Lohmann Information

Cuxhaven, April 2008

Prof. Dietmar Flock,
Editor

Editorial

Two years ago, when LAH and LTZ decided to discontinue the hard copy edition in German and English and change to a bi-annual online publication in English with German summaries, there were some questions whether the majority of our traditional readers would accept this change or cancel subscription. Actually, the number of subscriptions is increasing steadily and reached 2222 addresses in 120 countries for this issue. A preliminary analysis of the number of downloads of individual papers reflects the interests of our readers and will be used to plan future issues. Most of our readers have a major interest in poultry related topics, but we will continue to include information of general interest for scientists, producers and society as well.

Thanks to improved efficiency of plant and animal production, agriculture has been able to meet the growing demand for food and actually enabled the average person to consume more protein of animal sources at decreasing prices. The recent jump in world market prices for corn, soya and other food and feed components again raises the question: are there serious limits to food supply, or are the price hikes due to wrong political signals and speculation on the stock market? In developed countries like Germany, where we used to spend only 11% of available income for food, an increase of food prices by 50% may still be tolerated by many people, but the situation is becoming dramatic in several developing countries where families were barely able to get adequate nutrition at previous prices.

Can the recent jump in food and feed prices be explained by a sudden shortage of raw materials for human and animal nutrition, because more land is being used for bio-energy production? The Project “International Assessment of Agricultural Science and Technology for Development” (IAASTD) will hopefully shed more light on this issue on the basis of results presented at an international meeting in Johannisburg, South Africa, this month. Meanwhile, individual farmers need to decide in what type of production to invest, and politicians will hopefully take all available scientific facts into consideration when deciding on targets to slow down “global warming”.

All papers in this issue can be seen as directly or indirectly related to the competition between food, feed and fuel on a global or regional level. As “food for thought”:

1. **Prof. William G. Hill**, Institute of Evolutionary Biology, School of Biological Sciences of the University of Edinburgh, reviews statistical methods of estimating genetic changes and results of long term selection in different species of animals and plants, including egg-type and meat-type chickens, dairy and beef cattle, pigs and sheep, race horses and dogs, laboratory mice and drosophila, as well as maize. With the exception of race horses and greyhound dogs, significant progress has been documented in all species and is expected to continue in the foreseeable future.

2. **Dr. Roger J. Busch**, TTN Institute of Applied Ethics at the LMU in Munich, takes a critical look at the production of bio-energy vs. food from an ethical point of view. Ethical standards are subject to differences between countries and may change over time. Deficits in the perception of modern agriculture are seen not only in our German society. If representatives of agriculture inform consumers better about conflicting objectives, support for bio-energy is likely to decline with rising food prices.

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3. **Prof. Dr. Alois Heißenhuber, Stefan Berenz** and **Stefan Rauh**, Institute of Agricultural Economics of the TU Munich-Weihenstephan, present a detailed analysis of economic and ecological aspects of bio-energy production. After years of overproduction and decreasing farm prices for food and animal feed, tax benefits for bio-fuel have helped to stabilize farm income. However, food production will always have priority over bio-fuel production. Individual farmers must keep the future potential for income from energy vs. food in mind when investing in bio-energy. As preferred option for agriculture and rural development, the authors recommend the use of biogenic waste or the double use of agricultural products.

4. **Prof. Dr. Jürgen Zeddies**, University of Hohenheim, takes a look at the potential for renewable energy under global aspects. Based on FAO statistics for trends in population growth, per-capita food consumption and available land area for food or energy production, “exploitable area potentials” are derived from statistical models with simplified assumptions for selected countries and continents. With the use of fallow land reserves and yield improvements, acute price reactions for food and feed prices can be avoided. In the EU-27 and in other parts of the world, a significant potential for bio-energy production exists, but the question is still open to what extent bio-mass can be used for energy production while satisfying the primary demand for adequate and affordable food for human nutrition.

5. **Musa Freiji**, a widely known Lebanese entrepreneur who contributed significantly to the development of the poultry industry in the Middle East since his graduation from the American University of Beirut, addresses the broader question how agricultural production in the Arab region could be enhanced to reduce the dependency on imported grain in order to improve the balance of payments and support employment in agriculture. Based on FAO statistics for all countries in the Arab League and personal experience in several countries, he sees a huge potential e.g. in Sudan for better land use, but realization would require investments in a political climate of predictability for investors.

6. **Dr. Hans-Heinrich Thiele** and **Robert Pottgüter**, Lohmann Tierzucht GmbH, Cuxhaven, summarize management recommendations for laying hens kept in deep litter, perchery and free range systems. While most laying hens world-wide are kept in battery cages, EU directives and corresponding guidelines in individual countries will lead to the replacement of cages by alternative systems. Germany is presently in a transition phase, after which about 50% of the hens are expected to be kept in “Kleingruppenhaltung” (an advanced version of large enriched cages with more space per hen, nests, litter area and roosts), 50% in floor systems. The recommendations are based on long term experience with parents (most of which have always been kept on floor) and more recent experience with commercial layers in different countries. More detailed information for specific white-egg and brown-egg strain crosses is available from primary breeding companies and their distributors.

Please feel free to pass Lohmann Information to colleagues or send their name and address to the editor for future direct mailing.

With kind regards,

Dietmar Flock

Prof. Dietmar Flock,
Editor

Estimation, effectiveness and opportunities of long term genetic improvement in animals and maize

William G. Hill, Edinburgh, UK

1. Introduction

Genetic improvement in animals and plants for food consumption has been practised and realised since domestication. Intensive improvement, increasingly with incorporation of genetic principles, has been undertaken for a century or more. Much of this has been highly intensive and effective, notably in poultry. There are consequently concerns that genetic variation is being exhausted and continued gains cannot be expected. On the other hand, new technologies, in particular using molecular markers and, perhaps, transgenic methods, have become available, which in themselves provide the possibility of increasing responses by making better use of existing variability and indeed in generating new variability.

In this paper I shall review the magnitude and rates of changes that have occurred in some of our domestic species, mainly in animals rather than plants, in view of my area of knowledge and the potential readership. I shall also consider what opportunities there are for continued change and what influence these, using data from experiments which provide pointers. First, however, I shall review the methods for estimating genetic change, their assumptions and their limitations. None of this is new. The methods available differ greatly among domesticated species as does the information we have about genetic change because of different investments made in its estimation.

Much of the material presented here was first collected for an article (Hill and Bünger, 2004) on long term genetic change in laboratory and domesticated animals to celebrate 100 years of selection in the Illinois maize experiment. I shall also make use of material on crop species presented in other papers collected in the same issue of Plant Breeding Reviews (Janick, 2004)). Another source of information is a collection of papers reviewing genetic change in livestock (Hill et al., 2000). Whilst I shall focus mainly on the production traits and indeed the substantial changes that have occurred, concern has been expressed (e.g. by Rauw et al., 1998) about the deleterious correlated effects of such selection, and I shall consider what has been and is being done to counteract these undesirable changes. Information on some of the genetic changes has also been reviewed previously by Havenstein (2006) in this journal. The present review is not intended to be comprehensive.

2. Measurement of genetic change

Estimation of genetic change requires comparisons of genotypes bred in different years in the same environment or corrected for environmental differences, and the problems of doing so had extensive discussion, particularly many years ago (e.g. Hill 1972). Simple comparisons of mean performance across generations are a reliable estimate of the genetic change only if the environment is really constant. This seems to be feasible for laboratory populations, such as Drosophila maintained at constant temperature with a defined single feed source, but only for traits such as bristle number which are highly heritable and seem not to be overly dependent on the management. It becomes less feasible even in the lab for traits such as litter size in mice, where even under the best managed regimes, health problems may arise. The nearest approach in livestock would be random sample tests or similar trials maintained over years in defined conditions, but even so the possibility of, for example, changing disease state and feed quality can not be unequivocally ruled out.

Proper comparisons involve comparisons of different genetic groups, e.g. animals bred from parents of different generations maintained together in the same environment, i.e. a between-genotype, within-environment comparison. An important requirement is that there are no confounding effects if different generations are compared, for example due to age of parents. For species of plants propagated by seed, where seed storage under controlled conditions is reputed to have no effect on plant performance, such comparisons are straightforward (providing the material has been saved). For many livestock species maternal age effects are hard to eliminate, but comparisons through the sire are feasible although these measure only the additive component of change. Modern methods of genetic evaluation using “best linear unbiased prediction” (BLUP) enable breeding values to be predicted for animals in all generations, and thus a trend over many years computed. These require an overlap of generations however, standard for dairy cattle, but connections become weak for programmes run with annual generations. Whilst, as the name suggests, BLUP methods are unbiased, they are so only if the parameters are known without error. Selection is incorporated using the selection differentials and heritability, so simple use of BLUP comparisons, particularly in populations where sire use is short, cannot be regarded as fully reliable. Thus while BLUP is an excellent procedure for making comparisons of breeding values of near contemporaries, BLUP estimates of genetic change over many generations have to be treated with more caution, as do repeat mating designs, for the errors accumulate unless deliberate efforts are made to ensure inclusion of new offspring of sires over very long periods and equal treatment of them.

A further complication of such inter-generation comparisons when the period of contemporaries spans only few years is that estimated responses can be confounded with genotype x environment interaction. For example, assume a disease organism mutates regularly such that different host resistant genotypes are resistant or new diseases arise, and that some genetic resistance is built up, but the disease is then controlled by non-genetic methods. Inter-generation comparisons may then reflect the results of increased performance through increased genetic resistance to the current strain of pathogen, but with no long term benefit in that comparisons each side of the rise and fall of the pathogen actually do not include it.

Whilst seed, semen and ova (of most species) can be stored indefinitely with no likely or measurable important change, it is not an option in all species. An important method is, therefore, maintenance of a population which is bred but aimed to be constant, i.e. a control population. One method is to use inbred lines which, once established, are stable apart from mutation and residual variation; but while they are available for mice, they are not for cattle. They also have a potential disadvantage in that the lines or their cross represent few surviving and thus selected genotypes, which may not respond similarly to environments as the modern stock. Control populations maintained segregating need to be kept with large effective size in order to minimise genetic drift. They are therefore expensive to maintain and become increasingly more expensive as they become less competitive compared to modern stock. Also, increasingly, they may respond differently to the modern environment than do current selected populations, but they do also offer the opportunity to make comparisons using different management regimes, e.g. former and modern diets. A further concern is that, particularly if the controls represent the best available in the year of foundation, their performance may have deteriorated genetically since foundation as a consequence of natural selection, and it is difficult to assess the magnitude of such a change. The issue of whether the selected stock improved or the control populations or repeat mating populations declined has been a major source of debate.

One question which is often asked is how much of the phenotypic improvement seen in commercial performance is attributable to genetic rather than environmental changes. Whilst a basic question, it is not necessarily relevant, because one can adapt to meet or utilise changes in the other. For example, modern varieties of cereals yield more than old varieties in large part because they can be given heavier fertiliser treatment without lodging as they have been bred to have shorter straw. The genotypes and environment co-evolve. Indeed to a breeder, the only comparison really relevant is how his stock compares with competitors under current or potential management systems. Even so, if we are to assess the achievements of breeders and the opportunities for further change, we need to make cross-generation comparisons.

Whilst it is easy to point to limitations of most or all of the methods, we have to be grateful that good ones are available, and thank those who enabled them by providing the foresight, persistence, and continued funding for maintenance of seed or semen banks or control populations or controlled trials. The results of their work illustrate the power of genetic change but also illustrate some problems. We first consider poultry, for which we have excellent data on the large genetic improvements that have been made.

3. Broiler poultry

A control population, the Athens Canadian Random Bred Control population, was established in 1957 from crosses in 1955 of four broiler strains, three commercial and one experimental, since when it has been maintained without selection and apparent phenotypic trend. Based on comparisons with this control, a magnificent set of data on genetic improvement has been collected by Havenstein and colleagues in two trials, the first using 1991 commercial stock (Arbor Acres) and the second using 2001 stock (Ross 308). In each case the modern product was compared with the control using a modern diet and the one constructed to 1957 specifications. Havenstein (2006) illustrates the magnitude of change with photographs of broiler carcasses.

Body weights of controls and a 2001 commercial broiler are summarized in Table 3.1. This table shows that the much greater growth rates after 44 years of improvement are seen on both diets and that the major part of the improvement, about 80%, could be attributed to genetic change. In Table 3.2 changes in other traits are also compared and spectacular changes in, for example, meat yield shown together with a reversal of the earlier increases in fat content. In this table the differences between 1957 and 1991 and between 1957 and 2001 birds are also compared, from which rates of change during the 1990s can be seen. It is notable that response was still continuing apace, i.e. of the order of over 2% of the mean per year in body weight. Even if the control population had declined in performance when selection was initially relaxed, such a change could not contribute to the 2001/1991 comparison.

Table 3.1 Comparison of body weights of males at different ages between 1957 and 2001 strains reared on diets to 1957 and 2001 specifications. (Source Havenstein et al. 2003a)

Population	Diet	Body weight (g) at specified age				
		21d	42d	56d	70d	84d
2001	2001	791	2903	4402	5385	5958
	1957	647	2271	3173	4064	4661
1957	2001	210	641	1009	1412	1907
	1957	184	591	921	1305	1715

Table 3.2 Comparison of growth and body composition of 1957 control and 1991 commercial and of 1957 control and 2001 commercial broilers reared on the diet used in that year. The difference D_1 denotes changes between 1957 and 1991 and D_2 between 1957 and 2001, and $D_2 - D_1$ the estimated change between 1991 and 2001. (Sources: Havenstein et al., 1994, 2003a,b)

	1991 trial			**2001 trial**			**Diff.**
Year of population	**1991**	**1957**	**D_1**	**2001**	**1957**	**D_2**	**D_2-D_1**
Body weight (kg)	3.11	0.79	**2.32**	3.95	0.81	**3.14**	**0.82**
Carcass weight (kg)	2.07	0.50	**1.51**	2.81	0.48	**2.33**	**0.82**
Carcass yield (%)	69.7	61.2	**8.5**	74.4	60.8	**13.6**	**5.1**
Breast yield (%)	15.7	11.8	**3.9**	21.3	11.4	**9.9**	**6.0**
Carcass fat (%)	15.3	9.4	**5.9**	15.9	10.6	**5.3**	**-0.6**

A major concern has been whether improved growth performance has been at the expense of reduced fitness, in particular leg strength and viability. In the 2001 study of Havenstein et al. mortality rates were much lower than in the 1991 strain, both in the control and selected populations. In the later study, cumulative mortality (averaged over diets) for, respectively, the 2001 selected and 1957 control to 42 days was 3.6% and 2.1%, and at 56 days, 6.8% and 4.0%, indicating somewhat higher mortality in the modern strain (Havenstein et al., 2003a). At the same live weight, however, mortality was lower in the selected population. Leg abnormalities were not recorded in this trial, but selection pressure has been applied to reduce leg abnormalities by breeders, and this seems to have produced results. Changes can be estimated using industry comparisons of modern (*M*) lines with the lines from which they were derived maintained as unselected controls (*C*) since 1972. Results obtained by Aviagen were as follows, averaged over differences between three control (1972) and three modern (2005) lines selected from them: Live weight at 42 days, *M* 2595g *C* 1216g; Feed conversion ratio to 2kg live weight *M* 1.66, *C* 2.23; Mortality to 42 days *M* 4.2%, *C* 3.9%; and proportion of birds with good leg health (GLH) *M* 75%, *C* 68% (Fleming et al. 2007). Thus, despite the much superior growth rate and feed efficiency, average mortality and leg strength are similar in the selected lines to those of the controls (differing somewhat among lines, not shown). McKay et al. (2000) also show that the leg traits had been worsening, but then were improved by subsequently devoting selection effort to this fitness trait.

Turkeys Havenstein and colleagues (2007) have conducted a similar study to theirs with broilers in which turkeys from a 1966 control strain and 2003 commercials were compared on each of the diets typical for 1996 and 2003. Changes found were large indeed. For example, the number of days required to reach 11kg was approximately halved, and the corresponding feed conversion efficiency also halved (modern: fcr 2.13 at 98 days of age; control: 4.21 at 196d). Mortality rates were non-significantly higher in the controls.

4. Table egg poultry

Selection limits in egg laying poultry were first mooted over 50 years ago by Dickerson (1955), in part because gains in nucleus flocks were not being realised in commercial practice. Fortunately it seems that such pessimism was unfounded, as data both from comparisons using unselected control populations and stock evaluations show. Comparisons between unselected control lines derived from commercial stock over three periods from 1950 with the performance of a selected population of 1993 are shown in Table 4.1 (Jones et al., 2001). All measures of performance, namely age at first egg, egg production and egg weight, have improved, while body weight has remained relatively unchanged. Consequently there has been an approximately 30% improvement in feed conversion efficiency over the 40 year period from 1950, which was continuing after 1970. Even if selected lines had regressed in performance, this is unlikely to have affected comparisons between the control populations, all long relaxed before 1993.

Table 4.1 Progress in egg production: Contemporary comparison of egg production traits for unselected control lines (C) established from selected populations in 1950, 1958 and 1973, with a commercial population (S) of 1993. (Source Jones et al., 2001)

Population	18 wk wt g	Age at lay day	Hen day %	Egg wt g	Egg mass g/day	Feed Eff. g/g
1950 C	1440	182.9	56.9	56.5	34.2	0.319
1958 C	1336	172.6	59.7	61.8	37.0	0.345
1972 C	1331	166.3	64.2	61.0	41.2	0.378
1993 S	1429	154.9	73.4	63.6	49.3	0.426

Another source of information comes from German Random Sample Tests (Flock and Heil, 2002). In these tests, the environment was intended to be as constant as practical, but close to commercial conditions in terms of disease prevention and feed quality. Phenotypic changes over years should therefore mainly reflect genetic changes, but there can be no hard evidence that this is the case. Changes in mean performance over a 24 year period (1975-1999) are shown in Figures 4.1 and 4.2 for egg mass per hen housed and feed conversion ratio, the two economically most important traits. Individual points for 6 strains with the same shell colour.

Figure 4.1 Phenotypic trend for total kg egg mass per hen housed in German Random Sample Tests (Source: Flock and Heil 2002)

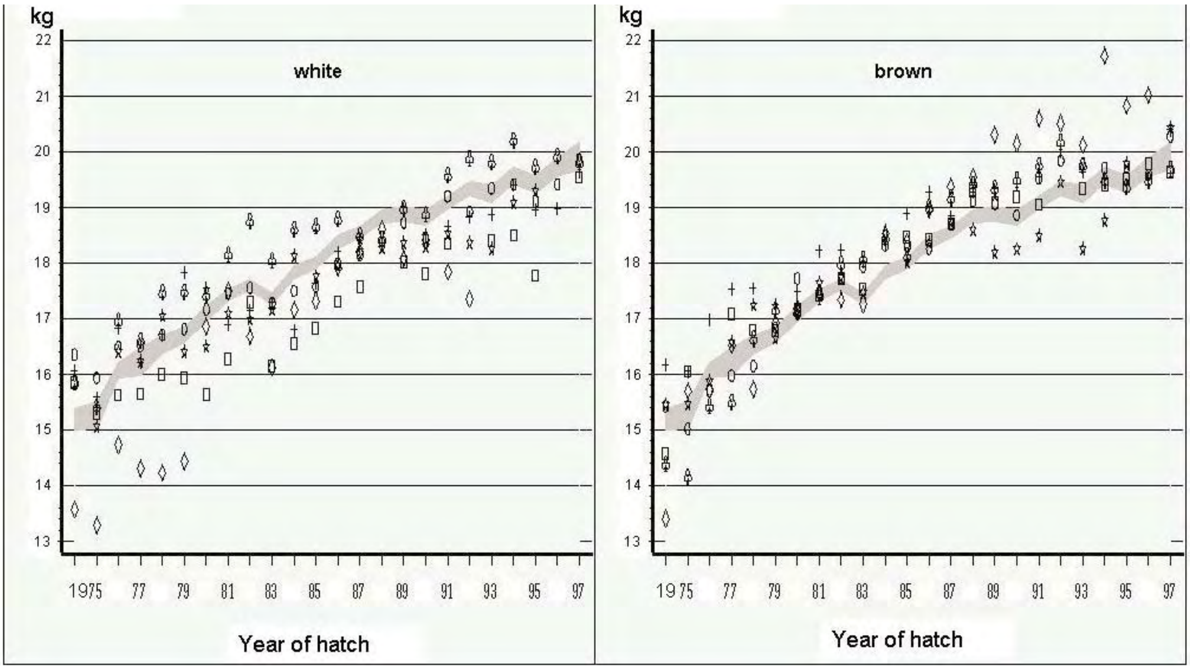
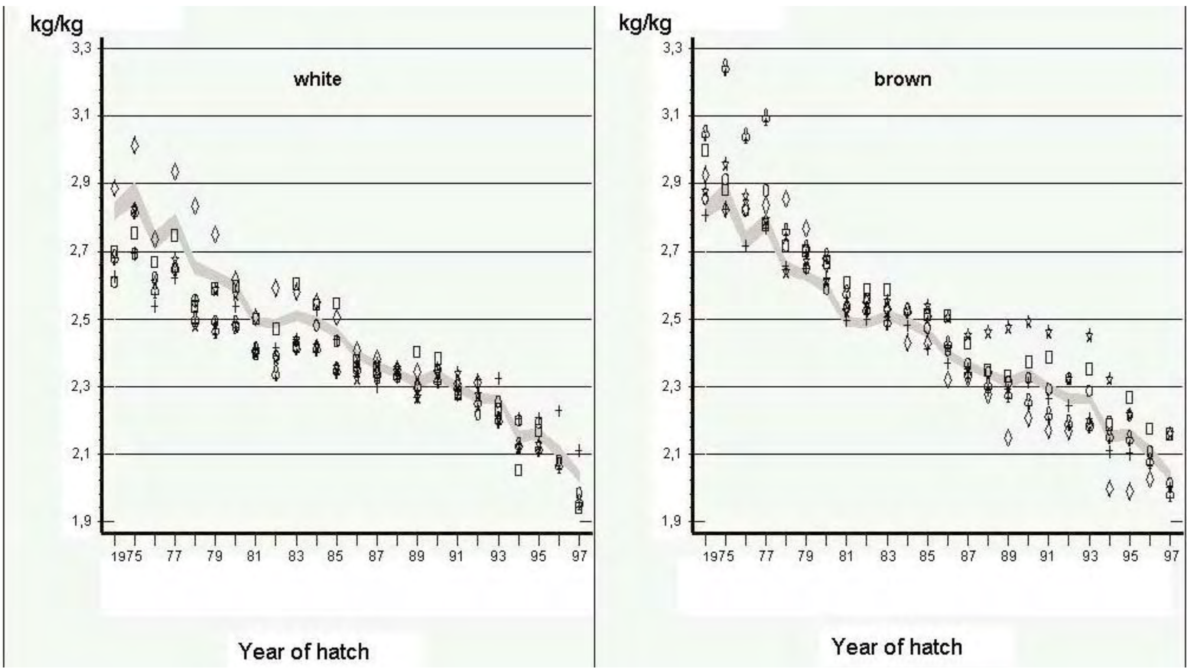


Figure 4.2 Phenotypic trend for feed conversion ratio (kg feed/ kg egg mass) in German Random Sample Tests (Source: Flock and Heil 2002)



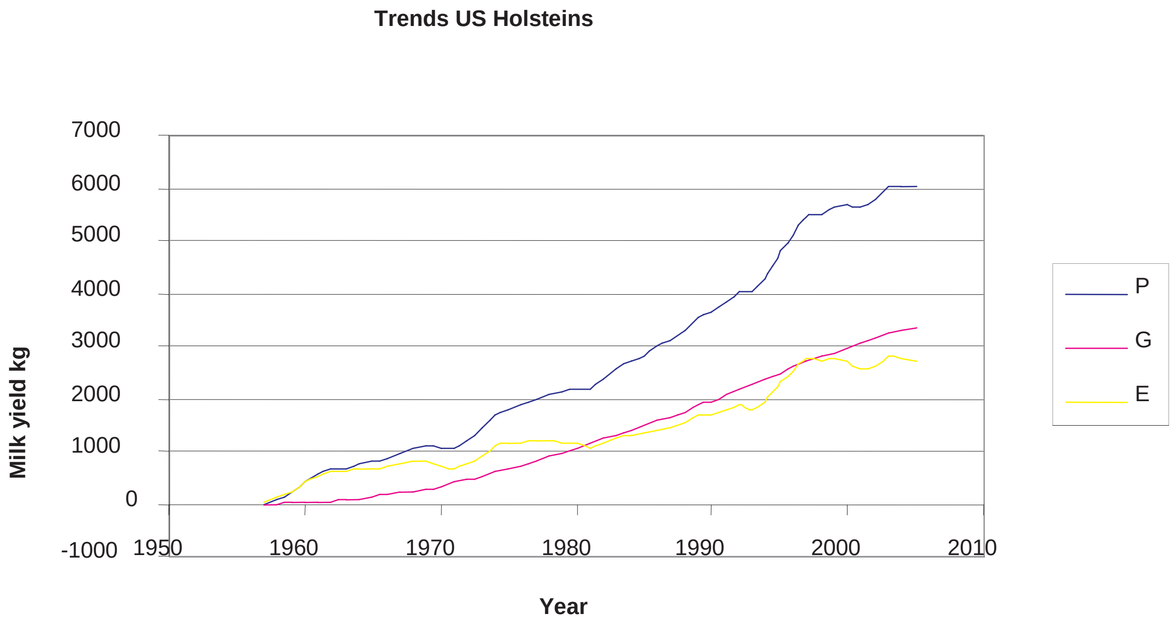
Least squares annual means are shown for 6 white-egg and 6 brown-egg strains as deviations from a 95% confidence interval for all strains. Changes have been large indeed, mainly in persistency of rate of lay, with reduction in age at first egg mainly during the first years of the period covered. Body mass at end of lay (500 days) was reduced more in brown egg strains, which contributed to improvements in feed conversion efficiency and egg income over feed costs.

As egg production itself is a fitness associated trait, there is less potential concern about declines than there may be with traits of the growing animal such as growth rate and leanness. Annual changes varied between the five stations included in the analysis, and the general trend of reduced laying mortality was reversed when beak treatments were discontinued (Flock and Heil, 2002).

5. Dairy cattle

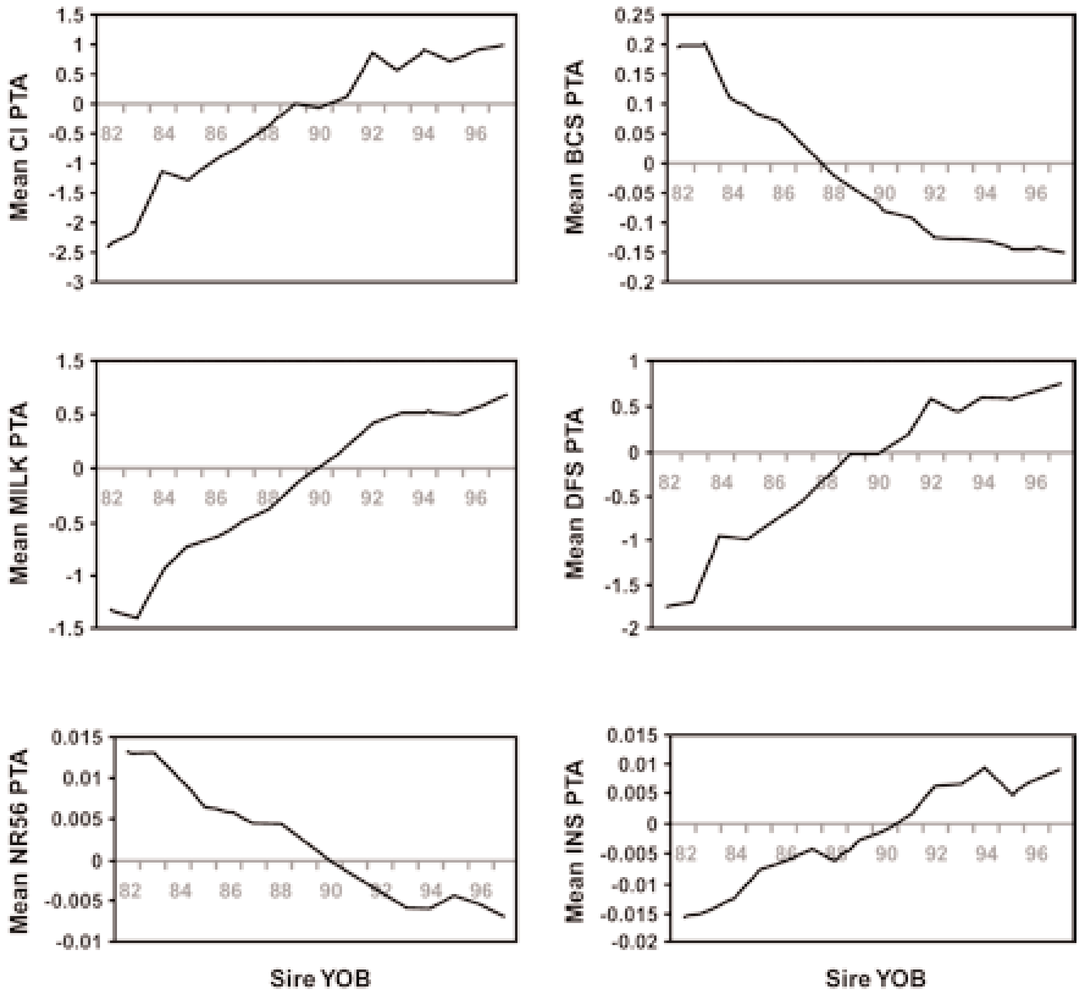
With the advent of progeny testing and increasingly sophisticated methods of breeding value prediction leading to animal model BLUP, rapid improvements in production traits have been effected. The clearest source is from trends in BLUP estimates over years, which although somewhat model dependent in the sense of depending on assumptions of parameter values and on how selection has been practised, are less so over time periods where sires of different years of birth have progeny spanning many overlapping years. Figure 5.1 shows these for US Holsteins, where the accelerating and continuous trend is shown. It is seen that approximately half the doubling in yield from about 6000kg to 12000kg over an almost 50 year period can be attributed to genetic change. There have been changes of similar relative magnitude in yields of fat and protein.

Figure 5.1 Phenotypic mean yields (P), mean breeding values (A) and environmental effects (E = A - P) for US Holsteins, derived from USDA data; mean yield in 1957 was 5859 kg. (http://aipl.arsusda.gov/eval/summary/trend.cfm)



There have, however, been substantial changes in fitness associated traits as a consequence, with estimates of reduction in fertility of the order of 1% per year. Examples of genetic trends in the UK in a number of traits are given in Figure 5.2. These show a strong positive trend in milk yield (as for the US data, not least a consequence of international movement of genes). This is accompanied by increasingly leaner animals (reduced condition score, a concern as animals lose weight in early lactation and may not be fertile till they start gaining again), and reductions in a number of measures of fertility (days to first service after calving, non-return rate to oestrus after insemination, number of inseminations per conception, and calving interval).

Figure 5.2 Genetic trends in production and health traits in the UK, expressed as transmitting abilities (PTA), for: calving interval (CI), condition score (BCS), milk yield in kg at day 110 (Milk), days to first service (DFS), non-return rate 56 days after service (NR56), and number of inseminations per conception (INS). (Source: Wall et al., 2003)



Largely as a consequence of these unfavourable changes in fitness associated traits, there has been a major shift in emphasis in programmes which had been mainly aimed just at production traits. Although such traits are more lowly heritable and often harder to record (e.g. indicators of lifespan), there is evidence of genetic variation and thus opportunities for improvement. The changes in milk yield (Fig 5.1) show accelerating rates until the 1990s, and it is likely that there has been some subsequent reduction in rates of improvement in production traits as more emphasis has been given to fertility and health traits.

6. Pigs

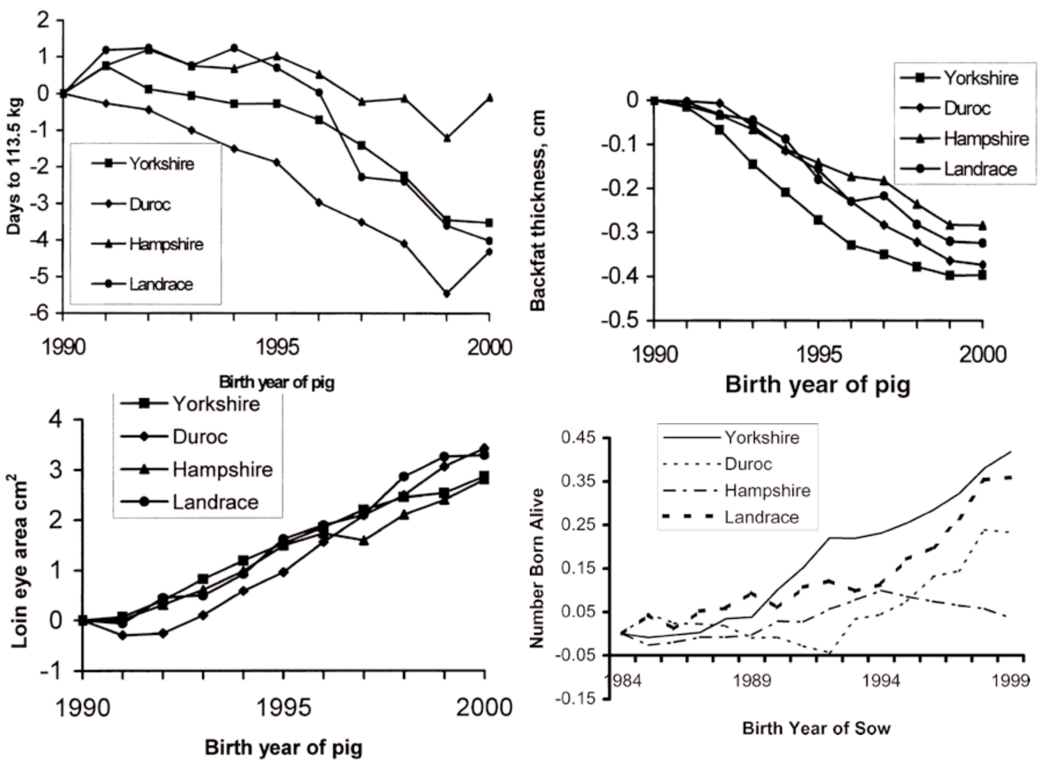
As with poultry, very great genetic change has been effected in pigs. Early organised selection programmes were through progeny testing, notably in Denmark, but subsequently there has been increased emphasis on performance testing for traits of growth and carcase, particularly with the advent of ultra-sonic fat depth scanning. More recently, there has been increased emphasis on reproductive traits, as better analysis methods became available and opportunities for further reduction in fatness diminished.

Long term changes can be illustrated only through phenotypic change, as there were neither control populations nor sophisticated BLUP evaluation. One source is mean performance in central tests in the Netherlands (Merks, 2000), shown in Table 6.1. This shows halving of fat depths over a 60 year period from 1930, much of it prior to introduction of modern breeding programmes. It is uncertain how much of this is due to change in management; for example simple feed restriction is effective in reducing fatness.

Table 6.1 Phenotypic trends for pigs in central test stations in the Netherlands in daily gain (DLG), feed conversion ratio (FCR) and backfat thickness (Fat). (Source: Merks, 2000).

Year	Landrace			Yorkshire		
	DLG (g/d)	FCR	Fat (mm)	DLG (g/d)	FCR	Fat (mm)
1930	500	3.5	45	550	3.4	48
1947	650	3.4	33	680	3.2	35
1972	788	2.6	26	815	2,5	27
1990	840	2.8	24	840	2.7	22

Figure 6.1 Genetic changes in four breeds of pigs in registered herds in the USA in growth traits and litter size (Source: Chen et al., 2002, 2003)



Published estimates of genetic change free of changes in management are available from BLUP analyses, with a nice set of results obtained for the 15 year period to 2000 for registered herds in the USA (Chen et al., 2002). These show substantial favourable changes in growth rate, lean growth rate, backfat and loin eye area; for example days to 113 kg live weight were reduced by 0.4 days/year on average (Figure 6.2). During this period, more so in later years, reproductive performance has also been improved, particularly in the Yorkshire breed which is used mainly as a dam line (a yearly trend averaging 0.03 pigs born alive), but with little change in the Hampshire, used primarily as a sire line. These figures do not relate directly to the performance of commercial crosses, as given previously for broilers, and so possibly underestimate the total changes. They may also be subject to sampling errors and bias through rapid turnover of sires and multi-trait selection. Even so, there has clearly been major and continuing improvement in pig performance. Increasingly emphasis is being given to health and welfare related issues, such as removing sow restraints and thus, for example, on other traits associated with piglet survival.

7. Beef cattle and sheep

As the main aim of this review is to assess long term improvement and these are likely to be greater in the intensive industries, only limited information is provided here on the grazing species. Recent analyses provide evidence of substantial improvement within breeds in the UK in the last decade (Amer et al., 2007). Results for sheep are given in Table 7.1; but they span a relatively short time (approx. 6 years) and sires are used for only a limited number of years, so estimates of change are not precise. These estimated trends using BLUP show for different types of breeds of increased growth rate and increased muscle depth, with inconsistent and small changes in fatness and litter size.

Table 7.1 Annual genetic trends in traits of sheep in the UK, averaged over breed types, for the period from 2000 (Source: Amer et al., 2007)

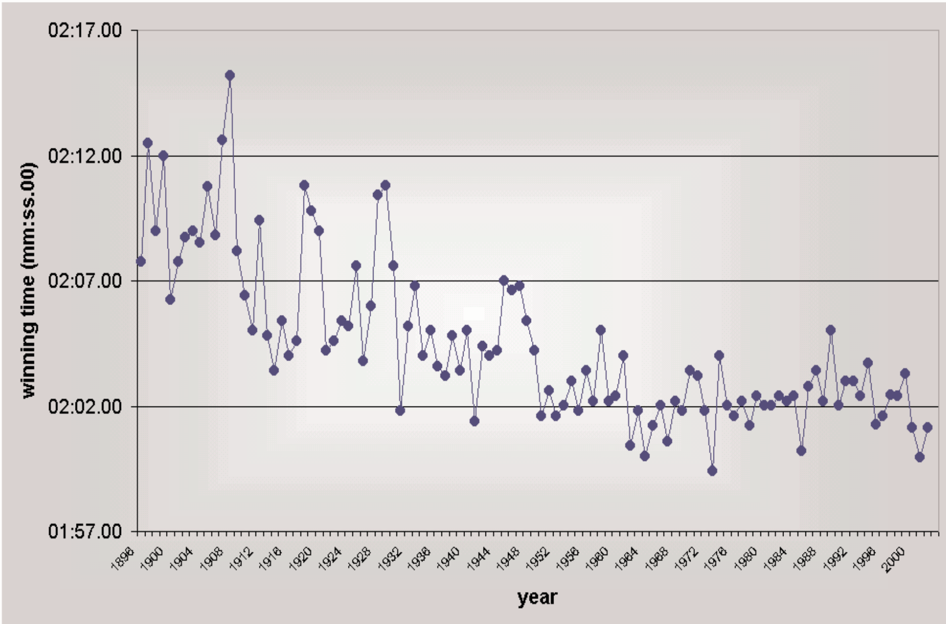
Trait	Breed type		
	Hill	Crossing	Terminal
8-wk live weight (kg)	0.05	0.14	0.15
Mature live weight (kg)	0.19	0.01	0.01
Litter size (lambs/ewe)	0.006	0.003	0.004
Live wt at scanning (kg)	0.14	0.30	0.34
Muscle depth (mm)	0.07	0.09	0.13
Fat depth (mm)	-0.001	0.002	-0.011

For beef cattle in the UK, over both the periods 1991-5 and 1999-2003, there were substantial annual increases in beef value, a function of weight and carcase merit, in terminal sire and dual purpose breeds, similar for the two: averaging £0.43/yr in the first period and £0.69/yr in the second (Amer et al., 2007). There were also, however, worsening figures for calving ease, with percent unassisted falling by 0.34%/yr in the terminal breeds and 0.11%/yr in dual purpose breeds, similar over the two periods. These changes presumably reflect direct and correlated consequences of selection for growth.

8. Racehorses and Greyhound Dogs

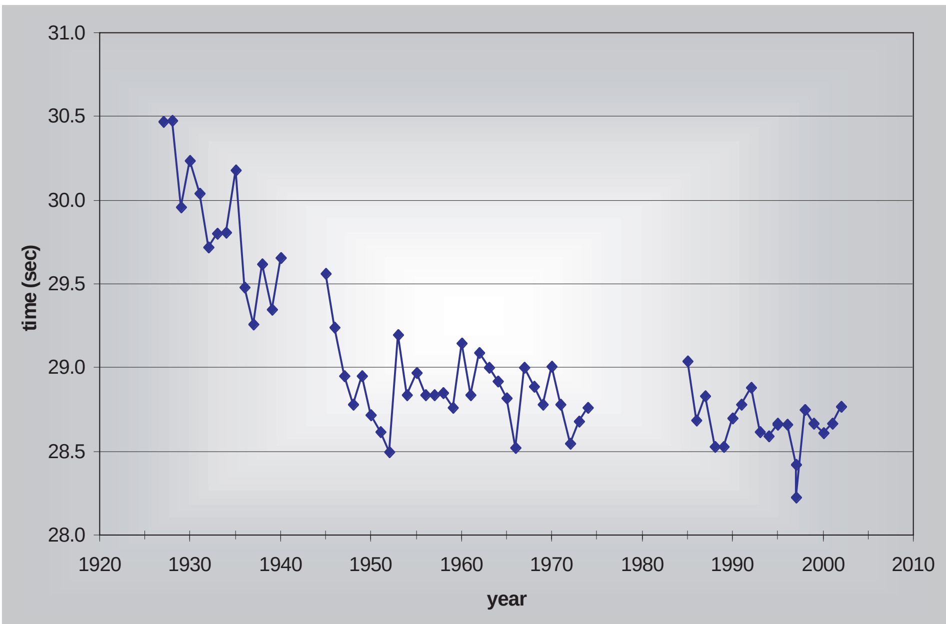
There are no long term estimates of genetic trend for racing animals, but their long history of selection merits their consideration here, as do the results. As a proxy, the winning times for Thoroughbred horses in the Kentucky Derby in the US are shown in Figure 8.1, spanning almost a century (for details, see Hill and Bünger, 2004). What is striking is that there has been little obvious change since about 1950, despite the enormous emphasis given to breeding, and the record for the race stands from 1973. A similar pattern holds for greyhound dogs (Figure 8.2). These are simple phenotypic estimates, but there is no need to argue that some of the response has been genetic! For trotters there is, however, evidence of continuing genetic change over the 20 year period from 1976 (Arnason, 2001), with a total reduction of about 5% in time over a fixed distance.

Figure 8.1 Changes in Thoroughbred horses: winning times in the Kentucky Derby. (Source: Hill and Bünger, 2004)



data source: http://www.drf.com/home/crown2001/kd/derby_stats.html

Figure 8.2 Changes in Greyhound dogs: winning times in the English Greyhound Derby (480m except 500m 1975-84, run at a different location in London after 1984). (Source: Hill and Bünger, 2004)



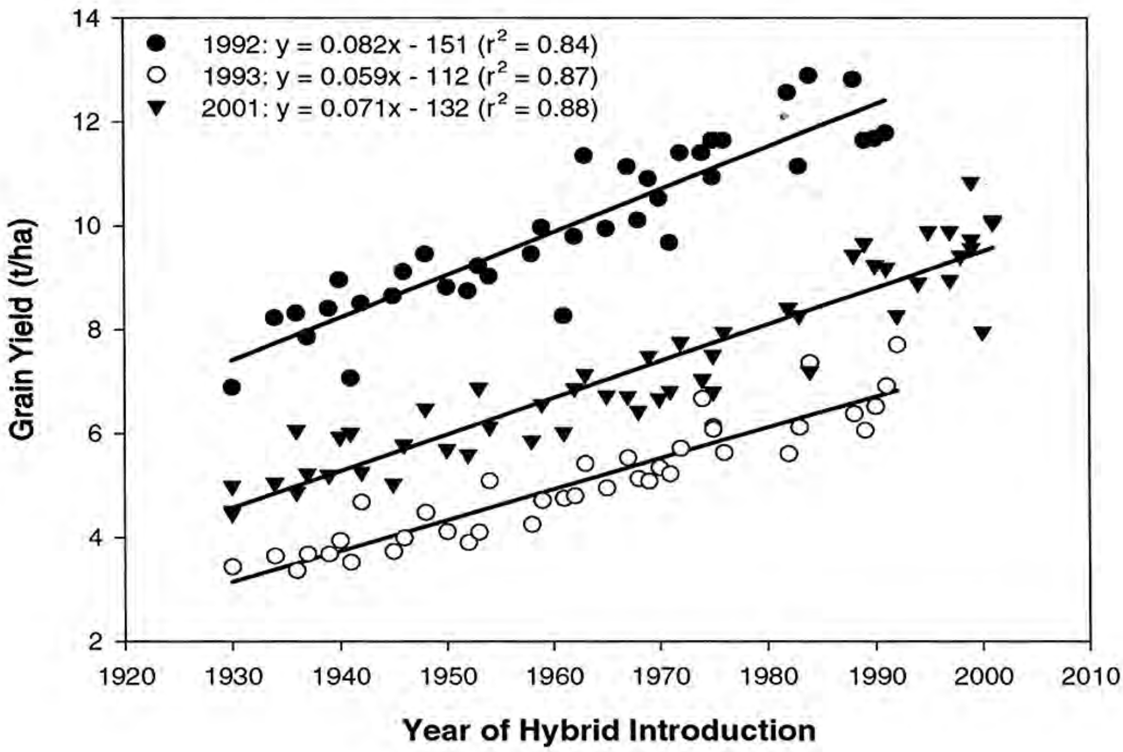
data source: http://www.greyhound-data.com

There has been quite extensive analysis of pedigree data in Thoroughbreds to estimate genetic parameters, and Gaffney and Cunningham (1988) and later others have reported values of almost 50% for Timeform ratings (relative performance measure used for handicapping) and winnings. Based on such analyses and using BLUP, Gaffney and Cunningham predicted there has been substantial genetic change, albeit while observing the lack of phenotypic change. They also note high selection intensities on performance, albeit rather long generation intervals. There are of course potential biases in heritability estimates, for example environmental covariance of sons and sires due to choice of trainer for offspring of the most successful stallions. Even so, there is recent evidence of no relationship between stud fee and earnings of offspring, surprising even in the absence of any genetic variation (Wilson and Rambault, 2007). Racehorse and Greyhound breeders have a different business model from those breeding and improving food animals.

9. Maize

We are familiar with the enormous changes in yields of crop plants over the years, and shall not review these in detail. As results of a maize selection experiment are discussed in the next section and it is one of our major feed crops, here data on maize improvement are included for illustration. Duvick et al. (2004) gave results for trials in which maize varieties introduced in different years were grown from stored seed in trials conducted in the Midwest of the USA in three different years. The regression of yield on year of introduction provides an estimate of genetic trend (Figure 9.1). This is seen to be almost linear over a long period, with increases in excess of 1% of the mean per year. Furthermore, although there are big differences between the years in growing conditions as shown by the large differences between them in average yields, there appears to be little substantial evidence of genotype X environment interaction in that differences between hybrid cohorts were similar within each of the environments.

Figure 9.1 Grain yield per hybrid maize variety in each of three trials in the US regressed on year of hybrid introduction. (Source: Duvick et al., 2004)

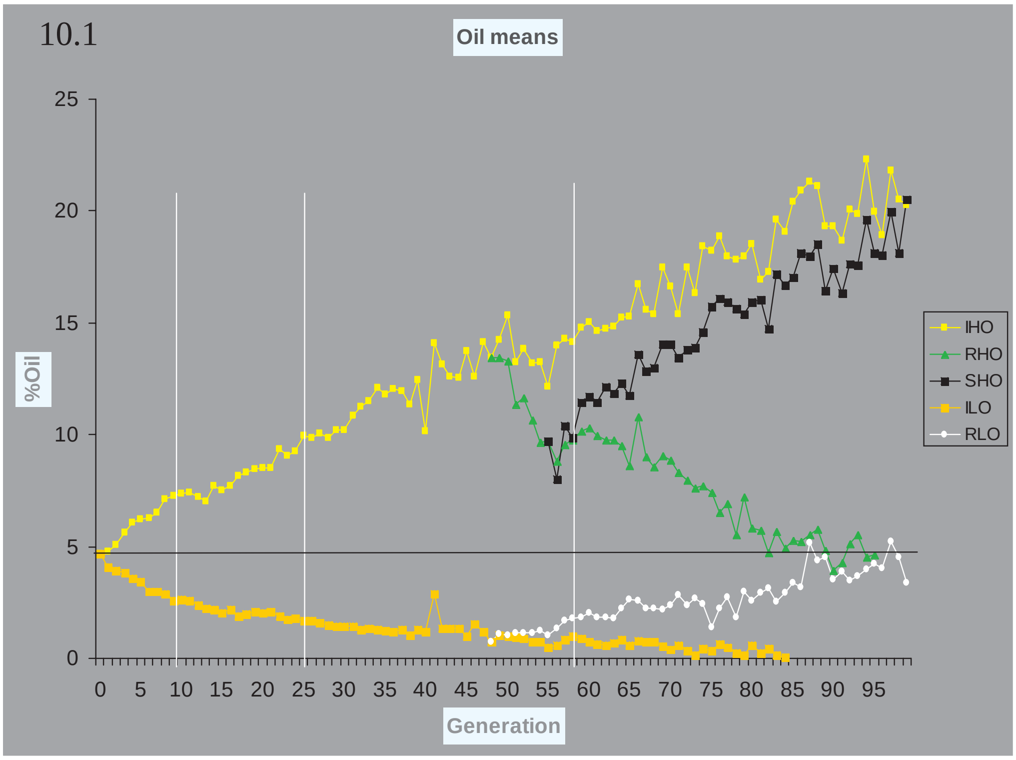


10. Results of long term selection experiments

Turning now to consider prospects for future improvement, pointers can be obtained from the outcome of some selection experiments that have been run for very long time frames. These span 100 generations or so, are bred mainly in closed populations, and are thus of duration as long as or longer than our intensive breeding programmes. Many experiments of shorter duration have been conducted, in addition to others of longer duration in Drosophila, in which large responses have been obtained, but we use the following as pointers.

The classic experiment is that of the Illinois corn (maize) experiment, which has now exceeded 100 annual generations of selection in separate lines high and low for oil and for protein percentage in the kernel. Results for oil content are shown in Figure 10.1, which shows results for continued selection and for lines in which the direction of selection was reversed. A plateau at essentially 0% oil has been reached in the low line, but the up line continues to respond. The pattern is similar in the protein lines (not shown), but the plateau in the low line is at ca. 5% protein, presumably near a minimum for a viable seed. What is striking is the continued, near linear, response upwards, and the fact that the reversed selection after 48 generations was so effective, illustrating the large amounts of variation still present then. The lines were maintained with typically only 30 plants selected per generation, although with different numbers at different times during the course of the experiment.

Figure 10.1 Results of 100 generations of selection in Illinois for high (H) and low (L) oil content in the maize kernel. In lines RHO and LHO the direction of selection was reversed, and in SHO it was reversed again. (Source: Dudley and Lambert, 2004)



The second example is that of Marks' selection lines for body weight from a wide genetic base of Japanese quail reared on one of two diets. Response continued in both lines for 97 generations (Figure 10.2), almost linearly after the first 20 or so generations. The third example is the Dummerstorf high growth selected line, in which response has continued for 100 generations (Figure 10.3) with an effective population size of about 60. Whilst there were some indications of curvilinearity, pointing towards a plateaux of response, plateaux had not actually occurred in this time.

Figure 10.2 Results of almost 100 generations of selection for increased 4 week body weight in Japanese quail on two different diets (P, T), with contemporary unselected controls (PC, TC). (Source: Marks, 1996)

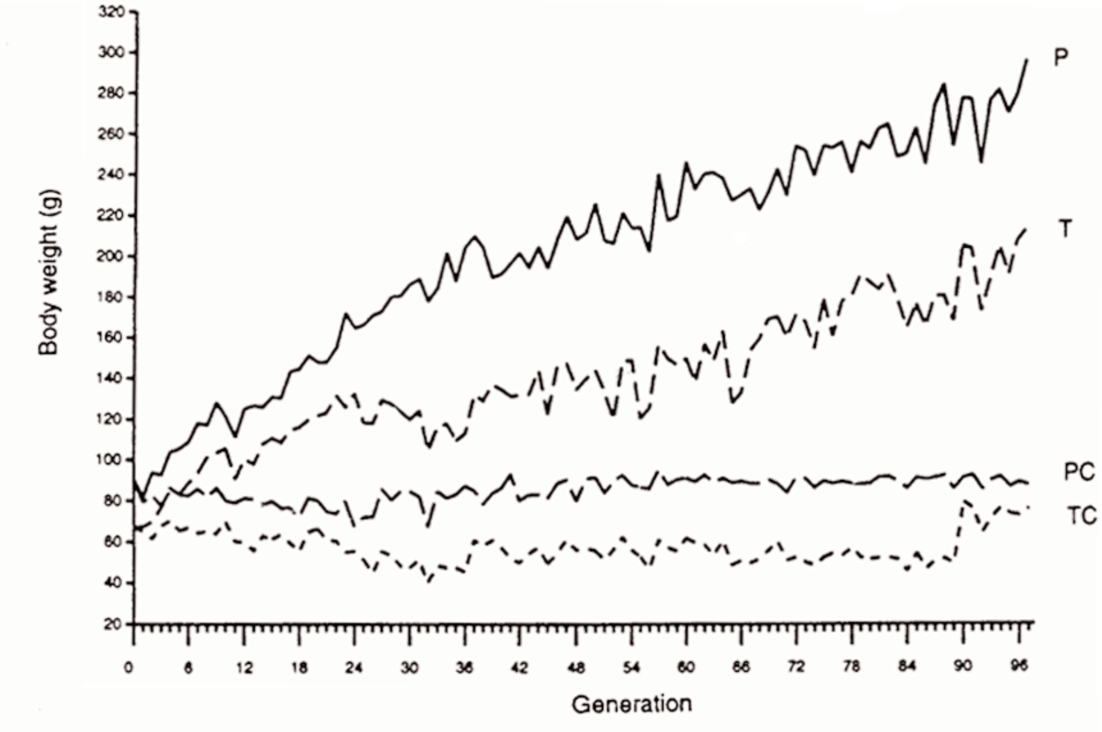
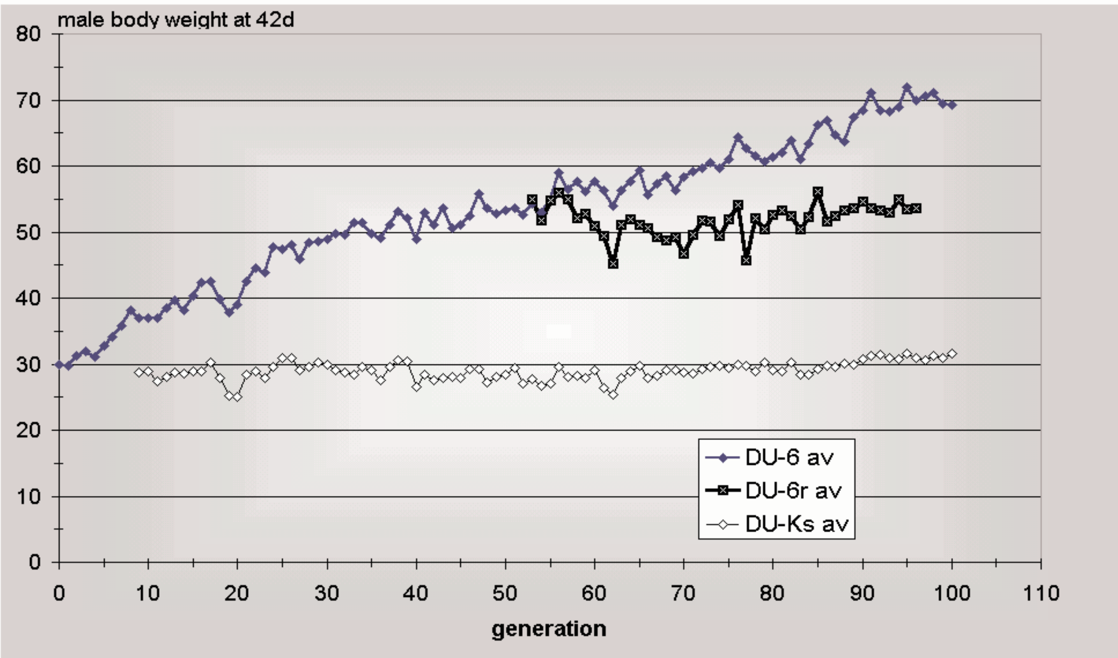


Figure 10.3 Results of 100 generations of selection (Du-6) for 42 day body weight of male mice, together with an unselected control (Du-Ks) and a relaxed selection line (Du-r). (Source: Renne et al., 2003)



These three experiments have been aimed at changing what are essentially growth or conformation traits. A 122 generation selection experiment has been conducted for litter size in mice (Holt et al., 2005), a trait with relatively low heritability and subject to more inbreeding depression. The high selected line was not closed, however, as selected lines were brought in from elsewhere. From an initial mean of about 10 animals born alive per litter, also approximately the mean of an unselected control population at the end, the mean of the selected line increased to about 20 and was still showing some response in the last 20 generations. A doubling of reproductive rate is not spectacular; nor is it trivial.

The laboratory selection experiments were conducted with much less intense selection that commercial breeders can achieve, but typically with smaller population sizes, and (except for litter size in mice) the populations were closed after their foundation. In some cases (for example in the Dummerstorf lines) when selection was relaxed, there was a regression in response, a feature seen much strongly in some experiments in Drosophila. Thus Yoo (1980) selected for abdominal bristle number in Drosophila for 80 generations, and while continued response was achieved, relaxation led to a big drop in response associated with genes having a positive effect on bristle number but a negative effect on fitness that were still segregating.

Very substantial changes have, of course, been observed in selection experiments run for fewer generations. Notably, Siegel conducted selection high and low for 8 week body weight in broilers, and the resultant lines diverged 8-fold in body weight after 37 generations (Liu et al., 1994). In the low lines, some birds show anorexia.

11. Prospects for continued improvement

Modern developments, such as the introduction of molecular genetic methods, should have an important impact on rates of genetic progress, particularly for traits that are difficult to record on live animals (e.g. meat quality), sex limited (e.g. egg number) or lowly heritability (e.g. mortality). Whilst much emphasis so far has been on identifying QTL affecting production traits, and there have been a few successes (e.g. DGAT in dairy cows), the impact has not yet been great. The alternative scenario of utilising high density mapping of the whole genome to identify regions of genomic effect and of similarity of relatives, ‘genomic selection’ (Meuwissen et al., 2001), seems to offer more opportunities and is now being introduced. I shall not review these but address the more long term questions: What are opportunities for long term improvement? What is likely to influence them?

An important concern is whether there has been a substantial loss in variability in the commercial populations. There is little evidence that is the case. One source of information is from estimates of genetic variation in quantitative traits within lines. In analyses of Ross lines by Koerhuis and Thompson (1997) estimates were 25% and 32% in two lines. These figures are similar to or higher than the ‘traditional’ estimate of 25% heritability of growth rate, e.g. in the early generations of Siegel’s experiment (Liu et al., 1994), albeit the modern estimates were based on more sophisticated statistical procedures. For egg production, Preisinger and Flock (2000) quote estimates of heritability of over 30% in the early phase of the laying period, 10% at peak lay (when most birds lay most days), and 20% in the mid-late period, values which would not seem out of line with historical estimates.

For dairy cattle, where the estimate of heritability used in the 1950s was about 25%, it is now 35% or more. Of course modern methods of analysis eliminating environmental and selection effects, better records and control of the environment enhance these later figures, but they do not indicate genetic variance is lacking.

A second kind of information comes from observations on variation at molecular markers in populations which are presumably do not influence the production traits and are indicators of neutral variability. A nice set of data collected on poultry has been provided by the International Chicken Polymorphism Map Consortium (2004), who compared SNP diversity within and between Jungle Fowl and modern broiler and egg laying stocks (Table 11.1).

Table 11.1 Estimation of molecular genetic diversity in chickens expressed as frequency of single nucleotide polymorphisms (SNPs) within and between populations. (Source: International Chicken Polymorphism Map Consortium, 2004)

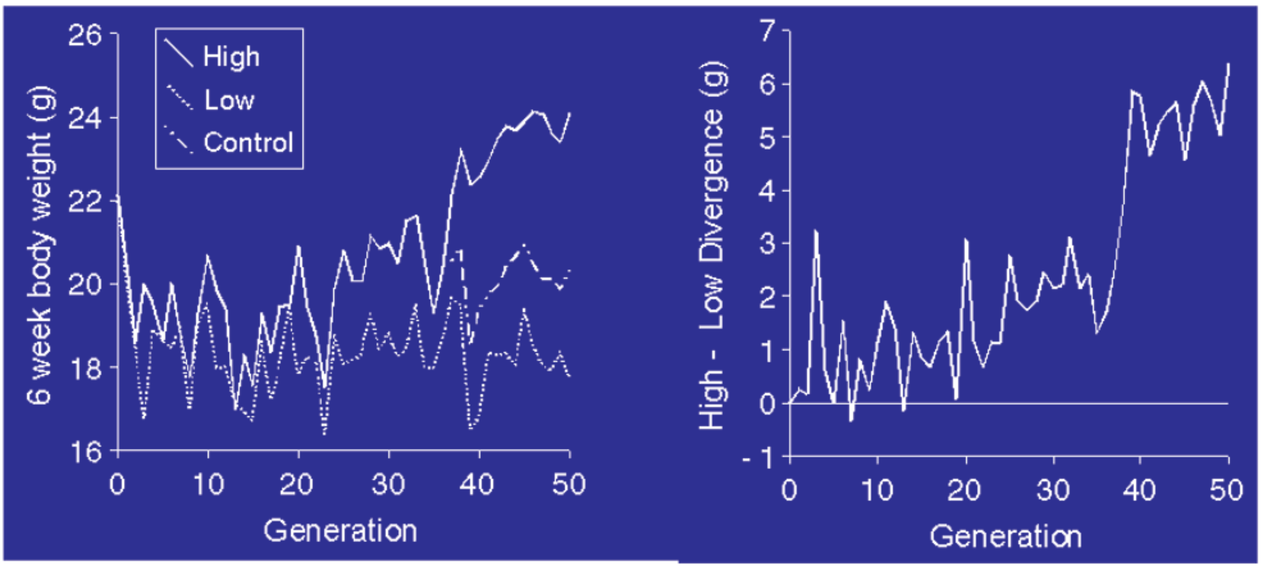
Comparison		SNPs/kb
Wild vs. domestic	Red Jungle Fowl vs. Broiler*	5.28
	Red Jungle Fowl vs. Layer**	5.21
Between domestic	Broiler – Layer	5.19
Within domestic	Broiler – Broiler	4.28
	Layer – Layer	3.72

*Aviagen male line. **White Leghorn line at Swedish University of Agricultural Sciences.

There is less variation within the egg layer stocks than within the broiler stocks, presumably because the former are typically maintained with lower effective population sizes as the primary selection trait is sex limited and accurate selection requires more emphasis on relatives' information. Although both broiler and layer lines are less variable than is the Jungle Fowl, they retain about 70% and 80% respectively of the molecular variation.

Calculations show that the long term selected experimental populations (see Section 10) would have lost much of their initial variation as a consequence of genetic drift (inbreeding) through finite population size, even if no selection had been practised to speed up fixation of favourable genes. It follows that the continued response must increasingly derive from new mutations that have arisen since intensive selection started (Hill, 1982). Selection experiments have been undertaken with selection starting from totally inbred populations, such that any response must have come from mutations that occurred since selection started. An example is given in Figure 11.1 (from Keightley, 1998).

Figure 11.1 Response to selection for 6 week body weight in a highly inbred line of mice. The left panel shows high, control, and low line means; the right panel shows the divergence. (Source: Keightley, 1998)



The responses are small compared with those seen from outbred base populations (e.g. Fig 10.3), but even so the divergence reached about 20% of the mean after 50 generations in a very small experiment. Evidence from this and other experiments suggest this is of the order of 0.1% new heritability per generation, seemingly a small figure but it arises each generation and thus accumulates. Such a level of mutational heritability would also be sufficient to explain much of the continued responses seen in these lab/field experiments. Whilst direct evidence is lacking, it therefore seems reasonable to argue that mutation is the source of variation which is fuelling the continued responses seen in the production traits and also help to explain why heritabilities are not falling for say milk yield and poultry body weight or egg number. There is therefore no reason to expect responses to cease as variation will not run out.

Recurrent mutation is not the only possible explanation for continued responses. A hypothesis currently in vogue is that these are consequent on the release of new variation hidden in epistatic combinations (Carlborg et al., 2006), using evidence of epistasis in crosses made between high and low lines of Siegel's high and low weight selected broiler lines (Liu et al., 1994). Such epistatic effects cannot, however, explain the results of experiments started from an inbred base (e.g. Fig 11.1).

The rate of loss of existing variation in a closed population is proportional to 1/Ne and the magnitude of variance maintained by mutation proportional to Ne, where Ne is the effective population size. Thus population size plays a crucial role in long term gains, so the simple message is to keep it high, a theoretical prediction supported by laboratory selection experiments (see e.g. papers in Jannick, 2004). Sophisticated methods have now been developed to maximise response at fixed rates of inbreeding (i.e. specified Ne), taking account both of optimum use of each potential parent and relationships among them (e.g. Villanueva et al., 2006). When we consider the impact of molecular methods, we also have to consider the impact on Ne. Simple concentration on one single QTL is likely to reduce Ne. It is possible that genomic selection, in which emphasis is spread across the genome, with an increased emphasis on individual genotype rather than family performance, will enable Ne to be increased.

Thus we can be very positive about continued responses. But what about the horses and dogs – why don't they run faster? I do not know, and can only speculate, but will do so briefly. A) One argument is that little selection is practised, but successful horses on the track are prized as sires and get the best mates. B) Another is that the thoroughbreds have a very narrow base population and thus lack variation. But mutation subsequent to its foundation over two centuries ago should have generated new variation, as for other traits in other species. C) There may be a 'physiological limit' for speed. But other animals can run faster (e.g. cheetah), and in any case it is genes which determine the physiology and genetic change could affect such a limit (within constraints of metabolic biochemistry). D) Mutations do occur, but all are deleterious with respect to speed. This is my favourite explanation, but is also weak. In a sense it implies a physiological limit – nothing can be better. But if there is also strong selection on confirmation, then odd looking horses would get rejected before they had a chance to run. We can speculate indefinitely.

Even if we do not understand all the results, particularly those for the horses and dogs, it is clear from what has been presented that breeders have been highly effective in producing very large genetic changes over very long periods, and that there is reason to expect continued rapid change.

Zusammenfassung

Langfristige Zuchtfortschritte bei Nutztieren und Mais: Schätzmethoden, Ergebnisse und Aussichten

Nach einem Überblick über methodische Fragen der Trennung genetischer und nicht-genetischer Veränderungen werden Beispiele von verschiedenen Nutztierpopulationen (Broiler, Legehennen, Milch- und Fleischrinder, Schweine und Schafe), Sportpferden und -hunden, Labortieren und Mais aufgrund der Literatur dargestellt und diskutiert.

Bei allen Nutztierarten und Mais konnten deutliche Leistungssteigerungen belegt werden, mögliche Ursachen stagnierender Rennleistungen bei Pferden und Windhunden werden aus genetischer Sicht diskutiert. Selektionsversuche mit Labortieren unter gleichen Umweltbedingungen über viele Generationen stützen die Prognose, dass bei Nutztieren und Nutzpflanzen auf absehbare Zeit kein Ende des Fortschritts wegen abnehmender genetischer Varianz zu befürchten ist.

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Bioenergy versus Processing: What is possible from an ethical point of view?

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Agricultural production and public perception

More than 90% of the German population have no personal relation to agriculture. Their conception of agriculture is - to a large extent - determined by aesthetic impressions and intermittent perceptions, often based on the negative example of crises (e.g. BSE, „rotten meat“, pollution of the environment).

Knowledge about agriculture is not widely spread. Evidently, representatives of agricultural production had no interest to enhance the knowledge base of the public. Instead, agriculture’s public communication is predominated by romanticized photographs. The actual mechanisation is often gladly avoided (including by the industry itself) – and complex interrelations of sustainability as guiding model for further development even more so.

„The public“ adheres to a form of agriculture which doesn’t exist any more.
The reluctance of agricultural industry to communicate the real complexity and mechanization of agricultural production could be understood as being „provident“ towards the public (protection from overload), but also provides the breeding ground for profound misunderstandings at the same time.

The role of ethical analysis in public communication

It seems to be necessary to reframe agriculture’s communication. Ethics might be helpful in this regard. Ethics can be perceived as systematic reflection of the differing moral concepts in a society – and of the interactions between moral concepts.

Evaluating the actions of a player, it is important to consider: What is his specific area of responsibility? For which aspects does the player carry a moral responsibility, and for which does he not (or no longer)?

If agricultural players could display their actions as also being ethically justifiable (i.e. doing well within the realms of possibility) they could change the type of communication with the public. Then, agricultural players could show that they are efficiently working on solutions for inescapable challenges concerning the whole society.

The problems of current and future developments

The shift of agricultural production – from processing to production of raw-materials for energy supply – increases the necessity to communicate underlying ethical standards to the relevant public. The crucial question is: Is the new field of activity of the „energy farmer“ compatible with the moral concepts which are effective in conjunction with agriculture?

In fact, CO_2 reduction serves as a strong political objective, triggered by a specific analysis of climate change. This induces a strong demand for renewable resources. The evident necessity to substitute at least partially fossil energy by renewables puts even more public attention on it.

There are clear advantages for agriculturists: long-term reimbursement for supply, side-stepping to a socially unsuspicious area (instead of animal husbandry with high standards; tillage with the use of pesticides or genetic engineering etc.).

But also new social and societal problems emerge which need to be solved:

- the interrelation of reduction in classical processing and at the same time potential „export“ of an animal welfare problem;

- the unlikely acceptance of tendencies to monoculture crop-growing practices;
- the unlikely acceptance of new crop-growing cultures;
- societal scepticism about global manufacturing: what are we doing better than the others?
- the inadequacy of the current political overall strategy based on the romantic fiction of national independence in energy supply.

Energy farmers and the production chain have to deal with problems too:

- missing reliable long-term framework conditions for producers;
- the unlikely long-term reliability of the raw materials base and material flow;
- the determination of utilisation of raw materials by volatility of the (global) demand (seller's market also in future?);
- the enhancement of conversion technology and efficiency;
- reliable availability of the required raw materials and the economic effects of scarcity.

Ethical decision-making aids

In order to reframe inevitable societal discourse it is necessary to give a voluntary commitment to sustainable development – which at the same time serves as ethical basis. Sustainability implies to consider economic, ecological and social aspects co-equally. These aspects get concrete by specific criteria for evaluation serving as targets to realise:

- guarantee of provision for the population (food and energy);
- sustainable utilisation of renewable and non-renewable resources;
- international fairness of trade;
- preservation of social resources;
- conservation of cultural landscape and the cultural functions of nature;
- potential for CO_2 reduction and/or net gain of energy.

A closer look into actual proceedings, however, shows that these ethically well-founded targets face some severe problems.

Firstly, the absolute yield of energy supply by renewables is questionable regarding their potential to reduce CO_2 emission and to enhance the net gain of energy. This might be a technical problem striving for future solutions but political commitments actually assert this efficiency.

Secondly, the public's acceptance of the use of renewables actually is the only criterion positively fulfilled. But the threshold to non-acceptance is near. Monoculture crop-growing and unfamiliar new cultures do not get societal support.

Furthermore, the provision for the population (food and energy) might become problematic if the present shift in production would continue or even be accelerated. Rising food prices already triggered critical attention of consumers in this respect. International fairness in terms of trade is also regarded sceptically. Perhaps third parties in weaker economies might participate more efficiently. But that might have undesirable negative effects on the domestic market. So consumers' judgements are ambiguous.

And finally, the farmers have to deal with a profound change in their self-image. Do they become energy suppliers for industrial use, leaving their traditional role of food und feed suppliers? This might introduce a new problem of generation gap in the farmers' families.

Forecast and recommendations

Taking into account the above mentioned problems, an ethical judgement will be ambiguous. But all ethical judgements on this subject area have an expiry date: if the available data change, ethical judgements might also have to change. The same applies to political regulations – or ought to. Agriculture is not suitable for populist actionism – even though it regularly celebrates a happy revival.

It is high time to clarify

- which technical data are adequately substantiated,
- which handicaps the stakeholders are prepared to accept,
- who is acting how with which interests – and on doing so is blinding out relevant factors and/or is concealing relevant information.

Is it romantic to hope for an enlightened discourse herein?
He, who has *no* visions – should consult a doctor!

Zusammenfassung

Bioenergie statt Veredelung – Das Machbare in ethischer Perspektive

Klimawandel und durch politische Regulierungsmaßnahmen bedingte Nachfrage nach nachwachsenden Rohstoffen haben Bewegung in die landwirtschaftliche Produktion gebracht. Die Landwirte haben ein neues Betätigungsfeld entdeckt: „Energie-Wirte“ gelangen in das Zentrum der öffentlichen Wahrnehmung. Was aus der Perspektive der Branche plausibel erscheint, muss es für eine allgemeine Öffentlichkeit aber durchaus nicht sein. Hier erwächst die Herausforderung für die Landwirtschaft, den Bürgern verständlich zu machen, weshalb sie in spezifischer Weise handelt. Dass die Primärenergieproduktion ein sinnvolles Aktionsfeld für Landwirte sein kann, lässt sich ggf. anhand spezifischer ethischer Kriterien aufweisen, die dem Leitbild einer nachhaltigen Entwicklung zugeordnet sind. Eine Branchen-Kommunikation, die nicht allein ökonomisch determiniert ist, sondern auf ethischen Grundwerten aufbaut, erscheint angesichts der weit reichenden Veränderungs- und Verschiebungsprozesse im Zusammenhang mit der Nutzung nachwachsender Rohstoffe unverzichtbar.

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Economic und ecological aspects of bio-energy production

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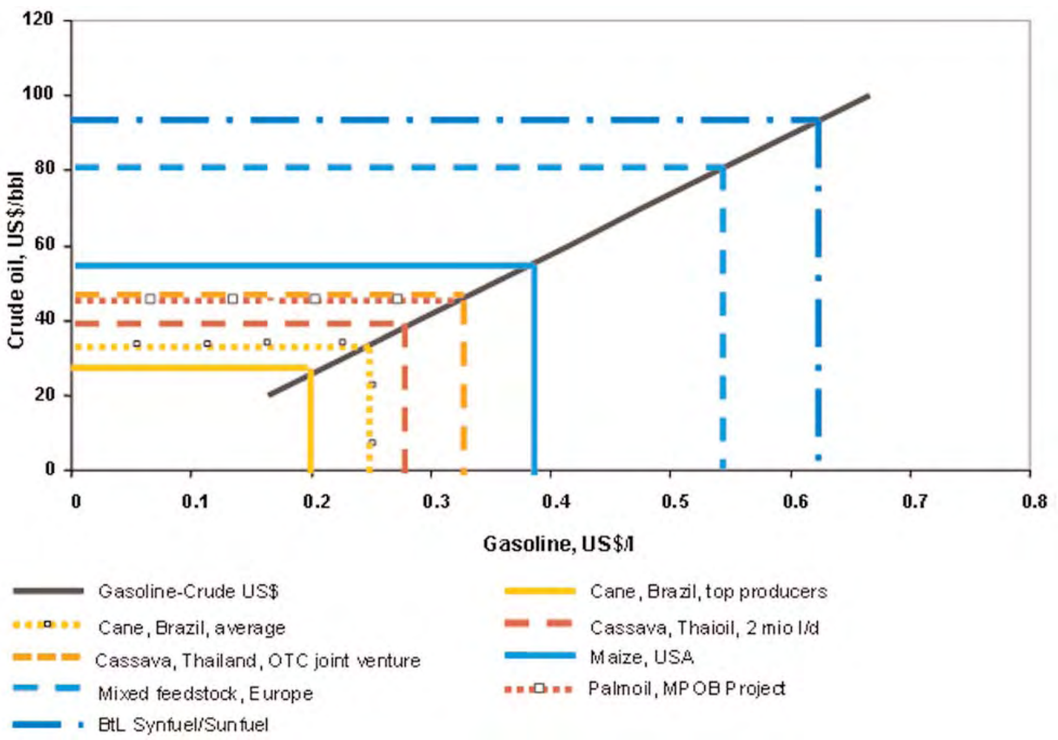
1. Introduction

Rising crude oil prices, high dependency on imports and in particular the realization that climate change needs to be slowed down by reducing carbon dioxide emissions, are used as arguments for the usage of renewable energies and for the expansion of the use of renewable primary products. This is supposed to reduce the rate of global climate change, at the same time developing new income opportunities for agriculture and forestry. New jobs and the usage of agricultural raw materials for bio-energy production could lead to a stabilization of producer prices and desirable effects on family income in rural areas.

2. Promotion by government policy

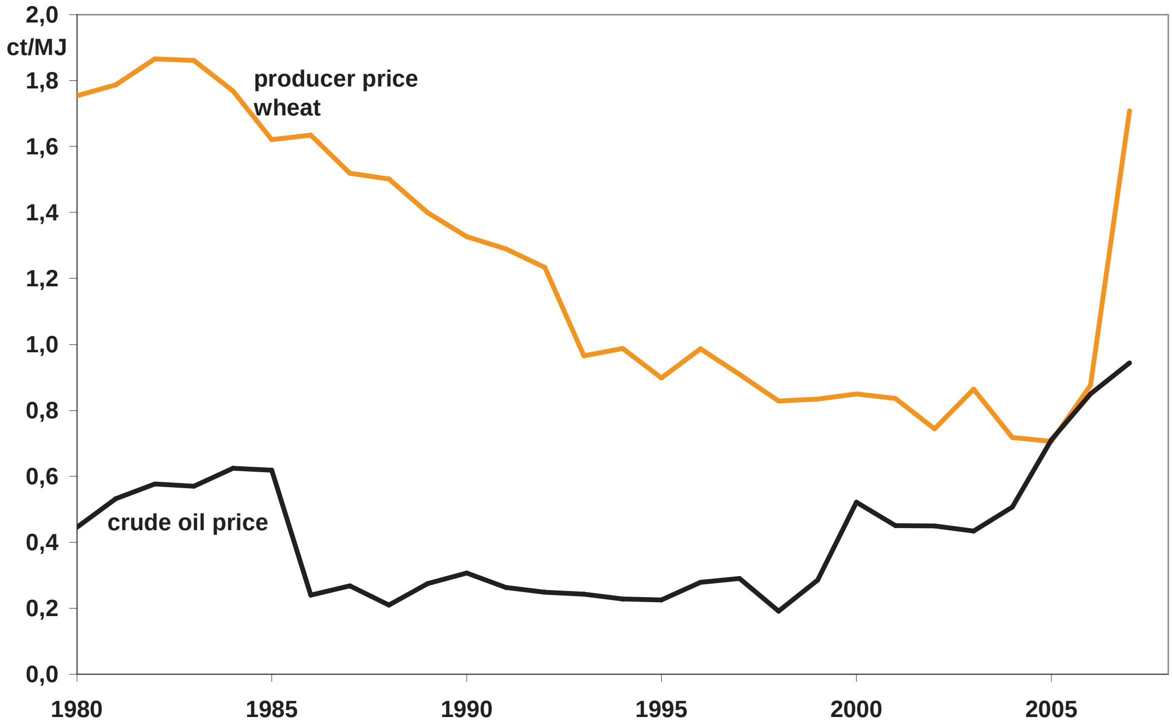
The rising of the crude oil price over the last years aroused the expectation of bio-energy already being competitive. In other countries this is already the case without interventions by the government. The equilibrium conditions specified in Figure 1 indicate at what crude oil price different forms of biofuel are (just) competitive. For the calculations in Figure 1, the price level of agricultural products in 2005 was used. In the meantime, however, prices for agricultural products increased significantly, especially from 2006 to 2007. The competitive conditions may still be the same, but the equilibrium level has shifted upward. This means that bio alcohol is still not competitive in Europe, even at crude oil prices exceeding $ 100 per barrel, because the prices for agricultural products are more than twice as high today than in 2005 (Figure 2). In any case, the use of biofuels only results from market interventions by the government. In the same way, this applies also to some other sources of renewable energy.

Figure 1: Parity prices between crude oil, gasoline and biofuels



Source: SCHMIDHUBER 2006

Figure 2: Price development of crude oil and wheat



Source: own calculations according to MWV 2008, ZMP (different years)

The following approaches have been adopted by government policy:

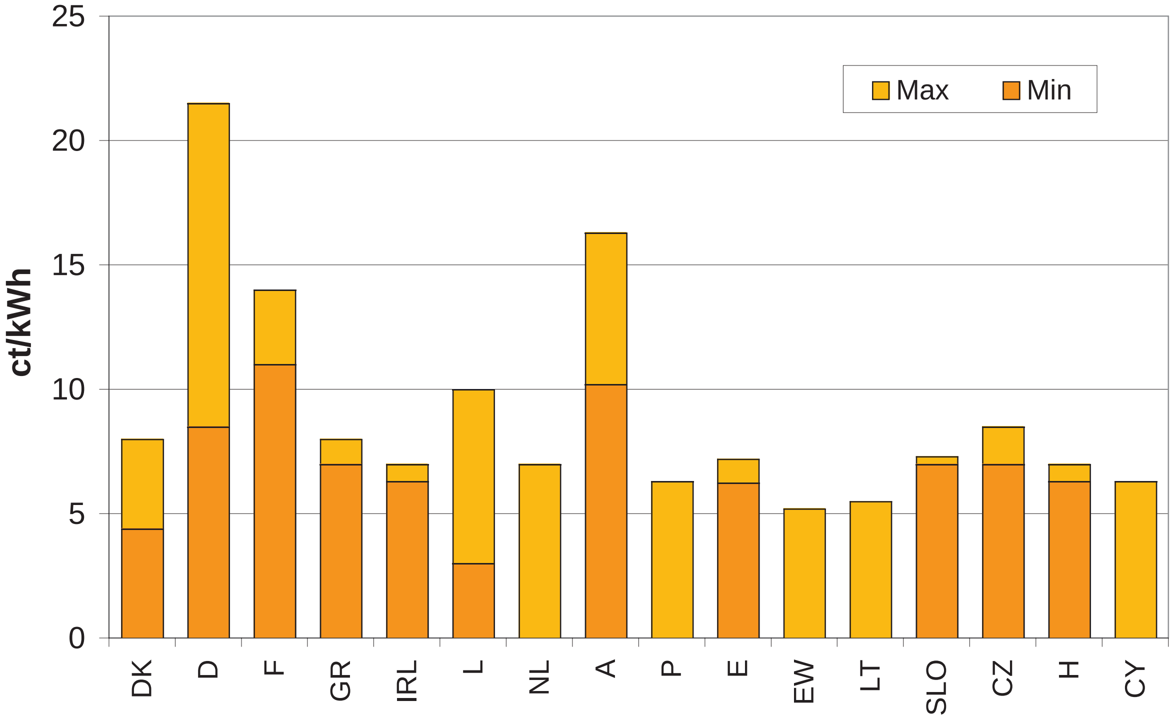
a) Increase in price of fossil energy
b) Price reduction of bio-energy
c) Purchase commitment of bio-energy at a fixed price
d) Admixture obligation for bio-energy

Concerning a) The price of fossil energy is increasing because of the tax on oil and the eco-tax. The burdens, however, are very different. Gasoline is the most burdened, diesel somewhat less (higher tax for cars with diesel engines), oil is significantly less burdened. Politically it is difficult to achieve equal burdens for all sources of energy.

Concerning b) A price reduction of bio-energy can be achieved either through direct subsidization or through a lower tax burden. Politically the easiest measure probably was to enforce a tax exemption for biofuels. This was first done with biodiesel (from rapeseed oil). Therefore this kind of fuel could be offered at the gas station at a slightly lower price than conventional diesel. The state lost the corresponding revenues from fuel tax, while car owners got the impression that biodiesel is cheaper than diesel.

Concerning c) The introduction of a commitment to purchase at a fixed price burdens the consumers of energy instead of the tax payers, who are affected in variant b). This was primarily done for electricity from renewable energy sources. As the share of renewable energy is still relatively small, the consumer does not realize that a very high price has to be paid e.g. for solar energy with about 50 ct/kWh. Concerning agriculture, the determination of the feed-in tariff for electricity from biogas plants was very important, in particular the so-called NawaRo surcharge for agricultural commodities of about 6 ct/kWh in addition to a base salary of about 10 ct/kWh. Moreover, this rate has been guaranteed for a period of 20 years (see Figure 3).

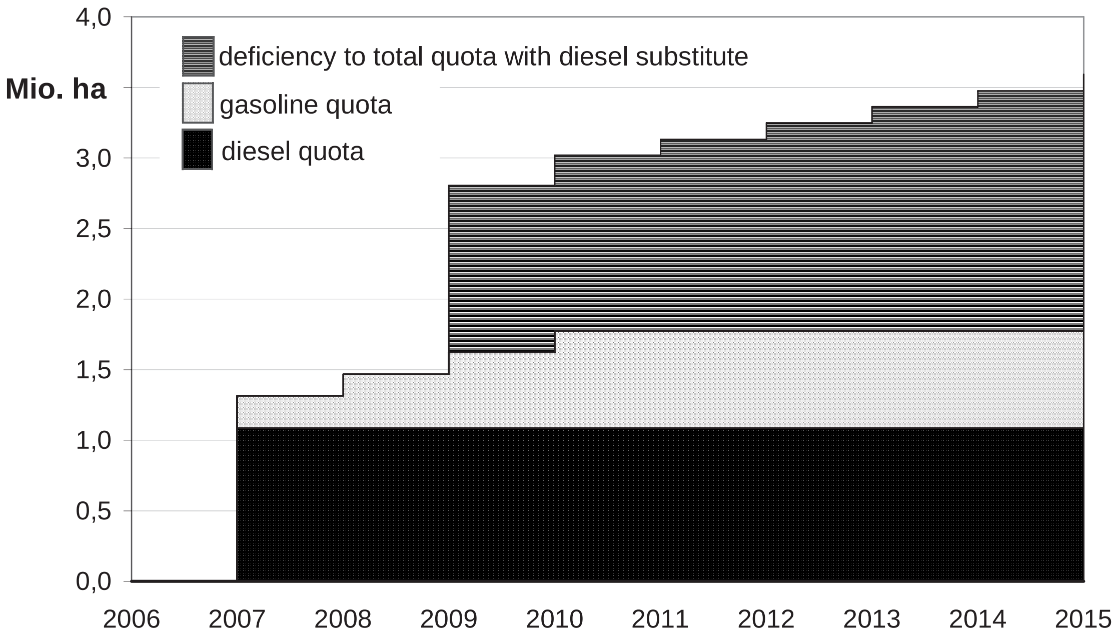
Figure 3: Feed-in tariff for biogas in selected countries



Source: own illustration according to THRÄN et al. 2005

Concerning d) The determination of a specific rate of admixture has recently been carried out for biofuels. Figure 4 shows admixture rates in Germany. As the mineral oil companies are free to decide where to buy the biofuel, the domestic production is no longer in the foreground. Ultimately, the admixture of biofuel can only help to protect the climate to the degree that biofuels burden the climate less than fossil fuels.

Figure 4: Admixture rates



basis: diesel and gasoline consumption 2007 in Germany
Trend-Verbräuche von Diesel und Benzin in Deutschland von 2007

Source: own calculations according to BGBL. 2006, MWV 2008

As a preliminary conclusion it can be said that the political interventions helped the renewable energies to achieve a breakthrough. This does not only affect agriculture but also the equipment manufacturers, which do not only supply the domestic market, but also increasingly markets outside Germany.

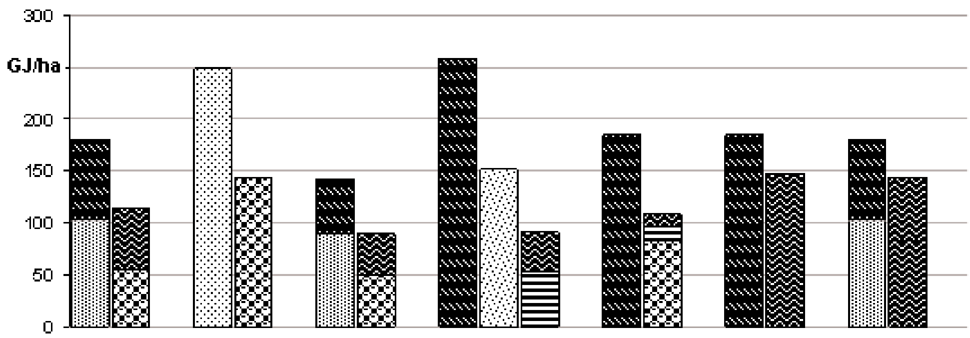
After a period of broad promotion of renewable energies, it is now necessary to re-examine the policy on subsidies, taking into account all experiences and side effects. It is now clear that not all objectives set concerning the use of bio-energy can be achieved at the same time. Some objectives are conflicting and require prioritization. In Figure 5 selected procedures of bio-energy production are compared. Large differences exist specifically in the energy output per unit of area.

The following issues are discussed controversially today: Is it ensured that bio-energy helps to protect the climate? Are the social costs of the use of bio-energy to reduce carbon dioxide emissions justified? Are consumers willing to accept higher food prices resulting from increased use of biofuel?

3. Selected processes of bio-energy production

For farms, a series of processes for the production of bio-energy is available. Figure 5 shows the most important indicators of selected procedures. Significant differences exist in the share of usable final energy and in the yield per hectare. Generally the production of biofuels generates consistently a lower yield per hectare than the production of heat, as in the first case a higher implementation loss through the conversion compared to the substitution in the case of heat generation arises. In the production of biofuel animal feed accrue as a by-product. In the case of biogas production, it is crucial to what extent the arising waste heat can be used. A recent variant is to feed the produced biogas into the gas distribution system after processing. This increases the utilisation level of the produced biomass. The processing causes additional costs and can therefore only be operated effectively with larger plants.

Figure 5: Primary und final energy content of different cultures



culture	wheat	sugar beet	rape	maize	poplar	poplar	wheat
main product	corn	beet	seed	silage	wood	wood	corn
yield [t fm/ha]	6,8	66	3,7	46	20	20	6,8
by-product	straw	---	straw	---	---	--	straw
yield [t fm/ha]	5,2		3,5				5,2
utilisation							
main product	ethanol	ethanol	pme	biogas	btl	wood chips	solid biofuel
amount per ha	2.620 l	6.770 l	1.540 l	7.980 m³	2.500 l	20 t	6,8 t
equivalent	gasoline	gasoline	diesel	heating oil	diesel	heating oil	heating oil
equivalent-amount	1.720 l	4.460 l	1.400 l	4.280 l	2.330 l	5.220 l	2.900 l
useful energy	kinetic energy	kinetic energy	kinetic energy	electricity & heat	kinetic energy	heat	heat
by-product	solid biofuel		solid biofuel		electricity & steam		solid biofuel
amount per ha	5,2 t		3,5 t				5,2 t
equivalent	heating oil		heating oil		heating oil		heating oil
equivalent-amount	2.180 l		1.460 l		1.240 l		2.180 l

Annotation: 1st column = product(s)/raw material(s) of cultures, 2nd column = energy recovery product(s) of raw materials, 3rd column = 2nd step of conversion (biogas to electricity ans heat)

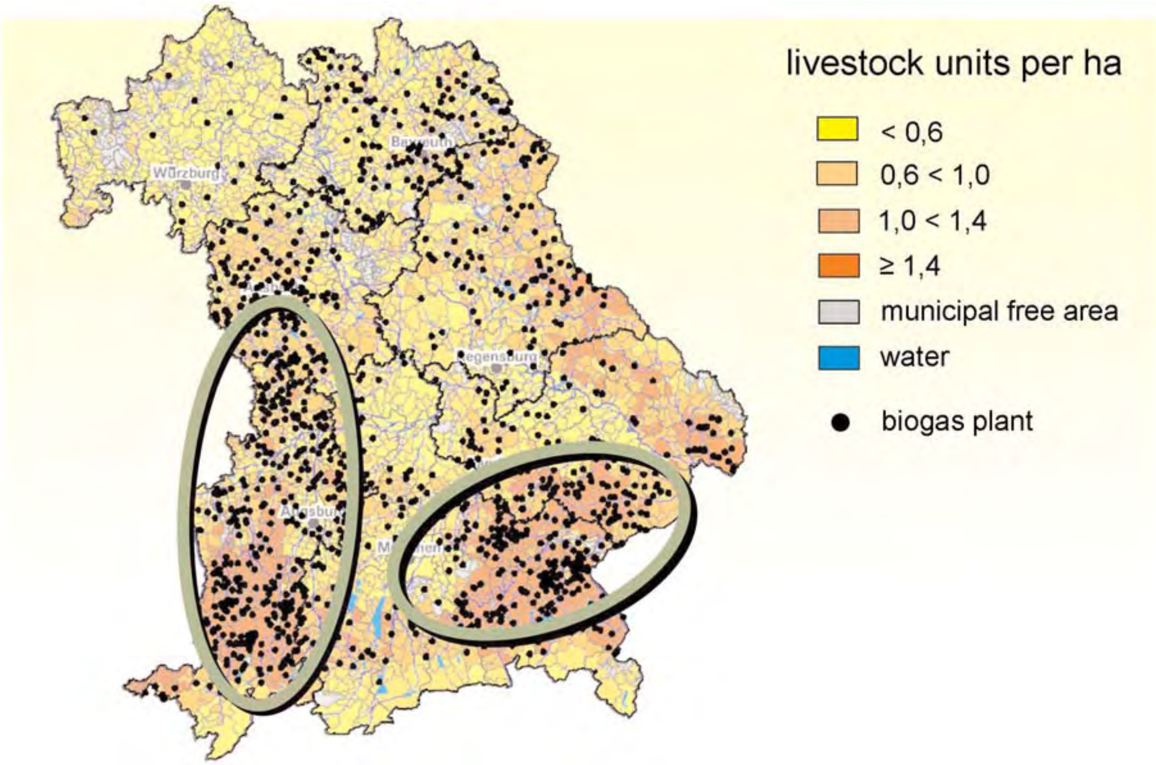
legend: corn; straw/hay/silage/wood; beet; liquid biofuel; biogas; electricity; heat

Abbreviations: fm: fresh matter, pme: plantoilmethylester, blt: biomass-to-liquid

Source: BERENZ, HEIßENHUBER 2007

As far as the procedures listed in Figure 5 are concerned, competition between food and energy production is strongest in the domain of biogas production. Since corn silage can be used as feed for cattle and/or for the biogas plant, expansion of biogas production will either require additional acreage for the cultivation of maize silage or a reduction of the cattle population. As shown in Figure 6, we find e.g. in some regions of Bavaria a high density of livestock and at the same time a significant concentration of biogas plants. This competition for land results in rising cost of land lease and biomass, which burden the production cost of bio-energy.

Figure 6: Livestock units und biogas plants in Bavaria (2006)

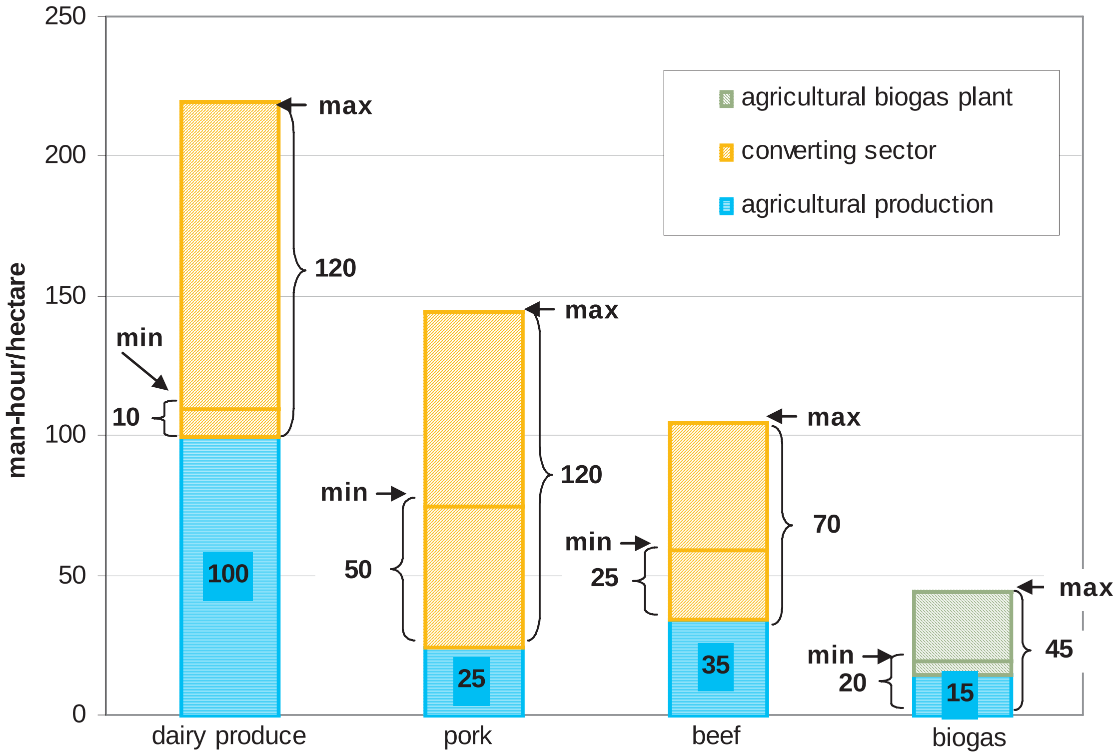


according to KEYMER 2007, RÖHLING, KEYMER 2007

An argument for the extension of bio-energy production is seen in the creation of additional jobs. Figure 7 shows the work hours required for important procedures of animal production on a farm. Furthermore it shows the work hours needed for the processing of agricultural products per unit of area, in the dairy or in the slaughterhouse. It also shows the different sources of biogas. From this comparison follows that the expansion of bio-energy production, represented by the example of biogas, creates additional jobs only if biogas is produced without reducing milk and/or meat production. This is possible if e.g. liquid manure or residual materials are used.

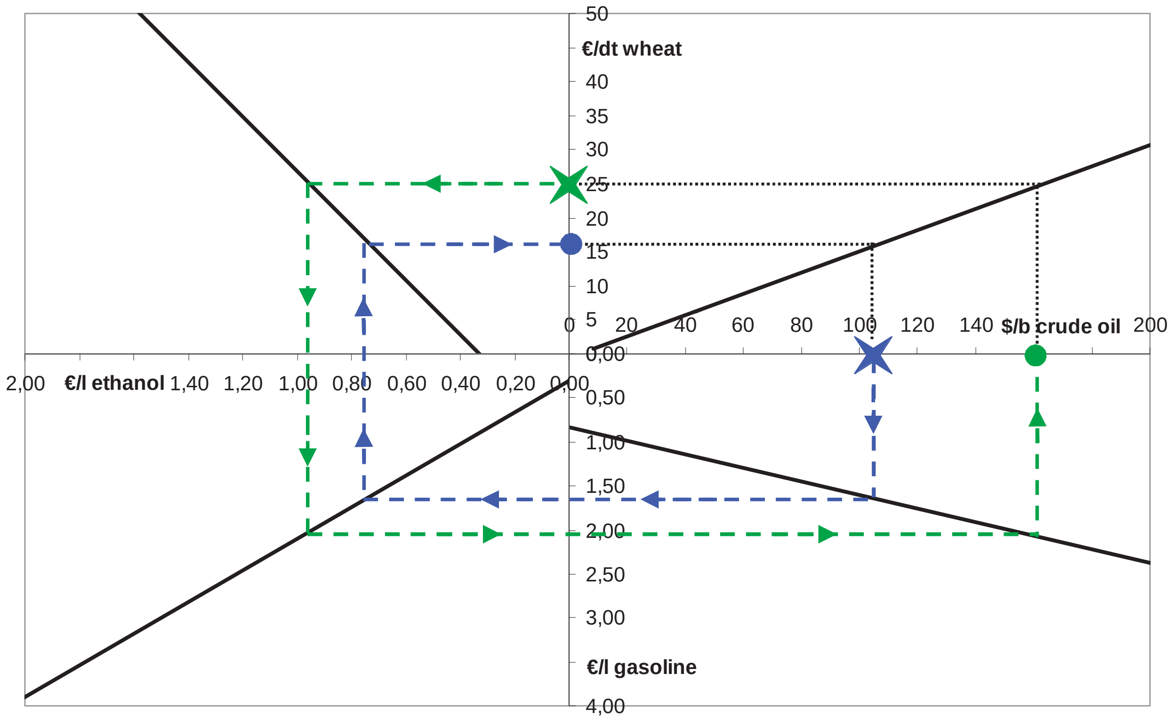
In addition to the biogas production (in Germany 2007 about 0.4 million hectares), the production of biofuels with approximately 1.1 million ha for biodiesel and 0.3 million ha for bioethanol occupies the largest amount of land. From the perspective of the commodity producer the situation has changed significantly in recent years. In 2005, the price of cereals was still about 10 € per 100 kg, currently prices are around 20 € per 100 kg. The cost of bioethanol production has increased correspondingly. As Figure 8 shows, at a crude oil price of almost $ 70 per barrel the price of gasoline (including taxes) is about 1.30 €/l. This kind of gasoline corresponds to a price of bioethanol of just 0.60 € per liter (excluding fuel taxes). The producer of bioethanol could keep the production cost at this level at raw material costs of about 10 €/100 kg for cereals. Currently, the bioethanol producer has to pay about 20 €/100 kg for the raw materials. Under these circumstances, domestically produced bioethanol is not competitive, especially as imported biofuels are significantly cheaper. The economic situation of biofuel producers in Germany is unfavourable, and many plants already shut down.

Figure 7: Working time required per hectare of selected value-added chains of agriculture



Source: own calculations according to RAUH und HEIßENHUBER 2008, AUER 2007, BERENZ et al. 2008, BVDF 2007, MÜLLER 2007, BMELV 2006, KTBL 2006, WEINDLMEIER 2006, FNR 2005, LFL 2003

Figure 8: Bioethanol from wheat as substitute for gasoline

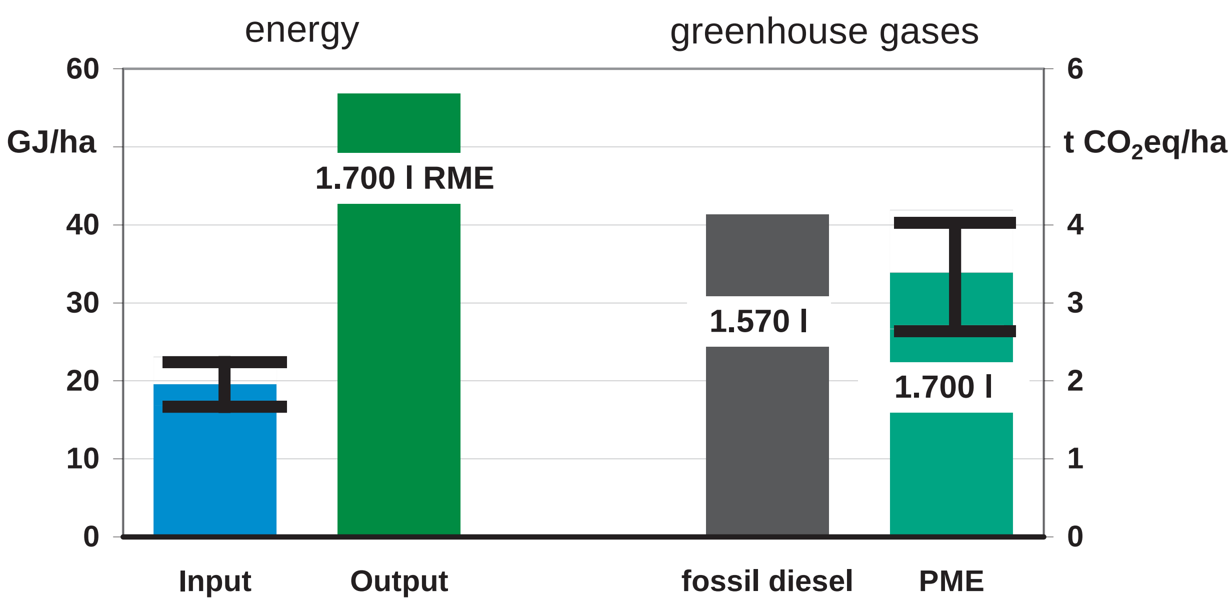


according to IGELSPACHER 2003, MWV 2008

4. Environmental aspects of bio-energy production

The use of bio-energy is justified with the saving of fossil fuels and with a reduction in the emission of climatically critical gases. Figure 9 shows the energy balance as well as the greenhouse gas balance of biodiesel (PME). Thus, the use of biodiesel instead of fossil fuel leads to a saving of fossil fuel. The main cause is the use of the solar energy stored in the crops. It should be pointed out that with the use of the oil from rapeseed by-products accrue as well, which is in the example of biodiesel the rapeseed cake, which remains after processing the rapeseed. This has to be considered in the balance. A clear assessment of the greenhouse gases is more difficult. In particular, the released amount of nitrous oxide (N_2O) varies considerably. Since nitrous oxide is about 300-times more damaging to the environment than carbon dioxide, the cultivation of rapeseed together with a subsequent use of biodiesel can even cause a burden for the climate in comparison to fossil diesel. The procedures of crop production need to be optimized with appropriate attention to nitrous oxide emissions. This applies for the production of renewable raw materials as well as animal feed.

Figure 9: Energy balance and greenhouse gas balance of biodiesel (PME)



included:	seed fertilizer (0% to 60% return of nutrients) pest management diesel mechanisation nitrous oxide depending on N-fertilisation (2,8 bis 4,9 kg N_2O ha^{-1} a^{-1}) energy demand plantoil and pme production
not included:	by-product rapeseed cake by-product glycerine hexane, bleaching earth, acids and bases, methanol oil mill, pme production plant

according to DREIER, TZSCHEUTSCHLER 2000, BOUWMAN 1996, BOUWMAN, et al. 2002, own assumptions and calculations

Calculations for other bio-energy lines (for example, the heat recovery of fast-growing wood) show that for them a more favourable greenhouse gas balance can be achieved. In general, procedures which substitute fossil fuels directly are superior to those procedures which need a chemical conversion. These differences can be seen in the costs of reducing climate-sensitive emissions (CO_2 reduction). For heat production, these costs are lower than for the production of biofuel.

Summary

Bio-energy is used in Europe mainly as a result of government policies. Justifications for government intervention are the reduction of CO_2 emissions and dependency on energy imports. Surplus agricultural production for many years favoured the governmental promotion of bio-energy. Recent supply shortage for agricultural products calls for a critical review of past policies of promoting bio-energy. The effect of increased production and use of bio-energy on the protection of the environment is discussed critically, keeping food production as first priority in perspective. In the amendment of the EEG, this requirement has probably been taken into consideration. Against this background, the admixture quotas for biofuels are critical. In view of the significant rise in food prices, arable land in Europe can only be used to a limited extent for bio-energy. Additional requirements are covered with the help of imports. Political decision makers will face increasing pressure from consumers to reduce promotion of bio-energy to avoid further increase in food prices.

Present information, based on recent price developments, leads us to the conclusion that agricultural food and feed production will have priority over bio-fuel production. For agricultural raw materials the price of fossil fuels is now the lower price limit, while the food market is more competitive. The preferred option for agriculture and rural development is the use of biogenic waste or the double use of agricultural products.

Zusammenfassung

Bioenergieproduktion aus ökonomischer und ökologischer Sicht

Der Hauptgrund für die Produktion und Nutzung von Bioenergie in Europa ist eine steuerliche Begünstigung, um CO_2 Emissionen und die Abhängigkeit von Energieimporten zu verringern. Solange die Landwirtschaft mit Überschussproduktion und entsprechend niedrigen Erzeugerpreisen zu kämpfen hatte, war die Erzeugung von Bioenergie eine plausible Alternative. Inzwischen hat sich jedoch das Verhältnis von Angebot zu Nachfrage derart verschoben, dass es an der Zeit ist, die politische Unterstützung der Bioenergie einer kritischen Prüfung zu unterziehen.

Wenn man die Sicherung der Lebensmittelversorgung als oberste Priorität gelten lässt, muss man sich fragen, was der Einsatz von Bioenergie zum Umweltschutz beitragen kann. In der Novellierung des EEG dürfte diese Forderung bereits Berücksichtigung finden. Vor diesem Hintergrund werden auch die Beimischungsquoten für Biokraftstoffe kritisch gesehen. Angesichts erheblich gestiegener Erzeugerpreise für Lebensmittel und Tierfutter kann nur ein kleiner Teil der landwirtschaftlichen Nutzfläche für die Produktion von Bioenergie genutzt werden. Der weitere Bedarf muss aus Importen gedeckt werden. Politisch wird der Druck steigen, die Förderung der Bioenergie zurückzunehmen, um einen Preisanstieg nicht zusätzlich zu forcieren.

Unsere Schlussfolgerung aus der jüngsten Preisentwicklung ist, dass die Produktion von Lebensmitteln und Futter für die tierische Veredelung vorrangig gegenüber Bioenergie sein wird. Bei den agrarischen Rohstoffen gibt jetzt der Preis der fossilen Energieträger die Preisuntergrenze vor. Die höhere Wettbewerbskraft liegt aber beim Nahrungsmarkt. Für die Landwirtschaft und den ländlichen Raum besteht vor allem die Chance der Nutzung von biogenen Reststoffen bzw. in der Doppelnutzung von agrarischen Rohstoffen.

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Global Potential for Energy Recovery from Renewable Resources

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Crop based bio-energy can be an important and increasing factor for the energy supply, if the agricultural sector is able to provide mass-produced energy crops. One relevant factor presently limiting the development of bio-energy systems based on energy crops is the availability of land for biomass production. Land availability for energy crop production depends on the overall amount of available agricultural land and the demand of land for food and feed production. The method of estimation of the potential is shown by Thrän et al. (2006) and Henze and Zeddies (2007). The results are derived from statistics of FAOSTAT, EUROSTAT and FAO and will be shown for selected countries and on global scale for continents.

Drivers for the future food and feed demand

There are various drivers which influence the actual and future food and feed demand. In the following overview, I will address the following main factors:

- Development of the global human population
- Per-Capita consumption of food (global per-capita consumption is changing slowly but at an increasing rate; production of animal products needs more acreage than production of plant products)
- Increase of yields of specific plant products due to progress in plant breeding, farming technology and assimilation of production systems (in Africa and Asia)
- Climate changes influencing the availability of arable land and the potential for crop production
- Loss of agricultural acreage by soil degradation (erosion, salinisation) and additional need of areas for non-agricultural purposes
- Competing needs for nature conservation and for flood protection
- Extensification to protect the environment
- Use of arable land for the production of raw material for the industry
- Use for attractive non subsidized exports

The main factors are the development of the global population and future per-capita consumption - driven by (1) developments of the world wide economic growth and resulting purchasing power and (2) developments of plant yields for food, feed and biomass production.

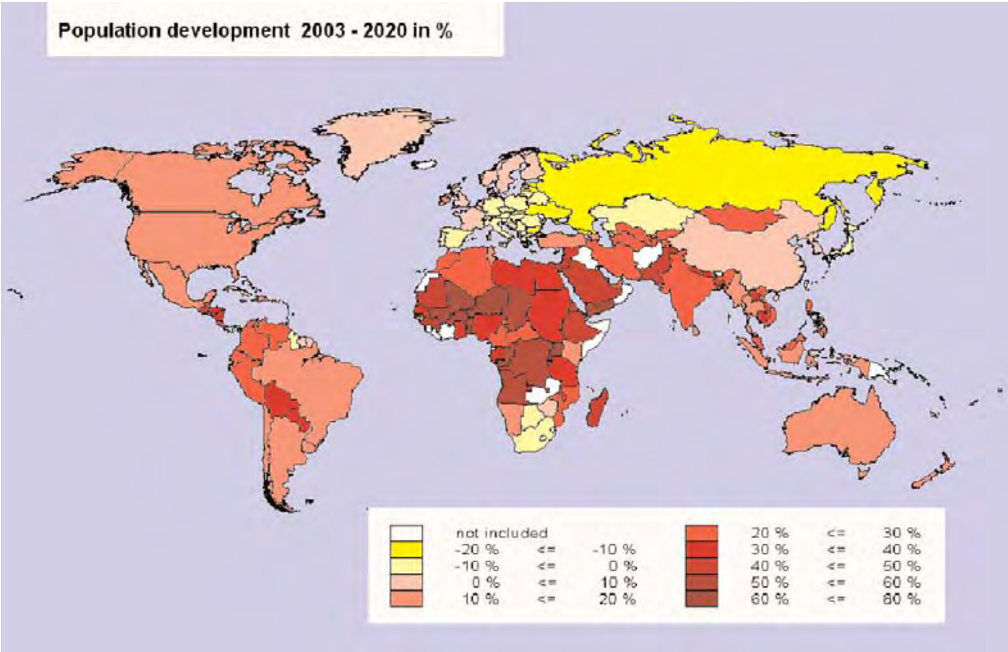
Important, but difficult to predict with sufficient accuracy, will be climate changes and their influence on agriculture.

Development of food consumption

The main variables determining the potential for food and non-food production are shown in Figure 1 and Table 1: population, per-capita consumption, self-sufficiency, area utilized for agriculture and crop yield. Self-sufficiency was calculated from the self-sufficiency portion of the most important food items, weighted by their proportion of the entire food consumption in grain units.

Food consumption is primarily determined by the development of a country’s population. In Germany and most of the EU-27 member countries, the population is constant or slightly decreasing, in the transformation countries Ukraine and Russia the decline is significant. On the other hand, continued strong population growth is anticipated in Asia, America, Africa and Australia (Figure 1 and Table 1).

Figure 1 Expected population development 2003-2020 (%)



Source: Own calculations

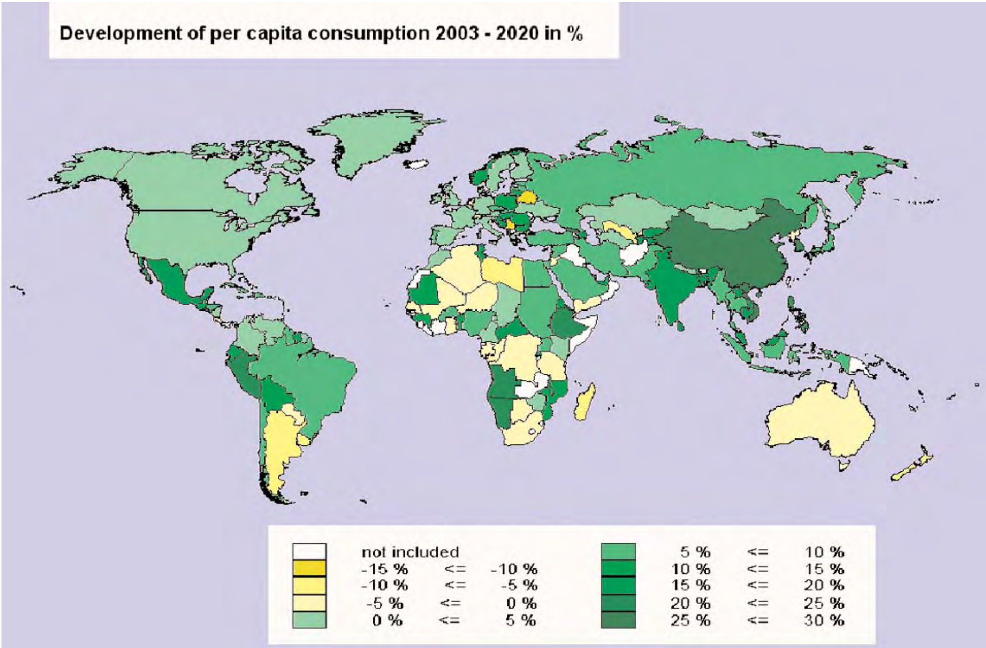
Table 1 Trends for key variables in selected countries

Country	Population			Per capita consumption			Share of self-sufficiency in food	Agricultural area			Rates of change in yield as % (weighted mean) of agricultural area	
	Ø 2002 - 2005 ('000)	Change in % 2003 - 2010	Change in % 2010 - 2020	Ø 2002 - 2005 (GE)	Change in % 2003 - 2010	Change in % 2010 - 2020	Ø 2002 - 2005	Ø 2002 - 2005 ('000 ha)	Change in % 2003 - 2010	Change in % 2010 - 2020	2003 - 2010	2010 - 2020
Germany	82,476	0.12	-0.34	1,178	1.48	0.00	1.0840	17,003	-1.31	-1.87	6.34	9.05
United Kingdom	59,470	1.92	3.10	1144	4.90	0.00	0.7628	16,985	-1.40	-2.00	0.00	0.00
Sweden	8,876	0.72	0.98	1232	4.00	0.00	0.9672	3,186	-3.62	-5.18	4.06	5.79
EU-27	484,638	0.34	-0.43	1186	3.17	1.26	1.0112	193,566	-2.93	-4.19	4.51	6.36
Australia	19,731	6.15	7.43	1,344	-0.78	-1.11	1.6357	442,940	-2.71	-3.87	0.25	0.36
Brazil	178,470	8.07	8.77	1,037	3.50	5.00	1.2182	263,013	4.96	7.09	4.53	6.48
China	1,311,709	4.67	4.76	572	14.00	15.00	0.9694	553,255	2.47	3.53	2.17	3.09
India	1,065,462	10.17	11.79	411	8.20	10.00	0.9671	180,180	-0.26	-0.37	7.80	11.14
Russia	143,246	-4.01	-6.17	903	2.80	4.00	0.8049	216,147	-0.84	-1.21	6.87	9.81
Ukraina	48,523	-5.12	-7.46	803	0.00	4.00	1.1452	41,352	-0.95	-1.36	5.00	7.00
USA	294,043	7.10	9.32	1,698	4.73	0.00	1.0663	415,605	-1.43	-2.04	4.38	6.26
Total	3,545,822							2,306,058				

Source: Own calculations

Per capita consumption is expected to change at different rates in different countries, increasing at above average rates especially in China and India (Figure 2, Table 2). A somewhat slower increase of about 5% is expected for Brazil. Continuing population growth and increasing per-capita consumption is expected for the USA until 2010, primarily due to high energy consumption for beef production. A small increase in per capita consumption is predicted for the EU-27 member countries, while stagnating per capita consumption is expected for Australia and rising per capita consumption in Russia and the Ukraine.

Figure 2 Development of per-capita consumption 2003-2020 (%)



Source: Own calculations

Table 2 Development of the global food demand and population until 2020

Country	Population			Per capita income	Per capita consumption			Share of self-sufficiency in food production
	Ø 2002 - 2005 ('000)	Change in %		US $/year	Ø 2002 - 2005 (GE)	Change in %		
		2003 - 2010	2010 - 2020	Ø 2002 - 2005		2003 - 2010	2010 - 2020	Ø 2002 - 2005
Germany	82,476	0.12	-0.34	28,500	1,178	1.48	0.00	1.0840
EU-27	484,638	0.34	-0.43	22,305	1,186	3.17	1.26	1.0112
Europe	791,611	0.00	-1.02	15,403	1,051	2.29	2.53	0.9710
North America	325,553	6.89	9.03	38,336	1,667	4.64	0.00	1.0760
Central America	169,921	10.16	11.47	4,980	738	6.32	7.12	0.8525
South America	362,096	9.17	10.63	2,966	924	3.21	3.96	1.1603
America	857,570	8.50	10.19	16,950	1,169	4.37	3.09	1.0673
Australia	19,731	6.15	7.43	25,260	1,344	-0.78	-1.11	1.6357
Oceania	5,935	5.19	5.75	13,484	969	-3.62	1.19	2.9162
Asia	3,677,249	8.23	9.60	2,535	495	9.13	10.43	0.9593
Africa	794,128	15.73	20.13	795	399	2.58	3.85	0.8154
Total 133 (134) countries	6,146,224	8.17	9.66	6,005	652	6.69	7.49	0.9613

Source: Own calculations

Self-sufficiency for food differs considerably between individual countries. The EU-27[1], China, India and the USA are close to self-sufficiency, while Brazil with its huge agricultural potential can export 20% of its production and Australia has even 160% self-sufficiency. Russia on the other hand depends strongly on imports, with about 80% self-sufficiency. The global situation and predicted developments are shown in Table 2.

Development of supply

The figures for **agriculturally utilised area** in different countries (Table 1) are based on the FAO statistics 1991 – 2005. The agriculturally utilised area is decreasing in industrial countries like Australia, USA, Russia and the EU, but increasing in threshold countries like Brazil and China due to increased utilisation of land for agriculture and to some extent deforestation. This trend is expected to continue in the coming years until 2020. Global changes in climate have not been taken into consideration, but they may lead to gains in arable areas e.g. in Northern Europe and/or losses in other areas e.g. in sub-Sahara countries of Africa. These effects have to monitored, but no hard figures will be available before 2020. Figures for continents are shown in Table 3.

Table 3 Global agricultural area and crop land until 2020

Country	Agricultural area			Crop land		
	Ø 2002 - 2005 ('000 ha)	Change in %		Ø 2002 - 2005 ('000 ha)	Change in %	
		2003 - 2010	2010 - 2020		2003 - 2010	2010 - 2020
Germany	17,003	-1.31	-1.87	11,855	0.72	1.03
EU-27	193,566	-3.07	-4.39	111,203	-3.02	-4.32
Europe	515,360	-1.56	-2.23	303,066	-3.23	-4.62
North America	483,137	-1.26	-1.80	221,089	-2.49	-3.55
Central America	138,814	1.96	2.79	35,295	2.66	3.80
South America	552,957	2.21	3.16	106,108	5.04	7.20
America	1,174,908	0.76	1.08	362,491	0.22	0.31
Australia	442,940	-2.71	-3.87	48,296	3.44	4.92
Oceania	17,800	-0.51	-0.73	1,800	-26.81	-38.30
Asia	1,409,777	1.10	1.57	471,114	2.38	3.40
Africa	1,027,978	2.15	3.07	183,583	6.06	8.65
Total 133 (134) countries	4,588,762	0.57	0.82	1,370,349	0.94	1.51

Source: Own calculations

[1] Within the EU, Great Britain shows a traditionally low degree of self-sufficiency. Sweden and Germany are close to being self-sufficient.

The assumptions regarding **future development of yield** are of cardinal importance for the prediction of potential production (Table 4). Estimates are derived from linear regression coefficients calculated for the period 1994 - 2005[2] for the relevant cultivars (grain, oil crops, root crops, sugar cane and sugar beet, starchy root crops and agricultural feed crops (e.g. corn silage). For strongly deviating trends within time series, rates of change were based on “educated guesses”.

Table 4 Global area for cereal production and yield development until 2020

Country	Cereal area Ø 2002 - 2005 ('000 ha)	Yield of cereal dt/ha Ø 2002 - 2005	Rate of change of yields (weighted mean) in % of crop land		Rate of change of yields (weighted mean) in % of agricultural area	
			2003 - 2010	2010 - 2020	2003 - 2010	2010 - 2020
Germany	6,892	65.2	9.73	13.90	6.34	9.05
EU-27	60,065	48.0	7.86	11.23	5.05	7.12
Europe	133,337	33.8	13.22	18.82	8.04	11.40
North America	73,038	54.5	9.71	13.87	4.36	6.19
Central America	12,942	27.6	6.86	9.81	1.97	2.84
South America	35,930	32.7	15.28	21.83	3.09	4.45
America	121,910	45.2	11.06	15.80	3.49	5.00
Australia	19,299	17.3	2.05	2.93	0.22	0.32
Oceania	134	68.8	12.01	17.15	2.71	3.86
Asia	291,214	33.6	9.50	13.58	3.43	4.92
Africa	92,133	13.7	8.24	11.77	1.63	2.35
Total 133 (134) countries	658,028	32.5	10.24	14.61	3.25	4.66

Source: Own calculations

In the countries dominating the world trade with agricultural products, i.e. Brazil, the USA, the EU-27 with large agricultural area states like France, Germany and Poland, yields are characterized by sustained significant increases. Noteworthy increases in yield were achieved in the past, even in the most densely populated countries of the world, China and India, and further increases in yield can be expected. In Russia and the Ukraine yields decreased initially after the political changes in the early 1990s and are still at a low level compared to the potential of soil and climate.

For areas with specific and apparently increasing drought, like Australia, yield increases were negative. They are quite frequently ascribed to the results of climatic change in this respect. Changes in climate will not only result in increased limitation of growth in yield as a result of temperature increases and rainfall deficits in arid areas, but also in growth impulses due to higher CO^2-concentrations and increased temperatures in other areas. However, these effects appear to be limited and insignificant until 2020.

[2] The growth rate per year is established from the regression coefficients with reference to the average yield level of the past three years. In Germany, for instance, it is 1.29% for grain. The average improvement rate per year, weighted with the area proportions of all cultures, is 0.97%; this results in a growth of 6.35% for the period 2003 - 2010, based on 2003. Based on this increase in yield, the improvement rate for the decade 2010 - 2020 with constant absolute increase in yield per year is 9.07%, based on 2010.

Land availability for non-food

Land availability for bio-energy or export is a result of development of demand and supply of food. Surpluses can be used for other purposes. The available land is shown for selected major countries (Table 5) and for continents (Table 6).

Table 5 Potential of agricultural land for bio-energy production for selected countries

Country	Potenial area Ø 2002 - 2005 in 1000 ha					Potential area in 1000 ha and %					
	Fallow land	Surplus: Crop prod.	Surplus: Milk prod.	Surplus: Beef prod.	Potential area for bioenergy	Ø 2002 - 2005	%	2010	%	2020	%
Germany	838	1,438	480	443	3,199	3,199	18.81	3,894	22.90	5,248	30.87
United Kingdom	58	140	-4,596	-461	198	198	1.16	-870	-5.13	-932	-5.49
Sweden	284	247	16	-53	547	547	17.15	423	13.27	411	12.89
EU-27	14,145	9,390	4,942	1,997	30,475	30,475	15.74	27,991	14.46	32,467	16.77
Australia	24,909	12,268	65,658	89,925	192,760	192,760	43.52	168,161	37.96	136,898	30.91
Brazil	12,560	7,596	-3,532	13,475	33,632	33,632	12.79	35,667	13.56	43,989	16.73
China	0	1,012	-18,749	-3,167	1,012	1,012	0.18	-78,321	-14.16	-154,401	-27.91
India	0	3,152	34	658	3,843	3,843	2.13	-16,773	-9.31	-37,903	-21.04
Russia	69,443	2,637	-4,151	-5,110	72,080	72,080	33.35	87,323	40.40	109,597	50.70
Ukraina	11,486	2,309	890	248	14,933	14,933	36.11	17,962	43.44	21,174	51.20
USA	67,493	23,510	-4,262	-3,270	91,003	91,003	21.90	64,732	15.58	51,961	12.50
Balance	200,036	61,874	40,830	94,755	439,738	439,738	19.07	306,743	13.30	203,783	8.84

Source: Own calculations

In ***Europe (EU-27)***, at least 30 million ha of land were available in 2002-2005 for bio-energy sources. Assuming increasing progress in yield, up to twice as much could be available in 2020. Essentially no additional contribution is expected from grassland, yields on grazing land are expected to remain unchanged.

Besides the USA, ***Australia*** is one of the countries with the highest grain export surplus. With more than 440 million ha of agriculturally utilized area, more than 20 ha of agricultural area is available per capita. However, a strong negative trend has been observed in recent years[3]. If this trend continues, the significant potential for bio-energy available in 2003 (almost 193 million ha), will drop to 137 million ha in 2020, because strong population growth coincides with a reduction in agriculturally utilised land area and yield per ha.

The ***USA*** has an agriculturally utilized area comparable to the size of Australia, but only 1.4 ha of agriculturally usable land per capita. Significant increases in yield per ha have been achieved and are expected in the future, based on cultivation of high yield maize varieties; utilization of genetically modified cultivars is expected to play a major role here. With an area of 91 million ha (beyond supply for the own population), the USA not only has a huge production potential based on higher average yields, but can also add to this potential from fallow areas, intensified irrigation and dual-crop production. However, all scenarios point to a decreasing area potential for bio-energy in the USA over time.

Brazil is currently one of the main exporters of agricultural products and at the same a major exporter of bio-ethanol world-wide. The agriculturally utilised area has been expanded significantly during the

3 Since yields have also been slightly regressive, structural changes could also be ascribed to influences of climatic change besides numerous economic factors.

past ten years, and at the same time average yield has increased at a faster rate than in the EU-27 and the USA. The area available for bio-energy is expected to increase only slowly from currently 33 million ha until 2010, but stronger after 2010 to reach 44 million ha in 2020 (while retaining the currently high proportion of utilising agricultural raw materials for bio-energy, especially bio-ethanol).

China can currently provide enough food for itself, but only about 0.4 ha agriculturally used area is available per capita, and this number is decreasing rapidly. On the other hand, China has been able to increase yield even more than highly developed industrial countries and is expected to continue this trend until 2020. Only about 1 million ha are available for bio-energy cultivation. Domestically produced dairy products and beef are short in supply and are being imported. If the additionally required foodstuffs for 2010 are produced domestically, which is assumed in our estimates, there will be a shortage of 78 million ha in 2010 and 154 million ha in 2020.
This area requirement is calculated on the basis of the less productive grasslands in the north and west of the country. However, China will not be able to satisfy the growing demand for dairy products and beef by utilizing only these areas, but will use high yield alfalfa and maize, thereby reducing the required area below the highly over-estimated figures shown in the table. Obviously major political efforts will be necessary to counteract the current trend of increasing imports of foodstuffs.

India has only 0.17 ha of area per capita. This area is utilised intensively by multiple crops and a significant increase in output has already been achieved by increased cultivar yields and an acceleration of the cropping index. The trends indicate that imports of foodstuffs will increase to feed the growing population, unless efforts to retain self-sufficiency from own resources are successful. Without a reversal of current trends, a deficit of 38 million ha of area potential is predicted for 2020.

Russia has of a huge agriculturally usable area of 216 million ha, about 1.5 ha per capita. The level of productivity was still quite low for 2002 – 2005, following a sharp decline after the transformation period in the 1990s, but a positive trend is seen in recent years. Russia possesses a significant area potential to increase the production of foodstuffs, mainly fallow areas which are currently not being utilised. Starting from an extremely low level, production will probably increase significantly more than reflected by the regression analysis during a period of profound political changes. The renovation of agricultural technology which started a few years ago will certainly have its effects on output. In the medium term Russian agriculture may also benefit significantly from the predicted global warming. With increasing agricultural prices, an area potential of more than 100 million ha can be made available for the generation of bio-energy or for export of food.

Statistics for the ***Ukraine*** reflect similar trends due to the transformation process as for Russia. The Ukraine is a country with agricultural surplus, but (contrary to Russia) it has not yet started to increase productivity by modernizing agricultural technology. Growing area and production potential can result in comparable orders of magnitude as in Russia. It is unlikely that past trends of decreasing per-capita consumption and yield per ha will continue. Our estimates indicate a growth potential for bio-energy of about 20 million ha.

Adding up the area potential per continent shows that the global potential for agricultural surpluses or bio-energy will decrease from almost 660 million ha in the base years 2002-05 to 255 million ha by 2010 and a deficit of 200 million ha in 2020, mainly due to an increase in the demand for food. It is calculated that Asia has a deficit of 250 million ha, Africa a deficit of 400 million ha to reach self-sufficiency in food production, without any reserves for bio-energy.

We have only estimated the area potential, not the production potential. The analysis shows, however, that the potential for food production for export is decreasing. Of all countries included in our study, only the EU-27, Brazil, Russia, the Ukraine, Argentina and Canada show a potential to increase the area of land used for agriculture. The USA and Australia will lose significant shares in the world market for agricultural products.

Table 6 Global potential of land for bio-energy

Country	Area potential in 1000 ha and %					
	Ø 2002 - 2005	%	2010	%	2020	%
Germany	3,199	18.81	3,892	22.89	5,244	30.84
EU-27	30,475	15.74	28,771	14.86	34,257	17.70
Europe	126,812	24.61	155,969	30.26	201,580	39.11
North America	126,123	26.11	99,826	20.66	89,169	18.46
Central America	17,952	12.93	-1,989	-1.43	-22,706	-16.36
South America	73,634	13.32	52,457	9.49	34,801	6.29
America	217,709	18.53	150,294	12.79	101,263	8.62
Australia	192,760	43.52	168,035	37.94	136,601	30.84
Oceania	13,182	74.05	13,632	76.58	13,958	78.41
Asia	62,234	4.41	-82,890	-5.88	-248,439	-17.62
Africa	45,494	4.43	-149,758	-14.57	-404,080	-39.31
Total 133 (134) countries	658,191	14.34	255,282	5.56	-199,116	-4.34

Source: Own calculations

Export-/Import balances and external trade of agricultural commodities

Based on estimated availability of area for non-food, the export-import changes to be expected in future can be calculated, subject to the assumption of an unchanged cultivation situation and taking into consideration the trends of domestic consumption as well as trends of domestic supply. In the EU, an above average growth is experienced. In Table 7 and Table 8 the import/export balances of the selected countries and the continents are listed.

If we assume that the countries in question will not expand bio-energy production and use additional output (from fallow areas and yield increase) only to increase export of food and feed, then grain surplus in the EU-27 for export could increase by 19 million t to about 78 million t in 2020. At the same time current oil seed imports of 20 million t could remain virtually unchanged, while the import gap for plant oils would increase slightly.

The agricultural surplus countries Australia and USA would in future be able to offer increasing export volumes of grain on the world market. Brazil would also be able to increase its export surplus for grain. Even China and India would exceed their requirement for foodstuffs substantially. However, they would not appear as exporters on the world market, because they will have huge deficits of oils, vegetables, etc. They will utilise excess grain areas for vegetables and feeds. Russia and Ukraine have significant production reserves, which can be added to the global grain market.

Overall, this results in a significant increase in export volumes for the provision of grain of these important agricultural production and foodstuff consumer countries. The EU, and increasingly China, will appear on the world market as importers of oil seeds, followed by India, with an increasing net import demand.

Table 7 Export-/Import balance of various countries

Country	Cereals net-export(+)/-import(-) Million t			Oilseeds net-export(+)/-import(-) Million t			Vegetable oil net-export(+)/-import(-) Million t		
	Ø 2002 - 2005	2010	2020	Ø 2002 - 2005	2010	2020	Ø 2002 - 2005	2010	2020
Germany	8.49	17.03	25.41	-5.78	-5.81	-6.20	-0.16	-0.19	-0.23
United Kingdom	0.99	0.70	-0.38	-1.41	-1.60	-1.92	-1.13	-1.24	-1.40
Sweden	1.14	1.26	0.80	-0.25	-0.23	-0.22	-0.04	-0.04	-0.04
EU-27	18.70	57.14	77.81	-20.05	-19.86	-21.19	-3.84	-4.14	-4.52
Australia	18.59	36.35	38.12	1.60	1.87	-0.27	-0.14	-0.17	-0.20
Brazil	-9.24	10.10	18.90	14.70	44.75	68.13	1.69	1.67	1.61
China	5.08	33.19	70.80	-16.94	-32.95	-55.16	-4.29	-5.46	-7.05
India	6.58	14.77	32.11	0.46	-6.95	-16.60	-4.71	-7.07	-10.24
Russia	4.08	67.05	96.58	0.29	3.50	3.47	-0.89	-0.97	-1.08
Ukraina	4.34	18.40	21.99	0.85	2.10	1.71	0.51	0.55	0.61
USA	78.78	239.43	282.89	28.87	65.30	64.29	0.37	0.42	0.48
Total	126.92	476.43	639.21	9.77	57.76	44.38	-11.29	-15.16	-20.39

Source: own calculations

Table 8 Export-/Import balances of the continents

Country	Cereals net-export (+) / -import (-) million tons			Oilseeds net-export (+) / -import (-) million tons			Vegetable oil net-export(+) / -import (-) million tons		
	Ø 2002 - 2005	2010	2020	Ø 2002 - 2005	2010	2020	Ø 2002 - 2005	2010	2020
Germany	8.49	17.03	25.41	-5.78	-5.81	-6.20	-0.16	-0.19	-0.23
EU-27	18.70	56.94	78.40	-20.05	-19.83	-21.03	-3.84	-4.14	-4.52
Europe	23.42	163.11	238.41	-20.49	-14.73	-15.10	-5.12	-5.68	-6.40
North America	94.32	282.90	327.85	32.79	75.13	73.87	0.69	0.87	1.11
Central America	-23.41	-12.80	-17.90	-5.94	-4.91	-4.59	-1.13	-1.30	-1.51
South America	2.76	34.43	50.64	22.78	58.17	87.29	5.96	5.91	5.73
America	73.67	304.53	360.59	49.63	128.39	156.56	5.53	5.48	5.33
Australia	18.59	36.35	38.12	1.60	1.87	-0.27	-0.14	-0.17	-0.20
Oceania	-0.79	1.34	1.77	-0.07	-0.08	-0.09	-0.12	-0.13	-0.14
Asia	-59.00	76.66	166.78	-31.36	-64.47	-110.82	5.66	-0.39	-8.50
Africa	-42.48	-28.80	-38.91	-0.28	-2.27	-5.89	-3.45	-4.67	-6.21
Total 133 (134) Countries	13.41	553.19	766.75	-0.97	48.71	24.39	2.36	-5.57	-16.12

ource: Own calculations

On the other hand growing production volumes, especially of soy beans in Brazil and the USA, will lead to a growing export surplus for these countries. The demand for oil seeds for foodstuffs can be covered, provided national promotion of bio-diesel production from oil seeds (as in the EU, the USA and Brazil) does not counteract this. An increasing import deficit emerges for plant oils, which have previously been made available for export by a few tropical countries, i.e. Malaysia and Indonesia. This deficit could be compensated at least partially by international trade of surplus oil seeds.

Conclusions

The availability of potential bio-energy sources can be estimated by different approaches. Theoretical and technical potentials must take into consideration the use of plant products in competition with demand for food and feed, nature conservation and other demands on limited area. Prognoses of economical potential require realistic estimates of future prices for agricultural raw materials, energy sources and statistical models which simultaneously take the competition between alternative land usage incentives to invest in new facilities into account. This can only be attempted for individual countries with complex models, but not for larger economic areas, like the EU-27 or the entire world. Although this study is based on simplified assumptions to establish the “exploitable area potentials”, the results and conclusions should be useful for political decision makers and all those who have to plan ahead.

Taking into consideration fallow land and yield improvements, the results show that substantial agricultural potentials could be utilised before acute price reactions and provision dependencies will arise for food and feeds.

A huge potential for bio-mass production as source of renewable energy exists in the EU-27, selected major countries and on all continents. However, the question is still open to what extent bio-mass can be utilised for bio-energy production in competition with adequate nutrition of a growing world population.

Zusammenfassung

Globale Potenziale der Energiegewinnung aus erneuerbaren Ressourcen

Während die letzten zwei Jahrzehnte der globalen landwirtschaftlichen Entwicklung von strukturellen Überschüssen bei fast allen Agrarrohstoffen für Nahrungsmittel gekennzeichnet waren, stellt sich die Frage, ob die Ressourcen der Agrarwirtschaft in Zukunft ausreichen, um die kräftig steigende Nachfrage nach Nahrungsmitteln zu decken und darüber hinaus Biomasse für Energieträger bereitzustellen. Im vorliegenden Beitrag wird die Nahrungsmittelnachfrage nach ausgewählten für die Welternährung wichtigen Ländern und für alle Kontinente bis zum Jahr 2020 abgeschätzt und der Angebotsentwicklung für agrarische Rohstoffe gegenüber gestellt. Aus den Entwicklungen beider lassen sich Potenziale für Bioenergie für Länder und global grob voraussagen. Während der Anteil der Weltagrarproduktion für die Verwendung für Bioenergie im Jahr 2007 noch unter 4 % lag, steigt dieser Anteil in den nächsten Jahren kräftig an. Gleichzeitig ist seit einigen Jahren die Nahrungsmittelnachfrage weltweit unerwartet kräftig gestiegen und das Angebot an Agrarprodukten und die Politik haben darauf nicht oder nur zögerlich reagiert. Die Bilanzierung der Wachstumsraten der Nachfrage- und Angebotsentwicklung agrarischer Rohstoffe weltweit und in wichtigen Regionen der Erde ergibt ein unterschiedliches Bild. Deutschland hat schon in den letzten Jahren ein beträchtliches Flächenpotenzial (ca. 3 Mio. ha) für Nahrungsmittelexporte und Bioenergieproduktion verwendet. Dieses wird bei stagnierender Bevölkerung und weitgehend unverändertem Pro-Kopf-Verbrauch durch zunehmende Erträge auf etwa 5 Mio. ha im Jahr 2020 ansteigen. Nach Aussetzung der Flächenstilllegung wird die EU-27 im Jahr 2020 über ein Flächenpotenzial von ca. 30 Mio. ha verfügen, das nicht für die inländische Nahrungsmittelversorgung benötigt wird. Große Zuschussgebiete für Nahrungsmittel und/oder Agrarrohstoffe entstehen in Asien und Afrika. Dadurch werden die Agrarrohstoffe bis zum Jahr 2020 deutlich knapper und die noch verfügbaren Produktionsreserven für die Deckung der Nahrungsmittelnachfrage bis dahin fast

vollständig benötigt. Daraus folgt, dass es dringend notwendig ist, die unter jahrzehntelangem Preisdruck nur mittelmäßigen Angebotssteigerungen signifikant zu erhöhen. Die bereits eintretende Steigerung der Agrarpreise bilden günstige Voraussetzungen dafür. Aber auch die Forschung muss wieder intensiviert werden, um die vorhandenen agrarischen Ressourcen tatsächlich auch für Bioenergie zu nutzen.

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The Poultry Industry in the Arab World - Present & Future

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Introduction

The Arab World consists of 22 independent countries spread over the south eastern part of Asia and all North Africa and most of the eastern part of Africa. Even though it covers vast areas of desert land, it enjoys huge natural resources such as petroleum, minerals, fish and fertile land; if properly managed and efficiently used for the benefit of its peoples, it will empower the Arab World, unified and cooperating, to produce all its needs of food. The total arable land area of the Arab World is 539 million hectares (only 39% of the total land area), representing 11% of the World (table 1). It is possible to reclaim and cultivate enough of this land and/or improve its productivity to self-satisfy the Arab World's food needs.

Table 1: Population and Land Use in the Arab World (Source: UN and FAO)

Country	Population Million in 2005	Arable Land 1000 km²	Arable m² per person	Cultivated Land, % of arable	Farmers pct. of population	Poultry Farmers 1000
Egypt[1]	75.498	3.424	45	84.70	11.38	15.600
Sudan	38.560	134.600	3491	12.06	20.55	3.640
Algeria	33.858	39.956	1180	19.18	8.27	8.800
Morocco	31.224	30.376	973	27.64	13.76	9.140
Iraq	28.993	10.019	346	57.39	2.10	1.660
Saudi Arabia	24.735	173.798	7026	2.07	2.56	13.150
Yemen	22.389	17.734	792	8.67	13.47	2.430
Syria	19.929	13.759	690	33.38	8.21	5,135
Tunisia	10.327	9.784	947	28.32	9.43	3.220
Somalia	8.699	44.071	5066	2.37	34.81	-
Libya	6.160	15.450	2508	11.75	1.53	3.215
Jordan	5.924	1.142	193	25.83	3.29	3.170
Arab Emirates	4.380	0.559	128	13.42	1.53	0.960
Lebanon	4.099	0.329	80	51.67	0.98	3.600
Palestine	4.017	0.345	86	32.75	7.09	2.410
Mauretania	3.124	39.570	12666	1.23	22.06	0.195
Kuwait	2.851	0.154	54	8.44	0.53	1.280
Oman	2.595	1.080	416	3.52	13.95	0.235
Qatar	0.841	0.071	84	25.35	0.36	0.170
Djibouti	0.833	1.701	2042	0.06	32.65	-
Bahrain	0.753	0.010	13	20.00	0.40	0.150
Comoros	0.682	0.147	216	54.42	39.59	0.250
Arab World	**334.778**	**545.729**	**1630**	**10.65**	**11.41**	**78.410**
Total World	6,650.000	4973.406	748		20.26	2318.000
Arab World %	**5.03**	**10.97**		**4.14**		**3.38**

1 FAO figures do not include reclaimed desert area added to cultivated land during last 20-30 years

In 2005 the Arab World's population reached 330 million, 23% of which live in Egypt and 31% in Algeria plus Morocco plus Sudan. The population of the Arab World represents 5% of the world population of 6.650 billion people. Only 36 million people or 10.4% of the population live from agriculture, compared to 20% of the world population who live from agriculture. Only about 78,000 people or 0.22% of the agricultural population are directly involved in poultry production in the Arab World, slightly more than the world average. This small number reflects the high degree of mechanization of the poultry industry with modern hatcheries, feed plants, processing plants and predominantly large production units. It should be noted that this figure does not include people employed in the supporting and complementary industries and the large number of rural families whose small poultry flocks do not contribute significantly to their income.

The poultry industry in the Arab world centers on the production of two edible products: table eggs and broiler meat. Many complementary industries revolve around the production of these two products: specialized breeding, grand parent and parent farming with dedicated hatcheries; cereal and oil plant production, processing of oil plants, vitamin and mineral production, production of finished feed; production of vaccines, medicinal products and disinfectants; slaughter plants including meat processing and further processing; table egg grading and processing; manufacturing of equipment, packaging materials, etc.. I will limit myself here to the production of table eggs and poultry meat.

Table 2: Per Capita Production of Eggs and Poultry Meat in the Arab World (Source: FAO)

Country	Population million	Egg Production Number per cap.		Poultry Meat Production kg per cap.	
	2005	2005	2015	2005	2015
Egypt	75.498	52	62	8.57	4.22
Sudan	38.560	24	29	0.75	1.00
Algeria	33.858	68	82	7.65	9.25
Morocco	31.224	133	146	10.03	5.68
Iraq	28.993	33	50	1.86	5.05
Saudi Arabia	24.735	96	115	22.01	23.18
Yemen	22.389	39	47	5.06	6.64
Syria	19.929	156	172	6.65	6.92
Tunisia	10.327	156	172	9.75	11.72
Somalia	8.699	-	-	-	-
Libya	6.160	195	215	18.35	23.82
Jordan	5.924	121	145	22.39	22.30
Arab Emirates	4.380	115	126	7.95	22.87
Lebanon	4.099	212	233	33.20	12.96
Palestine	4.017	170	200	21.09	25.30
Mauretania	3.124	34	37	1.95	2.30
Kuwait	2.851	165	182	16.32	4.89
Oman	2.595	61	73	2.31	10.50
Qatar	0.841	163	180	5.71	3.70
Djibouti	0.833	-	-	-	-
Bahrain	0.753	54	60	7.97	11.50
Comoros	0.682	17	22	0.67	3.18
Arab World	**334.778**	**71**	**83**	**8.62**	**8.28**
Total World	**6,650.000**	**146**	**157**	**11.15**	**12.00**

Current and Predicted Production

Eggs

Table 2 shows the average per capita egg and poultry meat production in the Arab World in 2005 and predictions for individual countries for 2015. Total production in the Arab World reached 23.9 billion eggs in 2005, representing 2.5% of World production[2]. Per capita production ranged from 17 eggs in the Comoro Islands to 212 eggs in Lebanon. The average of 71 eggs in the Arab countries is less than half of the World average of 146 eggs.

I expect that by year 2015 most of the Arab Countries will reach self-sufficiency with an average per capita consumption of 83 eggs. Production will increase by about 50% due to a 25% increase in population and an increase in per capita consumption. At that point I expect per capita consumption to range from 22 eggs in the Comoro Islands to 233 eggs in Lebanon. Per capita egg production and consumption in the Arab World is relatively low - about half of the World average and a third of some of the industrial countries (table 3).

Table 3: Per Capita Production of Eggs and Poultry Meat in Selected Industrial Countries (Source: FAO)

Country	Total Production in 2005		Per Capita Production	
	Eggs million	Poultry meat 1000 tonnes	Eggs number	Poultry meat kg
USA	88,826	15,945	299	53.68
Spain	13,376	1,048	325	25.48
Canada	6,650	1,000	209	31.50
France	17,416	1,229	288	20.34
United Kingdom	10,255	1,360	172	22.80
Japan	41,377	1,339	324	10.48
Italy	11,667	698	203	12.17

Egg trading among countries in the Arab region is quite limited except between close neighbors. This is because consumers demand fresh eggs. We can safely assume that egg production will continue to increase in all Arab countries to meet the growing demand due to population growth and increased per capita consumption. I will not delve into theoretical scenarios of future exports and imports of table eggs from and to the Arab countries, but increasing imports of egg products from countries with lower production cost cannot be ruled out.

Poultry Meat

The issue of poultry meat production in the Arab countries drastically differs from that of table egg production. The cost of poultry meat production is very similar in all Arab countries, especially because they import their feed ingredients, parent stocks, vaccines, medicines and disinfectants. Their cost of producing poultry meat is about double that of countries producing their own feed ingredients. Therefore each of the Arab countries sets its own policy as to protecting its local poultry meat industry or opening up for imports.

Table 4 shows that total imports in 2005 reached 1.126 million tons representing 31% of consumption. Most of the imports came to five countries: Kuwait, Saudi Arabia, Iraq, Arab Emirates and Yemen, where the policy facilitates imports and where frozen poultry meat is agreeable to consumers.
Since most of the Arab countries have become members of the World Trade Organization (WTO),

[2] FAO figures on egg production converted from kg to numbers, assuming average egg weight of 60 g.

Table 4: Imports of Poultry Meat and Per Capita Consumption in Arab Countries
(Source: FAO)

Country	Import 1000 tonnes		Consumption kg/cap.	
	2005	2015	2005	2015
Egypt	2.16	588.89	8.52	10.22
Sudan	0.04	0.05	0.77	1.00
Algeria	0.03	0.04	7.71	9.25
Morocco	0.24	234.18	9.73	11.68
Iraq	173.97	226.15	8.50	11.05
Saudi Arabia	474.82	617.27	38.53	42.38
Yemen	97.07	126.19	9.15	10.98
Syria	0.13	0.17	6.72	8.74
Tunisia	0.03	0.04	9.39	12.21
Libya	0.02	0.26	18.35	23.85
Jordan	19.74	29.61	22.11	26.53
Arab Emirates	118.26	133.63	42.13	46.34
Lebanon	0.38	79.94	23.37	28.04
Kuwait	170.22	204.26	57.10	60.00
Oman	20.76	26.99	15.42	18.50
Qatar	24.39	31.71	28.65	37.24
Bahrain	18.07	26.43	35.00	38.50
Comoros	5.20	6.76	8.31	10.80
Arab World	**1126.00**	**2333.00**	**12.28**	**14.89**

and since the cost of production of the major exporting countries such as Brazil, USA, Argentina, Thailand and others is half of that of the Arab countries, and since most Arab countries have become accustomed to buying frozen poultry meat, I can easily see the production of poultry meat dwindling and being replaced by imported frozen meat excepting the portion which is requested live or fresh. The latter will vary between 10 – 50% of the annual consumption in different countries, depending on consumer habits, their purchasing power and the protectionist policy of each of the Arab countries.

The total import volume of poultry meat into the Arab countries is predicted to double within the current 10-year period and represent 42% of consumption by 2015. Per capita consumption is predicted to increase from 12.3 kg to 14.9 kg by 2015, a modest increase compared to the current per capita consumption in major industrialized countries during 2005 (table 3). Worth noting is the vast difference in per capita consumption between individual Arab countries: from 0.8 kg in Sudan, 6.8 kg in Syria, 18 kg in Libya, 23 kg in Lebanon to as high as 57 kg in Kuwait – a world record, which puts the USA with 54 kg in second place.

While poultry meat consumption continues to increase, per capita production in the Arab World is expected to decline during the current decade due to increasing imports.

Repercussions of Avian Influenza in the Arab World

Since 1997 Highly Pathogenic Avian Influenza (HPAI) H5 and H7 has been plaguing the world. It has spread to more than 60 countries, killed millions of birds and caused 160 human fatalities. The importance of this disease and the noise it created lies in the possibility of its mutation to a degree which allows it to infect humans and eventually spread from human to human thus threatening to become pandemic. However, ten years after it started spreading, several measures have been taken to limit its spread and to minimize the probability of a pandemic actually developing.

The use of inactivated AI vaccines in most countries that were exposed to the disease has proven its effectiveness in limiting its spread and in protecting the vaccinated flocks contrary to the predictions of many scientists especially human doctors. Other factors that helped were bio-security measures and separation of poultry rearing from pig rearing. Industrialized countries, recently with isolated outbreaks only, due to improved diagnostics and control measures, exercised stamping out policies within zones of 3 to 10 km radius from the infected farm with strict prevention of bird movement outside the zoned area. This policy worked because fair compensation was paid to farmers. Furthermore, rural poultry keeping is rare in such countries.

In underdeveloped or developing countries, where governments could not exercise the stamping out policy and were not prepared to compensate farmers, they had to allow vaccination. Commercial poultry benefited from this permission, but rural poultry remained unvaccinated and thus at risk. The disease remained, infecting rural poultry and peasants as well. Nevertheless, vaccination and bio-security measures have proven effective in drastically reducing the spread of HPAI.

Low pathogenic avian influenza (LPAI) H9 spread in the Arab gulf countries (Iraq, Saudi Arabia, Yemen, Jordan, Syria and Lebanon) since the late 1990s. Governments of these countries permitted vaccination using inactivated H9 vaccines. This measure has limited its spread and economic losses of mortality and production. Luckily this LPAI stopped short of spreading to the African continent. Thus the Arab African countries remained free from this type of influenza.

Egypt was the only Arab country which was hit with HPAI H5N1 in early 2006. The disease has wiped out 40% of the poultry population in this country. It has changed the structure of the industry and the government's perception of its viability and thus its need to protect it. This has led the industry leaders to be reluctant to modernize it and revive it. The basic reason for the spread of the disease in a very short period was the widespread rural free range keeping of chickens, ducks, turkeys and pigeons in all governorates as well as commercial poultry keeping in primitive poultry houses of all ages in very close proximities and lack of bio-security measures in such farms and areas.

The permission to use inactivated H5 vaccines, late as it was, has saved all commercial poultry since mid 2006. However, lack of vaccinating the rural poultry has kept the disease spreading in such areas and caused fifteen human casualties amongst rural women who kept poultry in their houses and who were always used to slaughtering any bird that shows any sign of disease before it dies. Even though no single human casualty appeared in commercial poultry keepers and workers, the Egyptian government decided to prevent live poultry markets but failed in implementing this directive. It is worth noting that 70% of poultry sales used to occur in live markets within cities or villages.

The Egyptian veterinary authority prevented movement of live birds unless samples were checked and found free from the virus. In spite of such a measure, the government kept chasing live market outlet owners. In the absence of sufficient slaughtering capacities, this measure interrupted regular production and increased prices. The government then decided to open up imports with no tariffs for nine consecutive months. After absence for 20 years, imported frozen chickens reappeared flooding the catering and retail markets.

Poultry industry leaders expressed their readiness to develop the industry by moving most poultry keeping to the desert areas, establishing modern slaughtering facilities and improving bio-security measures. However, the Egyptian government adamantly expressed its intention to reduce the import duty from 30% to 0% within three years. This has led the investors to shy away from investing in new facilities thus modernizing the industry. They are keenly aware of the competition from countries with lower production cost such as Brazil, USA, Argentina and Thailand who produce their own feed and can increase their production to meet the added demand from several countries in the world.

Thus we see how the largest Arab country neglected to take appropriate measures to prevent the infection and spread of HPAI despite all the threats coming from the Far East since 1997, from the Middle East since 2002, from Italy since 2001 and from Turkey in the fall of 2005. The Egyptian government hesitated for a full month after the outbreak to allow the introduction and use of the inactivated vaccine, thus inflicting the worst avian influenza catastrophe in the Arabian world so far. Such losses besides the human casualties drove the government to remove the 30% import duty and allow imports of frozen poultry. The Egyptian poultry industry is valued at 2.6 billion dollars, and half a million people depend on it directly or indirectly. It has provided sufficient eggs and poultry meat for the Egyptian population for 20 years and was capable of exporting day-old chicks and hatching eggs worth 200 million dollars annually since 2002.

The Egyptian experience ought to be a lesson to the rest of the Arab world in order to take measures to prevent occurrence of the disease such as: impose bio-security – vaccinate against prevailing strains of AI – impose minimum distances between farms – stop free range rearing and impose housing such poultry – impose vaccination of rural poultry – extend free laboratory diagnostic services – prevent wild bird hunting – protect the local industry by appropriate import duties. Only such measures can save the poultry industries and entice investments in modern poultry farms, hatcheries and slaughter houses. Such measures will eventually create an industry capable of providing self-sufficient safe quantities of fresh table eggs and fresh poultry meat to its populations. Such measures will prevent shortages of such nutritious products to its populations in case AI invaded exporting countries such as Brazil or USA or others.

Open trade vs. protectionist policies

It has been an acceptable principle that an economic policy of any country must stem out of the interest of all sectors of societies. Normally, the private sector in free economies can take up the hardest tasks provided that the legislations are clear such that under normal conditions projects realize predictable profits. This principle ought to be applied on agricultural sectors as well including the poultry sectors.
USA and Europe have long realized this principle. They have not only protected their farmers from unfair competition from the imported goods, but they have gone extra miles to subsidize their farmers thus allowing them to keep producing sufficient safe foods for their populations. The USA and Europe have recently resorted to their farmers with lucrative incentives to produce more crops that can generate renewable energy. The farm bill in the USA is revisited every five years to ensure fair compensation to farmers; US farm subsidies have exceeded $180 billion annually. Europe on the other hand established the “Common Agricultural Policy” 40 years ago. Its objectives are periodically reviewed. The present yearly subsidy for European farmers exceeds 50 billion Euros.

Both USA and Europe stand firm on subsidizing their agriculture with the following justifications:

- Ensuring a stable supply of affordable and safe food for their populations.
- Providing a reasonable standard of living for their farmers, while allowing the agricultural industry to modernize and develop.
- Ensuring that farming could continue in all regions.
- Looking after the well-being of the rural societies.
- Improving the quality of food.
- Guaranteeing food safety.
- Ensuring that the environment is protected for future generations.
- Providing better animal health and welfare conditions.

Despite its huge size, farm subsidies in the USA and Europe do not exceed 0.5% of their GDP. The problem lies in the poor, underdeveloped and developing countries where GDP is low and governments lack the capability to subsidize. It is for this reason that I can see no real interest for such countries to rush and join WTO unless with their own favorable terms. On the other hand I cannot blame the industrialized countries for subsidizing agriculture, a practice which has so far resulted in innovation, productivity and technological advancements. I can blame the developing countries including the Arab countries for lack of protecting their farmers from competition of imported products including poultry meat. Such policies have so far resulted in worsening the economies of the Arab countries, in scaring investors and in increasing emigration of qualified citizens.

Balanced economies are the motto of developed countries. The USA has become the world's largest exporter of corn and soybeans, and is self-sufficient in cotton, rice, meat and dairy products. Europe strives to keep farmers producing wheat, dairy products, olive oil and meats. Canada, a NAFTA member, imposes high import duty on dairy products and meat exceeding 200%, even on such imports from its partner USA. Japan prevents imports of red meat and rice from the USA even though it is a member of WTO. The WTO trade agreement on agriculture has never been agreed upon or signed up till now, 50 years after the inception of WTO, mainly due to the insistence of the industrialized countries to continue subsidizing their farmers and to upgrade their food quality standards.

The Arab countries must adopt trade agreements with other countries based on their own interest and not necessarily bound to WTO which might be crippling to its economies. There is a big difference between free trade and trade agreements on exchanging products with free will that serves the interests of agreeing partners. The Arab countries are generally underdeveloped with high cost of production and thus inability to export. Their only refuge to initiate and encourage investments is a protectionist policy which is fully realizable and agreeable to WTO rules.

Possibilities to develop the poultry industry in the Arab World

Developing table egg production in the Arab world is possible and realizable – despite higher production cost compared to some other countries – because the market requires fresh eggs. Therefore table egg production will continue to increase to meet demand via adopting cages and environmentally controlled houses. FAO import figures for the largest 13 Arab countries during the period 2000 to 2005 ranged between 383 million and 415 million eggs. Such figures represent only 1.95% of the production of these countries.

On the other hand, meat production in the Arab countries depends on protecting this production from imports from countries whose cost of production is only 50% such as Brazil, USA, Argentina and Thailand. As shown in table 4, the Arab countries imported 1.126 million tons in 2005, representing 31% of total consumption. FAO import figures for the largest 13 Arab countries between 2000 and 2005 ranged from 465,000 tons to 770,000 tons or an increase of 66% in five years. This happened despite the fact that most of those countries impose import duties on poultry meat ranging between 20 and 70%. This means that the Arab countries are quite ready to increase their imports of frozen poultry meat at the expense of their local production.

This leads us to conclude that the development of the poultry meat industry in the Arab world depends on two options: increasing the import duties and/or reducing the cost of production. I believe that most Arab governments are not willing to adopt the protectionist policy. They will most probably reduce the import duties until fully eliminating them. This leaves us with the second option. Reduction of production cost depends on two factors:

(1) Improving productivity to levels achieved in the exporting countries. This includes reduction of mortality in broiler flocks to a yearly average below 5%, reduction of feed efficiency to below 1.7 and improving broiler parent productivity to over 135 broiler chicks per hen housed. Such achievements will reduce cost of broiler production by about 30%.

(2) Additional reduction in the cost of production can only come from producing corn and soybeans in the Arab countries at lower cost than the import prices. The cost to import these two feed items remained lower than the cost of producing them in any Arab country since 1960. Only during 2006 did their prices increase dramatically after the USA decided to encourage ethanol production from corn via extending financing of ethanol plants and subsidizing the price of ethanol. This prompted

increased plantation of corn at the expense of soybeans and even wheat and barley. Thus prices of these commodities sky-rocketed during 2007.

Recent studies indicate that the USA will increase its use of corn for ethanol production from 75 to 150 million tons by 2015. Feed corn will stagnate at 190 million tons. This means that prices of corn, soybeans, wheat and barley will not drop until other countries such as Argentina, Brazil, Australia, Canada, Ukraine and others increase their production to face the shortage. This leads us to believe that certain Arab countries may be able to produce their needs of corn and soybeans at prices lower than the cost of importing them by the equivalent of their freight cost or more. This factor might bridge the gap of the cost of producing poultry meat in the Arab countries compared to the cost of importing it.

Sudan is the only Arab country that produces its needs of sorghum (replacing corn) and sesame plus peanuts (replacing soybeans). Their prices have recently become 50% lower than corn and soybeans. The arable area in Sudan is 135 million hectares while only 16 million hectares or 12% are cultivated. Sudan would be capable of producing and supplying the rest of the Arab world with its needs of grain and oil seeds for the production of eggs and poultry meat if and when the required infra-structure is in place and investment is encouraged. Syria and Iraq are two other Arab countries with great agricultural capabilities.

Summary

In this review, the author takes a critical look at trends in poultry meat and egg production in the Arab World. FAO statistics on production and consumption for 2005 and predictions for 2015 are discussed in the context of increased feed cost on the world market, national policy re. liberalized imports vs. protection of local production and measures to control HPAI.

The author pleads for predictable government policy to encourage investment in land development to support productive employment and poultry meat production based on locally grown feed.

Zusammenfassung

Die Geflügelwirtschaft in der Arabischen Welt - Aktuelle Probleme und Zukunftsperspektiven

Auf der Basis statistischer Daten, die von der FAO und den Vereinten Nationen veröffentlicht wurden, gibt Tabelle 1 einen Überblick über die aktuelle Situation in den Ländern der Arabischen Liga. Die Einwohnerzahl in der Gesamtregion beträgt etwa 5% der Weltbevölkerung, von der landwirtschaftlich nutzbaren Fläche wird weniger als die Hälfte tatsächlich genutzt. Ebenso wie die Einwohnerzahl und die landwirtschaftlich genutzte Fläche pro Einwohner variiert auch der Anteil in der Landwirtschaft und insbesondere in der Geflügelproduktion tätigen Menschen erheblich.

Es wird damit gerechnet, dass im Laufe dieses Jahrzehnts die Eierproduktion und der pro-Kopf Verbrauch an Eiern weiter steigen wird, während die Nachfrage nach Geflügelfleisch zunehmend durch billigere Importe aus Ländern mit Überschuss-produktion an Getreide bedient wird. Im Interesse verbesserter Selbstversorgung mit Lebensmitteln und Entwicklung des ländlichen Raums durch produktive Beschäftigung wird dafür plädiert, bisher ungenügend genutzte Landressourcen durch staatliche Förderung zu mobilisieren, um steigenden Weltmarktpreisen für Futtergetreide nachhaltig zu begegnen.

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Management Recommendations for Laying Hens in Deep Litter, Perchery and Free Range Systems

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Introduction

The trend away from conventional battery cages towards deep litter, perchery and free range housing systems for laying hens has intensified in recent years. In West European countries in particular laying hens are increasingly kept in production systems that are consistent with ethical and moral principles of these societies. Organic farms managed in accordance with specific guidelines for organic farming are also gaining market shares.

The management of laying hens in deep litter, perchery and free range systems requires more expertise and time than conventional battery cages. Any farmer who decides to keep hens in these production systems should try to learn as much as possible from well-managed and successful operations. The management recommendations, most of which have been followed since many years in the management of layer and broiler parent flocks, draw on results of scientific studies as well as field experience and should help poultry farmers to optimize results under their specific conditions.

Design of laying houses

The first step in planning to build new houses or converting existing buildings to deep litter or percheries is to consult experts with sufficient experience. The construction of deep litter and perchery housing has to meet different and often higher standards than cage housing. Since the birds spend at least part of the time directly on the floor, this must be well insulated. The lower stocking density per m² of floor space compared with conventional cages and the corresponding reduction in heat production by the hens must be taken into account when designing ventilation and air-conditioning installations.

The dispersion of the hens within the building depends on its size, any compartments within the shed, but especially air flow and house climate. If the latter two factors are relatively uniform the hens will disperse evenly within the shed and feel comfortable. Otherwise the birds will crowd together in areas of the shed they find agreeable.

Nests must be easily accessible and preferably positioned in a central location in the laying house. To train hens to use the nests, all eggs laid on the litter floor must be picked up frequently to discourage other hens from using these “floor nests”. Possible reasons for preferring certain floor positions should be analyzed to make them less attractive. Eggs laid outside the nest are hygienically compromised and have to be marketed at discounts.

In deep litter or perchery housing dust is generated by hens using the scratching area and moving about. To minimize health hazards for the birds, a good ventilation of the shed is essential. If the deep litter house or perchery is combined with an outdoor enclosure, the building should be in a north-south direction to keep the walls from heating up at different rates and different amounts of light entering the building when the popholes are open. The design of the building and its installations should be user-friendly to allow easy servicing.

Deep litter housing systems for laying hens vary in design and layout depending on the type of building. The classic form consists of 80-90 cm high dropping pits covered with wooden or plastic slats or wire mesh, which take up two-thirds of the floor space. Feeders, drinkers and nests should be positioned on top of the dropping pit and the drinkers mounted at a distance of 30 to 50 cm directly in front of the nests.
The litter area with sand, straw, wood shavings or other materials occupies about one-third of the floor space and allows the hens to move about, scratch and dust-bathe. The littered scratching area may be replaced by perforated flooring. In this case it is recommended to provide a winter garden

where the birds can express their natural behaviors such as scratching and dust-bathing. Stocking densities should not exceed 9 hens per m² of usable floor space. Rails or other elevated perching facilities should be provided as resting places for the hens.

Percheries are systems where the birds can roam on several levels. All levels are covered with wooden or plastic slats or wire mesh and may have ventilated manure belts installed. Feeding and watering facilities are usually located on the lower tiers, while the upper tiers serve as resting areas. Depending on the perchery type, the laying nests are either within the system or outside the perchery. A stocking density up to 18 hens per m² floor area is permitted. Lighting programs and feeding times can be designed to encourage the birds to move around the different levels. When constructing a new facility, the house carcass and the perchery system will be designed to match; when existing buildings are to be equipped with a perchery system, the adaptability must be taken into account.

In free range systems a normal deep litter house or perchery is combined with an outdoor enclosure (4 m² floor area per hen) for the hens. This facility must be available to the birds during the day. Popholes along the entire length of the building provide access to the exterior. A winter garden attached to the poultry house has proved highly beneficial. The hens cross the winter garden to get to the outdoor enclosure. Winter gardens in front of the laying house have a positive effect on both litter quality and house climate: when the popholes are opened, cold air does not flow straight into the building and the indoor temperature is less affected than without a winter garden.

Requirements for pullets

Pullets destined for deep litter or perchery housing should be reared in comparable management systems. This ensures minimal stress during transfer, the birds settle down quickly in their new surroundings and production can start without problems.

Pullets to be housed in alternative systems should have their beaks carefully treated. Without proper beak treatment, injurious picking may develop any time during the laying period. Geneticists at Lohmann Tierzucht have been selecting against cannibalism and feather pecking for many years, but as long as these behaviors are observed in commercial farms, beak treatment is recommended in accordance with legal requirements. Egg producers should discuss their preferences with the pullet supplier in good time.

The bodyweight of the pullets should preferably be above the breeder's standard. A slight overweight gives the birds a reserve during the transfer phase. When weighing pullets on arrival, the fasting loss during transit must be taken into account. Since birds kept on litter floors and in percheries have approx. 10 %, with free range even +15 %, higher energy requirements for maintenance, the pullets must have learned to eat more than birds in conventional battery cages. The ability to consume sufficient feed soon after arrival in the laying facility is of paramount importance for the hens.

The more closely the growing facility resembles the production system, the easier it will be for the pullets to adjust to their new surroundings. Hens in floor housing and percheries must also be able to move around by flying and jumping. To learn these skills, facilities like rails or perches should be provided before the age of six weeks. In deep litter systems suspended feeder chains have proved effective.

In percheries it is important to ensure that the levels are opened before the chicks are six weeks old. Staggered feeding times on the different levels encourage the pullets to move around within the building.

Housing of pullets

Pullets should be transferred to laying houses in good time before the anticipated onset of production. The recommended age is 17 or 18 weeks. The move from the grower to the layer facility should be handled with care but speedily. Capture, transportation and vaccination are stressful to the hens. Gentle transfer and careful adaptation of the flock to the new surroundings are crucial for good production results. After transfer the hens should be dispersed evenly in the laying quarters and placed close to feeders and drinkers. Water and feed must be available immediately.

On arrival the light should be left on long enough so that the hens find their way around. Room temperatures should be within a comfortable range for the birds. They should not be disturbed during the first 24 hours after the move. Inspections should only be carried out in an emergency. The attendants should always be calm and quiet and wear the same clothing. If birds appear nervous, hyperactive attendants may be a cause.

Management during the early days

During the first few days after housing it is important to stimulate feed intake, e.g. by

- Providing an attractive meal type ration with good structure
- Running the feeding lines more frequently
- Feeding when the trough is empty
- Lighting of feeding installations
- Moistening the feed
- Use of skim milk powder or whey-fat concentrate
- Vitamin supplements

Pullets should never lose weight after transfer. They should continue to gain weight, or at least maintain their bodyweight. If possible without exceeding reasonable stocking density, the hens should be confined above the dropping pit or the perchery until they reach approximately 75 % production. Light sources should be placed so that the entire building and the nest entrances are well lit. Only the light above the dropping pit or in the perchery should be on toward the end of the light day.

Litter

Type and quality of the litter are important for the hens and the house climate. Different materials may be used:

- Sand or gravel up to 8 mm granule size
- Wood shavings
- Wheat, spelt, rye straw
- Bark mulch
- Coarse wood chips

Sand and gravel should be dry when put down. Wood shavings should be dust-free and not chemically treated. Straw must be clean and free of mold. A litter depth of 1-2 cm is sufficient. Litter should be put down after the hens have been housed to be spread by the hens. This helps to prevent the formation of condensation water between floor and litter in case of low room temperature. Straw stimulates the investigative and feeding behavior of the hens and reduces vices. Removal and replacement of litter in heavily frequented areas of the building may become necessary during the laying period.

A well designed winter garden has a positive impact on litter quality. This beneficial effect of a winter garden can be improved further by staggering the position of the popholes in the building and the winter garden.

House climate

Room temperatures around 18°C are considered optimal for laying hens in alternative systems, with a relative humidity between 50 and 75%. Lower temperatures during the winter months are no problem, provided the hens are adapted to them. But temperatures exceeding 30°C are less well tolerated. If room temperatures above 30°C cannot be avoided, sufficient air movement around the hens is essential to enable the birds to dissipate heat. Additional fans in the poultry house are highly effective in such situations.

Hens with access to a winter garden or an outdoor enclosure should get accustomed to colder winter temperatures. Plumage quality needs to be considered in temperature management programs in alternative housing. Activity of the birds, stocking density and the presence of popholes are important effects on air quality and room temperature.

Draughts are harmful for the birds who may try to escape them by congregating in poorly ventilated parts of the building. Increased mortality and floor eggs may be due to poor ventilation. The ventilation system should ensure that in summer warm air is removed quickly from the birds' surroundings and in winter the building does not become too cold. High concentrations of noxious gases should be avoided. Ammonia reduces bird comfort and is injurious to health. A well designed winter garden and the use of outdoor pens or wind protection (strip curtains) in front of the popholes prevent the ventilation system in the poultry house from breaking down if a negative pressure system is used.

In case problems occur with the ventilation system in deep litter or perchery housing, experts should be consulted.

Feeding

The high genetic potential of today's hybrid layers for efficient egg production can only be realized with a balanced diet. The nutrient requirement of a laying hen is divided into the requirements for maintenance, growth and egg production. Recommended nutrient allowances can be formulated for any production system, for alternative management systems as well as for conventional cages. The maintenance requirement of a laying hen is approximately 60-65 % of the total energy requirement. Compared with laying hens kept in cages, the maintenance requirement in alternative systems is higher due to the increased activity of the hens. It has been calculated at +10 % for hens producing barn eggs and +15 % for hens using free range.

The prerequisites for sufficiently high nutrient intake of hens are:

- a diet with a sufficiently high energy content, i.e. nutrient density
- and adequate feed intake

In case it is not economically viable to raise the nutrient density of layer diets, sufficient feed intake becomes more important for the expression of the hen's genetic potential. The feed intake capacity of a population of laying hens can be optimized by genetic selection, for individual laying hens it is determined mainly by:

- The hen's bodyweight
- Daily egg mass production
- Ambient temperature
- Condition of the hen's plumage
- Energy content of the ration
- Health status
- Genetic variation within flock

Feeding at onset of lay

When pullets are moved to the laying house at 16-17 weeks of age, they are not yet fully grown and should not be fed a layer diet. Layer diets with more than 3 % calcium should not be introduced too early. Until about 19 weeks of age the hens should get a pre-lay diet, the change to a high-density layer starter should be made when about 5% production is reached. The move to the laying house exposes hens to considerable stress. The development from pullet to mature laying hen is associated with fundamental changes affecting all major physiological and hormonal processes. The phase of juvenile growth and body mass increase ends on reaching sexual maturity, followed by the start of lay. However, the hens are not yet fully grown at onset of lay, their growth continues until about 30 weeks, when the weekly weight gain falls to less than 5 g.

The changes occurring during the transition phase from pullet to laying hen often lead to a reduced feed intake, which may drop to well below 100 g per hen and day. This rate of consumption does not meet the hen's nutrient requirement at that age and, based on the energy levels of commercial layer rations in Europe, must definitely be considered too low. A suboptimal nutrient supply at the onset of lay places a strain on the birds' metabolism as endogenous energy reserves have to be mobilized and it can contribute to the development of fatty liver syndrome.

During this phase every effort must therefore be made to increase the feed intake as quickly as possible to at least 120 g per bird and day. An effective way of boosting the nutrient intake is to offer the hens a ration with a higher nutrient density (11.6 – 11.8 MJ/kg) and correspondingly increased amino acid concentrations. An inadequate nutrient supply in early lay jeopardizes the success of the entire laying period and leads to irreversible loss of egg production.

Feeding during the laying period

Table 1 Recommended daily nutrient allowances for brown-egg laying hens in deep litter and free range systems*:

Nutrient	Based on 100 g daily feed intake			
	Unit	Phase 1	Phase 2	Phase 3
Crude protein	%	18.7	18.2	18.0
Methionine	%	0.44	0.40	0.38
Methionine+ Cysteine	%	0.80	0.74	0.70
Lysine	%	0.87	0.85	0.80
Tryptophan	%	0.21	0.20	0.20
Threonine	%	0.64	0.60	0.60
Arginine	%	1.04	1.01	0.98
Isoleucine	%	0.52	0.51	0.49
Calcium	%	4.10	4.30	4.40
Phosphorus, total	%	0.60	0.54	0.47
Phosphorus, available	%	0.42	0.38	0.33
Sodium	%	0.17	0.17	0.17
Chloride	%	0.17	0.17	0.17
Linoleic acid	%	2.00	1.60	1.20
Metabolizable energy	MJ	1.415	1.410	1.398

A universally valid conversion of these nutrient requirement data for all feeding situations, stated as nutrient content per 100 kg feed, is not possible, mainly because actual feed consumption per bird and day varies widely in real-life commercial situations. But when formulating diets for laying hens in alternative management systems it should be remembered that to achieve normal performance from hens in alternative systems requires both a diet with a higher nutrient density and the highest possible feed intake. The aim should be a daily consumption of 120 – 125 g feed per hen and day.

Phase feeding

The basis for any feeding program in alternative production systems must be the hens' nutrient requirement. This changes continuously as the birds get older. To match the hens' evolving nutritional needs requires diets formulated according to different criteria at each stage:

- Layer starter (phase 1) with high nutrient density for a safe start to the laying period
- Balanced phase 2 diet to ensure good laying persistency with a reduced protein and amino acid content
- Phase 3 diet for optimal shell quality and corresponding egg weights

Information on recommended nutrient allowances and feeding programs for white- and brown-egg layers is available on request from Lohmann Tierzucht.

The basic principles of phase feeding can also be implemented in laying hen operations with several age groups and only one feed silo. Here, too, the hens' changing nutrient requirements can be met by selecting appropriate feed types, although expert advice should be sought from a poultry nutritionist. But the best way of ensuring an optimal feed and nutrient supply is to have a separate feed silo for each age group. This variant is also preferable from an economic perspective. Larger holdings with several units should have two silos per unit. This facilitates cleaning of the silos and allows a quick change of diet if necessary. The alternate filling of two separate feed silos makes it easy to check the feed consumption of each flock with a view to determining the feed intake per hen. But in large operations modern, computer-controlled systems should be available for an accurate measurement of feed consumption.

Feeding and egg weight

The production of eggs of the correct weight for the market is of prime importance in alternative housing systems. Egg weight and shell quality are negatively correlated. Large eggs at the end of lay often have a poorer shell quality. Measures to control egg weight should therefore begin during the pullet rearing phase and be implemented early on. In high-production flocks a noticeable reduction in egg weight is very difficult to achieve during the laying period.

It is therefore advisable to talk to the pullet producer and the feed supplier as early as possible about the diet formulations to be used.

Condition of plumage and feed intake

Maintaining the hens' plumage in good condition throughout the production period should be a major concern of every poultry keeper. In doing so he fulfils his legal obligations under animal welfare laws, but well-maintained plumage is also essential for keeping the hens in good health. It protects against heat loss, thus restricting feed consumption. A bad plumage can easily increase daily feed intake by 10 g/day/bird and more. The increased feed and nutrient requirement of hens with damaged plumage is explained by the maintenance requirement, which accounts for 60-65 % of the total nutrient requirement and in this case is needed to maintain the birds' body temperature. A daily feed consumption of 130 g/hen/day (or more) is therefore not unusual in special situations.

Grit

Insoluble grit or fine gravel should be provided for free access feeding. Due to the specialized digestive system of birds, this can stimulate digestion and improve feed intake capacity. We recommend 3 g/hen once a month with 4 - 6 mm granulation.

Water

Good water is the most important part of the diet for all animals, including poultry. To ensure health and optimum egg quality the water supplied to the hens should be of potable standard. The poultry farmer should therefore always ask himself if he would be prepared to drink the water offered to his birds himself.

Feed and water intake are closely correlated. Under normal conditions the feed to water ratio is about 1:2. If hens do not drink enough, feed intake will be inadequate. Regular checks to ensure that drinkers are working properly are therefore recommended.

When ambient temperatures are high or if laying hens have health problems they consume more water. During hot weather water serves to regulate the hens' body temperature. Cool drinking water is best for this purpose and water temperatures above 20° C should therefore be avoided. During extremely hot weather with temperatures of over 30° C the feed to water intake ratio can shift to 1:5. In such situations cooling of the drinking water is beneficial. Water meters allow regular monitoring of the hens' water consumption. They are inexpensive and easy to install. A reduced or increased water intake can be regarded as a first warning sign of problems in the flock or with the technology. Minimizing water wastage reduces costs and improves the house climate.

Regular cleaning of the water lines in poultry buildings is essential and special attention should be paid to checking the supply tanks. If water from wells on the farm is used regular water tests should be carried out. The assessment of water quality should be based on the standards laid down in the Drinking Water Ordinance.

Flock control

In the early days after housing a special attention to detail will pay ample dividends later on. Every morning at dawn a thorough tour of inspection is necessary. This should comprise checks for the proper functioning of:

- drinkers,
- feeders,
- lighting installations and
- laying nests

The house climate should be checked and the condition of the flock and the hens' behavior assessed.

Laying nests

Laying nests should be easily accessible to the hens, preferably located in a central location. It is recommended to keep the entrance to the nest well lit whereas the interior should be darkened. Pullets should not be allowed access to the nests too early, only just before the onset of lay. This enhances the attractiveness of the nest and improves nest acceptance. During the laying period the nests should be opened 2-3 hours before the start of the light day and closed 2-3 hours before the end of the light day. Closing the nests at night prevents soiling and broodiness. Close-out prevents the hens from roosting in the nests overnight and also makes the nest less attractive to mites. Tilting floors have proved effective for close-out. They also help keep the nest box floor clean.

Floor eggs

The incidence of floor eggs can be reduced by incorporating the following experiences in the design of the laying house and the management of young flocks:

- The entire building should be well lit – dark corners should be avoided.
- Draughty nests disturb the hens during egg laying.
- The entrance to the nest must be clearly visible.
- Additional lighting of the interior of the nest improves nest acceptance at the onset of lay.
- Litter depth should not exceed 2 cm at the onset of lay. Light-colored litter material is preferable to dark material.
- Feeders and drinkers should be near to the nest (2 to 3 meters).
- Drinking water in the vicinity of the nest entices the hens to this area.
- Feeders and drinkers should not create attractive areas for egg laying.
- If nest boxes are mounted on the dropping pits the perforated floors should have a gradient of about 7° towards the nest.
- Slats in front of the nests should incorporate barriers every two meters.
- Pullets should not be moved to the production facility before 17-18 weeks of age.
- The laying nests should be opened just before the onset of lay.
- Hens should not be disturbed while laying, i.e. no feeding at this time.
- Do not carry out flock inspections during the main morning laying period.
- Floor eggs should be collected from early in the morning, several times a day.
- To reduce floor laying, an extra hour of light at the start of the day is often effective.
- Electric fencing and draughts may help in problem areas.

Lighting

The best light source for laying hens is a high frequency bulb emitting light within the natural spectrum (frequency range above 2000 Hz). Fluorescent tubes or energy-saving bulbs (50-100Hz) have a ‘disco effect’ on hens and encourage feather pecking and cannibalism. Light sources should have a dimmer switch.

Lighting programs

Great care must be taken to ensure that day length is not increased up to the point of stimulation for egg-laying and is not decreased during the laying period of a flock. This is easy to achieve in windowless buildings or laying houses with windows that can be blacked out, provided that foul-air and fresh-air shafts also have effective blackout facilities. In this case the most suitable lighting programs for the particular breeding products can be operated.

Table 2 Lighting program for darkened laying houses

Age in weeks	Light in hours		Light intensity	
	Program White Layers	Program Brown Layers	W/m²	Lux
17	8	10	1* - 2	4 – 6* / 5 - 7
18	8	11	3	10 – 15
19	9	12	3	10 – 15
20	10	13	3	10 – 15
21	11	14	3	10 – 15
22	12	14	3	10 – 15
23	13	14	3	10 – 15
24	14	14	3	10 – 15
25 **	14 –16	14 – 16	3	10 – 15

* for White Layers ** to end of production

Special considerations for hens kept in buildings with natural daylight

In housing where the hens have access to winter gardens or an outdoor enclosure, or if windows, ventilation shafts and other openings cannot be blacked out sufficiently to shield the birds completely from the effect of natural daylight, this should be taken into consideration when designing the lighting program. If flocks are moved into these production facilities or if the hens have free access to winter gardens or outdoor areas, the lighting program must be adjusted to the natural day length.

It makes a difference whether the housed pullets come from a windowless growing facility or were reared in a building whose windows were blacked-out in synchronicity with the lighting program or whether they were fully exposed to natural daylight during the growing period. In the case of hens which were unaware of the natural diurnal rhythm during rearing it is important to avoid excessive stimulation, and consequently stress, on transfer to open laying houses caused by an abrupt lengthening of the day (in spring and summer). An increase in the day length by not more than 2-3 hours is desirable.

In open housing the lighting program in the spring and summer months is determined by the lengthening of the natural day. When the natural day length begins to decrease again the day length should be maintained constant until the end of the laying period.

Crucial points to consider in the management of laying hens, the choice of light sources and the design of lighting program:

- Artificial light from fluorescent bulbs operating within a frequency range below 250 Hz is perceived as flickering by hens. Incandescent bulbs or fluorescent tubes operating at high frequencies over 2000 Hz are preferable.
- Artificial filtered light, but also unfiltered light from conventional light sources, restricts the vision of hens by limiting the light spectrum that is visible to them.
- Stimulation of hens in windowless housing follows the simple principle of shortening the light period until the desired stimulation has been achieved, followed by a lengthening of the light period. A reduction of the day length during the laying period is not allowed.
- If technically possible, open housing for laying hens should also have facilities for blacking out the windows. These could then be opened and shut in synchronicity with the lighting program.

The laying hen keeper and the pullet supplier should agree on the following in order to coordinate lighting programs during rearing and the subsequent laying period:

- If pullets are moved to open houses without a blackout facility an option is to design lighting programs synchronized with the hatch date of the flock. To avoid a “light shock” if transfer takes place during a period of very long days the step-down program during rearing should be modified in such a way that on transfer to the laying house the hens are exposed to an increase in day length of not more than two or three hours.
- Pullets should be reared in darkened housing or if windows are present, those should be opened and shut in synchronicity with the lighting program.
- Hens reared under artificial light and exposed to natural daylight later on, have to get used to it. The use of true light bulbs during pullet rearing can help.
- Pullets reared in buildings that cannot be darkened are affected by the length of the natural day, especially in the spring and summer months. Early maturing of pullets can only be prevented by adapted lighting programs, but light stimulation of such hens is difficult.

Animal health

Pullets destined for deep litter, perchery and free range systems are vaccinated in the rearing facility against viral (Marek’s Disease, IB, ND, Gumboro, ILT), bacterial (Salmonella) and parasitic diseases (coccidiosis). In alternative layer housing systems the infection pressure from fowlpox and EDS is so high that they should also be vaccinated against these diseases if there is any risk of infection. Combined vaccinations against IB, ND, EDS and sometimes also against ART are widely applied. Booster vaccinations against IB are advisable at 5-10-week intervals. A high infection pressure of Salmonella requires, in addition to the vaccinations given during rearing, an additional booster vaccination. Bacterial infections such as E. coli, erysipelas and Pasteurella multocida are common in alternative production systems. Outbreaks depend on the type of infectious agent, the infection pressure and the condition of the flock. Immune protection can also be achieved by combined vaccinations. Effective treatment of bacterial infections in laying hens is hardly possible. Preventative vaccination with flock-specific vaccines is therefore advisable. This initial outlay can help prevent high losses and a premature end to production. The bacteria causing erysipelas and Pasteurella infections are usually found in rodent pests in the vicinity of affected hens. Effective control of mice and rats is an important tool for prevention.

If high mortality rates or any other signs of disease are observed in the flock, a veterinarian should be consulted immediately.

Parasites

Roundworms and threadworms occur in hens and are transmitted via the droppings. If necessary the flock may have to be wormed.

Red poultry mites are a major problem in alternative production systems. They damage health and reduce the productivity of flocks. Heavy infestation can also cause high mortalities (by transmitting diseases). Infestation causes distress in the flock (feather pecking, cannibalism, depressed production). Continuous monitoring of the flock is therefore advisable.

Common hiding places of mites are:

- in corners of nest boxes
- under the next box covers
- on the feet of feeding chains, trough connectors
- on crossbars of perches
- on dropping box trays
- in corners of walls and
- inside the perches (hollow tubes)

Mites should be controlled with insecticides or other suitable chemicals. These should be applied in the evening as mites are active during the night. It is important that the treatment reaches all hiding places of the mites. More important than the amount of chemicals applied is their thorough and even distribution. The mite and beetle treatment should begin as soon as the flock has been depopulated, while the laying house is still warm. Otherwise the pests crawl away and hide in inaccessible areas of the laying house.

Vices

Watch closely for any signs of abnormal behavior. A sudden occurrence of it without changes in the lighting regime can have a variety of reasons. If these vices occur check the following factors:

- **Nutritional and health status** – bodyweight, uniformity, signs of disease
- **Stocking density** – overcrowding or insufficient feeders and drinkers cause distress
- **House climate** – temperature, humidity, air exchange rate or pollution by dust and/or noxious gases
- **Light intensity / light source** – excessive light intensity and flickering light (fluorescent tubes or energy-saving bulbs, < 200 Hz)
- **Ecto- and endoparasites** – infested birds are distressed and develop diarrhoea
- **Feed consistency** – finely ground meal-type feed or pelleted feed encourage vices
- **Protein/amino acid content of the diet** – deficiencies cause problems
- **Supply of calcium and sodium** – deficiency makes birds irritable

Outdoor enclosure

Access to outdoor enclosures should be managed in accordance with external weather conditions. For the first three weeks after transfer the hens should remain indoors. Then the popholes should be opened. If a winter garden is available this should initially be opened for just one week, before eventually opening the exit popholes 4-5 weeks after housing. Popholes should only be opened after eggs have been laid. Young flocks going outside for the first time need to be trained in the use of the outdoor enclosure. Food and water are only available indoors.

Range/Pasture

Hens readily accept the range if the pasture area is broken up by a few trees or shrubs which provide protection from predators. The area closest to the laying house is heavily used by the flock and the grass becomes worn. Depending on the condition of this part of the range, ground care and disinfection measures should be carried out. Pasture rotation has proved effective in practice. Young pullets visiting pastures with good vegetation for the first time tend to ingest numerous plants, stones, etc. This can often greatly reduce their feed intake capacity. Failure to consume sufficient food, especially during the phase of peak egg production, jeopardizes the hens' nutrient supply. In practice this often leads to weight loss, reduced production and increased susceptibility to disease. Young flocks should therefore be introduced gradually to using the outdoor areas.

Summary

This review calls attention to management factors which need special attention to optimize results under conditions of non-cage management, starting with rearing in a technical environment similar to the production unit and including optimal nutrition, health care and husbandry.

Zsammenfassung

Managementempfehlungen für die Haltung von Legehennen in Boden-, Volieren-, und Freilandhaltungen

Das Management von Legehennen in Boden-, Volieren- und Freilandhaltung erfordert gegenüber der herkömmlichen Käfighaltung wesentlich mehr Sachkenntnis und Zeit, die zur Betreuung der Tiere investiert werden sollte. Besondere Beachtung sollten folgende Gesichtspunkte finden:

- Junghennen, die in Boden- und Volierenhaltungen eingestallt werden, sollten auch in solchen Haltungen aufgezogen worden sein. Je ähnlicher der Aufzuchtstall dem späteren Produktionsstall ist, desto besser werden sich die Tiere im neuen Stall eingewöhnen.
- Die Tiere müssen bezüglich des Körpergewichts und der Uniformität dem Standard des Züchters entsprechen und sie sollten über ein gutes Futteraufnahmevermögen verfügen.
- Der Schnabel der Junghennen, die in alternative Haltungsformen eingestallt werden, sollte behandelt worden sein, um Federpicken und unnötigen Tierverlusten vorzubeugen.
- Nach der Umstallung in den Legestall im Alter von 17-18 Wochen ist darauf zu achten, dass die Tiere unverzüglich Futter und Wasser aufnehmen und weiter wachsen. Ein Körpergewichtsverlust oder ein Stagnieren des Wachstums der Hennen sind unter allen Umständen zu vermeiden.
- Ein gutes und im gesamten Stallbereich einheitliches Klima ist in Alternativhaltungen besonders wichtig. Staub und Zugluft sind zu vermeiden. Temperaturen von 18° C und eine relative Luftfeuchte im Bereich von 50-75 % sind optimal.
- Bei der Fütterung der Tiere ist zu beachten, dass diese einen um 10-15 % höheren Erhaltungsbedarf haben als in der Käfighaltung.
- Bei Einsatz eines hochwertigen Legestarter Futters können Defizite in der Futter- bzw. Nährstoffaufnahme zu Beginn der Legeperiode ausgeglichen werden.
- Phasenfütterung ist zur Steuerung des Eigewichtes und der Futterkostenoptimierung auch für Alternativhaltungen zu empfehlen.
- Gut konstruierte, im Stall räumlich richtig angeordnete Legenester, ein gutes Nestmanagement und angepasste Fütterungszeiten helfen, den Anteil verlegter Eier zu minimieren. Die Hennen müssen frühzeitig lernen, zur Eiablage das Nest aufzusuchen. Hennenhalter müssen zu Legebeginn dem Verlegen von Eiern durch geeignete Maßnahmen entgegenwirken.
- Herden in Offenställen brauchen spezielle, auf das Schlupfdatum der Herde und die geographische Lage des Stalles angepasste, Beleuchtungsprogramme.
- Infektionsdruck und Belastung der Tiere durch bakterielle Erkrankungen sind in Alternativhaltungen wesentlich höher als in Käfighaltungen. Dies ist bei der Gestaltung von Impfprogrammen und der Prävention von Erkrankungen zu berücksichtigen.
- Hennen müssen an Freilandhaltungen gewöhnt werden. Bei der Nutzung von Ausläufen ist insbesondere darauf zu achten, dass die Tiere im Stall immer genügend Futter aufnehmen.
- Freilandausläufe sind zu pflegen, um einer Kontamination des Bodens mit Schadstoffen und Parasiten vorzubeugen.