the ease of processing and the nature and properties of the end products. From a technical viewpoint ease of separation will reflect the percentage composition as well as the anatomical structure of the part of the plant being processed. In general, the material processed is a seed, perennating or storage organ which has evolved to contain a high level of one or more constituents in adapted tissue, usually endosperm or parenchymatous cell structures. In cereal grains the endosperm is the main storage tissue. However, the actual composition of this varies with different grains, as does the ratio of embryo weight to endosperm weight and the composition of the endosperm.

Starch

- 5.17 The simple chemical structure of starch (a polymer of alpha 1,4 D glucose) and the commercial ability to separate starch fractions of high purity, make it a suitable raw material for the production of many chemical and industrial products. The major sources of starch used in the EC are shown in Table 5.16, which also shows UK production figures for 1985.

Table 5.16 Sources of starch in EC countries (1000t).

	EC (10) (1985)	UK (1985)	EC (12) (1990)
Maize	2700	383	2850
Wheat	400	130	650
Potato	900	-	1000
Rice	10	10	10

Table 5.17 Characteristics of the major commercial starches.

	Maize	Wheat	Rice	Potatoes
Amylose %	23-27	19-28	14-25	20-24
Amylopectin %	73-77	72-81	75-86	76-80
Gelatinization C	64-71	53-64	61-78	56-68
Density (g/ml)	1.514	1.515	1.518	1.519
Crystallinity	0.39	0.36	0.38	0.25
Granule size (u)	10-15	20-40	3-8	20-185

The past and predicted future use of starch in the EC is shown in Table 5.18.

Table 5.18 Present and Predicted use of Starch (1000t) within the EC.

Use	1982	1984	1985	1990	2000
Total	3536	4100	4145	4550	5128
Feed/Food	2122	2410	2400	2414	2424
Industry	1414	1690	1745	2136	2704
Pulp/Paper	828	800	910	960	1300
Textiles		62	45	62	
Adhesives		88		100	
Chemicals/ Plastics	406*	350	400**	600	990*
Others	185	390	390	414	414

* Includes textiles and adhesives

** includes adhesives.

The expected growth rate for total starch consumption is around 1.5% per annum, with the industrial sector showing a slightly higher growth at around 3.2% per annum. As a result it is anticipated that non-food uses will increase from 40% of the total to over 50% by the year 2000. These figures assume that EC legislation in relation to the production of isoglucose (the European term for an enzyme-derived substitute for sucrose based on starch - known as high-fructose corn syrup in the US) does not change.

Starch-based products find a wide range of applications in the industrial and chemical sectors within the EC, as shown in Table 5.19.

Table 5.19 Use of Starch in the EC (1000t).

	Native Starch	Modified Starch	Hydrolysis Products	Total
Food	285.6	99.1	1499.9	1884.6
Animal Feed	86.6	59.8	31.1	177.7
Paper/Board	446.6	288.8		735.5
Textiles	13.8	48.2		62.0
Adhesives	17.8	70.3		88.1
Chemical & Pharmaceuticals	29.1	23.1	298.2	350.5
Other	165.5	88.1	136.9	390.4
Total	1045.3	677.4	1966.1	3688.7

5.18 Cereal starches may be used in their native form or be modified to change their basic characteristic dramatically using mechanical, thermal or chemical treatments as follows:

1. Hydrolysis, eg. maltose, sorbitol, mannitol, fructose syrups.
2. Degradation, eg. roast dextrin, oxidised starch, thin-boiling starch.
3. Pre-gelatinization.
4. Chemical derivatization, eg. starch esters, starch ethers and cross-linked starches.
5. Physical treatment.

Through additional fermentation or chemical processes, these derivatives can be used to yield further products including, potable alcohol, industrial alcohol, enzymes, vitamins, organic acids, amino acids and antibiotics. There are in fact over 700 starch-based products that are currently traded.

There has been no dramatic growth in any particular sector in the EC, nor is any anticipated in the next decade (with the possible exception of isoglucose production).

Any opportunities for oat starch appear to lie in the substitution of existing starch sources, unless new markets can be identified linked to the specific and unique characteristics of oat starch.

- 5.19 At present, maize starch dominates the market, in part due to the ease of separation reflecting a highly starchy endosperm, and in part due to the large embryo containing lipids as well as significant protein content.

Wheat starch and gluten is obtained from a normal ground flour. In contrast to maize, wheat produces two fractions - a A-starch which can be made fairly pure by processing, and a B-starch consisting of broken grains to which protein residues are attached. This results in lower yield and poorer material if the starch is to be used in the chemical industry. The separation is more difficult because the endosperm contains more protein than in maize and contains soluble cell wall components. However, in spite of these difficulties the processing of starch from wheat is the only sector to have shown growth in the EC in the last decade. This is due to the demand for wheat gluten for use in fortifying wholemeal and related high fibre breads. With a value of over £1000/t the process is attractive in spite of difficulties.

Starch from oats

- 5.20 With oats there are further complications. First oats have a higher glucan content, as discussed elsewhere, and second the starch contains intimately combined lipids. Such processes as have been suggested (Shukla, 1975) for fractionation include the use of solvents to produce a defatted flour, adding to the expense and difficulty of processing oats as compared with wheat.

As far as starch is concerned, oats (unlike other cereal crops wheat, corn, barley and rice or the root and tuber crops such as potatoes and cassava) have never been seriously considered from a commercial viewpoint. However, there are few current starch applications except those based upon waxy corn that could not be filled by oat starch if it could compete on a price basis.

5.21 In several applications the unique properties of oat starch would confer definite technical advantages in its use. Areas in which oat starch may find particular applications include the paper and adhesives industries where the use of starch is primarily determined by specific properties.

1. Adhesives-industrial glues and wallpaper paste. With continual worries about the use of certain solvents in adhesive preparations there is likely to be growing interest in the use of starches as a component of adhesives. The fact that oat starch gels are more adhesive than other starches makes this technically an area of potential opportunity. However, possibilities are likely to be in low quantity, highly specific applications.
2. Non-food grade carbanylethyl oat flours could find application as wet-end additives for production of brown paper and coatings. These acetylation, hydroxyethylation and oxidation products of oat flours are characterized by low-gelatinization temperatures, higher peak viscosity, higher shear stability, higher cold paste viscosity and little retrogradation. All of these pastes are buff-coloured and opaque and so would only be suitable for applications where translucency is unnecessary such as:
 - (i) Wet-end in pulping
 - (ii) In the size press
 - (iii) During coating.

Opportunities for starch use often depend on the proximity to a paper factory as well as the technical ability to produce a

product of suitable and consistent form. Paper manufacturers are looking for lowest cost raw material to meet their needs.

There is an increasing tendency for pulpers to make paper and paper makers to produce their own sizes and coatings; as a result the starch industry offers grades of starch aimed at giving the right results. This has possibilities for the incorporation of modified oat starches.

The relatively small size of oat starch granules makes them suitable for use as a dry dusting agent for chewing gums and sticky sweets in the confectionery industry.

The dry bonding properties of oat starch mean it could also find application in the formulation of compressed pharmaceutical tablets. This would exploit the small granule size and could replace the current usage of rice starch. Similar properties make it suitable for use as a filler in photocopier paper.

The high water absorption of oat starch makes it suitable for use in drilling muds.

Cosmetic manufacture is the only significant non-food, non-feed use of oat flour or oat starch. The slightly higher acidity relative to skin pH facilitates absorption of dirt and sebaceous secretions in products such as facepacks. The benefits of oat flour in cosmetics were reviewed by Miller (1977) and applications of oat starch in cosmetic or pharmaceutical preparations, which reflect its unique granular size, are discussed by Caldwell and Pomeranz (1973).

Lipids

- 5.22 Natural oils and fats are triesters of glycerol with fatty acids of differing chain length and different degrees of saturation. World production is between 60 and 70 mt. Of this, about 14% is used for non-food purposes. In Western Europe the industrial use is around 1.8 mt, but over half of this is of animal (tallow) origin. Food prices have a significant effect on determining

vegetable oil prices for the chemical industry which restricts use to some extent.

The major uses of oils and fats are shown in Table 5.20.

Table 5.20 Uses of fats and oils in industry.

	%
Soaps, detergents and cosmetics	40
Plastics, plasticizers, rubber and textiles	20
Paints and varnishes	14
Food additives	11
Lubricants	11
Other	2

The criteria which apply to the food industry include physiological properties, with a 'health' dependent move towards unsaturated oils, physical properties, availability and price, and oats could have a role to play here (see Chapter 3 para. 3.34). In contrast the chemical industry is more concerned with the length of the carbon chain, the number and position of double bonds, the presence of functional groups, the nature and value of by-products and again availability and price.

5.23 The need of the oleo-chemical industry is for plants which will produce oils with specific characteristics, some of which are briefly described below. If oats are to contribute to these needs, plant breeders must enhance the production of the following:

- (i) A high content of oleic acid
- (ii) A high content of C12 and C14 chains
- (iii) A high content of long-chain fatty acids (C20 - C24) with one central double bond
- (iv) A high content of fatty acids with functional groups such as hydroxy-, epoxy- and dien-.

If lipids can be generated with the right properties it is anticipated that the market for industrial use will double to over 3.5 mt for the EC by the year 2000. This growth will depend

also on the evolution of crude oil prices, since in many uses vegetable oils are in competition with hydrocarbons.

Proteins

- 5.24 The major use for processed proteins is in the animal feed market, although some separated soya and fungal protein is used in food products. In general the protein feeds used within the EC are grains or by-products of the agro/food industries. Both have value as sources of energy (feed units) and as sources of crude protein. However, in the present context it should be noted that the EC as a whole imports considerable quantities (over 20 mt) of oil-cake (50% of which is soya) as well as over 3 mt of maize derived by-products from the starch, fuel-alcohol and HFCS industries in the US. These represent the major source of imported animal feed protein. The use of oats to produce starch or vegetable oil could produce by-products which would reduce the need for such imports, (with the high lysine content making it an attractive product), although the feasibility and economics would have to be considered, with attention to tariffs and trade agreements under GATT.

Oat protein isolates could find uses in formulated foods. The good water- and fat-binding properties of the oat protein concentrates suggest potential use as a meat binder or extender. Oats as a source of high quality food protein could be developed if a large-scale industrial process was developed for the separation of alpha-polypeptides from beta-polypeptides which yield significantly greater quantities of methionine and lysine.

Gums and fibres

- 5.25 Concentrated gums could become a by-product of wet milling technology for manufacturing protein concentrates and separated oat starch. Since these gums are essentially stable to sugar and salt and retain high viscosity at low concentrations they could replace gelatine in vegetarian products. Prime areas of interest in oat gum include use as a thickening agent in ice cream, sauces, and salad dressings as well as other uses. Recent

studies on the preparation and properties of oat gum, the major component of which is oat B-glucan, has arisen in part from interest in dietary fibre and in part from work on novel food proteins in the last decade.

5.26 The interest in dietary fibre supplements arises from applications:

1. Generally as part of a healthy diet.
2. As a bulking agent for use with intense sweeteners.
3. As a slimming aid in a calorie-controlled diet.

Hence, there is a high probability of an increase in demand for such materials over the next five years, allowing for time required to achieve commercialisation.

Canadian Harvest, in collaboration with Du Pont Canada, have a pilot plant to produce 900 t/annum of fibre for use primarily in baked goods. A full-scale unit is targeted for production in Minnesota. This will use 180,000 t of oat hulls as the primary raw material.

Since oat hulls do not contain significant amounts of soluble dietary fibre they have limited uses as beneficial food additives. However, there is a potential for increasing their use via the Alkaline Peroxide process (Gould, J M, US patent 4,649,113) and also for new patents for application to basic food formulations.

The Alkaline Peroxide process claims to enable agricultural wastes to be enhanced in dietary fibre. The by-product stream is a potential source of xylitol, furfural and ethanol. The economics of using oat hulls in this process are probably related to the viability of this filtrate use. Further process development and economic analysis are necessary to give an accurate estimate of costs. Economic viability is likely to be

based on the availability of the raw material and transportation costs.

In the past the hulls were the major raw material used for the production of furfural and related products. However, this use has now decreased due in part to the use of alternative plant wastes and in part to the decline in demand for furfural from this source as an intermediate in the production of nylon.

Straw

- 5.27 So far discussion has been restricted to a consideration of the grain. Approximately equal tonnages of oat straw are produced. This is largely used as bedding and animal feed. In addition oat straw can provide a source of fuel, fibre and chemicals as well as enriched feed. In general these processes are not economic unless low or zero value is assigned to the raw material. Even then, transport and storage costs may make such uses unprofitable. However, if oat production was increased, due to increased demand for the grain, and large amounts of surplus straw became available (possibly through the adoption of whole crop harvesting) then such processes could be considered.

At present over 5 mt of wheat straw are burnt in the field since it is not economic to use it in any of these processes. There is no reason to believe that the economics for similar processes based on oat straw would differ. Hence, these aspects of oat straw use are not considered further in this report.

Oats Fractionation and Economic Considerations

Fractionation techniques

- 5.28 If oats fractions are to find new markets methods have to be developed for the large-scale fractionation of the groat. These could parallel those used in either the maize industry or those used in the wheat industry. However, in view of the complex nature of the distribution of chemical components in the groat as well as the higher value of materials such as the gums,

antioxidants and dietary fibre, novel procedures will probably be needed. Some procedures are thought to have been developed and patented in the United States, and this requires further investigation.

Some separation can be achieved through dehulling and grinding, followed by sieving to separate the bran fraction from the flour. This can form the basis for either dry milling or wet milling separations. In the dry process the flour fractions and bran would be de-fatted by solvent extraction and the resulting powders separated using air classification to yield protein and starch fractions. In a wet milling process defatted groats would be coarse ground using a hammer mill and then slurried to produce a batter similar to that formed during wheat starch processing. The soluble protein would then be separated from the heavier starch using centrifugation. The specific gravity of starch, 1.5 (wet) and 1.6 (dry), should facilitate the centrifugal separation of starch and protein using a wet milling process. However, the development of a wet milling process is hampered by the small size of oat granules which results in a slurry of a slimey nature. It has been suggested that air-classification is simpler, less costly and more space economic.

If markets could be found for products of fractionated oats such as the starch and high-protein fractions, oat lipids would be of value. A high-protein fraction extracted from oats can contain up to 20% oil. The oil is not bound and it is easily extracted. Furthermore conventional solvent extraction of oat flour before flaking, or solvent extraction of rolled oats, does not affect the starch and protein products, but is essential to facilitate their separation. Hence, the difficulty is to distinguish a process aimed at obtaining a single product from one aimed at generating the full range including gums and fibre.

Factors influencing growth of oat fractionation

Technical

5.29 An increased use of oats in an industry which aims to produce fractions enriched for specific chemical constituents depends on price, and technical and market factors. At present the separation industries as a whole which use plant raw materials fall into two groups:

- (i) the vegetable oil industries
- (ii) the starch processing industries.

Both are based on a few species, selected on the basis of composition, stability in storage and ease of handling and separation. If large quantities of oats are to be processed in this way they must compete with the established crops, or yield a minor component of sufficiently high value as to merit the investment costs.

As mentioned above the amylose/amylopectin ratio, size and form of starch granules, the swelling behaviour, the content of residual lipids and the viscosity properties are all factors which determine the quality of starch and the kind of use to which it may be put in specific industries. In order to improve the performance/price ratio in relation to industrial use, plant breeding becomes a most important factor. The needs are to increase the yield per hectare, to modify the composition, to alter the properties and chemical composition of the major constituents and produce a groat which is easier to fractionate. These are ambitious objectives, but they are ones in which both conventional selection, if directed towards specific goals related to potential commercial use, and in the longer term recombinant genetic techniques, could be used. A close co-operation is required between industry defining exactly what they want and the plant breeder.

5.30 The problem is that different sectors may have different goals, which may be conflicting. The starch producer will have different objectives from the manufacturer wanting dietary fibre

or the manufacturer of vegetable oils. For instance, breeding of low-fat oat varieties for food processing will have different objectives than the breeding of high oil oat varieties for feed production or production of vegetable oil for human consumption. These different objectives may not only result in variations in chemical composition of the groat but may result in significant differences in yield between oil-rich and starch-enriched strains. This would require calculation in agricultural terms of yield (in terms of tonnes of grain per hectare) and product yield (in terms of tonnes of lipid or starch produced per hectare) in order to evaluate the respective economic potential of each strain.

Economic

- 5.31 Later Chapters on Farm Economics and on Agricultural Marketing and Policy cover many of the economic considerations of oats. However, a few points particularly concerning industrial aspects are worth mentioning here.

The economics of starch production in the EC are very complex. The three main sources of starch - maize, wheat and potatoes - receive production refunds under EC legislation (implemented in 1986) with the aim of reducing the price of starch and making it more favourable as an industrial raw material. The aim is to make up the short-fall between world market and EC prices. For cereals, a single refund is determined by the difference between common intervention price and world price. The list of industrial products which qualify for the new refund system implemented in 1986 is periodically revised. The relative refunds to the different sectors are aimed to reflect the value of by-products as perceived by the EC at the time the regulations were brought in, but they have led to assertions that particular sectors have been favoured (House of Lords Select Committee on Biotechnology, 1987). Thus the price of a particular raw material to industry is dependent on several factors including changes in world prices and the dollar-ECU exchange rate, and the level and relative size of production refunds through the EC.

It is clear that if oat starch was to penetrate these markets to any extent, further complications related to the CAP and support through production refunds would have to be resolved.

Discussion

- 5.32 To penetrate existing industrial uses of cereals or other agricultural productions, or indeed generate novel areas of agro-industry, oats must be able to compete in terms of price, composition and/or technical superiority.

In general it is concluded that unless oats has a significant price advantage as a raw material, it will not compete in the major markets due to the fact that separation by fractionation into products enriched in respect of a particular morphological fraction, other than the separation of the hull, does not enhance the ease of harvesting pure oil, starch or protein fractions. Hence, more complex, costly and less efficient processes are required as compared to those used with maize - the major cereal processed in this way.

- 5.33 The key question relating to oat processing is the type of company which might consider it worthwhile investing in complex and expensive technology to generate the various fractions. The most relevant technical background lies in the starch processing industry. However, oat starch is not competitive with maize and there is not the demand for oat protein as for wheat gluten. Hence, to encourage the starch processors to use oats will require establishment of a clear demand of a high added-value fraction as well as consumers in the food industry requesting this material. Alternatively a large food company might set up its own facility if it found a high added-value use for a particular fraction (eg. a gum).

The amino acid spectrum of oat protein, as well as some properties of oat protein and other constituents such as glucans and anti-oxidants, are such that a market for these products could be developed. However, in order to attract commercial investment in oat processing an assured market would have to

exist, with established market values for the various possible intermediates. The problem is that the different constituents (protein, gluten, anti-oxidants, starch, oil, etc.) would find use in different types of product, and hence be subject to varying demand and value. The difficulty is to establish an economic process, generating the various fractions to meet a demand which is at present unquantified as is the potential market value.

Conclusions to Chapter 5

1. The major products produced by the present agricultural products processing industry are sugar, starch and derivations, oil and protein. The choice of raw material used within a specific sector is based on a number of factors, most importantly:
 - (a) raw material price;
 - (b) chemical composition and quality of raw material;
 - (c) technical aspects related to processing and separation.
2. At present, maize starch dominates the starch market and wheat starch is largely produced due to the demand for wheat gluten. There are compositional/processing difficulties for use of oats for starch, with oats having a high glucan content and intimately combined lipids. Oats have never seriously been considered as a commercial starch source. Oat starch, however, does have some technical advantages for particular applications (eg. adhesives and cosmetic manufacture).
3. A variety of plants is used to produce vegetable oil, and the need of the industry is to produce oils with specific characteristics, which plant breeders would have to enhance in oats. A high protein fraction extracted from oats can contain up to 20% oil, which is easily extracted.
4. The use of oats to produce starch or oil could produce useful protein by-products depending on the economic viability.

5. Gums could become a by-product of wet milling technology for manufacturing protein and oat starch, with these gums having uses as thickening agents etc.
6. It is likely that novel processing procedures would need to be developed for oats, in order to separate the different valuable fractions. Economic viability is likely to depend on finding markets not only for possible high value components such as gums, but also for starch, protein and oil. Different sectors may have conflicting objectives in terms of requirements from oats. Price and quantity available of raw material would be of major importance.
7. Plant breeders could have a role to play in breeding varieties with characteristics valued by industry.
8. Unless a clear market is seen to exist, processors will not be attracted to oats.
9. There appears to be a lack of information on the value of oat fractions for industrial non-food and novel food manufacturing uses.

CHAPTER 6 PLANT BREEDING

Introduction

- 6.1 Of all the technological factors affecting the production of oats plant breeding is perhaps of most importance. As discussed in Chapter 5 previously, plant breeding and genetic manipulation of oats are also important factors in future potential utilization of oats.

This Chapter therefore looks at the past, current and possible future role of plant breeding in the production and utilization of oats in the UK.

Classification

- 6.2 Oats rank among man's top ten most grown crops. They belong to Gramineae (the grass family), sub-family Festucoideae, but are in a different tribe (Aveneae) to wheat, barley and rye (Triticeae) and rice (Oryzeae). The common cultivated form of oats in the UK is Avena sativa. Like bread wheat (Triticum aestivum), this species is a hexaploid (three sets of seven chromosome pairs) believed to be derived from three ancestral species. The genus Avena also includes diploid, tetraploid and other hexaploid species described by Rahjathy and Thomas, 1974; Baum, 1977; Thomas (in press).

The breeding system

- 6.3 Cultivated oats (Avena sativa) are a self-pollinated and therefore in-breeding cereal like wheat and barley (but not rye). As a result, modern varieties are, at least theoretically, genetically uniform, homozygous and true breeding. Most new varieties are derived by hybridisation (crossing) of selected genotypes, followed by selection. Several methods of selection, each with their own advantages and disadvantages are available. Parents for use in hybridisation are usually chosen on the basis of possessing valuable characteristics (eg. yield).

In addition to "straight-forward" breeding, strategic breeding research particularly in the public sector is aimed at (a) improving the efficiency of breeding and selection methods, (b) identifying new genetic sources having valuable characteristics which can be introduced into cultivated oats, using special techniques as appropriate (c) identifying new opportunities for breeding radically improved varieties. Scientifically-based plant breeding is also heavily dependent on other disciplines including plant physiology, plant pathology, cereal technology, animal nutrition, economics and computer technology.

Oat breeding in the UK and elsewhere

- 6.4 It is difficult to quantify exactly the effort devoted to oat breeding in the UK and elsewhere in north-west Europe. It is however much less than that devoted to wheat and barley, but the exact information is confidential to individual organisations. The Welsh Plant Breeding Station (WPBS) at Aberystwyth, part of the Agriculture and Food Research Council (AFRC) Institute for Grassland and Animal Production, has taken the major lead in oat breeding and genetic research in the UK, and has been involved in oat breeding since 1919. Oat breeding at Aberystwyth has been reviewed by Lawes, Valentine and Jones (1983), whilst an outline of current funded oat breeding and research programmes at the WPBS is given in Appendix 6.1.

Although several organisations in the UK have an interest in trialling and marketing oats, the only other oat programmes in the UK apart from those of the WPBS, are those of Twyford Seeds Ltd. This company has increased its effort in both winter and spring oats from being part of a cereal breeders' brief to employing a person to develop larger breeding programmes (E Simpson, pers comm).

It is estimated that the winter or spring oat breeding programmes at the WPBS are about one-tenth of the size of the winter wheat breeding programme at the Plant Breeding Institute (PBI), Cambridge prior to privatisation.

- 6.5 Elsewhere in Europe, oat breeding and research appears to be of most importance in those northern European countries where it constitutes a relatively significant percentage of cereal production, such as Sweden.

Outside Europe, strong oat breeding and research programmes are carried out in North America and Australia. Programmes may be federal or state funded, with additional industry support (eg. Quaker Oats in the US). There is only one commercial oat programme (Coker) in the US (a broadly similar situation exists for the wheat crop).

Given the importance of the oat crop in the USSR, it is assumed that significant oat breeding is undertaken there.

Oat Breeding and the Development of Varieties

Historical background

- 6.6 A number of different oat varieties have been developed since conscious 'pure line selection' of oats began in 1820. By 1910, hybridisation (crossing selected genotypes) had become the accepted method of generating new variation in several European countries.

Breeding proceeded by intercrossing the products of previous cycles of selection, and less frequently, by introducing new genetic sources. Most of the effort was devoted to improving yield of 'good quality' grain. In the first part of the 20th Century when oat breeding was developing, oats were the most widely grown cereal in the UK. Early breeding programmes at the WPBS aimed at developing varieties for specific environments such as the infertile uplands and more fertile lowlands areas. However, most attention at WPBS and elsewhere, was given to breeding new varieties of oats for better soils.

- 6.7 Most varieties developed, have only represented marginal improvements over previous varieties, and have assumed little commercial importance.

Much spring oat breeding has proceeded by intercrossing the best varieties, making gradual improvements in yield and replacing one variety by another slightly better one on the NIAB Recommended List, rather than introducing new genetic sources.

Oats evolved as a spring germinating crop which overwintered as a dormant grain. It is not surprising therefore that the first varieties were spring oats, and most of the past and current breeding effort in the world is aimed at producing spring oat varieties. Winter oats are a more recent development.

Oat varieties available

6.8 Recommended Lists of spring and winter oat varieties are produced by the National Institute of Agricultural Botany (NIAB), Cambridge, for England and Wales, by the Scottish Agricultural Colleges (SAC) for Scotland, and by the Department of Agriculture for Northern Ireland (DANI) for Northern Ireland. Inclusion of varieties on the Recommended Lists is based on results of National and Recommended List trials conducted in each country of the UK over a period of years. The Lists contain details of yield and agronomic performance of the recommended varieties and are revised annually.

6.9 Few new spring oat varieties have been placed on either the NIAB or SAC Recommended Lists in recent years. Currently six varieties are recommended by NIAB for 1988; Rollo and Dula (Fully Recommended) and Keeper, Commander, and Major (Provisional) and Avalanche (becoming outclassed). Only two varieties, Dula and Matra, are currently on the Scottish Recommended List. Of these varieties, two (Rollo and Keeper) originated in the UK (from the now discontinued Nickerson RPB programme) and three (Dula, Commander and Major) from the Netherlands. Seed production figures (Anon, 1988b) indicate that Dula followed by Rollo are the most widely-grown spring oat varieties in England and Wales (63% and 28% of total spring oat seed area), whilst Dula, Leanda and to a lesser extent Matra are most popular in Scotland (37%, 27% and 13% of seed area respectively). The varieties currently

recommended appear (in Scottish trials) to differ very little in terms of yield, but substantially in terms of agronomic characteristics (see Chapter 7) such as disease resistance, straw strength and straw length.

- 6.10 Winter oats are the least winter-hardy cereal, but have a higher yield potential than spring oats. They are sown in autumn and develop slowly until spring. Early attempts at improving winter oats, producing varieties such as Bountiful, Marvellous and Resistance, were only partially successful. Improvements in yield and standing ability, combined with winter-hardiness were obtained by tapping the larger gene pool of spring varieties directly or via Bountiful and Marvellous in crosses made at the WPBS in the 1920's and 1930's. Subsequent varieties include Powys (released 1957), Penrhyn (released 1958), Pennant (released 1960) and Padarn (released 1962) described by Griffiths (1962), and more recently Peniarth (released 1965), Pendrwm (released 1968), Pennal (released 1977), Panema (released 1978), Bulwark (released 1984), Image (released 1987), Lustre (released 1987) and Solva (released 1988).

As with spring oats, some varieties such as Powys, Pennant, Pennal and Image have resulted from intercrossing the products of previous cycles, while others (eg. Padarn, Peniarth and Lustre) have introduced new genetic sources.

The NIAB recommended list of winter oats for 1988 (Anon, 1988a) contain six varieties; Pennal and Peniarth (Fully Recommended) and Solva, Image, Lustre and Aintree (Provisionally Recommended). For some 10 years, the winter oat acreage has been dominated by the two varieties, Pennal and Peniarth introduced in 1965 and 1977 respectively.

However, the three recently released varieties Image, Lustre and Solva represent a distinct yield advantage over Peniarth and Pennal, which until this year (1988) were the most widely grown varieties (110, 107 and 112 vs 103 and 95 in untreated trials. Anon, 1988a). Lustre has resistance to barley yellow dwarf virus (BYDV) (Catherall, Parry and Valentine, 1987) and soil-borne oat

mosaic virus (SBOMV) (Catherall and Valentine, 1987) as well as large grains of high kernel content (see Valentine, Jones and Middleton, 3rd International Oat Conference, 1988). On the basis of the results of NIAB trials (Table 6.1), the yield of Solva (6.9 t/ha) and Image (6.8 t/ha) is above that of the best winter barley on the NIAB Recommended List, and the annual rate of improvement in winter oats (Table 6.2) is above that of winter barley.

Table 6.1 Average yields (t/ha) of winter oat and barley varieties in NIAB trials 1983-87.

Winter Oats				
	Solva	Image	Pennal	
Untreated	6.93 (28)	6.81 (38)	6.38 (48)	
Fungicide treated	(7.31)+(4)	7.06 (7)	6.63 (17)	

Winter Barley				
	Two-row		Six-row	
	Kira	Igri	Pirate	Gerbel
Untreated	6.41 (63)	6.04 (135)	6.65 (135)	6.28 (135)
Fungicide treated	7.64 (38)	7.21 (96)	7.71 (96)	7.57 (96)

+ limited number of trials

() = number of trials.

Table 6.2 Annual improvement (t/ha) in yield due to variety for winter oats and two-row barley since 1977, and six-row barley since 1979.

	Winter Oats	Two-row winter barley	Six-row winter barley
Untreated	0.050	0.033	0.041
Fungicide treated	(0.062)	0.039	0.016

Two varieties with special characteristics, Pendrwm (good milling quality and resistance to SBOMV) and Panema (resistant to cereal cyst nematode) from the WPBS were not taken up by the seed trade.

Seed production figures (Anon, 1988b) indicate that Pennal and Peniarth, the most widely grown varieties, are likely to be replaced by Image and Solva.

- 6.11 More detail is given on the agronomic performance of spring and winter oat varieties in Chapter 7.

The only non-WPBS winter oat varieties to be recommended in the last 25 years are Maris Quest and Maris Osprey released in 1966 and 1972 respectively, from the discontinued PBI programme, and Aintree from Serasem, France, added to the 1988 Recommended List. The last mentioned variety has sacrificed yield in favour of stiff straw, earliness and resistance to mildew.

Valentine (1984a) indicated that a relatively small number of genetic resources have been successfully used to develop new varieties of winter oats at the WPBS. Most new genetic sources were spring oats, showing the ultimate dependency of winter oats on an evolving spring oat gene pool. As in spring oats, much emphasis has been placed in making radical improvements in the oat phenotype.

Naked Oats

- 6.12 Both spring and winter 'naked' or husk-less oats have been developed both at WPBS and elsewhere. Naked oats originated in China where they have grown for centuries, but several constraints have prevented them from gaining popularity elsewhere, mainly low yields, small seed size, incomplete expression of the 'naked' character, hairs (trichomes) on the groat surface which act as irritants, increased mycofloral growth and storage problems. However, naked varieties such as Terra and Tibor in Canada (Tibor has been released in Canada and is being evaluated by pig and poultry farmers and the milling industry), Manu and Caesar in Germany and Nuprime in France have been

developed showing improvements in yield and other characteristics.

In the UK, a spring naked oat Rhiannon, with exceptionally high nutritive value was produced in 1983 at WPBS. With the support of the H-GCA, the WPBS is currently engaged in breeding oats with increased yield of energy and protein (from A.maroccana) per unit area in order to improve the value of oats for livestock feed.

A naked winter oat, Kynon, has also been produced by WPBS and two further varieties are in National List trials.

Technology and Methods of Oat Breeding

Choice of genetic sources for use in breeding

- 6.13 Parents for use in hybridisation are usually chosen on the basis of possessing valuable characteristics. Genes must be present in at least one of the parents of a cross for there to be a chance of selecting progeny with the desired traits. Hybridisation re-assorts genes and gene combinations, but does not create variation de novo. Parental genotypes may be high-yielding finished varieties, unreleased lines, unadapted genotypes from elsewhere in the world, or wild species possessing specific characteristics.

Whitehouse once described much breeding as 'crossing the best with the best and hoping for the best'. In the short- and medium-term, this may be successful and commercially sound, but the repeated use of one or two superior varieties reduces genetic diversity and the potential for further improvement. Moreover, the reduction of genetic diversity may predispose the crop to serious disease and pest attacks. Well-known examples are the Irish famine of the 1840's caused by potato blight, and the southern corn leaf blight epidemic in 1970-71 on all US maize hybrids carrying T-type cytoplasmic male sterility which caused a significant rise in world cereal prices (Chang, 1979). In oats, all varieties derived from Victoria, constituting 80% of the oat area of the USA, were devastated by Victoria blight disease.

Losses ran into hundreds of millions of dollars before it was possible to replace susceptible varieties with varieties of other parentage (Coffman, Murphy and Chapman, 1961).

- 6.14 The general policy of the WPBS has been to carry out research aimed at making radical changes in the oat phenotype by identifying and transferring useful variation, particularly in unadapted genotypes and wild species, to adapted backgrounds. Thus new sources of resistance to mildew from A.sativa, A.byzantina and A.barbata, cereal cyst nematode from A.sterilis and crown rust have been identified and used both by WPBS and other breeders.
- 6.15 While superficially attractive, the use of high-yielding lines from elsewhere in the world, particularly from different continents, is difficult because these have been bred to grow under different environmental conditions. For example, spring oats in the UK take 90 days from sowing to ear emergence and 70 days from ear emergence to harvest, while those from Manitoba take 60 days from sowing to ear emergence and 31 days from ear emergence to harvest (Forsberg, 1986). These differences are genetically controlled. (Extended growth periods contribute to higher grain yield, so that it will be appreciated that earliness and high yield are somewhat conflicting objectives). Varieties from the USA also tend to be very susceptible to mildew, a disease which is uncommon there. While it is difficult (but not impossible) to utilize sources of variation from alternative gene pools, useful genetic variation for earliness, winter hardiness and resistance to barley yellow dwarf virus has been obtained, for example, from the USA and Canada, and the WPBS is also using a number of unadapted oats from elsewhere in the world.
- 6.16 Wild species have been used by the WPBS in the past as sources of disease and pest resistance. Mostyn and Maris Tabard and their derivatives contain major genes conferring mildew resistance from A.sterilis var. ludoviciana, a hexaploid wild oat, and made a valuable contribution to increasing the national yield of oats during the 1970's. Resistance to cereal cyst nematodes was identified in A.sterilis and used extensively at the WPBS and

elsewhere. A.sterilis has been shown to be a valuable but largely untapped source of high protein and oil concentration, genes for high winter hardiness, yield, barley yellow dwarf virus and crown rust resistance (Frey, 1986).

Wild hexaploid oats, particularly A.sterilis, can be readily hybridised with cultivated oats, and since there is no hybrid sterility, successive crossing to a well-adapted genotype can usually be used to introduce desirable genes into cultivated oats. In contrast, strong sterility barriers necessitate the use of chromosome manipulation to transfer genes from some diploid and tetraploid species. Transfer of alien variation from wild species of different ploidy into cultivated oats has followed from an understanding of the genetic relationships between species within Avena. (Thomas 1981).

Successful gene transfers from wild oat species have included the transfer of mildew resistance from the tetraploid A.barbata, (Thomas, Powell and Aung, 1980), high protein from A.maroccana, first described only in 1968, and very high resistance to mildew from A.prostrata, a diploid. Among other transfers in progress is that involving A.macrostachya, a rare perennial oat species found at a high altitude in the Algerian mountains (Baum, 1977). This has high winter hardiness similar to that of winter wheat.

Collections of these wild oats, mostly A.sterilis, have been made from 15 or more countries in the Mediterranean area and the Middle East. Of the 20,000 accessions in the USDA World Oat Collection, 45% belong to wild species. Nevertheless, more than 95% of the collection is hexaploid (Frey, 1986). Another major collection of wild oats is held in Canada.

Important priorities for the conservation of oat genetic resources were drawn up by the International Board for Plant Genetic Resources (IBPGR) Working Group (IBPGR, 1984). Certain species were identified as priorities for collection and study. These are outlined in Appendix 6.2.

The WPBS has participated in two collections (1985 and 1986) funded by IBPGR (see Appendix 6.2) and agronomic evaluation of new sources of genetic variation from these collections is being carried out.

Breeding methods

- 6.17 It takes 10-12 years (including breeders' trials, statutory trials and multiplication) to breed a variety. The WPBS has undertaken research to improve the effectiveness of breeding and speed breeding progress (eg. Valentine and Ismail, 1983; Valentine, 1984b, Valentine and Middleton, 1986). Kynon was produced in only seven years by a new breeding procedure called accelerated pedigree selection, described by Valentine, (1984b). A rapid procedure known as single seed descent is being used in spring oats (Valentine, 1987b).

The products of hybridisation are usually handled by pedigree selection, in which:

1. Superior types are selected in successive generations.
2. Families are kept separate and records taken.
3. Lines are exposed to several years of selection in which the plant breeder can use his skill.
4. The number of lines is progressively reduced as the amount of seed is increased.

While most European cereal breeders use various modifications of the pedigree selection, as described by Lupton and Whitehouse, (1957), other methods are also being used with great effect at the WPBS and elsewhere. These range from backcrossing (used to transfer simply-inherited characters) to partial backcrossing (to transfer a few characters) and convergent backcrossing (transfer of many genes). Accelerated generation procedures, for example using artificial conditions of photoperiod, light intensity and temperature or out-of-season nurseries may be used. Recurrent

selection, a method of breeding designed to concentrate favourable genes scattered among a number of individuals, should be an efficient way of pyramiding genes and has been shown by Stuthman, 3rd International Oat Conference, 1988 and Frey, 3rd International Oat Conference, 1988 to be highly effective in improving yield, protein and oil content.

Biotechnology

- 6.18 No biotechnology work on oats is known to be undertaken in the UK. Rines et al (3rd International Oat Conference, 1988) and Giband et al (3rd International Oat Conference, 1988) described some of the applications of biotechnology being investigated in the USA and Canada respectively. The term biotechnology includes tissue culture and molecular biology.

Tissue culture

- 6.19 Applications of tissue culture techniques include cell and protoplast culture (not yet possible in oats), tissue and callus culture, anther or microspore culture and embryo rescue. One interesting development has been the application of maize pollen to emasculated oat florets, when haploid plants have been recovered. Uses include the production of aneuploid stocks (for genetic research), the direct selection of recessive traits in tissue cultures and the production of pure-bred doubled haploid lines (two malting barley varieties, Doublet and Pipkin, were bred by the doubled haploid method at the WPBS).

Molecular biology

- 6.20 Day and Austin (1987) considered that the improvement of crops by breeding will continue to be based on the broad principles and practices developed this century but that molecular biology (defined as the direct manipulation by chemical and enzymatic methods of DNA, the structural material of genes) might provide new opportunities for changing crop plants by the turn of the twenty-first century. Molecular biological techniques include cloning genes, sequencing DNA, analysing regulation and the

expression of genes, gene mapping and gene transfer. Work has been initiated in Idaho in mapping RFLP's (restriction fragment length polymorphisms) which, together with isozymes, have a great potential for use as neutral genetic markers, linked to important agronomic characters and disease resistance.

Giband et al (3rd International Oat Conference, 1988) have described the progress in molecular biological research in Canada. Similarities between oat 11S globulin (a major lysine-rich storage protein) and similar polypeptides in rice, pea and soya have been found at the DNA level. A DNA sequence concerned with protein synthesis present in Hinoat, a high protein Canadian oat, has been shown to be absent in Donald, a low protein variety, giving some optimism that it may be possible to manipulate protein content as well as composition by molecular biological techniques in the future. Groups in Versailles, Moscow and Purdue are also investigating the DNA sequences of oat proteins.

Systems for transformation and regeneration of oats would also need to be established for the successful transfer of genes from hitherto unavailable genetic sources by molecular biological techniques.

It should be noted that there is substantial biotechnological work being carried out in the UK on wheat and barley.

The Potential and Limitations of Oats for Genetic Improvement

- 6.21 Plant breeding is the main means by which the potential of the oat crop can be altered. Scientifically-based plant breeding offers the means by which new oat varieties can be developed with radical improvements in desired characteristics, rather than merely replacing one variety with another slightly better one on the NIAB Recommended List.

Potential

6.22 In general terms, oats appear a relatively good target for breeding and genetic manipulation in that:

- (i) oats are generally well adapted to most British conditions especially compared to many 'alternative' crops such as sunflowers, soyabeans, grain maize etc;
- (ii) considerable genetic variation appears to exist in oats giving the opportunity to make radical changes to the oat phenotype;
- (iii) relatively good progress has been made in breeding for yield and other characters in oats, despite the lower level of funding on oats compared to wheat and barley. For example, yields of the winter oats Solva and Image are appreciably above those of the best winter barley on the NIAB Recommended List, and the annual rate of improvement of winter oats is above that of winter barley. There is no reason to believe that such progress may not be continued;
- (iv) oats appear to have potential for genetic improvement in characteristics such as protein and oil content which should give a higher value to oats for feeding livestock and possibly for industrial uses, and characteristics such as greater winter hardiness in winter oats, increased disease and pest resistance etc., which should make them more attractive to growers;
- (v) the area of applying biotechnology techniques to oats breeding has yet to be explored in the UK. This branch of science might have an important role to play in changing crop plants in the future.

6.23 In relation to the genetic manipulation of desired characteristics in oats, protein content appears to be much

discussed. Raymond (1987) noted that oats offered greater scope for increased protein content than other cereals, whilst Fowden (1986/1987 AFRC Annual Report) considered that naked oats presented an opportunity for replacing imported protein with a home-grown well adapted alternative cereal.

A quality survey of oats in W Germany (Gansmann, 3rd International Oat Conference, 1988) has indicated the best varieties for hull percentage, protein and oil content. The information does not exist in the UK, but it is known that Pennal (the most widely grown winter oat in 1987) has an appreciably lower oil concentration than Peniarth, and Dula (the most widely grown spring oat) has a particularly low protein content.

In Sweden, where oats constitute 30% of the cereal area, a system of payments for protein content for each individual delivery was introduced in 1987. It seems important that if certain characteristics are desired and valued by users, then producers should be encouraged to produce these characteristics through market/price signals.

Potential of oat breeding to produce oat varieties containing high proportions of desired/valuable fractions/constituents.

6.24 In the present agricultural climate, greater emphasis should be placed on improving the suitability of products for existing and new markets. There appears to be unexploited economically significant variation in the content of valued fractions in oats, particularly protein and oil contents.

For example, Table 6.3 shows a range of protein contents for husked spring oats.

Table 6.3 Crude protein (% DM) in spring oats.

<u>Avena maroccana</u>	30%
<u>A.maroccana</u> -derived spring oats	12.5-15%
Medium protein spring oats	12.0-13%
Dula	9-11%

Recent interest in improving protein content has centred on A.maroccana, a wild tetraploid found in Morocco first described by Murphy *et al* (1968) with a crude protein (DM basis) of 30%. At the WPBS, genes from A.maroccana have been transferred to A.sativa by cytogenetic means (Thomas, Haki and Arangzeb, 1980). H-GCA funded work identified a number of lines with whole grain protein concentration 20-40% and protein yield 22-57% greater than controls (Rogers and Thomas, 1987). A subsequent H-GCA funded programme which began in 1987, has confirmed the high protein content of A.maroccana-derived lines. Although previously untested, these lines had oil content ranging up to 1.5% DM above the control varieties (Butler-Stoney and Valentine, 1988). This variation is being exploited by intercrossing and crossing with advanced lines of winter and spring oats in order to (a) raise protein levels still further (b) to improve yield and agronomic characteristics.

- 6.25 A similar programme at WPBS for the improvement in oil content in winter oats from Pioneer, an old very tall North American variety, is being undertaken. In 1987, oil content ranged from 6.9 to 9.8%, with many lines having higher oil content than Pioneer (8.8%). Lines with high oil (and protein) content have also been identified in the main breeding programme, in most cases being associated with novel germplasm. Recent work in Iowa has used recurrent selection of Avena sterilis-derived material to produce oats with 15% oil in their groats. This level of oil could be significant to the economics of oil extraction from oats as well as in raising the energy level of the grain.

- 6.26 Naked oats show considerable potential for improvement in proportions of desired constituents in oats. Improvements in characteristics of husked oats through breeding, can be transferred to naked oats. Many possibilities exist, for example, alterations to amino-acid composition, to oat oil composition etc. Genetic variation appears to exist for most characters.

Limitations

6.27 Like other crops, oats have their production limitations. These limitations or constraints are covered more fully in Chapter 7 on agronomy; however the role of plant breeding in reducing these limitations is briefly discussed here.

- (i) Winter oats have a lower winter hardiness than wheat or barley, preventing it being grown in some areas.

Lines from Kentucky and Pennsylvania were identified in the early 1980's as having promising levels of winter-hardiness (Finkner, 1981; unpublished reports of the Uniform Winter Hardiness Oat Nursery 1981 and 1982; Valentine and Middleton 1983; Valentine, Middleton and Jones, 1984; Eagles, Williams and Toler, 1984).

Initial crosses were made in 1980, since when selection of high winter hardiness and good agronomic characteristics has been undertaken by WPBS in the breeding nursery at Gogerddan and at upland sites, and the best lines crossed with high yielding lines. An assessment of progress made last winter (1987-88) at an upland site, and a crown freezing test in Pennsylvania similar to that described by Marshall and Kolb (1982), showed that some lines containing as little $12\frac{1}{2}\%$ of the North American lines had high winter-hardiness and freeze test scores approaching those of the best donor parent. Work on genetically improving winter hardiness should include (a) accurate evaluation under natural conditions at several sites including Scottish locations(s); (b) refinement of laboratory testing methods assessing freezing tolerance and (c) physiological studies on the control of hardening and de-hardening responses and their associations with patterns of carbon metabolism, gene expression and nucleic acid metabolism. Similar work in Lolium has been undertaken by the Environmental Adaptation Group at the WPBS; (d) a greater understanding of the environmental factors and physiological mechanisms

involved in cold tolerance and winter hardiness is also needed to explain large interactions between genotypes and artificial vs natural conditions, and between genotypes and different years and locations, which would greatly improve the efficiency of selection for high winter hardiness.

In the longer-term, it should be possible to transfer winter hardiness from A. macrostachya with hardiness similar to winter wheat.

- (ii) Oats are prone to lodging. Stiffer strawed varieties such as Aintree and to a lesser extent Solva are now available. Continued improvements in resistance to lodging are envisaged by WPBS.
- (iii) Spring oats have a long growing season. Earlier oats will be valuable in Scotland and the rest of the UK. In the past, empirical attempts to breed early oats have resulted in reduced yield potential. Two early spring oats released in the last ten years have not succeeded. However new possibilities of combining earliness with increased growth rate and biomass, using recurrent selection to concentrate favourable genes, have been identified at the WPBS.
- (iv) Pest and disease limitations to oat growing are not great compared to other cereals. However, improved disease and pest resistance would be valuable; and progress seems to have been made in this area. Pests and diseases considered of importance are:

Cereal cyst nematode - resistance is being bred into high yielding husked and naked winter oats, in order that the frequency in which oats can be grown in a rotation is not limited. Two recommended varieties of spring oats (Rollo and Keeper) are resistant to cereal cyst nematode.

Oat mosaic virus - the recently recommended WPBS varieties are resistant or tolerant. Oats are in a much better position in this respect than barley, in which the majority of varieties is susceptible to barley yellow mosaic virus. Lustre, and many of its derivatives in the WPBS breeding programme, are also resistant (or tolerant) to BYDV. (Catherall, Parry and Valentine, 1987).

Mildew - various sources of resistance to mildew including A.barbata have been identified in the past and are now being transferred into commercially acceptable oats.

Barley yellow dwarf virus (BYDV) - only small effort is currently expended on this at present, although good resistance is present in Lustre. Incorporation of resistance (tolerance) to BYDV would minimise the need for undesirable insecticides as this virus is aphid-borne.

Conclusions to Chapter 6

- 6.28 1) The effort devoted to oat breeding in the UK and elsewhere in north-west Europe is much less than that devoted to wheat and barley. The WPBS has taken the major lead in oat breeding and genetic research in the UK, having been involved in oat breeding since the early 1920s. Few other oat breeding programmes exist in the UK, although significant programmes are carried out in North America and Australia.
- 2) Considerable genetic variation exists in oats to make radical changes to the oat phenotype. Wild species are a particularly important source of variation for disease and pest resistance, high protein and oil content, high winter-hardiness and possibly also yield.

- 3) Various breeding methods are available for the production of commercial oat varieties. Cytogenetic techniques have an important role in transferring important characters from diploid and tetraploid species to the cultivated oat. Biotechnology and molecular biology have by-passed oats in the UK, despite the important role that these branches of science might play in the future.
- 4) There appears to be significant potential for the improvement of oats and naked oats in terms of the needs of producers and current and potential users of oats. For example (i) improvements in resistance to lodging, high winter hardiness, earliness in spring oats, good disease and pest resistance have already been made and further improvements are possible, (ii) high protein and oil contents of oats could be developed, with a target protein level of 20% and a target (on a groat basis) level of 15% for oil. In this regard, naked oats have been bred which have higher levels of oil and protein than conventional (husked) oats, and improvements in the yield and/or protein and oil content of naked oats shows potential.
- 5) Genetic variation exists for most characters, and a number of breeding opportunities are possible such as the production of oat varieties with fractional properties of value to food or non-food industrial processors. However, it is important that oat breeding for such characteristics is only carried out where a clear and definite market exists. The chances of success may be diminished if too many characters are considered, so those of most importance must be identified, and the ease with which a character can be improved should be taken into account.
- 6) Conversely, it is important that plant breeding is capable of responding opportunistically to changes in agronomic and market requirements. For this reason it is important that genetic diversity is not lost and thus a wide genetic base of oats should be maintained.

CHAPTER 7 OAT AGRONOMY

Introduction

- 7.1 Over the past decade the oat-growing area in the UK has fallen from around 180,000 ha in 1978 to around 99,000 ha in 1987 (having risen to an estimated 121,000 ha in 1988). Indeed, the area sown to oats has continued to decline since the mid-1940s when it was over 1.3 m.ha. The decline in spring oat production has been part of this trend and in Scotland, the main area of spring oat production in the UK, the area has fallen from 51,000 ha in 1978 to 28,000 ha in 1987. In England and Wales, where most winter oats are grown, the area has fallen from around 124,000 ha to under 68,000 ha over the same period.

Distribution

- 7.2 Based on 1987 data (MAFF, DAFS), the broad distribution of the UK spring oat area is as follows:

Approx. % of total UK spring oat area.

Scotland	58%
England and Wales	37%
Northern Ireland	5%

Spring oat production is not recorded separately in England and Wales and it is therefore not possible to give any indication of regional distribution. Oats in Scotland are predominantly spring-sown and are concentrated in the main in the Grampian and Tayside regions. The winter oat area in Scotland is very small and is located mainly in the most climatically favoured parts of the country (eg Moray and Nairn, the Borders, coastal areas of Fife and Angus).

Winter oats constitute 75% of the total area in oats in England and Wales, the broad geographical breakdown of the winter oat area being:

Approx % of total winter oat crop in England and Wales.

Location

North (England North of the Humber)	10%
East (E. Midlands E. Anglia and SE)	50%
West (W. Midlands, S.W. and Wales)	40%

Climate and Soil

- 7.3 Spring oat production is generally associated with the cooler and wetter parts of the UK. It is widely accepted that spring oats will produce acceptable yields on poorer soils than required for wheat or barley. Oats, for example, can grow and produce reasonable yields on soils of lower pH than required for other cereals. Long-term observation trials (started in 1924) conducted by the North of Scotland College of Agriculture at Aberdeen show that spring oats can tolerate substantially lower soil pH levels than either wheat or barley.
- 7.4 Although tolerant of low soil pH, the bulk of the spring oat crop is grown at pH levels suitable for other combinable crops in the rotation. The optimum soil pH for oats is generally considered to be in the range 6.0-6.5. Oats are the most sensitive of the cereals to manganese deficiency and routine remedial treatment is frequently required. Manganese deficiency in oats tends to be most severe where such conditions as low manganese availability, high soil organic matter and over-liming are prevalent.
- 7.5 Spring oats are grown successfully on a wide variety of soils but coarse-textured soils and soils with a high clay content are generally less suitable. The former can result in reduced yield and poor grain quality, particularly in dry years, while in heavy soils establishment may be less than satisfactory. Soil type will influence the quality of spring oat grain. Grain of good quality is more likely to be produced under soil conditions conducive to a long grain filling period. Soil with a proportion of clay will retain moisture better than a sandy loam. The presence of a reasonable level of soil organic matter will help

water retention and oats grown after a grass ley benefit in this way.

- 7.6 Insufficient winter-hardiness is the main limitation to the northern geographical spread of winter oats. As with other cereals the more reliable yields are associated with well drained, but moisture retentive, soils. However, as for spring oats, winter oats are more reliable than wheat or barley on the wetter, less fertile soils that have a natural tendency to a low pH. The winter oat crop is notably vulnerable to frost lift and exposure of the thinner calcareous soils above the 150 metre contour. Lodging frequently prevents the oat crop fully exploiting the potential of highly fertile sites or of fields assessed to have a nitrogen index of 1 or above.

Farm Systems and Rotation

- 7.7 The oat crop has a well-established niche in the rotations of mixed farms where there are livestock enterprises having a reliance on home-grown grain for feeding, and is often associated with a less intensive farming system (eg sheep/grass systems). Historically the winter oat crop frequently had a supplementary role of providing early spring grazing for sheep.¹

Organic Production

- 7.8 Oats can be a useful low-input cereal demanding little in the way of fertiliser or fungicide, and returns on 'poorer' yielding land can compare favourably with higher input wheat and barley. This low-input nature of oats makes them highly suitable in an organic rotation, and there appears to be increasing demand for oats grown by approved organic methods. Information on the relative performance of varieties grown under these conditions is meagre.

¹ Trials at Rosemaund Experimental Husbandry Farm in 1974-75 found that in a lodging situation with the varieties Peniarth and Maris Osprey, both mid-March and early April grazing of winter oats by sheep, improved yields by reducing lodging and mildew levels in the crop, whilst providing valuable early grazing.

A few varieties were compared grown under organic conditions by the East of Scotland College of Agriculture in 1987.

Variety	Yield (t/ha)
Commander	4.03
Dula	3.97
Leanda	3.73
Major	3.88
Matra	3.17
SED	+0.28

Pest, disease and weed control is more difficult in winter oats, and for that reason they may be less suited to organic systems than spring oats.

7.9 Production of oats for milling or seed is carried out in the more intensive cereal-growing areas, with expenditure on nutrition and crop protection as required to produce maximum grain yield and quality. Where oats are part of a more intensive cereal system, certain rotational advantages are apparent:

- i) The crop is not susceptible to the barley - wheat race of take-all (Gaeumannomyces graminis) which can cause devastating yield loss in these cereals. Spring oats are also a low eyespot risk. Reports on the use of oats as a break crop have emanated from ADAS and Rothamsted indicating that a yield increase in wheat of around 10% can be expected in the crop following a single year of winter or spring oats. No such comparable work has been carried out in Scotland but it is assumed that similar yield benefits would apply.
- ii) In the present climate of over-production of wheat and barley and general interest in low-input systems, oats may have a considerable advantage over wheat and barley. For example, spring oats over a period of time appear to be more productive than spring barley, particularly in situations of reduced nutrient supply. In long-term observation trials conducted by the North of Scotland College of Agriculture the spring oat crop was clearly superior to spring barley in

a six-course rotation where major nutrient elements were omitted singly or entirely.

- iii) The spring oat crop is relatively late ripening and while this is rightly viewed in general as a disadvantage, this characteristic could, in early areas, serve to extend the harvest period and relieve pressure at a particularly busy time of year.

7.10 There are certain rotational limitations associated with spring oat production. Some of these are of less importance given the current low area of spring oats but would be potential hazards if there was an upsurge in oat production:

- i) Oats are very susceptible to cereal cyst nematode (Heterodera avenae) and although this pathogen has declined with increasing intensity of wheat and barley production (intensive production of these cereals favours fungi antagonistic to the nematode), any increase in oat production could re-activate the problem. However, there are two recommended varieties of spring oats (Rollo and Keeper) which are resistant to the pathogen.
- ii) Control of grass weeds (particularly wild oat) is more difficult in oats. There is a limited range of herbicides for the control of annual grass weeds and none for control of wild oat in the crop.
- iii) Oat volunteers can be a problem in subsequent crops.
- iv) Oat mosaic virus can be a problem in winter oats, but in Scotland appears to have little significance in the spring oat crop. Problems in winter oats tend to be most common on the lighter textured soils and where there is a history of 4 or more oat crops over the past 20 years.
- v) Spring oats are harvested late in the season and are thus less flexible than winter and spring barley in any sequence of combinable crops. In Scotland, for example, spring oats

could only be followed by winter wheat or a spring sown crop. Late harvesting also results in lodging and shedding of seed, and volunteers may then also be a problem.

Varieties

- 7.11 Oat varieties have already been partly covered in Chapter 6, and only agronomic considerations will be covered here.

Some idea of the relative popularity of spring oat varieties can be obtained from recent figures for seed production published by NIAB and DAFS:

Variety	% of total spring oat seed area	
	England & Wales	Scotland
	(1987)	(1986)
Alfred	1.7	1.8
Astor	-	7.4
Avalanche	1.2	5.0
Cabana	-	3.0
Commander	4.3	-
Dula	63.0	36.7
Keeper	0.9	-
Leander	-	27.1
Major	0.5	-
Matra	-	12.6
Rhiannon	0.5	-
Rollo	27.8	4.8

- 7.12 Dula and Matra are currently recommended in Scotland. None of the newer varieties in trial have out-performed Dula and Matra to any significant degree. Leanda has been in commerce for many years and still finds favour with some producers. Avalanche is low yielding and has very weak straw. Cabana, Commander, Major and Keeper have no significant advantages to offer in comparison with the recommended varieties Dula and Matra. Only Dula is common to the SAC and NIAB Recommended Lists of spring oats. Rollo, Commander, Keeper, Major and Avalanche are recommended by NIAB but do not have sufficient merit to justify inclusion in the Scottish List. Appendix 7.1 shows results of Scottish trials on those varieties carried out 1983-87.

There is a need for the inclusion of new varieties on the Lists, particularly with improved grain yield, grain quality and early ripening characteristics, to widen the choice of variety and encourage more widespread production of the crop.

- 7.13 For winter oats, for some 10 years the acreage has been dominated by two varieties, Peniarth and Pennal. Peniarth has been much favoured by the oat millers but Pennal, with a marginal advantage for yield and notably shorter stiffer straw, has been the farmer's preferred variety where quality and winter hardiness were not prime considerations. The current Recommended List (NIAB 1988), boosted by the four provisionally recommended varieties Solva, Image, Lustre and Aintree is longer than for many years. The latter varieties offer yield advantages ranging from 5-10% and 10-15% over Pennal and Peniarth respectively. Areas entered for seed production (NIAB 1988b) for harvest 1988 show the following breakdown between main varieties:

<u>Variety</u>	<u>% of total winter oat and seed area</u>
Image	36.1
Peniarth	20.6
Pennal	25.3
Solva	8.4
Lustre	5.4
Aintree	2.1
Kynon	2.0
Craig	0.1
	<u>100.0</u>

Data in the table in Appendix 7.2 (MAFF R & D Project) provides a guide to the performance of certain of these varieties in ADAS (SE Region) variety and husbandry trials over the three seasons 1986-1988. Comments on the data are:

- * Rosette is an attractively stiff-strawed high-yielding oat with good quality grain that failed to get onto the NIAB List due to its extreme susceptibility to mildew.
- * Bulwark represented a major breakthrough in yield. Hard winters confirmed the unreliability of the variety on the score of winter hardiness.

- * There is a fairly consistent trend for Image and Solva to outyield Peniarth and Pennal.
- * Lustre has tended to yield marginally below the level of Pennal - a trend that is the reverse of the National picture.
- * Solva appears to perform slightly better than Image on yield, standing power and specific weight.
- * The two newer arrivals, Aintree and Craig, performed well in 1988 - in a relatively kind summer that did not test straw strength; Aintree's ratings for early maturity and standing power are notable and agronomically attractive.
- * The Naked Oat Kynon is of topical interest. There were no husbandry problems with the variety in the 1986-87 trial; it established and overwintered satisfactorily as did the other varieties. On the scant evidence of this one trial any budgeting for this variety should perhaps assume a yield that is no more than some 70% of the expected yield of Image or Solva.

Field performance and market preference will dictate to what extent the Provisionally Recommended varieties with their higher yield potential are taken up by growers. After a fairly static varietal situation the scene appears to be set for varieties to make a notable impact on average yields and hence total oat production. Contact with one of the oat milling breakfast food companies indicates no general acceptance of the newer higher yielding varieties. Test milling on Image and Lustre will continue with the 1988 crop after which time the place for and acceptability of each of these varieties should be clearer. Lack of supplies to date has meant that there has been only a limited amount of commercial test-milling of Solva and virtually none in the case of Aintree and Craig.

Crop Establishment

- 7.14 Spring oats require a relatively long growing season and are usually harvested later than spring barley or winter wheat. Early sowing should be considered essential and it is logical to advocate that the spring oat crop should be given priority at sowing time. Early sowing is also important to avoid damage from frit fly (Oscinella frit). Data from time of sowing trials over the past 15 years are not available from ADAS sources but in Scotland such data are available from NOSCA long-term observation trials at Aberdeen relating sowing date to yield of spring oats.

Establishment of the spring oat crop is usually achieved by drilling after ploughing and whatever secondary cultivation is deemed necessary to achieve the required seedbed. Non-ploughing methods of establishment for spring cereals have been less successful than for winter cereals and there appears to be no R & D data on establishment of spring oats using direct drilling or other non-ploughing techniques. It could be surmised that the combinations of an increase in grass weeds and lack of effective herbicides to control them would make establishment of spring oats by non-ploughing methods an unattractive proposition in practice.

From Scottish data and experience the seed rate for spring oats should aim to produce an optimum plant population of 350-450/m². Actual seed rate will depend on thousand grain weight and drilling conditions but in Scotland is usually around 190 kg/ha. Plant populations and seed rates recommended for England and Wales are usually somewhat lower than those recommended for Scotland.

- 7.15 For winter oats, no drilling trials to provide a guide to optimum drilling date have been undertaken over the past fifteen years. However, the normal cereal drilling date husbandry considerations apply but tend to be even more important with winter oats than with winter wheat. They include:

- * Aphid transmitted Barley Yellow Dwarf Virus (BYDV) problems, the reaction in oats being even more severe than in winter wheat or winter barley. After consideration of site and the normal level of BYDV pressure, the severity of the problem is linked with drilling date - the earlier the drilling, the greater the aphid vector pressure and the higher the risk of early virus transmission and major effects on the crop plant. It is particularly important to pay heed when there are notable BYDV levels in the cereal crop preceding the oats; chemical desiccation of all cereal volunteers and grasses before ploughing or seedbed preparation is recommended in this situation. After crop emergence the monitoring and control as necessary of the aphid vectors is essential.
- * Lodging problems and diseases. In general the earlier the drilling the higher the tiller number and the greater the risk of mildew build-up over the winter and of lodging problems in the summer. Fungicides can effectively cope with the former problem; growth regulators delay but rarely prevent lodging in weak strawed winter-proud oat crops.
- * Cereal volunteer problems. September - early October drilling can result in high levels of admixture in the oats via the volunteers from the previous crop - and rejection for the milling market. The ideal (frequently not possible) is the sequence - shed corn germinates - plough - drill.
- * Frost lift and winter hardiness. Late October - November drillings are vulnerable to the early onset of severe (frosty) weather during the crop establishment phases. Wheat going into the winter without a tiller usually survives; oats in the same situation frequently do not.

Clearly, the importance of any one of the above considerations will vary according to site, field history and geographical location. A mid-October drilling date usually proves to be a satisfactory, middle-of-the-road approach in the S East, S West and S Midlands; a target date $2-2\frac{1}{2}$ weeks earlier than this

would be the aim at the northern end of the winter oat belt or on exposed sites at altitude further south.

- 7.16 Ideal plant populations are much less well researched than for either wheat or barley. Green (1984) recorded yield components from 17 treatments that had produced a yield of 7.5 t/ha or more in 1982 husbandry trials with the variety Peniarth. The mean situation in this study was that 243 plants/m² (range 197-313 plants/m²) were the basis for a yield of 8.00 t/ha (range 7.50-9.3 t/ha). A similar analysis (of over 7.50 t/ha yielding plots) in 1984 gave a mean of 345 plants/m² as a basis for a 8.12 t/ha yield.

With lodging a particularly important problem in the winter oat crop, the scope for reducing this problem (while maintaining or increasing yields) by using lower than normal plant populations is being studied in current husbandry trials (MAFF/CSG Commissioned R & D project). The yield trends from the trials and the above yield component data combine to confirm that a safe range for optimum yields is to establish 250-300 plants/m² - with above average yields being obtainable from the lower 150-200 plants/m² range. Seedrates (to achieve target populations) are calculated in the normal way after determination of the thousand grain weight (TGW) of the seed sample and estimation of percentage survival rate for the particular conditions of the field. Typically TGWs of oats are in the 31-35 g range - notably lower than for wheat and barley - and accordingly target seed rates for the crop will usually be (or should be) well below those that are common for wheat and barley. When estimating probable survival rates for particular seedbed conditions it is safe to calculate that loss due to grain hollowing by slugs (with 'normal' husked varieties) is usually considerably less than for other cereals; but oat seedlings are palatable and subject to post-emergent grazing by the pest.

Research (ARC Letcombe circa 1977) and farm experience in the 1973-1980 period indicated that establishment of winter oats by direct drilling or following minimal cultivations gave similar yields to those achieved by more traditional methods based on the

plough - when essential guidelines on straw disposal and suitable soil types were followed. There was a trend (advisory observation) for direct-drilled oats to be less vulnerable to frost heave problems (than when following the plough) on exposed chalkland sites in the south-east.

Inputs

Nutrition

7.17 Fertiliser requirements for spring oats are similar to those recommended for other spring cereals. Spring oat varieties however, are relatively weak-strawed in comparison with barley and situations where excessive release of soil nitrogen can be anticipated are best avoided. Current recommendations for fertiliser nitrogen do not differentiate between spring barley and spring oats but, in the absence of any definitive experimental work, it is usually recognised that it may be prudent with spring oats to reduce the nitrogen rate by some 20%. In relation to this Lang and Holmes (1972) compared the effect of 17, 34 and 68 kg N/ha on a range of spring oat cultivars following grass leys in 16 experiments from 1961-66. Nitrogen increased yields in dry summers and decreased yield in wet summers and on average it was found profitable to apply 17 kg N/ha after ley. Lodging increased linearly with increase in nitrogen application. Some MAFF-commissioned work in 1984 compared the effect on yield of 60, 90 and 120 kg N/ha as part of a longer experiment. No significant response in grain yield of spring oats to increasing rate of nitrogen was recorded. A general observation pertinent to this review is the paucity of good recent experimental evidence for current recommended rates of fertiliser nitrogen for spring oats.

Phosphate and potash recommendations are based on analysis of soil reserves. Many soils in Scotland are naturally low in phosphate and have the capacity to fix phosphate strongly. In these situations placement of phosphate (and potash) by combining drilling is very beneficial. This practice is particularly important in areas of Scotland where cold spring weather and low

soil temperatures are a feature of the climate. In these circumstances phosphate availability is very low and placement of phosphate and potash is of great benefit in the early establishment phase of the crop.

Details of current fertiliser recommendations for spring oats are given in SAC Publication No. 160 'Fertiliser Recommendations' and in MAFF Reference Book 209 'Fertiliser Recommendations'. Spring oats are particularly sensitive to manganese and copper deficiency both of which are exacerbated by over-liming. Response to zinc has been identified in other cereals in north-east Scotland though not as yet in spring oats.

- 7.18 For winter oats, the current advisory approach is to group winter oats with other cereals as being unlikely to show responses to fertiliser applications of phosphorus and potassium when soil reserves are at Index 1 or above (MAFF Reference Book 209). At these levels a maintenance approach to P and K manuring is considered satisfactory with application rates being related to yield history and the straw disposal policy for a particular field. It is desirable where soil indices for P or K are at 0, that at least part of the required dressing should be combine drilled. At higher indices there is little or no advantage to combine drilling. At indices for P and K of 2 or above the annual maintenance application can be applied at any time of the year or at appropriate levels to other points in the rotation.

Work at Rothamsted using oats as one of six arable crops in a long-term rotation experiment perhaps raises a query over the use of potassium. The trial suggests a large difference between varieties in their response to this nutrient, a finding that could be worthy of further investigation.

MAFF/ADAS trials (CSG - Commissioned R & D) testing spring nitrogen top dressings on medium to heavy textural soils at sites in Wales and the South East, found optimum applications with a mean of 118 kg/ha compared to the current recommendation (MAFF Reference Book 209) of 100 kg/ha (in N Index 0 situations) for these soil types.

At most sites in this series, nitrogen rates at or above 120 kg/ha have caused at least 50% lodging in the crop despite overall use of plant growth regulator and this presents a major practical limitation to the use of higher nitrogen rates. Timing effects have mostly been small and inconsistent. The trials have included two varieties Pennal (7 sites) and Peniarth (5 sites), the latter weaker strawed and more prone to lodging.

Two levels of nitrogen - 100 and 140 kg/ha - were frequent treatments in husbandry trials (ADAS Agronomy SE Region 1982-88) on weak-structured silty-loam soils (Curtisden Series) in Kent and E Sussex. Typical lodging levels with Peniarth (in the presence of CCC) at N levels of 100 and 140 kg/ha were 11% and 43% respectively; there was rarely an economic yield response to the higher N level with this variety. A summary of yield and lodging responses with other varieties to these two nitrogen levels during the period 1985-88 is given in Appendix 7.3, four of the five trials reported showing a significant and economic yield response to the 140 kg/ha N level. Summarizing, where the stiffer strawed varieties are grown under the soil and fertility conditions of the SE Region trial series, the use of 140 kg/ha N is probably merited.

Advisory experience confirms that winter oats are most sensitive to manganese deficiency and timely attention to a known or detected deficiency of this nutrient is essential. On mineral soils, where oats are normally grown, the deficiency is associated with a soil pH of 6.5 or above and as such can be induced by over-liming. The problem may occur for some years following the ploughing out of old permanent pasture.

Growth Regulators

- 7.19 The 'grass roots' interest in this topic revolves around the need for more effective treatments than currently available to reduce, delay or preferably prevent lodging in the winter oat crop. Chlormequat (CCC) products have been available as an aid to lodging control for many years. Results from a series of five

trials using CCC products on winter oats (ADAS SE Region 1984) found that CCC had a useful role to play in reducing lodging. Research on the use of CCC in spring oats (Blackett and Martin 1970, Gill et al 1974), found that even in potential lodging situations, Chlormequat was unlikely to be profitable.

Lodging is of common occurrence in commercial spring oat crops and growth regulators more effective than chlormequat would be of great benefit.

Weed Control

- 7.20 There is an adequate range of products with label recommendations for use in oats to cover the normal run of broad-based weed problems in the crop. However, the available 'armoury' for grass weed control is not satisfactory. There is an absence of effective black-grass and wild oat herbicides (in fact, there are no herbicides for control of wild oat). The lack of chemical control for wild oat in cultivated oats has probably limited (perhaps particularly for winter oats) the uptake of oats as an alternative crop.

Disease Control

- 7.21 The common diseases of oats include mildew (Erysiphe graminis), crown rust (Puccinia coronata), brown foot rot (Fusarium spp), leafspot (Pyrenophora avenae), sharp eyespot (Rhizoctonia cerealis), Septoria (Septoria tritici-avenae) and occasionally true eyespot (Pseudocercospora herpotrichoides).

Mildew is the most common foliar disease of oats in the UK and can develop rapidly causing premature senescence and loss of yield and quality. Choice of variety offers some measure of control but in many years spraying with an effective fungicide may be the only means of control. For spring oats data from NOSCA and other institutes are available to relate fungicide use to control of mildew and other diseases.

Considerable data concerning spring oats is available from NOSCA trials and can be quoted to substantiate yield response to foliar disease control. In general, yield response to fungicide in these trials was substantial with an increase in yield of around 10% easily achieved.

In contrast, yield responses to disease control by fungicides tends to be notably less with winter oats than with winter wheat and winter barley, as the following table indicates:

Cereal	Typical % yield increases from disease control by fungicide compared to untreated controls	
Winter wheat		15-20%
Winter barley		10-15%
Winter oats	typically +	1-8% and 5%

[Source NIAB Farmers Leaflet No. 8]

This trend to lower response from fungicide use means that, on economic grounds, the winter oat crop is a candidate for 'managed' disease control, in other words, fungicide use when a combination of disease presence, weather conditions and varietal susceptibility suggest a need.

For winter oats, current recommended practice is to base fungicide spraying action on disease levels determined at GS30-31 and at GS39. Common, and easily identifiable problems at these growth stages include mildew (Erysiphe graminis) at GS31 and GS39 and crown rust (Puccinia coronata) from GS39 onwards. The current Recommended List (NIAB 1988) provides a useful guide to varietal susceptibility to these two major diseases. No clear advisory guidelines or thresholds exist for dealing with other problems which can include:

- General stem base ill-health which can be one of a complex of brown foot rot (Fusarium spp), true eyespot (Pseudo cercospora herpotrichoides) and sharp eyespot (Rhizoctonia cerealis).

- Oat leafspot (Pyrenophora avenae).
- Leaf 'blotch' symptoms due to Septoria and/or Helminthosporium.

Late season CSG-commissioned R & D programme on disease incidence and control in winter oats due to commence in autumn 1988 may provide answers to some of the above 'grey' areas.

For spring oats, there also appears from literature searches to be little critical data available on control of diseases other than mildew. Work at the North of Scotland College of Agriculture in 1974 compared the effect of several fungicides on Septoria. Good control of the disease was achieved with triadimefon seed treatment and this was associated with a significant increase in grain yield.

- 7.22 Two virus diseases are of importance - the aphid transmitted Barley Yellow Dwarf Virus (BYDV) and the soil-borne fungal transmitted oat mosaic virus (OMV). BYDV causes severe stunting and is preventable for winter oats by appropriate and timely aphicide programmes in the autumn. In spring oats, it occurs sporadically, but in some seasons can be serious on a local scale. OMV in Scotland at least, appears to have little significance in the spring oat crop. However, for winter oats, the disease can be a problem. The virus is transmitted by the primitive soil-borne fungus Polymyxa graminis and is usually found in association with a second soil-borne virus, Oat Golden Stripe (OGSV) - the full significance of which is as yet uncertain. There has been frequent reporting of the condition from the counties of Kent and East and West Sussex. Affected plants usually show yellowish flecking of the leaves by the end of March and susceptible varieties normally fail to 'grow away' and remain stunted with yield losses ranging from 25 to 50% in the infected stunted patches. Over the past five years confirmed oat growers have dropped winter oats from their rotations when faced with the evidence of a widespread presence of the virus on their farms. The problem is not necessarily associated with a

history of intensive oat growing. One holding currently cooperating and hosting ADAS trials has the virus as a widespread problem on fields that typically have grown the crop no more than 3 times in the last 16 years.

The Welsh Plant Breeding Station have a breeding interest in the problem and access to an infested site that allows them to identify various levels of sensitivity or tolerance to the virus in their varieties and breeding lines. Rothamsted Experimental Station are developing diagnostic methods for both of the viruses involved (OMV and OGSV). They are also studying the transmission of the virus by the soil-borne Polymyxa vector.

ADAS SE Region Plant Pathology are screening 8 varieties in their 1988 trial at an infected site at East Grinstead in W Sussex. At the practical advisory level it is encouraging that whereas the two old standard varieties Peniarth and Pennal are known to be highly susceptible to OMV, the three provisionally recommended higher yielding varieties Image, Solva and Lustre are rated as having either resistance or tolerance to this virus problem. There is farmer interest in testing the economic significance of these ratings under commercial field conditions.

Pest Control

- 7.23 Oats in common with wheat and barley can be affected by aphids (as vectors of BYDV and direct pests), frit fly, leatherjackets, slugs (usually post-emergence leaf grazing only), wireworms and yellow cereal fly.

Advisory guidelines to pest thresholds and pest control are available for wheat and barley and in practice satisfactorily control the same problems in oats. However, of these pest problems two that can be more serious in oats than in other cereals are BYDV (see above) and the frit fly (Oscinella frit). The third generation of this fly is an important pest in emerging and young shoots of winter cereals. The attack is on the central shoot of the cereal; shoot yellowing and death, and frequently plant death follows. The second generation of this pest can

attack oats when in ear, damaging oat grains and causing either blind spikelets or black shrivelled grains, and it is this generation which has most serious effect.

Frit fly attack on spring oats causes an increase in secondary tillering resulting in uneven ripening, a higher proportion of small grains and loss of yield. The oat plant becomes relatively immune from damage once the 4-leaf stage is reached. Early sowing should ensure that oats reach this stage before the frit fly larvae emerge. In the event of frit fly attack on a backward crop, damage can be alleviated by the use of sprays such as chlorpyrifos or triazophos.

Yields and Yield Variation

- 7.24 Data are available from MAFF, DAFS and H-GCA to illustrate yield and yield variation by time, by country and by region. Winter and spring oat data are not separated in these national statistics. There have been substantial rises in oat yields over the last decade.

For gross margin analysis the Scottish Agricultural Colleges use yield levels of 3.5, 5.5 and 6.5 t/ha to represent low, medium and high yield levels respectively.

Low, average and high production levels for winter oats (for budgeting purposes) are put by Nix (1988) at 4.0, 5.5 and 6.5 t/ha respectively. An average (3 year) yield of approximately 4.9 t/ha is used for budgeting purposes in ADAS (1988).

Nationally, the winter oat crop is more vulnerable than other cereals to two aspects of weather - hard winters and rain, thunderstorms and gales in July to early August. Yield variations will occur according to the incidence of these weather factors.

New oat varieties available show potential for making a significant impact on average yields.

Harvesting and Storage

7.25 The particular problems and considerations here in comparison with other cereals are:

- i) slow, difficult combining in lodged crops and loss of yield from shedding;
- ii) increased drying costs;
- iii) increased bulk and hence cost of storage.

Most winter oat crops have lodged areas by harvest, whilst frequently, harvest problems are exacerbated by green sappy straw at a time when the grain has reached a moisture level suitable for combining.

The bulk density of the oat crop is such that, per tonne stored, it requires 39% and 25% more cubic capacity than wheat or barley respectively. This represents a considerable economic consideration.

The 'sweet smelling' requirement of the milling oat contract requires particular attention to harvesting, drying and storage. Damaged grain that is not properly dried and stored is particularly liable to develop rancidity and produce odours. It is probably safe to assume that huskless (naked) oats will be more vulnerable to skinning and damage by the combine than the traditional husked varieties.

Spring oats are late ripening and harvesting may be beset with problems of slow and difficult combining in lodged crops, loss of yield from shedding and increased drying costs. The timing of harvest is important in relation to quality, in that oats should not be harvested too early. Immature oats, particularly after drying, are more likely to produce off odours. Combine setting needs to be accurate to avoid damaged grain or production of naked oats. In some seasons uneven ripening of the crop may be evident and the use of a desiccant such as diquat may be

justified. Diquat may only be used in oats intended for stock feed.

Conclusions to Chapter 7

Agronomic Limitations of the Oat Crop

- 1) The northern spread of winter oats is limited by winter hardiness factors. Frost heave is a problem on exposed chalks.
- 2) Further expansion of the spring oat crop is severely limited by the lateness of ripening of current varieties. The crop would become more attractive to growers if early ripening varieties, consistent with good yield, were introduced. The requirement for early ripening is particularly important for Scottish conditions.
- 3) The oat crop is very prone to lodging making harvesting difficult and reducing yield (green straw at harvesting is an additional problem for winter oats), again making the crop a less attractive proposition for many growers.
- 4) Oat production is limited by a number of diseases of which for spring oats perhaps mildew is the most important. Control of other diseases affecting oats has not received much attention. Oat mosaic virus is a problem for winter oats, and has resulted in hitherto keen oat growers giving up the crop. The incidence of the problem would increase if the winter oat acreage were to expand notably. Field responses to disease control by fungicides are less than for wheat and barley.
- 5) Of the pests affecting oats, cereal cyst eelworm influences considerations of frequency of oats in a rotation, and this pest could be a potential limitation to future expansion of the crop.
- 6) The wild oat problem is widespread, and would represent a considerable barrier to increased production with the current lack of control. Similarly, control of annual grass weeds is a problem especially black-grass and barren brome for which no herbicides giving adequate control are available.

- 7) Farms geared to cereal seed production are frequently disinterested in oats. Oat volunteers in subsequent cereal crops can cause seed certification problems (because they are occasionally confused with wild oats).
- 8) Production of the spring oat crop is limited by susceptibility to manganese deficiency (and to a lesser extent copper and zinc).
- 9) Organic production of oats may be limited by lack of information on basic technology for this method of production (eg choice of suitable varieties, effective weed control, use of acceptable fungicides, use of foliar feeds, sources of organic nitrogen).
- 10) There is generally a paucity of recent research and development derived information for farmers on oat husbandry, particularly concerning oat quality.

Agronomic Potential of the Oat Crop

- 11) Applying known husbandry to the newer varieties (mainly winter oats) could make a notable impact on average yields.
- 12) The ability to 'fine tune' husbandry for the oat varieties in respect of nitrogen, plant populations, fungicides etc., and having well-researched agronomic recommendations for oat varieties under varying circumstances would give better prospects for higher and more consistent yields.
- 13) Organic production of oats is likely to expand. Oats appear particularly suited to organic production methods. From the aspects of insect, disease and weed control winter oats are likely to be less easily handled in organic systems than the spring crop.
- 14) Depending on price and consumer response, the growing of naked oats could have significant potential.

15) In addition to these areas oats already have advantages which may not be fully appreciated by cereal growers such as:

i) The particular value of oats in a rotation, associated with low risk of eyespot and take-all.

ii) Oats are more reliable than wheat or barley on the wetter less fertile soils and soils of lower pH.

iii) For winter oats, autumn drilling and early August harvest are attractions on heavier land allowing for timely drilling of following crops.

iv) New varieties are now available.

CHAPTER 8 FARM ECONOMICS

Introduction

- 8.1 The reduction in oat acreage over the last 20 years has been largely because the financial returns from growing wheat and barley have been better. This in turn has been largely due to the preferential price support under the CAP for wheat, barley and other competing crops, and to the general 'cinderella image' of oats, with technological advances, research and development of oats having been much less than for the main cereals. For example, Silvey (1986) has estimated that varietal improvements contributed to 44-45% of the observed increases in wheat and barley yields between 1947 and 1983, compared to just 27% in oats.

This Chapter looks at the comparative economics of oat production at present (eg using current yields and prices) and examines the prospects for improving the financial returns through technological improvement such as the development of new oat varieties.

Comparative Economics of Oats Production

- 8.2 The profitability of growing oats is influenced by three key factors: (i) grain yields, (ii) grain prices and (iii) production costs. Each of these factors is examined in turn. Finally, the costs and returns to farmers of producing oats under a range of conditions and circumstances are estimated and compared with winter- and spring-sown varieties of wheat and barley.

Comparative Yield of Oats

- 8.3 Over the period 1982 to 1986, the national average yield for oats was 4.7 t/ha, compared with 5.1 t/ha for barley and 6.7 t/ha for wheat (MAFF, 1987a).

Table 8.1 shows average oat yields in the countries of the UK and compares them to wheat and barley yields. Table 8.2 shows average yields for oats by region for England and Wales.

Table 8.1

Average yields (t/ha) for oats, barley and wheat in England, Wales, Scotland and Northern Ireland during 1982-86.

	Oats	Barley	Wheat
England	5.0	5.2	6.7
Wales	4.4	4.6	6.1
Scotland	4.1	4.8	7.2
Northern Ireland	2.9	4.2	5.2
United Kingdom	4.7	5.1	6.7

Table 8.2

Average yields (t/ha) for oats by Standard Statistical Regions for England and Wales during 1986-87.

Yorkshire & Humberside	5.4	Northern England	4.6
East Midlands	5.2	East Anglia	4.5
West Midlands	5.1	Wales	3.6
South-east England	4.9	North-west England	3.3
South-west England	4.6	England & Wales	4.8

Sources: MAFF (1987b; 1988b).

8.4 A very large part of the explanation for these differences in regional yields probably lies in the regional distribution of winter oats, rather than in climate. Roughly 60% of the UK oat area is planted with winter varieties (Silvey, 1986), which yield on average 0.8-1.0 t/ha more than spring oats (Agro Business Consultants, 1987; Nix, 1987), with the majority of winter oats being sown in England (see Chapter 7).

Thus while soil and climatic conditions may be locally important, at the national level the prime determinant of expected yields is taken to be variety. The yields for winter- and spring-sown oats, barley and wheat assumed in this study are shown in

Table 8.3. A distinction has been made between 'average' and 'premium' yields. The latter have been based on those reported by the National Institute of Agricultural Botany (NIAB, 1988), while the former are intended to represent expected yields under average growing conditions and management. Since national statistics only distinguish between winter and spring-sown crops in the case of barley, 'average' yields have been based on figures employed by Agro Business Consultants (1987) and Nix (1987).

Table 8.3

Projected 'average' and 'premium' yields for winter and spring varieties of oats, barley and wheat (t/ha).

	Winter oats	Spring oats	Winter barley	Spring barley	Winter wheat	Spring wheat
'Average'	5.3	4.5	5.7	4.8	6.8	4.7
'Premium'	6.2	5.7	6.2	5.9	7.5	5.6

Comparative Price of Oats

8.5 Over the period 1981 to 1987, oats have commanded only about 95% of the price for barley and 85% of that for wheat (H-GCA Weekly Bulletin). However, the relative price of oats has fluctuated widely, resulting in significant changes in the relationship between oats and other feed grain prices, as shown in Chapter 9. One of the primary reasons for this is the absence of direct price support through market intervention for oats (H-GCA, 1987). As a result, prices for oats fall sharply during years of high cereal availability, while those for feed wheat and barley are cushioned through intervention buying.

Therefore, the price that oats can expect to fetch, relative to wheat and barley, will depend to some extent on the supply and demand situation in the cereal market. Currently (1988), the prices that growers might expect to receive for oats, barley and wheat of both milling and feed quality are shown in Table 8.4. In each case, the prices given are those before deduction of the

co-responsibility levy of £7.06. These price levels are also reasonably consistent with the long-term price relativities.

Table 8.4

Expected ex-farm grain prices in 1988 for oats, barley and wheat of milling and feed quality (£/t).

	Milling/Malting quality	Feed quality
Oats	102	94
Barley	108	95
Wheat	110	98

Source: Nix (1987).

Comparative Costs of Production

- 8.6 The lower price and yield of oats is, to some extent, offset by (i) higher prices for the straw and (ii) lower growing and harvesting costs. In particular, although the price of cereal straw varies considerably depending on the region and the season, oat straw generally fetches about twice that of wheat and one-and-a-half times that of barley. Thus, the Scottish Agricultural Colleges (1987) report prices of £20, £15 and £10/tonne for oat, barley and wheat straw respectively.

At the same time, the costs per hectare of growing oats tend to be 10-20% less than those for wheat and 5-10% less than those for barley. Estimates of the average costs of seed, fertiliser, sprays and sundry miscellaneous items for winter- and spring-sown crops of oats, barley and wheat are shown in Table 8.5. However, these figures only represent part of the costs of producing grain. To them must be added the labour and machinery costs involved in cultivating and harvesting the grain crop. These are also shown in Table 8.5.

Table 8.5

Production costs per hectare for winter- and spring-sown oats, barley and wheat (£/ha).

	Oats		Barley		Wheat	
	Winter	Spring	Winter	Spring	Winter	Spring
Seed	39.6	52.0	41.8	45.6	43.2	66.0
Fertiliser	58.4	49.6	70.0	58.5	84.6	56.9
Sprays	30.0	22.0	55.0	30.0	85.0	35.0
Sundries	5.0	3.0	5.0	3.0	5.0	3.0
Labour & machinery	168.3	166.1	168.3	166.1	168.3	166.1
Total	301.3	292.7	340.1	303.2	386.1	327.0

In the majority of the years, it will be necessary to dry artificially a proportion of the grain crop. In an average year, Nix (1987) estimates that 67% of the crop will require to be dried. Furthermore, except where the cereal straw is burnt, then baling costs will be incurred. A close correlation between straw and grain yields exists (Gallagher and Biscoe, 1978), so that the expenses of both drying and baling will vary with yields. Based on straw-to-grain ratios reported by MAFF (1984) and drying and baling costs of £5.5/t and £10.7/t (Nix, 1987), the projected costs of handling the straw and grain are shown in Table 8.6 for both 'average' and 'premium' yields.

Table 8.6

Projected average annual costs per hectare for drying the grain and baling the straw for winter- and spring-sown oats, barley and wheat. Costs presented for both 'average' and 'premium' grain yields.

	Yield level	Grain yield t/ha	Drying costs £/ha	Straw yield t/ha	Baling costs £/ha
Winter oats	Premium	6.2	22.8	4.0	42.8
	Average	5.3	19.5	3.4	36.4
Spring oats	Premium	5.7	21.0	3.7	39.6
	Average	4.5	16.6	2.9	31.0
Winter barley	Premium	6.2	22.8	4.3	46.0
	Average	5.7	21.0	4.0	42.8
Spring barley	Premium	5.9	21.7	3.5	37.5
	Average	4.8	17.7	2.9	31.0
Winter wheat	Premium	7.5	27.6	5.6	60.0
	Average	6.8	25.1	5.1	54.6
Spring wheat	Premium	5.6	20.6	4.2	45.0
	Average	4.7	17.3	3.5	37.5

Comparative Profitability of Growing Oats

- 8.7 Based on the yields, grain prices and costs in Tables 8.3 to 8.6, the projected margins per hectare for oats, barley and wheat are shown in Table 8.7. The gross margin¹ is derived by subtracting the co-responsibility levy, together with seed, fertiliser, spray and miscellaneous costs, from the value of the grain and straw. The net margin² equals the gross margin minus the direct labour and machinery costs involved in cultivation, harvesting and drying the crop. The results are presented for both grain of feed and milling quality and for 'average' and 'premium' yields.

¹ The Gross Margin of an enterprise is its enterprise output less its variable costs. Enterprise output includes the market value of production retained on the farm. Variable costs must be specific to the enterprise and vary in proportion to the size of the enterprise (ie. number of hectares). The gross margin is not a profit figure, in that the 'fixed costs' of rent, labour, machinery and overheads have not been taken into account.

² The Net Margin of an enterprise is its gross margin less direct labour, machinery and other 'fixed costs' which can be attributed/charged to the enterprise.

Table 8.7

Projected yields, prices and margins for oats, barley and wheat. Results shown for both winter (W) and spring (S) varieties at two yield levels and two grain qualities.

Crop Variety	Oats		Barley		Wheat	
	W	S	W	S	W	S
'Average' yields						
Grain yield, t/ha	5.3	4.5	5.7	4.8	6.8	4.7
Straw yield, t/ha	3.4	2.9	4.0	2.9	5.1	3.5
Milling quality grain						
Grain price, £/t	102	102	108	108	110	110
Straw price, £/t	20	20	15	15	10	10
Gross margin, £/ha	438	359	464	391	533	358
Net margin, £/ha	214	145	232	176	285	137
Feed quality grain						
Grain price, £/t	94	94	95	95	98	98
Straw price, £/t	20	20	15	15	10	10
Gross margin, £/ha	396	323	390	329	451	302
Net margin, £/ha	172	109	158	114	203	81
'Premium' yields						
Grain yield, t/ha	6.2	5.7	6.2	5.9	7.5	5.6
Straw yield, t/ha	4.0	3.7	4.3	3.5	5.6	4.2
Milling quality grain						
Grain price, £/t	102	102	108	108	110	110
Straw price, £/t	20	20	15	15	10	10
Gross margin, £/ha	536	489	519	511	610	458
Net margin, £/ha	302	262	282	296	362	237
Feed quality grain						
Grain price, £/t	94	94	95	95	98	98
Straw price, £/t	20	20	15	15	10	10
Gross margin, £/ha	486	443	438	434	520	391
Net margin, £/ha	252	216	201	219	272	170

8.8 Concentrating on the comparative net margins per hectare, it is evident that oats are competitive with winter barley and spring wheat, but can be expected to produce margins, which are 5-15% lower on average than those for spring barley and 10-25% lower than those for winter wheat.

However, the immediate prospects for any significant expansion of oats at the expense of spring wheat or winter barley would appear

limited. First, there is probably only about 20,000 ha of spring wheat in the UK (Nix, 1987). Second, as indicated earlier, because of the absence of direct price support measures, annual prices for oats are very much more variable than those for wheat or barley. Thus, at 1985/86 prices, winter barley would have yielded a net margin 5-10% higher than that for winter oats, instead of 5-10% lower as in Table 8.7. Therefore, a switch to winter oats would involve financial risks for the grower. Against this, a limited increase in the oat acreage may be expected in major cereal-growing areas, where oats could conceivably be used as a break-crop to combat the problem of take-all. Experiments at Rothamsted over a 3-year period have shown that the average yield of wheat following oats was 9.5 t/ha, compared to 7.7 t/ha from wheat following barley (Prew *et al.*, 1986). However, in general for oats to displace wheat or barley in a major way, there would need to be an improvement in the financial returns from growing the crop.

Prospects for an Improvement in the Net Margins for Oats

- 8.9 Comparative improvements in the financial returns to oat producers can be attained in three ways: (i) by lowering production costs, (ii) by increasing grain yields, and (iii) by increasing the value of the grain through improvements in its nutritional quality. The last of these objectives may be achieved either by breeding improvements in conventional 'husked' varieties of oats or by switching to newer, and as yet untried, varieties of 'naked' oats (see Chapter 6). The prospects for each of these are explored in turn.

Lowering the Costs of Production - Organic Systems

- 8.10 The opportunities for reducing the costs of growing oats appear limited (they are comparatively low already), unless there is a move away from conventional farming methods towards 'organic' systems of production, in which artificial fertilisers and chemical sprays are dispensed with. Based on unpublished data supplied by N. Lampkin (University College of Wales, Aberystwyth), the comparative costs and returns of growing winter

oats under 'organic' and 'conventional' farming methods are presented in Table 8.8. In each case, the yields assumed are representative of average on-farm levels. Some reduction in labour and machinery costs associated with fertiliser spreading and spraying might be expected with 'organic' farming. However, against this, there must be some allowance for mechanical control of weeds, costing perhaps £14/ha (N. Lampkin, pers. comm.). Thus, the overall machinery costs for 'organic' cereal farming are assumed to be £156/ha. The market for 'organic' oats as a livestock feed is assumed to be extremely limited, and so the profit margins are only shown for grain of milling quality. In the case of organically-grown oats, the profit margin has been estimated including and excluding the price premium of approximately £58/t that the crop may be expected to command (N. Lampkin, pers. comm.). Also shown are the comparable figures for winter wheat, based on data from Nix (1987).

Table 8.8

Comparative costs and returns from typical 'conventional' (Conv) and 'organic' (Org) systems of winter oat and winter wheat production.

Crop Production method	Oat			Wheat		
	Conv		Org	Conv		Org
Grain yield, t/ha	5.3		4.0	6.8		4.0
Straw yield, t/ha	3.4		2.6	5.1		3.0
Grain price, £/t	102	102	160	110	110	165
Straw price, £/t	20	20	20	10	10	10
Co-responsibility levy, £/ha	37	28	28	48	28	28
Seed costs, £/ha	40	44	44	43	53	53
Fertiliser costs, £/ha	58	0	0	85	0	0
Spray costs, £/ha	30	0	0	85	0	0
Sundry costs, £/ha	5	5	5	5	5	5
Gross margin, £/ha	438	383	615	533	384	604
Labour/mach. costs, £/ha	168	156	156	168	156	156
Grain drying costs, £/ha	20	15	15	25	15	15
Straw baling costs, £/ha	36	28	28	55	28	28
Net margin, £/ha	214	184	416	285	185	405

8.11 From Table 8.8 it is evident that 'organic' farming is likely to be a more viable proposition in the case of oats than wheat. Thus, even without a price premium, the net margin for

organically-grown oats is projected to be over 85% of the 'conventional' figure, despite an expected yield reduction of 1.3 t/ha. In comparison, the average net margin for 'organic' wheat only appears to be about 65% of the 'conventional' figure without a price premium. Moreover, where a premium attaches to 'organic' produce, then organically-grown oats would appear to compare very favourably with 'conventional' systems of wheat production. In fact, so long as the price paid for the grain exceeds £130/t, 'organic' oats is projected to be more profitable than winter wheat.

However, the quantities of 'organic' cereals than can be sold on the UK market at a significant price premium are likely to be limited for the foreseeable future. As shown in Table 8.8 without the price premium, the lower yields for organically-grown oats more than offset the lower production costs, so that profit margins are reduced, compared to 'conventional' methods. Furthermore, to maintain soil fertility under 'organic' farming, cereals must be grown in rotation with livestock/forage enterprises, which tend to have low financial returns, depressing the overall net farm income. Accordingly, the prospects for improving the competitiveness of oats through a reduction in production costs seems limited. Nevertheless, oats would appear better suited to 'organic' methods of production than wheat or barley.

Increasing Grain Yields

- 8.12 Based on Table 8.7 and assuming unchanged grain prices, the minimum improvement in grain yields required for winter and spring oats to be competitive with wheat and barley in terms of net margins are shown in Table 8.9. The necessary increases are shown separately for situations involving both 'average' and 'premium' yields, as well as for grain of 'feed' and 'milling' quality. The calculated yield increases allow for both a rise in saleable straw, as well as extra grain drying costs.

Table 8.9

Minimum improvements in yield (t/ha) for winter and spring oats to produce an equivalent net margin per hectare to wheat or barley sown at the same time. Results presented for two yield levels and two grain qualities.

Crop	Yield level	Grain quality	Required yield increase rel. to:	
			Barley	Wheat
Winter oats	Average	Milling	0.18	0.73
		Feed	None	0.35
	Premium	Milling	None	0.62
		Feed	None	0.22
Spring oats	Average	Milling	0.32	None
		Feed	0.06	None
	Premium	Milling	0.35	None
		Feed	0.03	None

In practice, growers are unlikely to switch to oats, unless the crop obviously realises a better margin than the alternatives. How large a financial advantage is required before a switch occurs is difficult to answer, but a realistic figure might be a 10% improvement in the net margin. Ignoring spring wheat because so little of the crop is grown in the UK, the yield increases needed for winter oats to provide a 10% higher net margin than winter barley or wheat are shown in Table 8.10 as are the corresponding yield improvements for spring oats versus spring barley.

Table 8.10

Yield improvements (t/ha) required for oats to produce a 10% higher net margin per hectare than winter barley, spring barley and winter wheat. Results presented for two yield levels and two grain qualities.

Yield Level	Grain quality	Yield improvement relative to:		
		Winter barley	Spring barley	Winter wheat
Average	Milling	0.42	0.50	1.02
	Feed	0.02	0.18	0.57
Premium	Milling	0.08	0.66	0.98
	Feed	None	0.28	0.53

The current gap of 0.9-1.2 t/ha between 'average' and 'premium' yields for oats, shown in Table 8.3, clearly indicates that it

could be relatively easy to lift yields by the 0.1-0.6 t/ha necessary for the crop to be competitive with barley. However, this ignores the fact that the situation is not static and that both wheat and barley yields can be expected to continue rising. Therefore, for oats to become economically attractive, yield increases will have to be faster than those of other cereals. Some impression of the likelihood of this can be gauged from comparison of yields of average farm crops with those for the highest-yielding varieties on the current NIAB Recommended List (NIAB, 1988) for the different cereals. This provides a guide to the current unexploited potential for yield increases.

Such a comparison is presented in Table 8.11 from which it is clear that the gap between average and top yields is significantly greater for oats than for barley or wheat. Thus, compared to winter barley and winter wheat, the current unexploited potential for yield increases is between 0.7 and 0.9 t/ha greater for winter oats. On the other hand, for spring oats the gap between average and top yields is more like 0.4 t/ha greater than for spring sown barley. All this would suggest that there is a greater immediate prospect for increasing on-farm yields of oats than those of other cereals.

Table 8.11

Comparison of average farm yields with the yields of the top varieties on the 1988 NIAB Recommended List for oats, barley and wheat (t/ha).

	Winter oats	Spring oats	Winter barley	Spring barley	Winter wheat
(1) Top NIAB varieties	7.0	6.1	6.5	6.0	7.8
(2) National average	5.3	4.5	5.7	4.8	6.8
(3) Difference (1)-(2)	1.7	1.6	0.8	1.2	1.0

Improving Grain Quality of 'Husked' Oats

8.14 Breeding for improved grain quality can be expected to increase overall returns to oat growers by improving the value of the grain. In the absence of yield increases, the minimum improvements in grain prices required for winter and spring oats to yield net margins 10% higher than those currently projected

for wheat and barley (Table 8.7) are shown in Table 8.12. Again it is assumed that, unless oats provide at least a 10% better margin than alternative cereal crops, they will not be sufficiently attractive for any substantial switch in acreage to occur. From Table 8.12, it can be seen that, in relative terms, the price of oats needs to rise by between £1-8/t to be economically attractive relative to winter barley. The corresponding improvements required, relative to spring barley and winter wheat, are £4-11/t and £8-19/t respectively.

Table 8.12

Minimum improvements in the grain price (£/t) for winter and spring oats to produce a 10% higher net margin per hectare than wheat or barley. Results presented for two yield levels and two grain qualities.

Crop	Yield level	Grain quality	Required price increase rel. to:	
			Barley	Wheat
Winter oats	Average	Milling	7.8	18.8
		Feed	0.3	9.7
	Premium	Milling	1.3	15.5
		Feed	None	7.6
Spring oats	Average	Milling	10.8	1.2
		Feed	3.6	None
	Premium	Milling	11.2	None
		Feed	4.4	None

8.15 In particular, improvements in both the metabolisable energy (ME) and crude protein (CP) contents of the grain are likely to increase its value as a livestock feed (see Chapter 4). Any increase in the price paid for oats of feed quality will affect average returns to growers. Chapter 6 discussed the prospect of improving the nutritional value of oats by plant breeding, and concluded that oats appeared to have significant potential for such improvement and possibly greater potential than wheat and barley.

Assuming improvements in energy and protein content, through plant breeding, of 10 MJ/kg DM and 35 g/kg DM respectively, this implies anticipated target ME and CP values of oats of 13 MJ and 140 g/kg DM respectively. The expected increase in the market

value of oats resulting from such improvements are presented in Table 8.13. This shows the projected increase in market price per tonne, as a result of improvements in ME content ranging from 0.25 to 1 MJ/kg DM and in CP content from 10 to 35 g/kg DM. The effect of combined improvements in energy and protein content on price appear simply to be additive. Details of the method used to forecast the price increases are contained in Appendix 8.1.

Table 8.13

Value added (£/t) to oats through various increases in the metabolisable energy (ME) and crude protein (CP) content.

ME improvement MJ/kg DM	Value added £/t	CP improvement g/kg DM	Value added £/t
0.25	1.5	10	0.40
0.50	3.4	20	0.80
1.00	7.1	35	1.40

Compared to price increases of £0.3-4.4/t required to make growing oats for livestock feed economically attractive with winter or spring barley (Table 8.12), the projected increases in grain prices through immediately foreseeable improvements in ME content of oats appear significant. On the other hand, improving the ME value of oats by 1 MJ/kg DM would appear inadequate on its own to make winter oats an obvious competitor to winter wheat, which requires a minimum price increase of £10/t.

Prospects for 'Naked' Oats

8.16 Naked or huskless oats are a form of oats in which the grain threshes free from the husk. The resulting grain has a higher energy and protein content than conventional 'husked' oats as discussed in Chapter 6. Table 8.14 shows the comparative nutritive value of naked oats and husked oats (and wheat and barley) used in the economic assessment of naked oats.

Table 8.14

Comparative nutritive value of naked oats, husked oats, barley and wheat.

	Naked oats	Husked oats	Barley	Wheat
Metabolisable energy, MJ/kg DM	14.7	12.0	12.8	13.6
Crude protein, g/kg DM	119.0	105.0	128.0	123.0
<u>Essential amino-acids</u>				
Lysine, g/kg DM	5.0	4.3	4.5	3.4
Methionine & cystine, g/kg DM	6.2	3.7	5.2	4.3
Threonine, g/kg DM	3.9	3.7	4.5	3.5
Tryptophan, g/kg DM	1.5	1.2	1.8	1.6

Sources: Values for metabolisable energy and crude protein are taken from MAFF (1986), while figures for amino-acids are based on Lasztity (1984).

The likely costs and returns to growers from naked oats are shown in Table 8.15. Since the immediate market for the grain is as an animal feed, attention has been confined to assessing the economics of growing it for feed. As none of the crop is currently traded, the grain price has had to be based on commercial assessments of its market value and on projections by Doyle and Valentine (1988). Using the technique outlined in Appendix 8.1, Doyle and Valentine (1988) estimated that naked oats should command a price premium of about £16/t compared to feed quality wheat, implying a price of £114/t for naked oats. This projection is in fairly close agreement with assessments made in 1987 by three UK feed companies, who anticipated that the grain should fetch between £12 and £25/t more than feed wheat. The grain yields for winter and spring varieties are based on the results recorded by the Welsh Plant Breeding Station for Kynon during 1985-86 and Rhiannon during 1982-83 respectively (J. Valentine, pers. comm.). Finally, the production costs used are those reported by Nix (1987) for conventional 'husked' oats.

Table 8.15

Projected costs and returns from growing winter and spring naked oats.

	Winter	Spring
Grain yield, t/ha	4.8	4.0
Straw yield, t/ha	3.1	2.6
Grain price, £/t	114	114
Straw price, £/t	20	20
Co-responsibility levy, £/ha	34	28
Seed costs, £/ha	40	52
Fertiliser costs, £/ha	58	50
Spray costs, £/ha	30	22
Sundries, £/ha	5	3
Gross margin, £/ha	442	353
Labour & Machinery costs, £/ha	168	166
Grain drying costs, £/ha	18	15
Straw baling costs, £/ha	33	28
Net margin, £/ha	223	144

8.17 Based as they are on experimental yields, the net margins in Table 8.15 strictly need to be compared with those calculated for 'premium' yields of husked oats, barley and wheat of feed quality, given in Table 8.7. The minimum improvements in yield or grain price required for winter- and spring-sown naked oats to be competitive with the other cereals are presented in Table 8.16. Again, it is assumed that for the crop to present an obvious economic attraction to growers, it must realise a net margin 10% higher than the alternative crop. From Table 8.16 it is evident that winter naked oats probably represent an attractive alternative to winter barley at current yield levels. However, to compete with winter varieties of conventional (husked) oats or wheat, yields would need to rise between 0.5 and 0.75 t/ha. On the other hand, yields of spring naked oats need to be increased by around 1 t/ha to be of real interest to growers.

Table 8.16

Minimum improvements in yields (t/ha) and grain prices (£/t) for winter- and spring-sown naked oats to realise a 10% higher net margin than husked oats, barley or wheat of feed quality. Results presented for 'premium' yields.

	Winter naked oats	Spring naked oats
Yield improvement required (t/ha) relative to:		
husked oats	0.50	0.86
barley	None	0.89
wheat	0.70	0.39
Price improvement required (£/t) relative to:		
husked oats	11.3	23.4
barley	None	24.2
wheat	15.9	11.0

8.18 However, the prospects for increasing both the yield and nutritive value of naked oats (see Chapter 6) are considered significant (Doyle and Valentine, 1988). Through the use of the existing variation available in husked oats, it may be possible to increase yields to levels similar to those of husked oats in a relatively short time. This would imply raising yields of winter and spring naked oats by between 1.4 and 1.7 t/ha, which would be more than sufficient to make the crop competitive with alternative cereals.

In the longer term, Chapter 6 discussed possibilities for significantly improving the energy (ME) and crude protein (CP) values of the grain. It is considered that CP levels could be raised to 260 g/kg DM (Pomeranz *et al*, 1973; Thomas *et al*, 1980) and the ME content to 15.7 MJ/kg DM (Frey and Hammond, 1975). These figures compare with the current CP and ME contents of 120 g/kg DM and 14.7 MJ/kg DM. Already, a spring variety of naked oats (Rhiannon) has been bred, which has a crude protein content of 150 g/kg DM. However, improvements in the nutritive value of naked oats on their own are unlikely to be sufficient to make the crop an attractive alternative to spring barley or husked oats. Estimates made by Doyle and Valentine (1988) have indicated that a combined improvement in the ME content of the

grain by 1 MJ/kg DM and in the CP content by 100 g/kg DM would increase the potential value of the grain by about £14/t. This compares with the projected necessary price increases (see Table 8.16) in the absence of yield improvements of £11-24/t.

Conclusions

- 1) In terms of net margin per hectare, at current prices and average yields, oats appear to be competitive with winter barley (feed quality) and with spring wheat. For 'premium' yields, the net margin of winter oats appears higher than the net margin for winter barley (at 'premium' yields) for both milling and feed quality grain.

However, despite this, the acreage in oats is continuing to decline. This may partly be attributable to the fact that, because there is no direct price support for the crop, the price of oats is very much more variable than that of wheat or barley. Therefore, there are greater financial risks in growing the crop.

- 2) It is likely that, for oats to displace wheat or barley in a major way, there would need to be an improvement in net margins to growers by between £20 and £100/ha. This could be achieved by (i) lowering production costs, (ii) increasing yields or (iii) improving the value of the grain.
- 3) Opportunities for lowering production costs for oats seem limited, unless there is a switch to 'organic' farming. The returns from 'organic' oats compare favourably with those for conventionally-grown cereals, including winter wheat. However, the quantities of 'organic' produce that can be currently sold on the UK market at a sizeable premium are probably limited and without that premium 'organic' farming is unlikely to be economically attractive. Furthermore, the high net margin from 'organic' oats hides the fact that to maintain soil fertility only about 50% of the area of the farm can be in cereals in any year. The remaining 50% must be in forage or livestock enterprises which may realise comparatively poor returns under 'organic' farming.

- 4) Assuming that the immediate prospects of increasing average oat yields by up to 0.6-0.7 t/ha seem reasonably good, such a yield improvement would be sufficient for oats to show at least a 10% better net margin than winter- or spring-sown barley.
- 5) There are also fairly good prospects for improving the market price that oats would fetch by improving the nutritional value of the grain. This could be achieved either by breeding varieties of conventional 'husked' oats with a higher energy and protein content or by investing a greater breeding effort in the new, and as yet, untried varieties of 'naked' oats. The advantage of the latter is that they have a very much higher energy and protein content than 'husked' oats. Against this, the grain yields of naked oats are lower. However, if plant breeding could raise 'naked' oat yields by 1 t/ha, then 'naked' oats would realise better returns than even winter wheat.

CHAPTER 9 MARKETING, POLICY AND TRADE

Introduction

- 9.1 This Chapter aims to review and assess the marketing structure for oats, and the policies affecting oats, particularly in comparison to other cereals in the UK. Possible means of improving marketing and possible policy changes beneficial to oats production and utilization are briefly explored. In addition, potential opportunities for trade are considered.

The Oats Marketing System

- 9.2 Figure 9.1 contains an outline of the channels through which oats from the 1986 harvest passed during the 1986/87 marketing year, the last for which full data was available. The system starts with the manufacturers of farm inputs, included as the initial feature of the production of the crop. There appears to be little restriction on the availability of these inputs, although the availability of new varieties of seed may provide some restriction on the uptake of innovation.

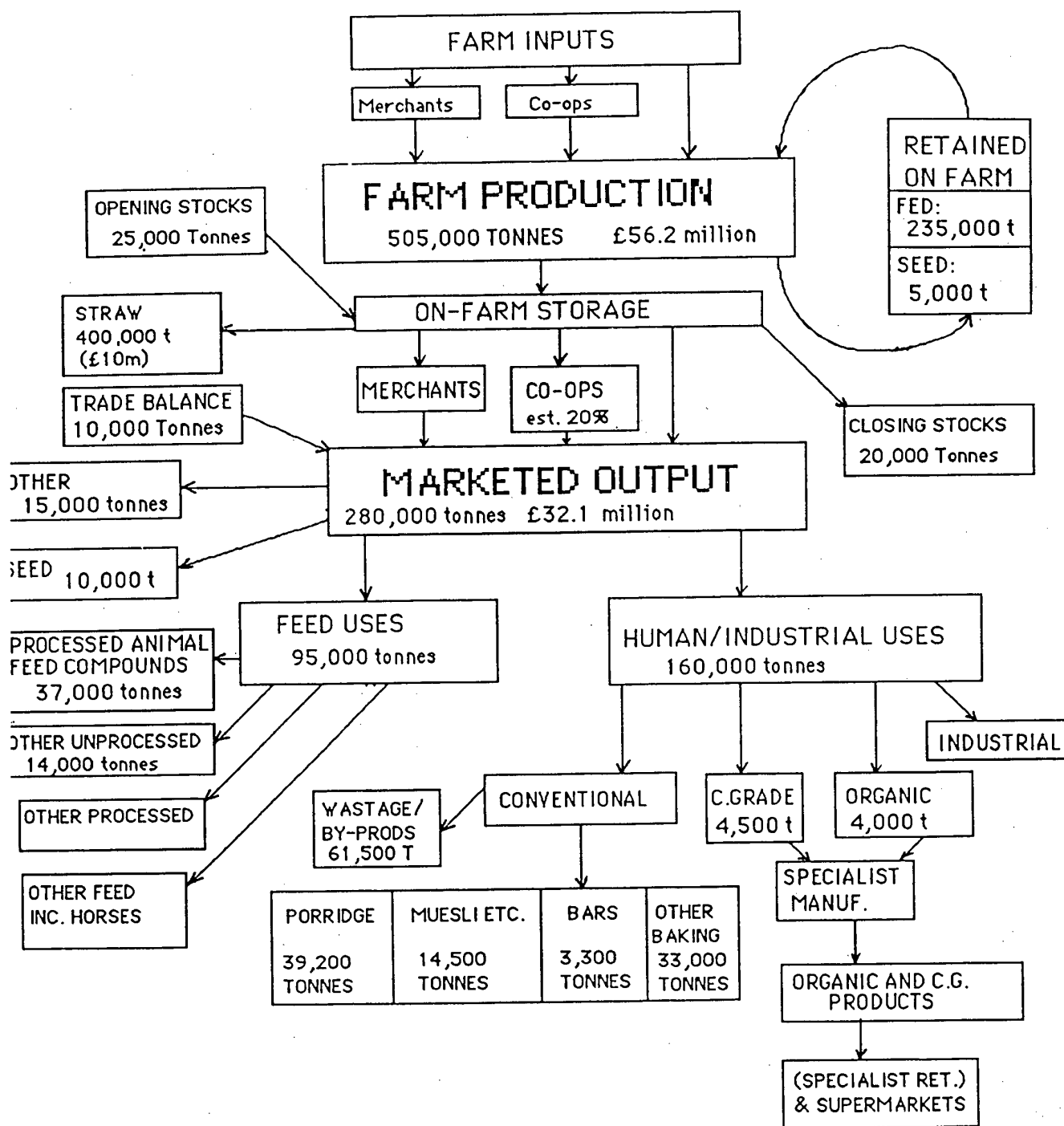
For the 1986/87 year, there was a substantial level of stocks from the previous crop, and these added to the total UK availability of grain. These stocks complicate the issue of reconciling the total UK production figures, trade balances and closing stocks, particularly as some data is quoted for Great Britain only.

In general terms, about half of the 1986 crop was marketed from farms, leaving about 240,000 t retained and used as feed or seed. The majority of this tonnage is used for feeding to animals. There are, however significant differences in the quantities grown each year, and therefore in the total amounts marketed, although the proportion tends to remain at approximately half the tonnage available.

The remainder of the crop is used primarily in the milling sector, with a smaller amount incorporated in mixes by animal

Figure 9.1

THE U.K. OATS MARKET (1986/87
MARKETING YEAR)



(Numbers may not reconcile
due to roundings and
estimates)

Sources: HGCA
MAFF
Elm Farm R.C.
Trade Sources

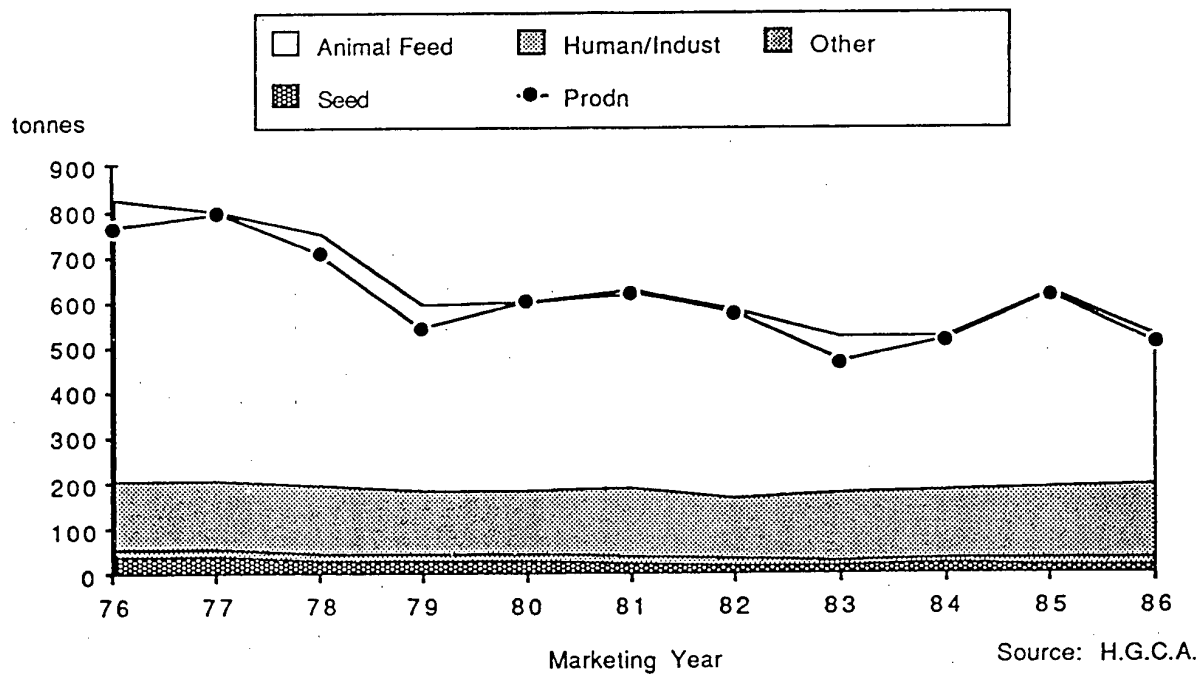
feed compounders. The balance between the human/industrial usage and the use in compound feed is generally dictated by the price of the crop, with around 160,000 t purchased by millers, but the purchases by compounders varying greatly according to the relative value in least-cost terms. Figure 9.2 illustrates the changing trends in oats usage, with the downward trend in production largely absorbed by the feed market, both on-farm feeding and that used by compounders.

- 9.3 The distribution system for that part of the UK oats crop which is marketed is similar to that for other grain crops, with a proportion passing direct from farmer to end-user, with transport provided either by the farm business or the buyer, and the balance using traditional merchant or co-operative merchant channels. A problem voiced by some merchants is that the total quantity of oats available, and amounts from individual suppliers, tend to be relatively small, and are not necessarily suitable to their large-scale automated units and storage volumes. It is possible therefore, that new technological and varietal developments will be accepted by, and tested through the smaller merchants and feed compounders.

A variant of this problem also applies to potential growers of the crop, who must make decisions regarding their own distribution of grain. For example, the Scottish oat-growing sector is constituted by farmers with an average 7 ha under oats; at a yield of 5 t/ha, this represents a farm crop of 35 t which again may be economically unviable with respect to storage and distribution. The balance of the tonnage to the human and industrial market is currently wholly absorbed by products for human consumption, but the industrial market is a possible area for increased usage of the crop in the future. Within the milling process for products destined for human consumption, there are losses and wastage, and approximately 40% of the original tonnage reappears as oats by-products.

A small proportion of the tonnage for human consumption by-passes normal channels and is incorporated in products labelled as organic or conservation grade. There are conflicting standards

Figure 9.2 Changing trends in oats usage.



for organic produce, but at present the estimated market is a very small part of the total recorded. The conservation grade standards are less stringent but retain an appeal to consumers. The total tonnage is again small at present.

- 9.4 The total oats market is small, with the 1986 harvest realising an approximate value of £56.2 million. This is in contrast with wheat (£1,548.8 million) and barley (£1,092.6 million). In addition to grain sales, some 400,000 t of oats straw was marketed in 1986 (the straw is a useful feed ingredient), with a value of £10 million.

The relative importance of trade is described elsewhere in this report, but exports of the 1986 harvest were negligible (5000 t), and imports were at a relatively low level. These imports vary according to the quality and quantity of home-produced grain available, although a proportion of them are represented by imports of high value oats (particularly from Australia) for feeding to racehorses. In the 1987/88 marketing year, a significant tonnage was also imported from Eire to Northern Ireland.

Marketing of Oat Products

- 9.5 Oats can be nominally divided into only two classifications, representing crop suitable for milling, and that useful only as animal feed. There is considerable blurring of the boundaries between these uses, both with respect to specialist feed crops such as oats fed to racehorses, but also due to the differing quantities of the various qualities available in any one marketing year, dictating perhaps the relaxing of standards of millers if enough of the highest quality grain is not available.
- 9.6 In general oats for human consumption - the premium market - should be clean plump grains, of good colour, of high bushel weight (about 50kg), and of not more than 14% moisture when sent for milling. There are no specific requirements in terms of oil and protein content although some users prefer lower oil content particularly for the manufacture of oat flour. Users themselves

stress that specification tends to be more subjective than that for wheat or barley. The largest UK oat millers are Quaker, Morning Foods and Jordans.

As seen from Chapter 3, the human market is characterised by a changing emphasis in usage from traditional breakfast cereals and oatmeal biscuits, to one where modern equivalents such as mueslis and cereal bars are becoming increasingly popular with consumers. Research by millers and bakers seems to suggest that the taste and flavour characteristics of oats are important to consumers, as is the healthy image associated with cereal grains. Figure 9.1 shows the approximate breakdown of the use of milled products and indicates that in fact porridges still make up the bulk of the tonnage taken, due to the fact that the oats are not combined with other cereals (and fruit etc.), as is the case with mueslis. The tonnage registered as 'Other Baking' is primarily made up of biscuits, with a small amount used in specialty breads and other products.

The organic and conservation grade products are an increasing feature of the market for human consumption, although as evident in Figure 9.1, the quantities are small at present. These products appeal to consumers concerned about the environment as well as the additives and residues present in many foods. The organic/conservation grade oat market is dominated at present by two millers, Wm. Jordan (Millers) and Morning Foods Ltd. This market is currently growing, from a small base, with the 4000 t registered as organic including those farmers in transition to full organic status.

- 9.7 Oats used for animal feedingstuffs can be divided into two sections - that used on the farm where it is produced as part of a mixed farming operation, and that used by animal feed compounders as part of their mixes.

The crop retained on farms has declined with the decrease in oats production, but some producers maintain that oats fed to livestock have properties which the alternatives lack. Some sheep producers in particular, seem to consider oats as a useful

feed for their animals, although as described in the section on 'Prices', farmers do appear to vary the quantity they retain for home feeding, depending on the prevailing market price for feed oats. A small (non-random) sample of oat growers questioned backed up this assertion by stating that although they found it a comparatively difficult crop to store, they maintained its usage in rations, particularly for young cattle and sheep.

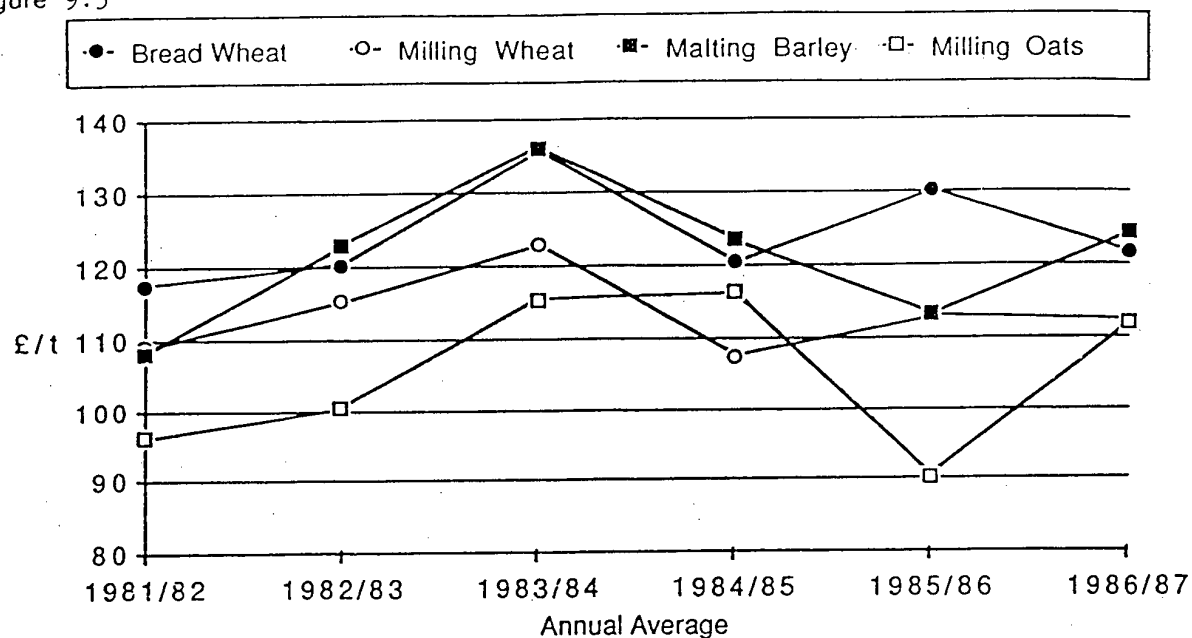
Oats purchased by feed compounders are either used in conventional least-cost rations where their relative value as a feed ingredient is considered in terms of their price relative to other possible ingredients in the ration, availability, and economics of handling, or as a vital part of coarse mixes. It is in this latter use that the oats portion of the mix is particularly relevant, as the visual appeal of the feed to the buyer represents perhaps the unique selling point of the product. Inclusion of oats in the mix lends important visual and textural signals to the perceived quality of the feed. This market is characterised by individuals buying through local outlets in small (eg. 25kg bags) quantities, for feeding particularly to small animals, horses and ponies.

Oat Prices

- 9.8 The system of prices for oats is particularly governed by two factors, notably the lack of intervention support under the CAP in a grain market otherwise characterised by such support, and the comparatively small proportion of the total crop tonnage that is marketed through conventional channels. As explained above, typically nearly half of the crop is retained on farms for feeding to farm livestock, thus by-passing such channels where 'market' prices might be recorded. The 52% of oats marketed in 1986/87 contrasted with 63% for barley, and 85% for the wheat crop.

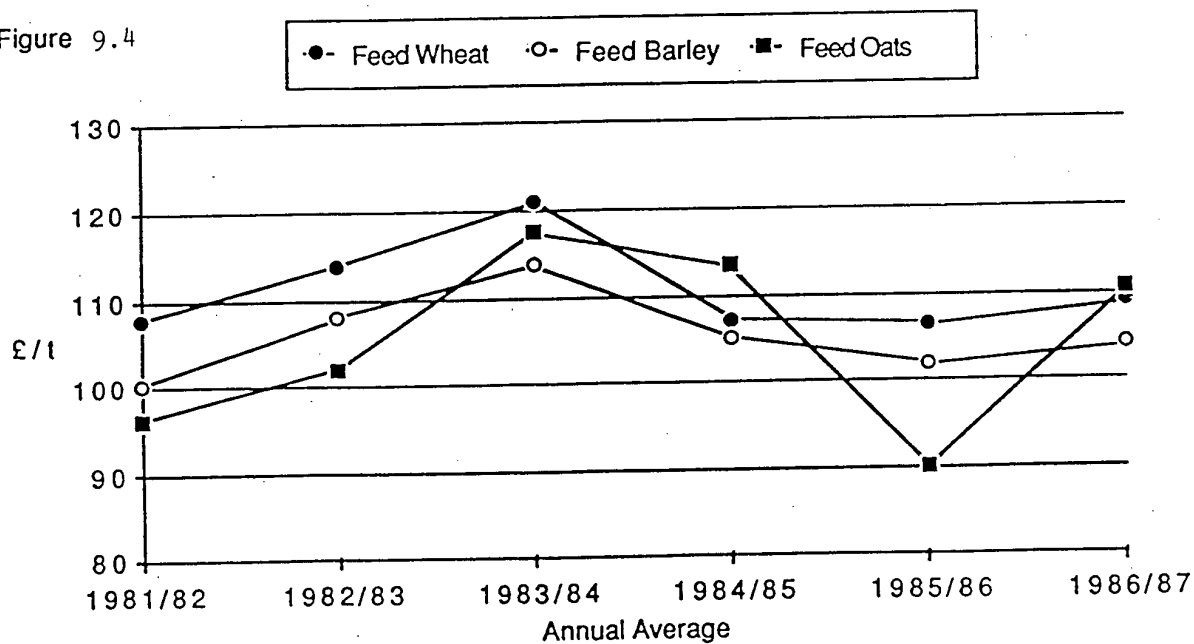
Figures 9.3 and 9.4 show price trends for oats over the 1981/82 - 1986/87 period, with those of wheat and barley shown for comparison. It seems that the price of milling oats has tended to be less than that for malting barley or milling and bread

Figure 9.3



Source: H.G.C.A.

Figure 9.4



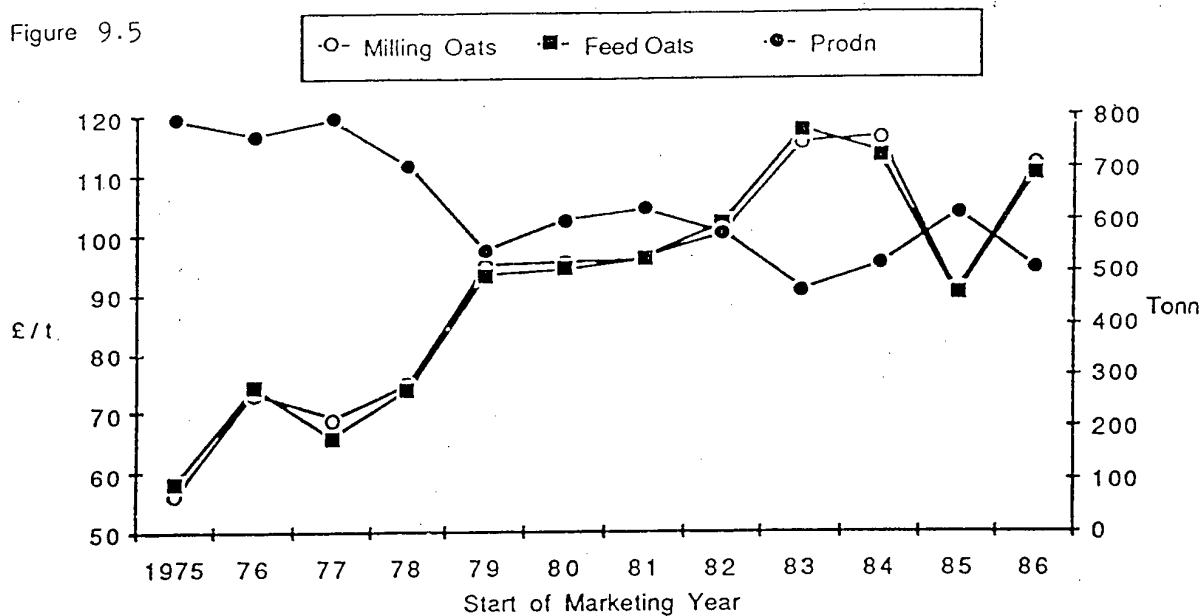
Source: H.G.C.A.

wheat (although this does not include the price of oats grown on contract). The price of feed oats however, appears to be higher than feed wheat or barley in some years and lower in others. Perhaps surprisingly, Figure 9.5 shows that milling oats do not appear to command a significant price premium compared to feed oats. Of the average yearly prices from 1981/82 to 1986/87 years, the price of milling oats has been above that of feed oats four out of seven years, with an insignificant average premium over feed oats over the period (0.4%). This may well be due to the main premium prices being paid by millers with direct contracts with oat producers. Figure 9.5 also shows that oat prices tend to vary considerably with the quantity of crop on the market.

Annual average oats prices, as shown in Figures 9.3 and 9.4, tend to move in similar trends to the nominally equivalent grades of wheat and barley, although it is important to note that the swings in price tend to be of rather higher order than those for the other products. This is a critical difference between the oats crop and the other cereals, which have a floor price to support them and therefore do not experience such variable price levels from year to year. There is inevitably a seasonal trend to prices which is presented as Figure 9.6, and certain users of the market also referred to the activities of speculators distorting some of the more predictable price rises through the marketing season.

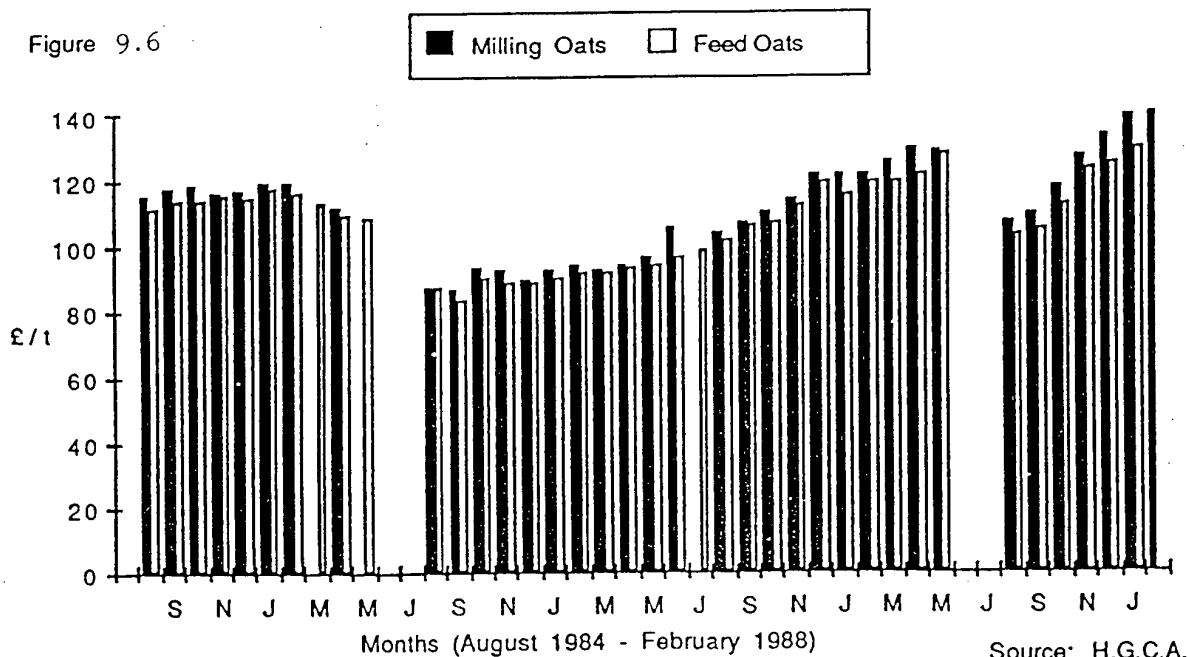
- 9.9 The question arises as how and to what extent do these price trends and variations affect producers' decisions to grow oats. In an attempt to provide some clue to this, a brief empirical analysis of the determinants of area planted was conducted. MAFF average weighted ex-farm prices over a twelve-year period were deflated using the index of agricultural input prices and compared with figures for total oats hectares planted. These plantings areas were calculated using H-GCA data displaced by one year, to determine whether average prices in the 'previous' year had an effect on the area planted in the 'current' year. The plantings areas were converted to an index representing the area after the removal of the long-term downward trend effect of

Figure 9.5



Source: H.G.C.A.

Figure 9.6



Source: H.G.C.A.

declining oats hectarages. The results of this analysis are presented as Appendix 9.1.

In general, it appears that changes in area planted are dependent not so much on the absolute level of oats prices in any previous year, but rather on the relative price premium or discount shown by oats in relation to wheat and barley. This is naturally to be expected where crops are, in growing terms, reasonably good substitutes for one another.

Price and demand

- 9.10 The demand for oats from farmers, millers, and animal feed compounders apparently show significantly different characteristics. In interviews (the small sample referred to above), those farmers wishing to keep grain on the farm for home-feeding show signs of a fairly elastic demand for oats of feed quality, as they tend to decide how much of the crop to keep depending on the prevailing market price. Commercial animal feed compounders voice a similar view of a relatively elastic demand for oats, dictated by the technical considerations of their least-cost ration formulation techniques, where relatively small variations in price will render the crop more or less attractive compared to the available alternatives. The one market, accounted for to some extent by imported grain, where normal price signals are apparently not of consequence, is the racehorse market, where users are prepared to pay up to £200/t for their supplies. There may be a possibility for some important substitution in this market, although the value of the 'final product' may be such that input prices are of little consequence. Recent evidence from Canada suggests that racing performance on the various feeds available may be the final arbiter of demand (Financial Times, 1988).

Trade sources in the milling sector suggest that for this (milling) outlet, the user is again rather more concerned with the quality and appearance of the grain than with its price. The miller is generally manufacturing a product with high added value, and in some circumstances the oats component of the final

product may be relatively small. Thus some users suggested that the prices for milling oats indicated in published statistics in fact undervalued the true payments made to producers who met the standards required. With an increasing demand for oats of milling quality, and a limited increase in supply (also subject to year on year fluctuation), the competition between buyers can become intense, and thus the demand for this part of the crop is relatively inelastic.

Contracts

- 9.11 Part of the reason for this possible understatement of true milling prices is that a proportion of the milling crop effectively passes directly from producer to buyer, via a contract between the miller and the producer. These contracts are set in a number of ways, depending on the miller, but generally refer to an estimated volume (often related to hectarage), on some agreed price basis. The ultimate price received by the producer will depend on the quality of the grain supplied, and the availability of such supplies at the time of marketing.

Contract terms dictate the basis for pricing the oats, and fall into three main categories. Oats can be priced according to some premium over the prevailing H-GCA market prices at the time of the sale, with the farmer making some prior commitment to supply to a certain market. Timing of delivery may or may not be included in such a commitment. Some contract prices relate to the prevailing price of another crop, usually barley, again offering a premium (or discount). Other contracts are fixed at a set price. These set-price contracts apply to the crop for all uses, but particularly for the specialist organic and conservation grade purposes, where recent prices of up to £200/tonne for good quality organic oats were quoted, due primarily to competition for limited supplies.

Companies differ in their sources of supply under contract arrangements, although the large millers tend to procure their requirements from all parts of the UK (with contract terms

reflecting the costs of distribution). Apart from the specialist markets, there appears to be no consistent pattern of farm size or type. Generally farmers experienced in growing the crop are encouraged to enter into contracts, in an attempt to ensure a reasonably consistent supply of quality oats, even in poor growing seasons. Most millers are attempting to encourage farmers in the growing of the crop, particularly with the provision of information on production and marketing. This might also limit the problems suffered by millers who have contracted to farmers for certain tonnages and who then experience problems of varying supply - either by farmers not producing the required tonnage, or by them finding improved markets elsewhere and reneging on the quantity they declare available.

- 9.12 Trade sources in the milling sector express the view that the price pattern between years for the crop is one of the major problems with regard to its orderly production and marketing. As described above, the prospective grower must decide the acreage to plant in the light of limited market information, and an evident history of price fluctuation. In a market where supply and demand are in relatively close balance, these price changes do lead to significant shifts in supply, and therefore uncertainty for millers. A general strengthening of market volume, in both feed and milling uses, would induce more confidence and stability in producers and users.

Marketing Arrangements for other Cereals

- 9.13 This is a brief description of the marketing system for cereals other than oats, to enable comparisons to be made between the arrangements for the oats crop and its near-competitors.

The main marketing difference between the other cereal crops (wheat and barley), and the oats crop is one of scale. The 1986 oats harvest of half a million tonnes is dwarfed by the production of wheat (13,910 mt) and barley (10,015 mt), and indicates the position of oats as a minor crop in the UK. It is largely due to these scale differences that the marketing arrangements for wheat and barley are relatively more advanced

than those for oats. Wheat and barley crops have the benefit of EC support regimes to maintain a greater stability of price, and prospective growers tend to be able to make decisions on a rather firmer price base than for the oats crop. The influence of trade, particularly in the availability of alternative markets via UK ports is also an important feature of the market of the two main grains, which exists in very small measure for the oats market.

- 9.14 The other influences of scale relate to the physical, financial and informational handling of the crops. For wheat and barley, the major distributive networks are all available, with large volumes suiting both capital-intensive conventional merchants, and also co-operative agencies, able to offer incentives in the form of pooling arrangements or payment terms that would not be applicable to smaller volumes. Futures markets around the world deal in the major feed grains, aiding producers, traders and buyers in their decisions regarding sale and storage of the commodity. The small volume of oats traded in the UK mitigates against the economic viability of such a facility. Market information for the major grains is voluminous and regular, whereas for the oats crop in the UK information on prices, stocks and production volumes is not reproduced as frequently, thereby representing a further source of inefficiency in the orderly marketing of the crop. Economies of scale in the dissemination of information perhaps dictate that oats are covered less comprehensively.

In comparison with the other grains, a rather greater proportion of the oats crop is retained on farms, with only 15% of wheat and 37% of barley retained in 1986/87. Both are also major components in compound animal feeds, and the volume available ensures economies in storing and using the product in automated feed mills.

Alternatives for the UK Oats Market

- 9.15 It is considered important for a review of this sort that a number of alternative possibilities for the improved marketing of

oats in the UK are considered. The notion of an 'improvement' in the marketing of an agricultural product has been extensively discussed elsewhere (Pickard, 1982; Warren, 1985), but the context in which the phrase is used here is that it is apparent that the market for oats suffers from inefficiencies in areas of production volumes, prices, and information dissemination, and that therefore consideration should be given to ways of overcoming these problems.

Marketing Board

- 9.16 A marketing board is defined as 'a compulsory horizontal marketing organisation for primary and processed natural products operating under government delegated authority' (Hiscocks, 1972). The marketing boards which currently exist for other products, particularly those for milk and potatoes, were set up under Government legislation to represent producers and have various considerable powers to influence the market for the product concerned. Such organisations are not currently under consideration and indeed Barker (1981) suggests that '....the heyday of the Marketing Board is past...', partly due to the opposition to Boards from the EC Commission. However, a form of compulsory co-operation such as a marketing board would render the net scale of producers relatively larger, and as such would furnish them with greater powers to bargain with their buyers. This would not, however, overcome the fact that for animal feeding the variety and type of competition is such that prices could not be bid up relative to the other sources of supply. In the milling sector, the competition that currently exists seems to suggest that farmers able to produce for this market are receiving satisfactory prices in any case, and that increased bargaining power may not be an issue.

The one important feature of such an organisation that would favour its introduction would be if it had powers to stabilise price, through policy instruments assigned to it. This would be beneficial to the entire market, and should lead to an improvement in the year to year supply balance. However, the current scale of the market would suggest that a marketing board

would be neither economic nor effective, and although in Canada for example relatively small boards do exist (Nova Scotia Grains MB 1986 turnover CAN\$2million), their functions are perhaps rather less comprehensive than a full-scale market intervention agency such as the Milk Marketing Boards in the UK. As oats is also a relatively easy crop to grow at short notice, with close production substitutes, there is unlikely to be consensus of regular producers to recommend or maintain its institution.

The advantage of a monopoly organisation of some description is that, given the legislative powers to prescribe policy, such an organisation is in a good position to instigate and enforce such measures as are required. In this way, measures such as the formal linking of the oats price to that of another crop (to avoid fluctuations related to price premia/discounts), intervention (in the form of guaranteed prices and buffer stocks) or advanced price fixing (to even out production decisions and therefore supply), could be relatively easily policed.

A similar (but definitionally distinct) type of organisation is described below.

The Home-Grown Cereals Authority

- 9.17 The H-GCA was set up in 1965 with a brief to '...encourage more orderly marketing...' and to '...help achieve fair and reasonable market prices...', and has limited powers to enable it to carry out these functions.

The provision of market information has been mentioned above as an important feature in the process of 'orderly marketing' and certain farmer-interviewees felt that oats have been neglected in this area. Again, the influence of the policy environment is important here, and consideration of the Authority's powers to publish guide prices and forward contract details (not operated since 1974) would be appropriate. It seems that the EC intervention arrangements for the major feed grains has made publication of such information unnecessary, but it should perhaps be considered for the oats crop, to give producers

incentives to plant consistent quantities and thus contribute to the stabilisation of the market.

There is evidence that the Authority is showing some renewed interest in the oats crop at present with the sponsoring of research and development work, which will ultimately improve the marketing prospects for oats. In considering the organisation in comparison to a marketing board with stronger legislated powers, Barker (1981) feels that '...the success of the Commissions in improving the marketing of commodities is unlikely to have been surpassed by the alternative of producer marketing boards.'

An Oats Futures Contract

- 9.18 The London Grain Futures Market operates an environment for the trading of futures contracts for wheat and barley (and other agricultural products). The mechanism of the futures market can help producers and buyers stabilise their respective incomes by hedging against their prospective physical trades, and can therefore protect producer incomes on those crops traded. This would be an important benefit for the oats market, enabling producers particularly to better judge the future returns to them from growing oats. There are several factors, however, which mitigate against the successful introduction of such a market.

One of the main requirements for a futures market is a high volume of trade, for efficient operation and economies of administration and delivery, and the oats market in its current form could not provide this. There also seems to be some delay in farmer adoption of such innovations (Sheldon, 1986), and the volume of each contract would have to be relatively small (possibly around 20 t) to enable the average oats producer to make use of the market. Such markets are also benefitted by the activities of speculators who might not be attracted by relatively low value contracts, although conversely the relative variation of prices in the oats market might be attractive. There is currently an oats contract traded at the Chicago Board of Trade in the United States, the size of which is 5000 bushels, so oats do represent a tradeable crop, given adequate volume.

Contracting

- 9.19 The use of contracts by millers has been outlined above. The trend to use these contractual arrangements is increasing, with some buyers claiming two-thirds or more of their regular (non-organic) purchases pass through these channels.

A formalising of this contract system would benefit one part of the oats market. The operators in the milling sector are in competition with one another for producers willing and able to supply oats of the correct specification, and this competition is often severe. If regular proficient oats producers could be offered regular long-term commitments to supply, then the prospect would be for a stabilisation of the milling market. Problems would inevitably arise with respect to quality in poor years, but with some form of central co-ordination this problem might be minimised, and if producers are also encouraged and educated in the growing of the crop the net effect would be an improvement in the marketing of this part of the crop.

The problems of such an arrangement, however, are that the milling sector would become divorced from the feed market, which might further undermine prices in the market as a whole, and that a small number of producers might be considered as premium suppliers of oats, with the residual market unattractive to others considering alternatives to wheat and barley. The issue of competition within the milling sector might also become pertinent with such a system.

The Role of BOBMA

- 9.20 The British Oats and Barley Millers Association (BOBMA) is the group within the Food and Drink Federation representing millers. BOBMA members generally require a stable market for milling oats, with the feed sector's stability also seen as important, and a quality supply. It is the intention of the group to help promote the production of oats, with education and advice to farmers, although to what extent there is a consistent applied approach is

not known. There is, however, an important role for members in encouraging consistency of supply by offering incentives to those producers who can regularly meet their needs. Individual companies are also engaged in research and development.

Voluntary Co-operation

- 9.21 The advantages associated with effective voluntary co-operation include especially the increased bargaining power offered to individual producers to influence the market. Co-operatives are also usually able to offer advantages associated with economies of scale with regard to management, storage and finance. In the case of the oats crop, although statistics are difficult to extract, the co-operative sector seems relatively small. Problems of scale apply to co-operative merchants as well as conventional businesses, and thus storage problems may be a factor. However, the advantages offered to producers in terms of pricing and financing arrangements may be significant, particularly if some form of 'pool' pricing is operated by the co-operative. This is essentially a means by which producers' cash-flows for an arable crop can be improved, with regular payment over the marketing season. The problem with oats might be two-fold, with relatively small production volumes making such arrangements uneconomic (although trials in Hampshire with a 500 t beans pool are imminent), and with the relatively atomistic nature of production rendering distances to central facilities prohibitive. However, it might be important to consider the role of the co-operative sector again, even in terms of a number of specialist oats marketing co-operatives strategically located.

Quality/Grade Stipulation

- 9.22 There appears to be a case for improving the identification of the product, using more accurate and consistent quality parameters. The definition of quality standards is important in improving the marketing of any commodity, as it enables consumers/users to more accurately assess the product they are purchasing, and encourages regular purchase of similar produce. There is an important pricing issue relating to the various

grades, which suggests that if the grades are truly representative, then there will be a more accurate and consistent pricing pattern to grains of the various qualities. In poor years, and with a continued tight balance between supply and demand, there will still be relaxation of the standards that millers, say, require, but if the market increased to any great extent it would be important that buyers could effectively communicate their requirements to prospective suppliers.

Promotion

- 9.23 Effective promotion of the crop would be an important advance in its marketing. The publicity surrounding 'alternative' crops is aiding this process, but along with the provision of market information, promotion and communication of the agronomic and economic possibilities of the crop would appear to be a neglected area. The improvement of this communication would be an activity for those organisations currently involved in the sector. Given proven qualities of oats in certain situations, gross margins similar to competing alternatives, and competitive prices with effective marketing arrangements, farmers would be attracted into the sector only if the information was communicated to them in an assimilatable and convincing form. The brief of a central body such as the H-GCA would appear to include provision for this type of activity.

In terms of demand, promotion is entirely at the product level, with little generic publicity at the farm or retail level, largely due perhaps to the lack of a suitable source of funds

Agricultural Policies and Oats

Support policy for oats in the European Community

- 9.24 Oats is included in the list of cereals covered by the EC cereals regime (see Reg 2727/75 Art. 1). The EC oats market is protected from generally lower priced imported oats from the rest of the world by the usual variable import levy (VIL) system. This levy is essentially the difference between world prices (c.i.f. Rotterdam) and the oats threshold price. Since there is no target price for oats (the usual basis for fixing threshold prices), the oats threshold price is fixed in relation to the threshold price for a substitute grain. Barley is the reference grain used - the oats threshold being set at 96.2% of the barley value. The factor used is designed to reflect relative feed values. Although oats compares favourably in terms of digestible crude protein and fibre, these attributes are considered to be more than offset by lower metabolisable energy and organic matter levels.

Border protection from the variable import levy system has a price enhancing and stabilising effect on the EC market compared to the world market.

Internal support arrangements

- 9.25 Protection from low-priced foreign supplies provided by the VIL system may not be sufficient to support prices on the internal market when domestic production is either temporarily or permanently in excess of domestic demand. The EC's intervention system is the additional measure put in place to provide a price floor in the cereals market.

Significantly however, oats does not qualify for intervention support buying. Cereals eligible for intervention are wheat, durum, barley, maize, rye and sorghum. The intervention system was intended to prevent price from falling below a predetermined support level - the intervention price - by diverting produce from the market into public store when production was 'excessive'

in relation to domestic demand. Any accumulated stocks would be released onto the domestic market if prices there recovered sufficiently; or exported abroad using export subsidies. When conceived the intervention system was intended primarily to stabilise the market intra-seasonally - by taking grain off the market in the post harvest glut and providing additional supplies later in the year. In recent years the system has had to contend with structural oversupply and fewer opportunities for stock release onto the EC market. Expensive storage and export subsidy costs have been the result.

It is argued that though oats is not explicitly supported through intervention purchases, some indirect support is given through intervention purchases of feed wheat and barley. This is plausible and partially true, but in practice the oats market does seem to exhibit more inter-year price variation than other grains, with cyclical fluctuations and a more volatile and unstable market than for other grains. This volatility is likely to be a limitation to farmers considering growing oats, and millers questioned would like to see more stability in the market to provide a less risky environment for farmers to grow oats on a regular basis.

The question arising here is whether intervention arrangements for oats would be the best way of imparting greater stability to the market. The availability of open-ended support via intervention has been a major contributing factor to the development of surplus production for all eligible cereal crops. Would oats be added to this list if intervention were provided? There is effectively 'automatic co-responsibility' in the oats market at present, where prices react to clear the market within the same season to prevent surpluses emerging. This situation is however unsatisfactory for farmers and users alike. Millers have partly overcome the problem by negotiating supply/purchase contracts with farmers.

- 9.26 Some millers contend that recent developments in EC cereals policy designed to combat the problems of surplus cereals production and excessive budgetary expenditure on surplus

disposal measures do not take into account the special characteristics of the oats market. There is no oats surplus as such - in fact millers may argue the converse. BOBMA have lobbied MAFF for exemptions for oats from the coresponsibility levy which will be levied on all cereals at 6% from the start of the 1988/89 season. The increase from last two season's 3% is part of the cereals stabiliser package agreed in February 1988. The additional 3% levy will apply, in the first instance, until 1991/992. An important exemption to the levy is grain utilized on the farm where grown. Since the majority of oats is used as animal feed on the farm where grown, a substantial proportion of production will be exempt. There is also a 'small farm' exemption.

The package agreed for cereals establishes a maximum guaranteed quantity for cereals of 160 mt. If the 1988 Community harvest exceeds this amount then intervention prices for 1989/90 will be reduced by 3%. This rule will apply in the subsequent three years. If the threshold is repeatedly surpassed then support prices could be cut by 12% in nominal terms. That is the plan. The reality may be very different if Farm Ministers are reluctant to implement such cuts when the time comes - as the 1985 price fixing negotiations illustrated. Estimates of this year's crop suggest the 160 mt will be exceeded. The size of the crop also determines whether the 'additional' 3% levy is fully reimbursed (production less than 160 mt), partially reimbursed (production less than 3% in excess of 160 mt), or not reimbursed at all.

It could be argued that the levy system is too broad brush in its approach and would give inappropriate production signals in the case of oats. In effect, producers of oats would in present circumstances be contributing budgetary resources for the funding of disposal measures for other crops which, in some cases, they may not even grow at all. On the other hand it could be argued that financing of surplus measures for other cereals is helping to hold up the price of all cereals, including oats, because of the substitution possibilities between grains in end uses, principally the animal feed market. A case could therefore be

made that oats producers should be subject to the co-responsibility levy.

Some oat millers expressed the desire to see oats excluded from the set-aside scheme as they would like to see more oats grown rather than less. One likelihood is that cereal farmers considering participation in the scheme will cut back their more marginal or least productive land. Farmers in more marginal cereal growing areas might also find the scheme more attractive. If both these assertions were true, and oats were grown to a greater extent on this type of land, then the set-aside scheme could give rise to a disproportionate cutback in the area planted to oats compared to barley and wheat. The lack of intervention support for oats might also contribute to this effect.

Oats and the environment

- 9.27 An increasing concern of the public, taken on board by the EC Commission, is the impact of modern agriculture on shaping the environment through changes in landscape, pollution, wildlife habitats and so on. Environmental issues are likely to become progressively more important parameters in agricultural policy making. The question arises as to whether oats might be seen as having a potential role in creating the more 'environmentally friendly' agriculture which society desires. For example, before the introduction of herbicides and pesticides, oats played an important role in crop rotations designed to reduce the incidence of pests and diseases. Oats is less responsive to fertiliser application than other cereals and therefore less is applied. The peak of oats growing was when mixed farming systems were dominant - with oats grown to feed farm animals for fattening and horses to provide draught power. This might be considered a visually more attractive system providing more amenity benefits and habitats for wildlife.

Oats policy in the United States

- 9.28 It is often said that current developments in the US are good indicators to future developments in the UK and elsewhere. This applies, for instance, to changes in consumer tastes, spending patterns and diets. It also has some validity in relation to agricultural markets and policy - for example, the use of set-aside to control agricultural surpluses has now been introduced in the EC after many years of use in the US.

In recent years US agricultural policy has tended to move in the direction of providing greater support for producers of oats - reflecting in part the wish to increase production of a crop for which the US has been a net importer since 1982.

The main instruments used to support farm price and incomes have their origins in the Agriculture and Consumer Protection Act of 1973. The loan rate mechanism provides a price floor for 'eligible' producers, while deficiency payments are used as an additional element of producer income support if market prices fail to reach a policy determined target price. The deficiency payment per bushel of grain is equal to the difference between the target price and the market price or loan rate whichever is higher. The oats loan rate is derived from the loan rate for maize - the oats loan rate is set at a minimum of 52% of the maize rate reflecting relative feed values per bushel. On a weight basis the percentage would be 91% due to different bushel weights (oats = 32lbs/bushel; maize = 56lbs/bushel).

The 1973 Act did not however provide target price support for oats, only loans. This is likely to have reduced the attractiveness of this crop still further in farmers' minds. The need to import oats in significant quantities in the eighties was probably a major reason for the extension of target prices and deficiency payments to oats in the 1981 Agriculture and Food Act.

Trade

Export potential for oats

9.29 The price of oats in world markets is closely linked to the price of other grains due to substitution possibilities between them - particularly maize and barley in the animal feed market. The price differentials between each of the grains reflect relative feed values. On this count oats has traditionally traded at a discount to both maize and barley. Table 9.1 shows price series for Canadian barley and oats which supports this contention (the series chosen on the basis that Canada is a major exporter of both crops).

Table 9.1 World Oats Prices.

	Oats Feed No 1 in store Thunder Bay		Barley Feed No 1 in store Thunder Bay	
	Can \$/t	US \$/t	Can \$/t	US \$/t
1977	77	72	77	72
1978	82	72	83	73
1979	111	95	117	100
1980	125	107	131	112
1981	131	109	138	115
1982	89	72	91	74
1983	88	71	92	75
1984	128	99	132	102
1985	113	83	122	89
1986	85	61	92	66
1987	79	59	74	56
Dec 1987	102	78	67	51

9.30 Owing to conditions of excess supply, export prices for grain have in general slipped markedly in dollar terms throughout the first half of the 1980s and oats have proved no exception. Grain prices have, however, strengthened considerably since 1987/88 and

with a poor United States harvest this year because of the North American drought and falling stock levels, price prospects look favourable - at least in the short term. Strong prices for oats in 1987/88 were caused by a poor Scandinavian harvest and a fall in production in the US. USDA estimates of the 1988/89 US oats crop (July 1988) are even lower, indicating a crop of only 3.7 mt which would make it the smallest harvest this century. US oats imports, as a result, are set to almost double - from 0.5 to 0.9 mt. Export potential for countries with surplus oats available is therefore particularly promising this year. Oats has even been trading at a premium over barley in recent months reflecting the tight supply situation.

9.31 Despite relatively buoyant world market conditions in 1988/89, EC market prices for cereals have continued to exceed world market levels and hence export refunds are still required - albeit at substantially reduced levels. As far as oats is concerned the EC has not pursued an active export strategy. Export subsidies have been available in most seasons but they are normally below those granted to other grains, such as barley, and are less attractive to traders. This is partly because oats supply and demand have been more closely matched than other cereals - reducing the necessity to export large amounts. As oats prices are less constrained in the downward direction due to the absence of intervention, good harvests can also be accommodated by lower prices and increased domestic demand.

9.32 The export potential for oats from the UK is difficult to assess with the main considerations being that:

- the market prospects for oats cannot be considered in isolation; they are inextricably linked with the market prospects for other cereals.

- in the short to medium term, considering current oat varieties, there appears to be an opportunity to export 'high quality' oats, for example for horse feed - but even here there are significant question marks over the size and growth of this market and on the extent that other countries might pursue it.

The exploitation of such a market, also depends on the availability of oats for export, which in turn depends on the degree of support given to oats and the ability to export - dependent on world/EC price differentials and the magnitude of export subsidies.

- in the longer term, the prospects for oats are partially dependent on how science and technology can be used to improve the consumption and production characteristics of oats in relation to other competing crops and at what cost. Clear communication between the scientific community, industry (producers and users) and agricultural policy makers is needed. If, for example, a high protein and/or high oil oat variety is developed, with characteristics that make it competitive with soyabeans and other oilseeds with relatively little or even no government support, the market prospects would be considerable.

- export potential is also determined by the support governments (here the EC) are prepared to finance in the form of export subsidies, and the price gap they have to bridge between the EC and the world market.

Conclusions to Chapter 9

1. The total oats market is relatively small at present, with the 1986 harvest of 505,000 t realising an approximate value of £56.2 million. Of this, just over half was marketed from the farm, the remainder retained and used as feed or seed. Oats marketed in 1986/87, amounted to 280,000 t and was valued at £32.1 million. Around 95,000 t of this went for livestock feed and 160,000 t for human food, particularly porridge. Trade in oats is very small.
2. There has been an increased use of oats in biscuits and cereal bars and an increasing market for organic and conservation grade oat products, whilst consumption of traditional breakfast cereals has tended to decline. Oats used for livestock feed has tended to decline over time, with oats purchased by feed compounders fluctuating with price and availability.

3. Research by millers and bakers suggests that the taste and flavour characteristics of oats are important to consumers. Similarly, oats are considered a vital part of coarse mixes by animal feed compounders with important visual and textural characteristics particularly for small animal and horse and pony feeds.
4. Oat prices fluctuate considerably from year to year (as do supplies), apparently more than prices for wheat or barley. Growers' decisions to plant oats appear to be dependent on the relative price of oats in relation to wheat and barley in the previous year.
5. Demand for oats is relatively price inelastic for millers and relatively price elastic for feed compounders. Millers are particularly concerned about the quality and appearance of oats and obtaining adequate supplies. For this reason, many have entered into contracts with farmers.
6. Oats marketing suffers from (i) fluctuating prices and supplies from year to year (ii) diseconomies associated with low volume of production and marketing.
7. Mechanisms for improving oats marketing in theory include a marketing board, an oats futures market, voluntary co-operation, quality/grade standards, a further extension of contract arrangements with growers and generic oats promotion.

Of these, there could be some scope for an increasing role for the co-operative sector, whilst a marketing board is unlikely to be either economic nor effective and an oats futures market unlikely to be practical. The extension of contract arrangements might benefit the milling sector but could undermine the livestock feed sector. Quality standards would improve marketing and encourage consumers/users to purchase and producers to grow quality oats, whilst effective promotion would also aid marketing.

8. Oats are protected by the EC variable import levy system but are not price supported by the EC intervention system unlike wheat, durum, barley, maize, rye and sorghum. This is one of the causes of the greater fluctuation in oat prices.
9. The 'set-aside' scheme could give rise to a disproportionate cut-back in the area planted to oats compared to barley and wheat.
10. Oats might be an 'environmentally desirable' crop suited to low input/mixed farming/organic systems, and this might be a consideration of the EC Commission.
11. The export potential for oats from the UK is difficult to assess. However, there may be an opportunity to export 'high quality' oats, for example, for horse feed.

CHAPTER 10 CONCLUSIONS AND RECOMMENDATIONS

Introduction

- 10.1 Specific conclusions relating to each Chapter of this report have already been given. This Chapter is intended to briefly cover the general conclusions about the potential for the production and utilization of oats in the UK that have emerged from this study. In addition, a number of recommendations on research and development activities related to oats are presented.

Conclusions

The International and UK Oats Market

- 10.2 World oats production accounts for only 2.6% of total global grain production. Oats production worldwide has tended to decline over the last 10-15 years. The USSR and the United States are the largest producers, and production and utilization of oats in the USSR has grown rapidly. Around 75% of the world oat crop is used for livestock feed. The United States has been the main importer of oats, followed by the USSR. The main exporters are Sweden, Finland, Australia and France.

Production of oats in the EC has also fallen from 12 mt in the mid 1950s to 6/7 mt currently, and represents around 4.3% of the EC grain harvest. The largest producers and users of oats in the EC are West Germany followed by France. Around 88% of oats in the EC are used as animal feed.

In the UK, the area devoted to oats has fallen from over 1 m ha in the mid 1950s, to less than 0.1 m.ha in 1987, with output declining from over 2.7 mt to 0.45 mt over the same period. Utilization of oats for livestock feed has declined, whilst remaining fairly static for human food uses.

Food, Nutrition and Health

- 10.3 Oats currently make only a very small contribution to the UK diet, with a relatively narrow range of oat products available. Despite this, oats have a good nutritional profile and a healthy, natural image with consumers. A number of health benefits of consuming oats have been recorded, including lowering of blood cholesterol levels and improved bowel function.

Food manufacturers see the potential for new snack foods using oats, as well as novel food uses for oats, such as an emulsifying agent from oat oil which could find varied uses in the food industry. There are a number of constituents of oats whose significance in food and nutrition is, as yet, only poorly understood.

Livestock Feed

- 10.4 Use of oats in livestock feed has been limited by their high fibre/low metabolisable energy characteristics and by price and availability. However, oats do form an important part of feed formulation and diets of several species of livestock, particularly horses. Beneficial (secondary) effects of feeding oats to various species have been found, such as the reduction in the level of saturated fatty acids in milk and the increased 'spreadability' of butter fat when dairy cows are fed oats.

Naked oats appear to have significant potential for livestock feeding, particularly for non-ruminants, as they have higher protein and oil levels than conventional oats and a higher metabolisable energy and lower fibre content. Realised potential will depend on price and availability.

Information on the feeding value of oats other than the grain is largely lacking.

Industrial Uses for Oats

- 10.5 The industrial use of oats in the UK on a large commercial scale has previously never been seriously considered. There are difficulties associated with processing oats to produce oat fractions such as starch, oil, protein and other constituents such as gums and antioxidants. Novel processing procedures might need to be developed for this fractionation although some procedures have been patented. Economic viability is likely to depend on finding markets for each oat fraction unless one very highly valued one could be found. Price and the quantities available of the raw oat material would be of major importance.

Recently, a high value fraction with excellent emulsifying properties has been identified, and markets for the by-product fractions are being investigated.

There appears to be a lack of research in the UK, in comparison to that undertaken in the USA and Canada, on the value of oat fractions for industrial non-food as well as novel food manufacturing uses.

Plant Breeding

- 10.6 The effort devoted to oat breeding in the UK and elsewhere in north-west Europe is much less than that devoted to wheat and barley. In the UK, the Welsh Plant Breeding Station (WPBS) at Aberystwyth has taken the major lead in oat breeding and genetic research. However, biotechnology and molecular biology has bypassed oats in the UK, despite the potential role of these approaches. Considerable genetic variation exists in oats to make radical changes to the oat phenotype, and there appears to be significant potential for the improvement of oats and naked oats in terms of the needs of producers and current/potential users (eg. industrial) of oats, and significant progress has already been made. However, the chances of success may be diminished if too many characters are considered.

It is important that plant breeding is capable of responding to changing needs and that genetic diversity is maintained and widened.

Oat Agronomy

- 10.7 Around 58% of spring oats is grown in Scotland, 37% in England and Wales and 5% in Northern Ireland. The winter oat area in Scotland is very small. In contrast, around 75% of the oats area in England and Wales is devoted to winter oats, with only 10% of winter oats in England and Wales grown north of the Humber.

There are a number of agronomic/husbandry limitations to growing oats in the UK. The northern spread of winter oats is limited by winter hardiness factors, whilst expansion of the spring crop is severely limited by late ripening. Both crops are prone to lodging causing harvesting difficulties and reducing yields.

There are a number of disease, pest and weed problems associated with oat growing, notably mildew, oat mosaic virus (winter oats), cereal cyst eelworm and wild oats and black-grass. Manganese deficiency can be a problem for spring oats.

However, the advantages of oats for growers include:

- (i) the value of oats in a rotation associated with low risk of eyespot and take-all;
- (ii) the greater reliability of oats than wheat or barley on wetter, less fertile soils and soils of lower pH;
- (iii) winter oats may have advantages of allowing timely drilling of following crops (on heavier land);
- (iv) new oat varieties (including naked oats) are now available to growers, where applying known husbandry could make a notable impact on average yields;

- (v) oats appear particularly well suited to organic methods of production.

There appears to be a lack of recent oat agronomy research and development information available to advisers and growers, particularly concerning the newer varieties and in relation to grain quality.

Farm Economics

- 10.8 In terms of net margin/ha, at current prices and average yields, oats appear to be competitive with winter barley (feed quality) and with spring wheat. For 'premium' yields, the net margin for winter oats appears higher than the net margin for winter barley.

The oats area has continued to decline, partly due to a more variable price than wheat or barley (perhaps also because yields near to 'premium' yields have not often been achieved for oats as they might have been for wheat and barley, either because of husbandry practices or due to the quality of land on which oats are commonly grown).

An improvement of £20-£100/ha in net margin would probably be required for oats to displace wheat or barley in a major way.

Organic production of oats offers high net margins to growers, but with husbandry constraints and probably a limited market.

Assuming immediate prospects of increasing average oat yields by up to 0.6-0.7t/ha, this would result in at least a 10% better net margin than winter or spring sown barley.

The net margin for oats could also be increased through breeding oats with higher energy and protein content and by improving (eg. the yield of) naked oats.

Oats Marketing, Policy and Trade

- 10.9 The oats market in the UK is relatively small at present, with the 1986 harvest of 505,000 t worth £56.2 million. Nearly half of this remained for use on the farm, the remainder (plus trade and stocks) being mostly marketed for human food (160,000 t) and for livestock feed (approximately 95,000 t).

There has been an increased use of oats for biscuits and cereal bars, and an increased market for organic and conservation grade oat products, whilst consumption of traditional breakfast products has tended to decline. The use of oats for livestock feed has also tended to decline, with oats purchased by compounders fluctuating with price and availability.

Taste, flavour and textural characteristics of oats are important to consumers. Oat prices fluctuate considerably from year to year (as do supplies), with growers decisions on planting apparently mainly dependent on the price of oats relative to wheat and barley the previous year.

Demand for oats by millers is relatively price inelastic but relatively elastic for feed compounders. Millers are particularly concerned with the quality of supplies and have entered into contracts with growers to try to ensure adequate supplies of good quality. The main UK millers are Quaker, Morning Foods and Jordans.

Practical and appropriate mechanisms for improving the marketing of oats might include an increasing role for the co-operative sector, quality standards/grades and oats promotion.

Oats, although protected by the EC variable import levy are not supported by the EC intervention system as are wheat, barley and other cereals. This is a major reason for the greater fluctuation in oat prices and for the decline in oat growing in comparison with wheat and barley.

'Set-aside' could result in a disproportionate cutback in the area of oats planted. However, oats might be considered as an 'environmentally desirable' crop by the EC Commission.

Recommendations

Introduction

10.10 A number of possibly beneficial areas for research and development have been identified in this Review. Some of these areas are already receiving attention and research funds. In some cases these might show significant benefit if such funds were increased, whereas in others the current level of effort and resources devoted may be considered adequate.

This section summarizes the identification of possible areas for research and development where the potential benefits would appear to be significant, and so possibly warrant the further allocation of funds.

The International and UK Oats Market

10.11 A limited, but further and more detailed study of the production, utilization and trade of oats in other countries of the world (particularly in Northern Europe and North America) should be carried out. This would help to further identify possible areas of potential for oats in the UK.

Food, Nutrition and Health

- | | | | |
|-------|----|---|------------------|
| 10.12 | 1) | A comparison of oat consumption patterns in the UK and in other countries, particularly those with a high consumption, is needed. This would help to identify potential oat products and markets. | (3.9)* |
| | 2) | Research and development of novel, new and neglected oat food products should be encouraged. | (3.32)
(3.33) |

* Paragraph reference to main report where supporting evidence/discussion of the recommendation is given.

- 3) Further evaluation of the use of oats and oat constituents in food systems is necessary with due attention to research carried out in other countries such as North America. This would facilitate increased oat usage in food manufacture. (3.22)
 An example would be further research into the B-glucan-rich soluble fibre (gum) fraction. At present, most of the food gums used in the UK are imported. Current interest in the (3.34)
 development of additive free food suggests that it may be timely to carry out further research into the use of antioxidants from oats. (3.33)
- 4) Continuing research into the nutritional and physiological properties of oats and oat constituents would be desirable in order to (3.22)
 fully evaluate their potential. Work in this area (3.31)
 is being conducted in other countries and should prove generally applicable (although work related to problems of free fatty-acids and bitter substances may be needed of relevance to the UK).
- 5) The potential value of naked oats to the food industry should be further explored. (3.35)

Livestock Feed

- 10.13 1) There is a need to systematically measure the (4.12)
 nutritive value (eg ME) for a representative (4.13)
 range of current oat varieties in all of the (4.14)
 important farm species including cattle, (4.16)
 sheep, pigs, poultry, horses and possibly (4.20)
 goats. (4.23)
- 2) The feeding value of oats other than the grain such (4.32)
 as whole-crop silage and the value of oats for (4.33)
 grazing systems should be further explored.

- 3) There is a need for feed compounders to have access (4.35)
to reliable and up-to-date estimates of the feeding
value of different oat varieties. Assessment of the (4.36)
value of naked oats for livestock feed is necessary, (4.37)
and some research in this area has been funded.

Industrial Uses for Oats

- 10.14 1) The potential value of oat fractions for industrial (5.32)
non-food and novel food manufacturing uses should be (5.33)
further explored. If these further investigations
show a positive economic potential for fractions of
oats, then a pilot industrial process for oats
fractionation should be considered.
- 2) In order to be fully evaluated by industry, oat (5.2)
fractions need to be produced at a realistic pilot (5.33)
plant scale. This is an option which may not
at present attract specific industrial interest
from a single sector, since, with the exception
of an emulsifier, there appears to be no single
product or fraction which could justify
development of such an agro-refinery for oats.
However, a number of industrial outlets would
exist for specific fractions if they were
available. The possibilities of funding a
joint pilot plant supported by various
interests under the ECLAIR programme of the EC
could be investigated.

Plant Breeding

- 10.15 1) Effort should be devoted to ensuring a wide genetic
base for oats using lines from elsewhere in the world
and from wild species. (6.13)
- 2) Breeding research should be geared towards several
objectives including:

- i) increasing the livestock feed value of oats (6.24)
and naked oats by increasing energy and (6.26)
protein levels;
 - ii) increasing the yield and reliability of yield
for oats;
 - iii) breeding improved varieties for increased (6.27)
disease and pest resistance particularly against
mildew, oat mosaic virus in winter oats and
cereal cyst eelworm;
 - iv) breeding improved varieties to reduce lodging, (6.27)
improve winter hardiness in winter oats and
earlier ripening for spring oats.
- 3) The potential role of biotechnology should not be (6.18)
forgotten. Biotechnology work carried out on oats (6.20)
elsewhere in the world and work carried out on other
cereals should be capitalised upon as far as possible
for oat breeding in the UK.
- 4) The WPBS has taken a leading role in oat breeding and (6.4)
genetics in the UK and would be the obvious choice for
directing resources toward plant breeding initiatives.
The Cell Biology Group at WPBS might also have a role to
play in the area of biotechnology.

Oat Agronomy

- 10.16 1) There is a need for well researched agronomic
recommendations for the newer varieties of oats
(eg naked oats), grown under varying conditions.
Research toward this end would provide information
to growers as to the circumstances where growing (Concl.)
oats might be most appropriate to their farm (11 & 12)
system and would also enable growers to 'fine tune'
husbandry in respect of inputs.

- 2) There is a lack of information on the effect of various agronomic husbandry practices on oat grain quality. Research is needed to assess the interaction of husbandry practices, grain yield and grain quality. Discussions with processors and users of oats may be required to establish what, if any, further grain characters might usefully be recorded in future husbandry trials.

- 3) Given the potential and current interest in organic production of oats, research should be (7.8) directed toward problems of weed control, disease (Concl.) control, organic nitrogen nutrition for organic (9 & 13) systems, as well as issues concerning oat quality and yields. The value of oats in an organic rotation should be further assessed.

- 4) In particular, agronomic research should be directed towards problems of the oat crop associated with:
 - (i) Lodging; (7.20-7.23)
 - (ii) Oat-mosaic virus;
 - (iii) Cereal cyst eelworm;
 - (iv) Wild oats and black-grass.

Farm Economics

- 10.17 The economic value of new and improved oat varieties and of likely potential improvements to oats (for example, an increase in the proportion of a particular fraction) should be periodically assessed. This would help to direct and support plant breeding and other research programmes and provide useful information to producers and advisers, and users/potential users of oats.

Marketing, Policy and Trade

- 10.18 1) The possibility of instigating simple grading schemes for oats should be explored, with an accurate definition of the various qualities and standards required by the markets for oats. (9.22)
- 2) There is a need for more information on oats and promotion of oats both to producers and consumers. A centrally funded effort at education and information with the aim of promoting oats may be appropriate, with for example, generic oats promotion carried out by a central body. It is therefore recommended that discussions should be held with all interested parties to determine the desirability and feasibility of setting up such a body to take overall responsibility for the promotion of oats. (9.23)
- 3) The likely effects of set-aside on oats production should be assessed. (9.26)
- 4) The 'environmentally desirable' elements of oat production should be appraised to determine whether on such grounds increased oats production in the UK and EC should be promoted. (9.27)
- 5) Possible export markets for oats should be further explored. (2.5)
(9.32)

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CHAPTER 3

OATS FOR HUMAN FOOD

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APPENDIX 1.1

LIST OF CAS OATS REVIEW CONSULTANTS

<u>Name</u>	<u>Organization</u>	<u>Area of Specialisation In Oats Study</u>
Mr N. Beard	Dept. Agricultural Economics and Management, Reading University.	Agricultural Policy and Trade
Dr J. Coombs	Commercial Consultant (Agro-Industry) CPL Scientific Ltd, Bucklebury, Reading	Industrial and Food Manufacturing
Mr C. Doyle	AFRC IGAP, Hurley Research Station, Maidenhead, Berks	Farm Economics
Ms J. Everington	ADAS Feed Evaluation Unit, Stratford on Avon, Warwickshire	Livestock Feeding and Nutrition
Mr W. Paterson	Crop Husbandry Div. North of Scotland College of Agriculture, Aberdeen	Crop Husbandry and Agronomy (Spring Oats)
Mr R. Green	Arable Agronomy, ADAS Wye, Ashford, Kent	Crop Husbandry and Agronomy (Winter Oats)
Mr R. Loader	Dept. Agricultural Economics and Management, Reading University	Marketing
Dr J. Valentine	AFRC, Welsh Plant Breeding Station, Aberystwyth, Dyfed	Plant Breeding and Genetics
Dr R. Welch	Dept of Biology University of Ulster, Co Antrim, N Ireland	Food, Nutrition and Health

APPENDIX 1.2

The Centre for Agricultural Strategy is grateful to the following, amongst others, for their help and co-operation.

British Oats and Barley Millers Association.

AFRC Institute of Food Research, Norwich.

AFRC Institute of Arable Crops Research.

The British Food Manufacturing Industries Research Association.

Hannah Research Institute.

AFRC Institute of Engineering Research.

The East of Scotland College of Agriculture.

BBO Farmers Ltd.

The North of Scotland College of Agriculture.

The British Nutrition Foundation.

British Hay and Straw Merchants Association.

Morning Foods Ltd.

United Kingdom Agricultural Supply Trade Association Ltd.

Department of Agriculture and Fisheries for Scotland.

AFRC Welsh Plant Breeding Station.

ADAS Feed Evaluation Unit.

AFRC Institute for Grassland and Animal Production (Hurley Research Station).

Agricultural Development and Advisory Service (ADAS).

BOCM Silcock, Basingstoke (feed compounders).

Dalgety Agriculture.

United Biscuits Ltd.

Quaker Oats Ltd.

Federation of Agricultural Co-operatives.

Organic Farmers and Growers.

Wm. Jordan Ltd.

Nabisco Ltd.

Elm Farm Research Centre.

The Guild for Conservation Food Producers.

Mr N Lampkin, University College Wales.

Mr G Hutchinson, Queens University, Belfast.

APPENDIX 2.1

TABLE 2.1

SUPPLY/DEMAND BALANCES IN THE EC¹ OATS² MARKET

August/July years to 1985/86, July/June thereafter; in million tonnes

	Usable Prod	Δ Stocks	EC imp	EC exp	Internal Use					Self suff	Area	Yield	
					A	S	I	L	H	Total			
1973/74	9,7	-0,1	0,7	0,2	9,7	0,4	0	0,04	0,3	10,1	96,0	2,32	3,4
1974/75	9,8	+0,1	0,3	0,1	9,2	0,4	0	0,04	0,3	10,0	98,0	2,28	3,5
1975/76	9,4	-0,3	0,3	0,1	9,1	0,4	0	0,03	0,3	9,8	95,9	2,33	3,3
1976/77	7,0	+0,1	1,0	0,2	7,0	0,3	0	0,03	0,3	7,7	90,0	2,20	2,6
1977/78	7,7	+0,1	0,4	0,1	7,3	0,3	0	0,03	0,3	8,0	96,3	2,02	3,2
1978/79	8,6	+0,2	0,4	0,2	7,9	0,3	0	0,10	0,3	8,6	100,0	1,92	8,3
1979/80	7,6	-0,2	0,2	0	7,3	0,3	0	1,00	0,3	8,0	95,0	1,75	3,6
1980/81	7,4	+0	0,2	0,1	6,7	0,3	0	0,10	0,3	7,4	100,0	2,11	3,5
1981/82	7,1	-0	0,2	0,1	6,5	0,3	0	0,10	0,3	7,2	98,6	2,02	3,5
1982/83	7,7	+0	0,1	0,1	7,0	0,3	0	0,10	0,3	7,7	100,0	2,09	3,7
1983/84	5,4	-0,1	0,2	0	5,1	0,3	0	0,08	0,3	5,8	93,1	1,75	3,1
1984/85	6,8	+0,4	0,2	0,1	5,8	0,3	0	0,1	0,3	6,5	104,6	1,67	4,0
1985/86	7,1	+0,1	0,1	0	6,5	0,2	0	0,1	0,3	7,0	98,6	1,69	4,1
in thousand tonnes													
1984/85	7787	475	168	103	6544	375	1	107	350	7377	105,6	2,35	3,2
1985/86	7843	-30	76	24	7059	331	50	115	370	7925	99,0	2,37	3,2
1986/87	6000	-478	103	48	5736	306	1	95	397	6533	91,8	1,99	2,9

Usable Prod - Usable Production

Δ stocks - Change in stocks

EC Imp - Extra EC imports

EC Exp - Extra EC exports

Internal Use

A - Animal Feed, S - Seed

I - Industrial use, L - Market losses

H - Human consumption

¹ EC-9 to 1979/80; EC-10 to 1985/86; EC-12 thereafter

(NB; EC-12 figures are also given for 1984/85 to 1985/86 for comparison)

² includes mixed summer corn

Self Suff - sufficiency (%)

Area - Area (million ha)

Yield - Yield (t/ha)

Source: Eurostat, EC Commission

APPENDIX 2.1

TABLE 2.2

SUPPLY/DEMAND BALANCES IN THE UK OATS MARKET

August/July years to 1985/86, July/June thereafter; in '000 tonnes

	Usable Prod	Final Stocks	Δ Stocks	Imports	Exports	Internal Use				Self Suff	Area	Yield
						A	S	H&I	Total			
1973*/74	1251	51	-24	25	34	1057	60	145	1266	98.8	332	3.83
1974*/75	1983	81	+31	32	7	882	55	135	1077	100.6	295	3.74
1975*/76	898	44	-37	36	8	760	54	145	963	93.0	267	3.42
1976/77	764	48	+4	73	4	621	45	148	830	92.0	235	3.42
1977/78	790	42	-6	14	9	592	42	149	801	98.6	195	4.06
1978/79	706	43	-1	52	7	555	31	148	750	94.1	180	3.92
1979/80	542	37	-6	48	3	407	34	140	593	91.4	136	3.99
1980/81	601	47	+10	10	-	415	31	140	601	100.0	148	4.08
1981/82	619	35	-12	2	5	436	26	151	628	98.6	144	4.30
1982/83	575	37	+2	21	2	425	21	134	594	96.8	130	4.43
1983/84	466	21	+14	39	1	341	21	147	481	96.9	108	4.32
1984/85	516	22	+1	7	0	337	27	145	522	96.5	107	4.89
1985/86	615	25	+3	15	0	435	20	155	625	98.4	134	4.59
1986/87	505	20	-5	15	5	330	20	160	525	96.2	97	5.16
1987/88	450	20	0	10	5	250	25	165	455	98.9	99	4.57

1986/87 provisional

1987/88 forecast

* figures include mixed grain

Usable Prod - Usable Production

Final Stocks

Δ Stocks - Change in stocks

Imports

Exports

Source: MAFF, HGCA

Internal Use

A - Animal Feed

S - Seed

H&I - Human and Industrial use

Self Suff - Self Sufficiency (%)

Area - Area ('000 ha)

Yield - Yield (t/ha)

APPENDIX 2.1

TABLE 2.3

AREA, PRODUCTION AND YIELD FOR THE PRINCIPAL UK GRAINS

Soft Wheat				Barley			Oats			Total Cereals		
	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield
1955	788	2641	3.35	929	2983	3.21	1042	2752	2.63	2954	8913	3.02
1956	928	2891	3.11	940	2845	3.02	1037	2526	2.43	3085	8701	2.82
1957	855	2726	3.19	1061	3004	2.83	949	2179	2.29	3011	8263	2.74
1958	894	2755	3.08	1115	3221	2.88	896	2172	2.42	3027	8448	2.79
1959	781	2830	3.62	1237	4080	3.30	819	2222	2.71	2936	9408	3.20
1960	851	3040	3.57	1365	4309	3.16	797	2091	2.62	3101	9681	3.12
1961	739	2614	3.54	1549	5054	3.26	700	1851	2.65	3055	9708	3.18
1962	913	3974	4.35	1613	5866	3.64	613	1775	2.90	3197	11789	3.69
1963	780	3046	3.90	1907	6705	3.51	522	1461	2.80	3259	11354	3.48
1964	893	3793	4.24	2036	7523	3.69	454	1346	2.96	3424	12789	3.73
1965	1026	4171	4.06	2183	8191	3.75	408	1232	3.01	3654	13708	3.75
1966	906	3475	3.84	2481	8724	3.51	366	1120	3.06	3786	13424	3.54
1967	933	3903	4.18	2439	9215	3.77	409	1386	3.39	3821	14635	3.83
1968	978	3469	3.55	2401	8271	3.44	380	1224	3.21	3809	13129	3.44
1969	833	3364	4.04	2413	8664	3.59	381	1308	3.42	3694	13566	3.67
1970	1009	4236	4.19	2243	7529	3.35	375	1217	3.25	3712	13259	3.57
1971	1097	4815	4.39	2288	8558	3.74	362	1360	3.76	3810	14965	3.93
1972	1127	4780	4.24	2288	9244	4.04	315	1249	3.96	3799	15515	4.08
1973	1146	5002	4.37	2267	9007	3.97	281	1080	3.84	3752	15295	4.08
1974	1233	6130	4.97	2214	9133	4.12	253	955	3.78	3747	16379	4.37
1975	1035	4488	4.34	2345	8513	3.63	232	795	3.42	3654	13820	3.81
1976	1231	4740	3.85	2182	7648	3.51	235	764	3.42	3685	13262	3.60
1977	1076	5274	4.90	2400	10531	4.39	195	795	4.06	3706	16727	4.51
1978	1257	6612	5.26	2348	9848	4.19	180	706	3.92	3811	17263	4.53
1979	1370	7168	5.23	2343	9623	4.11	136	542	3.99	3869	17416	4.47
1980	1441	8470	5.88	2330	10325	4.43	148	600	4.08	3938	19480	4.95
1981	1491	8710	5.84	2329	10230	4.39	144	620	4.30	3981	19629	4.93
1982	1663	10320	6.20	2222	10960	4.93	130	575	4.43	4031	21919	5.44
1983	1695	10800	6.37	2144	9980	4.66	108	465	4.32	3962	21304	5.38
1984	1939	14957	7.71	1978	11055	5.59	107	516	4.89	4038	26590	6.59
1985	1902	12050	6.33	1966	9740	4.95	134	615	4.59	4016	22475	5.60
1986	1997	13910	6.97	1916	10005	5.22	97	500	5.16	4024	24475	6.08
1987	1994	11869	5.95	1830	9230	5.04	99	452	4.57	3936	21680	5.51
1988est	1874			1913			130			3924		

Area in '000 ha

Production in '000 t

Yield in t/ha

Source: MAFF, HGCA

APPENDIX 6.1

Outline of Funding of the Current Oat Breeding and Research Programmes at the WPBS

The WPBS is part of the AFRC's Institute for Grassland and Animal Production. Its programme of work on oats is shown below:

PU71	Funding Body
a) Breed winter oats for livestock and human use	MAFF
b) Breed spring oats for livestock and human use	MAFF
c) Assess yield, disease resistance and other characters of advanced lines and of innovative cereals varieties	MAFF
d) Evaluate and exploit new sources of disease resistance and screen breeding material	MAFF
e) Transfer desirable characters from wild species to the cultivated oat for exploitation in breeding	MAFF
f) Develop efficient methods of selection and incorporate novel genetic variation in cereals	MAFF
PU 77	
d) Assess genetic relationships between species of <u>Avena</u> and the cytogenetic structure of the cultivated oat	DES
PU 85	
f) Exploit genetic potential of oats for use in animal feed	HGCA

Parts of (a), (b), and (c) concerned with the testing and multiplication of advanced lines have been designated as 'near-market'. Proposals from several companies to fund these parts of the work and to market WPBS finished varieties are presently being considered by WPBS.

APPENDIX 6.2

IBPGR Priorities for the Conservation of Oat Genetic Resources

Important priorities for the conservation of oat genetic resources were drawn up by the International Board for Plant Genetic Resources (IBPGR) Working Group (IBPGR, 1984). Certain species were identified as priorities for collection and study. These were: Avena prostrata, a new diploid species restricted to a few locations in Southern Spain, the best source of mildew resistance (immunity) in the genus; A.damascena, (diploid) only existing as a single collection from a site in Syria; A.maroccana, (tetraploid) found only in Morocco with groat protein content up to 30%; A.murphyi, (tetraploid), found in very restricted areas of southern Spain and northern Morocco, with high protein and disease resistance and under threat from arable cropping; A.canariensis, (diploid), restricted to two islands in the Canaries with a remarkably short growing season, and A.macrostachya (perennial tetraploid outbreeder), with extreme winter hardiness and possibly BYDV resistance. Less important species such as A.barbata (tetraploid), A.sterilis and A.fatua (hexaploids) have enormous distribution ranges and were considered menacing rather than menaced, while A.ventricosa, A.clauda, A.eriantha, A.hirtula and A.wiestii (diploids) required no special collections. Two Avena species, A.atlantica (diploid) and A.agadiriana, have been discovered recently (Baum and Fedak, 1985 a,b), and their cytogenetic relationships with other oats established (Leggett, 1986, 3rd International Oat Conference, 1988).

The WPBS has participated in two collections (1985 and 1986) funded by IBPGR. Collected samples included representatives of all but two of the biological species, including A.atlantica and A.agadiriana. In addition, the identification of new areas of distribution of A.damascena and A.marocanna should considerably extend the exploitable genetic variation found within Avena (IBPGR, 1986; Leggett, pers comm.). The agronomic evaluation of new sources of genetic variation from these collections is now underway.

APPENDIX 7.1

Spring Oats - Scotland

Summary of results from trials 1983-87

	Yield control (%)	Ripening (days to control)	Straw length (cm)	Lodging (%)	Mildew (%)	Septoria (%)
Mean of controls	5.67 (t/ha)	165	102			
*Dula	101	0	5	31	9	5
*Matra	103	1	-5	53	12	6
*Cabana	99	-1	-1	54	15	5
*Leanda	97	0	1	28	13	3
Avalanche	87	-1	3	76	0	2
Commander	100	1	2	40	0	9
Major	101	0	11	34	12	18
Keeper	102	-1	7	54	0	3

*Control varieties

APPENDIX 7.2

Table Varietal performance - ADAS SE Region
Winter Oat Husbandry Trials 1986-88

Variety	Yield t/ha			Straw length (cm)		% Lodging		TGW (g)		Sp Wt(kg/hl)	
	'86	'87	'88	'87	'88	'87	'88	'87	'88	'87	'88
Peniarth	7.60	5.66	5.88	133	120	70	Nil	31.2	31.2	54.0	52.
Pennal	7.70	6.57	6.36	107	94	Nil	Nil	32.3	32.1	50.5	50.
Bulwark ⁽¹⁾	8.20	7.29	-	118	-	Nil	-	33.3	-	50.2	-
Image	8.67	7.05	6.26	118	111	65	Nil	31.8	35.9	51.1	48.
Lustre	7.40	6.15	6.27	124	114	49	Nil	38.1	35.8	51.6	49.
Rosette ⁽²⁾	8.40	-	-	-	-	-	-	-	-	-	-
Solva	-	7.37	6.56	120	99	22	Nil	33.7	33.1	53.7	50.
Kynon ⁽³⁾ (Naked oat)	-	4.72	-	115	-	Nil	-	32.3	-	65.4	-
Craig ⁽⁴⁾	-	-	6.88	-	99	-	Nil	-	31.8	-	51.
Aintree ⁽⁴⁾	-	-	7.00	-	104	-	Nil	-	30.1	-	51.
(SED)	-	(±0.28)	(±0.22)	(±2.76)	(±1.90)	(±5.2)	-	(±1.95)	(±1.15)	(±1.11)	(±0

Notes:- (1) Bulwark not in 1988 trial

(2) Rosette in 1986 trial only

(3) Kynon in 1987 trial only

(4) Craig and Aintree in 1988 trial only

APPENDIX 7.3

ADAS SE Region (Agronomy) trials 1985/88.
Nitrogen effects on yield and % lodging on varieties other than Peniarth on sites atN Index 0.

Year	Site	Variety	Nitrogen kg/ha				Statistical significance* of yield comparison
			100		140		
			Yield t/ha	% lodging	Yield t/ha	% lodging	
1985	Cranbrook Kent	Pennal	6.54	4	7.12	47	S
1985	Brede E. Sussex	Bulwark	6.21	4	6.50	27	S
1986	Cranbrook Kent	Pennal	7.31	Nil	7.62	Nil	S
1987	Cranbrook Kent	Image	6.68	66	6.98	64	NS
1988	Cranbrook Kent	Image	5.87	Nil	6.18	Nil	S
Mean of 5 trials			6.52	15	6.88	36	

* P = 0.95 S = significant difference

NS = difference not significant

Appendix 8.1 Method for projecting grain prices

Basic method

Using a computer program, least-cost rations were formulated for 3 classes of stock, dairy cows, beef steers and pigs. In each case, diets were formulated so as to satisfy the energy, protein and amino-acid requirements of the animals, subject to limitations on total feed intake. Using the program, an estimate was made of the maximum price at which a given cereal feed (e.g. naked oats) would be incorporated in the diet, in relation to imported maize gluten and soyabean meal costing £100 and £160/t respectively. These 'maximum' price were assumed to reflect the true current (early 1988) values of the cereal as a livestock feed.

For each class of livestock the calculations were performed separately and the resulting values, weighted by the proportions of UK feed grains consumed by dairy, beef and pigs, to give a single projected feed value. Specifically, based on Doyle and Valentine (1988), the weights were taken to be 0.48, 0.21 and 0.31 respectively. The 'weighted' value represents the maximum price at which the grain would be bought by livestock farmers. To derive the likely price that cereal growers would receive, allowance was made for haulage and marketing costs by reducing the price by £3/t (Farmers Weekly, 6 Feb 1987, p. 72).

Further details about the general principles of least-cost ration formulation can be found in France and Thornley (1984, pp. 262-267), while more specific details about the method employed are available in Doyle and Valentine (1988).

Key assumptions

The assumed nutritive values of husked oats, naked oats, barley, wheat, maize gluten and soyabean meal are shown in Appendix Table 1, while typical daily energy and protein requirements for (i) a dairy cow yielding 25

kg/day, (ii) a 350 kg steer and (iii) a 50 kg pig are presented in Appendix Table 2.

Appendix Table 1
Chemical composition of various feeds

		Husked oats	Naked oats	Barley	Wheat	Maize gluten	Soyabean meal
ME,	MJ/kg DM	12.0	14.7	12.8	13.6	12.7	13.4
DE,	MJ/kg DM	12.8	16.0	13.0	14.7	13.8	14.0
CP,	g/kg DM	105.0	119.0	128.0	123.0	232.0	507.0
RDP,	g/kg DM	84.0	95.0	102.0	98.0	139.0	304.0
UDP,	g/kg DM	21.0	24.0	26.0	25.0	93.0	203.0
CF,	g/kg DM	103.0	20.0	50.0	20.0	84.0	72.0
<u>Amino-acids</u>							
Lysine,	g/kg DM	4.3	5.0	4.5	3.4	8.4	30.1
Methionine + cystine,	g/kg DM	3.7	6.2	5.2	4.3	5.4	9.1
Threonine,	g/kg DM	3.7	3.9	4.5	3.5	9.2	31.0
Tryptophan,	g/kg DM	1.2	1.5	1.8	1.6	1.8	6.2

Abbreviations: ME = metabolisable energy (cattle); DE = Digestible energy (pigs); CP = crude protein; RDP = rumen degradable protein; UDP = undegradable protein; CF = crude fibre.

Sources: Energy, protein and crude fibre values are taken from MAFF (1986). The amino-acid composition comes from Lasztity (1984).

Appendix Table 2
Energy, protein and amino-acid requirements of dairy cows, beef cattle and pigs

		Dairy cows	Beef cattle	Pigs
ME,	MJ/head/day	181	56	-
DE,	MJ/head/day	-	-	25
CP,	g/head/day	-	-	260
RDP,	g/head/day	1413	420	-
UDP,	g/head/day	443	10	-
Lysine,	g/head/day	-	-	15
Methionine + Cystine,	g/head/day	-	-	7
Threonine,	g/head/day	-	-	9
Tryptophan,	g/head/day	-	-	2
Limit to DM intake,	kg/head/day	14.0	6.3	2.0

Source: MacDonald et al. (1981)

Appendix 9.1

The regression equations relating price premia/discounts of average oats prices (deflated by the index of purchase prices of the means of agricultural production (Annual Abstract of Statistics 1987)) versus wheat and barley prices in the same years, to the following year's plantings of oats (having accounted for the long term trend) are as follows:

Percentage Premium/Discount of oats over barley (yr n-1) vs Plantings of oats (yr n):

$$\text{Plantings (Y)} = 105.1899 + 2.0901 \% \text{Premium (X)}$$

$$(R=0.6301)$$

Percentage Premium/Discount of oats over wheat (yr n-1) vs Plantings of oats (yr n):

$$\text{Plantings (Y)} = 115.6035 + 2.0939 \% \text{Premium (X)}$$

$$(R=0.7814)$$

Sources of Information:

Index from: Annual Abstract of Statistics. Plantings figures from: Home-Grown Cereals Authority. Prices from: Annual Review of Agriculture.