CHAPTER 6

EMERGING OPTIONS AND THEIR IMPLICATIONS

Harry Aiking, Joop de Boer, Johan M. Vereijken,
Anita Linnemann, Frank Willemsen,
Radhika Apaiah & Dick Stegeman

6.1 TOWARDS CROP-BASED SOLUTIONS[1]

The preceding chapters provide strong evidence for the notion that the use of meat protein in the world is extremely unbalanced, leading to a serious disturbance of the natural structures and biogeochemical processes on which life depends. To put it simply, in the developed countries, in particular, far too much meat protein is consumed to be globally sustainable. As a consequence, there are, on the one hand, excessive emissions in the meat producing countries themselves and, on the other hand, overtaxed natural resources (water, land) in countries that provide much of the meat and feed (developing as well as developed countries). Moreover, the situation is rapidly deteriorating as the world population continues to grow and increasing income in rapidly industrialising countries (China, Brazil) acts as a force driving up meat demand.

In view of the nature of this problem, crop-based solutions are called for. This should involve the development of products based on plant proteins that replace meat in a sustainable way. That is the key to the so-called protein transition. However, the PROFETAS projects have demonstrated that this solution will not just require the substitution of one type of protein by another. A satisfactory way of replacing meat proteins will require a whole package of options, which take into account how proteins are linked to other natural and societal issues. The protein transition can be realized only if it is based on a combination of linkages that will satisfy a whole set of constraints. The linkages include:

- crop choice (addressed in Section 6.2)
- envisioned use of by-products (6.3.1)
- consequences for other natural resources (water and energy) (6.3.2)

[1] Harry Aiking & Joop de Boer

H. Aiking et al. (eds.),
Sustainable Protein Production and Consumption: Pigs or Peas?, 155–191.

- food-related issues conceived by key stakeholders in the market (6.4)
- issues put forward by governmental and non-governmental policymakers (6.5)
- contours of an evolving "global food economy" (6.6)

Although these linkages can be highlighted from three different angles (environmental sustainability, technological feasibility and societal desirability) this chapter aims to develop them in Sections 6.2-6.6 as a number of cross-cutting themes at a relatively general level in order to avoid being bogged down by too many details. Moreover, crop-based solutions will require a global vision that reaches far beyond the scope of PROFETAS.

As a first approximation, in PROFETAS the world was initially assumed to be rather homogeneous. From the results described in Chapter 2 it has become clear that, globally, the environmental benefits of a transition from meat to plant protein can conservatively be estimated to be on the order of a factor 3-10 for land and energy requirements as well as eutrophication, but even on the order of a factor 30-40 for water requirements and over 60 for acidifying pollution. To what extent and where, however, this might lead to decreased environmental pressure as a result of decreased pork production or, conversely, to increased environmental pressure as a result of locally increased plant protein production is less straightforward.

Among other things, the location of benefits or detriments strongly depends on the actual crop choice (Section 6.2). This crop choice also depends on future developments in the areas of texture formation, protein-flavour interactions and plant breeding (Sections 3.2-3.5). Furthermore, crop choice is complicated by the emerging fact that the protein transition cannot be realistically uncoupled (Section 6.3) from both the biomass transition (towards sustainable energy production) and the water transition (towards sustainable use of freshwater).

From a societal point of view the question should be raised how the future of NPFs will be decided when decision makers in industry and government are considering the issues on their agenda. Commitment by the actors who are important for the prospects of NPFs is the theme of Section 6.4. The analysis of actor commitment has been elaborated with a section on actual feedback from Dutch actors (Section 6.5). The final part of this chapter puts the main findings into the broader perspective of an evolving global food economy (Section 6.6).

6.2 CROP OPTIONS[2]

6.2.1 Introduction

The major crops from which proteins are derived for application as an ingredient in man-made food products are soy and wheat, soy being the most important one. Next to protein preparations, the processing of these crops yields two other commercially valuable bulk products, i.e. starch from wheat and oil from soy. In fact, wheat and soy processing have been invented to obtain these latter components. However, especially for soy the isolation of protein preparations has become more and more important from an economic point of view.

The protein preparation derived from wheat (termed wheat gluten) is mainly used in the baking industry, among others to enhance the baking quality of wheat doughs. From soy, a number of protein preparations are produced: defatted meals, concentrates and isolates, with a protein content of about 50, 70 and over 90%, respectively. There are numerous applications for soy protein preparations as ingredients in human food: they are used, for example, in soups, desserts, dressings, bakery products and, last but not least, processed meat products.

On a much smaller scale other crops are used to produce protein preparations to be used as ingredients in human food. Examples are pea, lupine and rice. In the feed industry many other plant protein preparations are used. These protein preparations are mainly derived as by-products from oil (rapeseed, sunflower) or starch processing (corn, potato). However, soy protein preparations dominate in the feed industry, too.

The major source of protein for the production of meat substitutes is soy (Section 3.1.2). However, due to climatic causes, soy is only grown on a very small scale in Europe. Because the PROFETAS programme aims at developing NPFs from proteins derived from crops that are or can be cultivated in Western Europe, a different crop should be selected. To this end a desk study was performed before starting the actual PROFETAS programme. The results of this study are described in the next section. Subsequently, the choice of the crop will be evaluated in the light of the

[2]Johan M. Vereijken & Anita Linnemann

results obtained within the PROFETAS programme. Finally, other options will be discussed.

6.2.2 Desk study

Before the PROFETAS programme actually started, a desk study was performed in which eight crops were compared with respect to their suitability as a protein source for the development of NPFs. These eight crops were selected because they can be cultivated in temperate climates such as in Western Europe and have an assumed potential to be the protein source of NPFs. This potential was based on the economic perspective for commercial protein production, the functionality of the proteins and the relatively low impact on the environment by the cultivation of these crops, as derived from discussions with crop specialists, technologists and environmental experts.

The crops studied are two legumes (lupine, *Lupinus* spp. and pea, *Pisum sativum*), two non-legume grain crops (quinoa, *Chenopodium quinoa* Willd. and triticale, x *Triticosecale*), two leafy crops (lucerne, *Medicago sativa* and grass, *Lolium* and *Festuca* spp.) and two other crops, rapeseed (*Brassica napus*) and potato (*Solanum tuberosum*) that are being processed to yield starch (potato) and oil (rapeseed). From all these crops the seeds are the source for protein production except for the leafy crops and potato; from these crops leaves and tubers are the source, respectively.

The desk study was split into two parts, which have been published separately (Dijkstra *et al*., 2003; Linnemann and Dijkstra, 2002). The aim of the first part was to analyse and evaluate the primary links of the production chain. In the second part, the focus was on technological issues of the production chain.

6.2.3 Primary links of the production chain

In the first part, the perspectives of the eight crops as possible sources of protein for NPFs were analysed with respect to the primary links of the production chain. The suitability of the crops is determined by classifying them with regard to the aspects most relevant to these links. The aspects taken into consideration were familiarity of farmers with the cultivation of the crop, perspectives for rapid crop improvement, protein production (kg/ha), protein quality (absence of unwanted substances) and familiarity with usage for human food in Western Europe. The classes used were + = moderately good, ++ = fairly good and +++ = good.

Familiarity of farmers with the cultivation of the crops

Some of the crops are already being cultivated in Western Europe on a large scale and hence have the advantage that the farmers have experience with them. These crops are pea, triticale, lucerne, grasses, rapeseed and potato. The suitability of these crops was therefore classified as good (+++). Lupine has been cultivated more extensively in the past than nowadays. Quinoa, however, has no history of cultivation in Europe. The suitability of the latter two crops was thus classified as fairly good (++) and moderately good (+), respectively.

Perspectives for crop improvement

The crops differ significantly in the basis that is available for crop improvement. This basis includes genetic materials, scientific knowledge and infrastructure. Not surprisingly, the ranking of the crops with respect to this aspect is similar to that of the familiarity of farmers with the cultivation of the crops.

Protein production in kg/ha

Large differences exist in the amount of protein that the crops potentially yield per hectare (see Table 6-1). A subdivision into three groups was made as follows: (a) good (+++): lucerne and grasses (> 2000 kg/ha), (b) fairly good (++): pea and lupine (1000-2000 kg/ha), (c) moderately good (+): triticale, quinoa, rapeseed and potato (< 1000 kg/ha).

Table 6-1. Crop and protein yield.

Crop	Yield (ton/ha)	Relevant raw material	Protein content (%)	Potential protein yield (kg/ha)
Pea	3-5	Seed	25	1250
Lupine	3-5	Seed	33-40	2000
Triticale	6	Seed	11-14	800
Quinoa	3-4	Seed	14-16	650
Lucerne	8-14	Leaves	20	2500
Grasses	10-16	Leaves	20	2500
Potato	45	Tuber	1	450
Rapeseed	3.5	Seed	19-22	700

Protein quality

None of the crops in this study yields relevant raw materials (seeds, tuber or leaves) that are completely free of antinutritional factors (defined as factors that have a negative effect on nutritional quality such as phenolic compounds, enzyme inhibitors, (glyco)alkaloids) and/or poisonous substances. However, for pea and lupine, food grade flours and protein-rich products are commercially available, indicating that the quality of the protein is good enough for further processing into human foods. Pea and lupine are therefore classified as good (+++), where the other crops are classified as fairly good (++).

Familiarity with usage for human food in Western Europe

Some of the crops have a long history of usage in the diet in Western Europe, but others are completely unknown. The products prepared from unfamiliar crops will require an additional effort in time and money from marketing divisions, before their usage is well accepted among consumers. This implies that the acceptability of protein from pea and triticale is expected to be good (+++), and that of lupine fairly good (++). Introducing protein from quinoa, lucerne, grasses, rapeseed and potato in the diet of consumers will need more explanation and advertising (+).

Judgement

The suitability of the eight crops for the production of protein in Western Europe was judged by weighing up the pros and cons of the elements of the primary production chains that were studied. The result is that pea, lucerne and grasses are the most promising (+++). Fair prospects (++) are foreseen for lupine, triticale, rapeseed and potato. The possibilities for quinoa (+) lag significantly behind those of all the other crops.

6.2.4 Technological aspects of the production chain

In the second part of the desk study the emphasis was on the technological aspects of the production chain. This includes the processing technology, and functional and nutritional qualities of the derived proteinaceous products.

Processing methods

For all eight crops methods are available to process the eight raw materials into protein-rich products such as protein concentrates and isolates. However, there is much less experience with the processing of quinoa than with the processing of the other crops. The technology to isolate potato protein, which is now used by industry, results in a preparation consisting of denatured and strongly aggregated protein, which can only be used for nutritional purposes in feed. Pea and lupine are used industrially as sources for the production of protein concentrates and/or isolates intended to be used in human food.

Functional properties

The term functional property has been defined as “any physicochemical property which affects the processing and behaviour of protein in food systems, as judged by the quality attributes of the final product” (Kinsella, 1976). Examples of such functional properties are emulsifying, foaming, gelling and water-holding properties. The set of functional properties which a given protein preparation exhibits, depends on the nature of the proteins present (i.e. it depends on the plant species and, usually to a lesser extent, within the species, on the variety), but also very strongly on the technology by which the protein is processed. Furthermore, functional properties are affected by factors such as protein concentration, pH, ionic strength, temperature and the presence of other components such as carbohydrates. In addition, some properties are variety-dependent. Finally, different laboratories use different tests and/or conditions to assess functional properties. In conclusion, it is virtually impossible to compare functional properties of protein products in a scientifically satisfactory, reliable manner.

Nutritional properties

For similar reasons as for functional properties, literature data on the nutritional properties of protein preparations are hard to compare. Furthermore, to assess these data the relevant question is whether one wants to aim at the highest possible nutritional value, or, in contrast, whether one is satisfied with a proteinaceous product that has no traceable amounts of antinutritional and/or poisonous components. To be a source for the production of NPFs, it is essential that a suitable protein source can deliver sufficient protein without these latter components to a yet to be defined end product. This can be achieved with all eight sources.

Judgement

It was concluded that the technological possibilities of the eight crops cannot be used to discriminate between their suitability as a starting material for NPFs. Pea and lupine have a slight advantage over the other crops, because their concentrates and isolates are already commercially available.

6.2.5 Overall judgement

Based on the desk study, pea, lucerne and grasses have the highest potential as protein sources for the production of NPFs. Among these three, pea has the slight advantage that industrially protein preparations are already being produced. Because one model crop should be selected, the pea was chosen. Next to the elements considered in the desk study other elements were taken into account, the most important one being the resemblance, both with respect to biochemical and functional properties, between the major pea and soy proteins. Compared to other plant proteins, a lot of literature is available about soy proteins with respect to production, functionality and applications. This includes literature on aspects that are of the utmost importance for the production of NPFs such as thermal behaviour and texturisation.

It should be kept in mind that despite the desk study, the choice for pea proteins as model proteins to develop NPFs is at least partly arbitrary. Not all elements of the production chain have been taken into account, for instance, the environmental aspects (see Section 2.4). Furthermore, no selection could be made based on the information available with respect to the technological aspects of the production chain.

6.2.6 PROFETAS programme results

With respect to the choice of the crop to be the starting material for the development of NPFs, the PROFETAS programme did not yield decisive additional results. It should be emphasised that none of the projects was intended to contribute to this choice, but they were intended to deliver tools to develop NPFs and they succeeded well in this respect. Nevertheless, it is worthwhile to discuss their results in the framework of crop choice for NPFs.

Two projects are directly linked to the primary production, i.e. the projects on crop growth (see Section 3.4) and genetic modification (Section 3.5). Both projects yielded new technological instruments: a new method for genetic modification of peas and an innovative crop growth model. The latter model is generic and can be used for any arable grain/seed crop. The newly developed technology for genetic modification of pea may also offer new perspectives for the genetic modification of other legumes such as soy. However, it is not possible to compare this technique with techniques for genetic modification of other crops in terms of crop choice (e.g. required time, effectiveness and efficiency). To this end more experience with the newly developed technique is required.

Two other projects are directly linked to functional properties of pea proteins: NPF texture formation (Section 3.3) and NPF flavour retention (Section 3.2). The main objective of the latter project was to get insight into protein-flavour interaction using pea proteins as model proteins. It succeeded well, but with respect to crop choice, it did not yield additional discriminating information, for the results are largely generic and – except concerning the relatively pea-specific saponins, maybe – the insights can be used for other protein sources.

The project on texture formation yielded some information concerning crop choice. The results appear not to be directly in favour of pea protein.

Peas contain a protein fraction (a part of the vicilin fraction) that hampers the gelation at near neutral pH. However, a similar protein fraction is present in other seeds (e.g. soy), too. More discriminating is the observation that another pea protein fraction, legumin, is inherently less able to form a well-structured gel network than its corresponding counterpart in soy, i.e. glycinin. Furthermore, in contrast to soy glycinin gel networks, those of pea legumin were found to be susceptible to rearrangements during re-heating that caused gel strengthening. This makes the behaviour of pea legumin gels less predictable when re-heating is required (as, for instance, for preparing NPFs at home). So pea legumin seems to be less well suited for NPF production than soy glycinin. However, legumin is only one of the protein fractions present in peas and combinations of the protein fractions (as in commercially produced pea protein isolates and concentrates) might behave in a way that is more comparable to corresponding soy protein combinations. Furthermore, differences in gelling behaviour, despite its importance in texturing, might not result in differences after texturing the proteins by techniques other than gelling, such as extrusion.

Another argument pleading against the use of peas derives from the fact that pea processing will also yield starch. The amounts of pea required to produce enough protein to replace 40% of present meat consumption will result in an amount of starch that nearly equals present global starch production. In contrast, the use of the protein fraction from oil seeds such as soy will result in an amount of oil that equals about 10% of the present oil production. However, it is certainly not excluded that a major part of the pea starch will be used for the production of NPFs. This type of issue will be dealt with in more detail in Section 6.3.

6.2.7 Other options

At the start of the PROFETAS programme, peas were selected as the model crop to derive proteins for NPF development. Most of the arguments are still valid. Rapeseed, however, especially the "double low" varieties called canola (low in two antinutritional factors of rapeseed) are now becoming the starting materials for the commercial production of concentrates and isolates. This leads to a higher ranking of this crop.

Based on the results of the PROFETAS programme, especially those on texture formation (Section 3.3), one could argue that crops having the legumin type of protein and lacking the vicilin type of protein might have an advantage over peas, since one of the vicilins is hampering gelation. Examples of such crops are sunflower (*Helianthus annuus*) and rapeseed/canola, both familiar oil seed crops. Processing these crops yields oil instead of starch, which might also be advantageous. However, the proteins from these oil seeds also comprise, in relatively high amounts, a type of storage proteins not present in pea or soy, so-called 2S albumins. The presence of this type of protein will most likely affect the behaviour of the legumin type of proteins and, hence, have an effect on properties relevant for NPF production, taste and texturing. This would evidently require further investigations.

For crop choice the other components that are or can be obtained during processing of the relevant parts of the plant (seed, tubers or leaves) should also be taken into consideration. As already mentioned, crops that also yield oil may be favoured over crops that also yield starch. This would rule out cereals such as wheat and corn and tubers such as potato. During processing also fibre fractions will be obtained. At present, these fractions have little applicability, just like the parts of the plant that are not being used, such as straw. However, things may change. For instance, in the framework of sustainable energy production a lot of research has been performed, aimed at evaluating the use of fibres, starch and oil for the production of sustainable energy. Especially, with respect to the use of oil and starch for production of biofuels (bio-ethanol and biodiesel) a lot of information is already available.

For crop choice, environmental aspects should also been taken into consideration. Next to issues such as amounts of pesticides and fertilisers used for cultivation, water usage for both cultivating and processing crops is likely to become an important parameter for crop selection (see Section 6.3). In addition, agronomical differences between crops should be considered. Such agronomical differences include cropping systems (crop rotation, mixed cultivation of two crops) and sensitivity towards biotic stress (resistance to pests and diseases) and sensitivity towards abiotic stress (drought resistance, tolerance to high and low temperatures). Such cultivation issues will likely affect crop choice because they contribute to consistency of the yield (and hence income of the farmer) and to consistency of the crop supply (hence, attractiveness for food producers and processors, respectively).

In this respect, when talking about crop selection, it may be considered that molecular biology (biotechnology) might contribute to improving crops as a source for NPF production. This may not just concern the proteins themselves (their composition, ratio of protein types, amounts; see Sections 3.5 and 3.8), but also the plant as a whole. For instance, genetic modification might conceivably contribute to an improved straw stiffness for plants such as peas, resulting in a better resistance to lodging. Although at present the technological feasibility and social desirability of such developments is unclear, such technological achievements might result in higher yields and better suitability of crops to be a source of NPFs.

It should be kept in mind that NPFs need not be produced from proteins derived from a single crop. It may well be that the required combination of functional properties and the performance with respect to each of these functional properties cannot be met by proteins derived from one single crop. As an illustration, some of the present meat substitutes are based on two crops (wheat gluten and soy proteins, in addition to significant amounts of egg protein).

Last but not least, it is to be expected that, primarily due to soil and climate conditions, different crops will be used in different regions of the world. For instance, in warm regions of Asia soy is a good candidate, delivering both oil and proteins. Furthermore, soy based NPFs may suit Asian consumer preferences better than in Europe, because soy protein products such as tofu and tempeh have been part and parcel to the Asian diet for centuries. In Africa, groundnuts might be an option, since it is a familiar crop and delivers both proteins and oils. A legume that is also quite familiar in both Africa and Asia (especially India) is chickpea. However, as with peas the main non-protein constituent is starch. As already argued, in more temperate regions, such as Europe, Canada and Australia oilseeds such as rapeseed and sunflower might be interesting options.

6.2.8 Conclusions

At the start of the PROFETAS programme, peas were chosen as the model crop for the development of a technological toolbox to produce NPFs. Most of the arguments for this choice are still valid. However, the results of the PROFETAS programme suggest there are other options as well. Under the present conditions – which could easily change as a result of changing world market prices or newly emerging technologies – in Europe oilseed crops seem to have an edge, particularly, certain oilseeds lacking a vicilin type of protein. However, it should be emphasised that selecting potential crops for NPF production was not a PROFETAS priority. Such would require dedicated research regarding differences in cultivation aspects (both with respect to agronomical and environmental issues), as well as developments in breeding. Furthermore, outside Europe other crops are likely to be used as the starting material for NPFs production.

Looking into the future, other developments, for instance those aimed for in programmes concerning sustainable energy production and water usage, may well affect crop choice. Therefore, links should be established with relevant research programmes in those and other transition areas.

6.3 COMBINED CHAINS[3]

6.3.1 Introduction

The chains that have been chosen as models for the protein transition studied in PROFETAS are the pork chain and the pea-NPFs chain. Neither of these chains exists as an independent entity, for they require inputs from other chains and produce inputs for other chains. When looking towards future options it is important to note that lessons can be learned from studying the pork and pea chain, but these chains serve only as models and other chains may be more suitable for a protein transition.

Although the focus of the programme is primarily on Europe, it is inevitable that when dealing with transitions of the magnitude envisaged, effects on a global scale are taken into account. This is especially true when looking at uses of – from the perspective of the PROFETAS programme – by-products. In small volumes these products may be sold on the basis of a specific characteristic of that by-product, but on a larger scale it is easily conceivable that any niche markets will be flooded. A considerable amount of by-product will have to be sold in bulk, based on “bulk” characteristics. Section 6.3.2 will be devoted to the linking between the (meat and pea) protein chains, on the one hand, and agricultural input chains and by-product output chains, on the other hand. Section 6.3.3 sketches the potential consequences of altogether replacing feed crops and the opportunities this might entail for the global environment.

6.3.2 Proteins and by-products

As the PROFETAS programme studies a transition from meat protein towards plant protein there are specific trends that need to be distinguished:

(A1) A decrease in meat production means a decrease in inputs into the meat chain. This should not pose a major problem when crop products such as seeds are concerned, but it may incur environmental and monetary costs where wastes from agriculture and from the food industry are currently fed to pigs.

[3] Frank Willemsen, Radhika Apaiah, Dick Stegeman & Harry Aiking

(A2) A decrease in meat production means a decrease in outputs from the meat chain. This would lead to a decrease in such varied by-products as manure, fat, sausage casings, felting, leather, gelatine, etc. In the West-European situation a decrease in manure would probably be classified as a positive environmental effect.

(B1) An increase in protein crops grown would mean an increase in inputs into the protein crop chain. Depending on the cropping method and the crop involved this will result in an increase in the use of water, land, fertilisers, energy and pesticides.

(B2) An increase in protein crops grown would mean an increase in non-protein output from the crop chain, such as oil, starch or cellulose.

In the following paragraphs the interactions between different chains will be discussed, as well as possible substitution between chains. A decrease in available animal fat for example, may be offset or even more than offset by an increase in available vegetable oil. Likewise, the increased land use for protein crops may or may not be compensated by a drop in land use for feed crops, etc.

(A1) Effects of a decrease in meat chain inputs on other chains

In the PROFETAS programme the pig chain was chosen as the meat protein model chain. Although the meat chain uses other inputs such as water, energy and antibiotics, we will focus on the feed use of the pig chain. An important characteristic of pigs is that, unlike cattle and sheep, for example, they are unable to digest cellulose and, therefore, require approximately the same kind of nutrients as humans.

In Western Europe pigs are fed a complex mixture of seeds from purpose-grown crops and wastes from various stages of other chains that lead from crop to end product for human consumption. Presently, both parts of this mixture are about equal in size, but it is important to take into account that soy, for example, used to be grown primarily for its oil, whereas nowadays its protein-rich feed ingredients have gained importance. Another noteworthy trend is that, as a result of the increasing level of quality that consumers expect, more food that is deemed fit for human consumption will be rejected and that this food will often end up in pig feed.

If demand for inputs into the pig chain decreases, the producers of feed crops will have to adapt. For purpose-grown crops, this may lead to any or all of the following effects, depending on price and the choices available to the primary producer (farmer) of the crop:

- The producer continues to supply the pig feed market albeit at a lower price.
- The producer supplies a different market with the same crop.
- The producer supplies a different market with a different crop.

- The producer stops growing crops.

All except the first option are potentially interesting as far as a protein transition is concerned. The "different market" for crops that are currently grown for pig feed could be the food market and such a crop may be suitable as a source of NPFs. It also may be the industrial market (technical products ranging from adhesives to antibiotics, binders, cosmetics, inks, paints, etc.) in which the crop may be used to replace by-products from the pig chain.

The "different crops" can be crops for the (protein) food market and/or for biomass. Land being taken out of production is under the current pressures not very likely, but as the land becomes available, it could decrease the pressure on land use elsewhere.

For the "wastes" the situation is slightly different. As the price of the waste streams goes down, there are several options available:

- Industries may improve the efficiency of their processes, resulting in less waste.
- Industries may choose to have their waste processed differently.
- Industries may cease production of the main product from which the waste stream originates.

In the latter case it is difficult to see links with the protein transition. The effects however, would need careful study in terms of sustainability and social desirability. An improvement of the efficiency of a production process, for example, will usually result in environmental benefit, but processing waste differently, e.g. land filling or incineration, may be detrimental to the environment. Processing waste in a sustainable way, therefore, is an important discipline for study, which is also acknowledged by policymakers. The European Commission financially supports research on further processing by-products into higher added value products. Ceasing the production of certain products may or may not be more sustainable and social desirability must definitely be a question here. A final remark on the use of waste in animal feed is that using waste streams in this way has recently been reduced, because of the risk of contaminating the human food chain through unsuitable wastes. This development is putting great pressure on the food industry, and particularly the meat industry, because due to the BSE crisis the use of animal waste streams (including swill) is bound by many restrictions and may not be used for feed products for the same species anymore.

(A2) Effects of a decrease in the meat chain outputs on other chains

The meat chain produces a lot of associated outputs in different stages of the chain. First of all, there are outputs during the growth of the animals, mainly manure. In the Western European situation, where fertiliser of artificial and animal origin are both abundant, a decrease of these outputs is unlikely to have an effect on other chains, or it would have to be a marginal increase in artificial fertiliser use.

Second, during slaughter several by-products are produced that are subsequently used to produce leather, gelatine, glues, etc. It would be very difficult and time-consuming to have to consider all these products separately. Although they represent a considerable volume, at this stage it is difficult to say how much of an effect on other chains would be noticeable. However, it is assumed that in almost all applications good, but perhaps more expensive, alternatives for the meat by-products are available.

Third, a category of wastes emerges either during slaughter or in further processing afterwards. These consist of cut-offs, unpopular cuts of meat and fat. Currently a common destination for many of these is the pet food industry. Here, also, it is unclear what kind of effect a decrease in this sector will have on other chains. In terms of the energy value and chemical structure, animal fat is comparable to most vegetable oils (both are triglycerides), so that a decrease might be countered by an increase in, if necessary chemically hardened, vegetable oil production.

(B1) Effects of an increase in inputs to the protein crop chain on other chains

Linked with a considerable increase in growth of protein crops are increased land and water use and (depending on cropping system and crop) increased fertiliser use, increased use of agricultural chemicals and fuel. Such increases will primarily cause a greater demand for land, water, etc. and thus affect other chains. Considering the rationale of the PROFETAS programme, the increases should be offset by corresponding decreases in feed crop production. Because of the inefficient conversion of plant protein into meat protein (on average 6 : 1) the total amount of protein crops produced will, no doubt, decrease by the transition. In many cases feed crops are comparable to protein crops for human consumption so that it would not be difficult to assess the environmental impact. As the plant protein chain in the PROFETAS programme is to a large extent virtual, it should be possible to choose the protein crop so that it is a very close match with feed crops. The consequences of choosing different protein crops for NPF production will have to be studied more intensively.

(B2) Effects of increased outputs from the protein crop chain on other chains

Although the plant protein foods that are the object of study in PROFETAS are rich in protein, processing steps will inevitably yield one or more fractions low in protein, but high in non-protein substances (depending on the crop, primarily either starch or oil), in addition to the desired protein fraction (see Section 3.7). If a large part of the world's meat protein consumption were to be replaced by NPFs, the sheer volume of the non-protein fractions that would arise is immense. This rules out any niche markets for the non-protein fractions and so they would have to compete with other bulk agricultural products on a global scale.

To understand the effect of the extra non-protein fractions we may compare the present volumes of these fractions with potential volumes if 40% of the meat consumption (equivalent to about 18 million tons of protein) is replaced by plant protein consumption. Taking peas as an example of a possible protein rich raw material containing much starch, the production of 18 million tons of protein will come with the production of about 36 million tons of starch. This is on the same order of magnitude as the present global starch production (i.e. 48.5 million tons in 2000). Thus, using peas (with the present composition) as the protein source will affect the present market situation severely.

If we look into more detail at the oil fraction, soy may be taken as an example. The world consumption of vegetable oil is over 90 million tons now (of which the larger part is used in food production). If soy is used to supply 18 million tons of protein, about 9 million tons of soy oil is liberated. This is about 10% of the present consumption and, therefore, no severe long-term effects were to be expected if it were extra production. Interestingly, a protein transition of this sort would result in a shortage of soy oil, rather than in a surplus, as will be seen in the next section.

For the non-protein fractions, applications are likely to be food, feed, industrial raw materials and energy. Use as food (and due to the volume we may say staple food) is for some crops already a reality, for example, if we look at soy, where the oil fraction is used as cooking oil and as an ingredient for a wide variety of food products.

Considering the rationale of the PROFETAS programme (avoiding inefficient animal conversion for reasons of sustainability), use as feed is only an option for fractions high in non-starch polysaccharides, especially if no other use for this fraction is developed. Use as feedstock for the chemical processing industry is currently under investigation for various stocks. In fact, a trend towards using all components of a crop – coined the "biorefinery" concept by analogy to mineral oil fractionation – has recently emerged. Use for retrieving energy, although currently not a very economical option, is interesting because of the possibility of producing CO_2-neutral fuel. Both oil and starch are used to produce the automotive fuels biodiesel (resembling diesel) and ethanol (resembling petrol), although the production of such biofuels currently needs subsidies to be viable in the market. This option will be dealt with in the following section.

6.3.3 Opportunities for the global environment

In the preceding section the changes in the meat protein and plant protein chains were assessed separately. But if one takes a larger perspective and looks at the position of protein crops in world agriculture, food and feed crops are closely related. As the PROFETAS programme assumes the replacement of meat with plant protein based products, a useful way to look at this relation is to look at the total current area of feed crops and assume that by discontinuing the production of animal feed altogether this land will become available for a protein crop that can then be used as the basis for an NPF. The land that is left over can then be used for any other use (crops, nature). Please note that this is an extreme scenario aimed at examining maximum values for changes in land use. Therefore, little consideration is given to economic and institutional constraints that no doubt would have a role to play if such changes were actively pursued.

The amount of land currently used as cropland is about 1.5 Gha (=15 million sq. km). Of this area around 400 Mha is used for growing feed crops (FAO, 2005; OECD, 2004a).

Table 6-2. World land area and its uses (FAO, 2005). (* Figures for "Forest and woodland" and for "All other land" are from 1994, the last year in which FAO included these categories in its agricultural land use statistics. All other figures refer to 2002, the most recent year included by FAO.)

Land use type	**Current Area (10^6 ha)**	
Arable & permanent cropland	1,500	
of which for feed		*400*
Permanent pastures	3,500	
Forest and woodlands*	4,200	
of which managed forest		*500*
All other land*	3,900	
Total	13,100	

From Table 6-2 it is not immediately clear that there is any shortage of arable land. But any expansion of the arable land area would have to come from either the "Permanent pastures", "Forest and woodlands" or "All other land" categories. The "All other land" includes deserts, mountain ranges but also built up areas, and cannot be used for cropland. Converting land that is in the "Forest and woodlands" category would probably not be considered desirable, although a likely development for some areas, as it will encroach upon areas that up till now had been relatively unspoilt, and which are reserves of biodiversity. What is reported as "Permanent pastures" may look promising, but these lands are often used as pasture for the very reason that they are unsuitable as cropland. This is mentioned explicitly, for example, in

"World Agriculture: towards 2015/2030" (Bruinsma, 2002). Therefore, we will assume in our calculations that the current land use is a fair estimate for what is the most suitable land use.

The main crops grown for feed are grains and oil crops of which the grains are most often used entirely as feed whereas oilseeds are crushed and only the resulting "cake" is fed to animals, the oil being mostly used for human consumption. What options there would be if the feed area were used for food is displayed in Table 6-3 below.

Table 6-3. Comparison of alternative uses of the feed area. Sources for "Present": areas and amounts from De Haan et al. (1997) with oilseed area attributed to feed crops estimated on a weight basis, and protein contents from FAO (2004) and Berk (1992); for "Pea": conservative estimates for yield and protein content from Linnemann and Dijkstra (2002), and fractions resulting from air classification from Tyler et al. (1981); for "Soy": a medium high yield value from FAO (2005), cake and oil amounts from De Haan et al. (1997), and cake protein content from Berk (1992).

	area (10^6 ha)		**amount (10^6 tons)**	**products**	**use**
	100	oilseeds	70	oil	human
Present			140	cake	livestock
	300	grains	800	grains	livestock
	52	pea	53	protein fraction	human (NPFs)
Pea			103	starch fraction	any
	348	other uses			any
	25	soy	15	oil	human
Soy			58	cake	human (NPFs)
	375	other uses			any

Table 6-3 clearly shows that the feed route supplies protein for human consumption rather inefficiently. Thus, 800 Mt of grains are presently produced which, assuming a protein content of some 10%, provide 80 million tons of feed protein, plus 140 Mt of oilseed "cake" providing another 64 Mt of protein. With an estimated production of 144 Mt of feed protein, at the very most 29 Mt of meat protein can be produced, assuming a conversion efficiency of 20% based on Smil using USDA long-term statistics for poultry (Smil, 2002). In reality, however, not all the protein will be fed to poultry and therefore the efficiency will be lower still.

Alternatively, the production of 29 Mt of pea protein for human consumption would require only 52 Mha of land (based on separation into two main fractions by means of air classification). This would create a starchy fraction (not pure starch) of 103 Mt. Such a quantity of starch would be very difficult to market as a bulk product as it would have to compete with starches that are produced more cheaply from higher yielding crops. However, 348 Mha would be freed to be used for food production, biomass for energy, nature conservation or other uses, depending on societal developments.

Producing 29 Mt of protein from soy would require about 25 Mha of cropland. In this case, the major side-product is oil, which can be used for human consumption without any difficulty. Use as a stock for industrial products is currently a niche market, but use as starting material for biofuel is increasing, due to a variety of factors. Just as in the "pea" scenario, the remaining 375 Mha could be devoted to any other use.

It should be noted that under the current production a considerable amount of oil for human consumption is produced, but this would be reduced (from 70 Mt to 15 Mt) in the case of soy for direct human consumption and no oil is produced at all if peas are grown for protein. This shortage might pose a considerable problem, initially, but not one that cannot be redressed. More compelling may be the question whether there will be a demand for the huge starch fraction that is left when peas are grown to replace meat protein. So pea production for protein replacement frees up less land than the soy option, provides an even larger gap in the supply of vegetable oil and yields a potentially problematic amount of starch. Although the scenario presented is used to examine extreme changes in land use world-wide, it is interesting to further complete the picture by paying attention to some marked benefits and some consequences for the meat sector and consumers.

Using the freed-up area for biomass could provide the first enormous benefit. Assuming a biomass yield of 15 tons/ha of dry mass, a value that we believe is realistic (Van den Broek, 2000), the remaining 375 Mha would yield $5.6*10^9$ tons of dry biomass. Using a higher heating value of 19 GJ/ton (Hoogwijk *et al.*, 2003), this amount of biomass could provide 100 EJ of energy, over 25% of the current energy use.

In that respect, it should be noted here that in the most recent FAO outlook (Bruinsma, 2002) the production of biomass other than for food has not been addressed whatsoever. Recently however, the OECD called for "policy changes to promote biomass" (OECD, 2004b). Even though one might argue as to how quickly the rise of a biomass-for-energy sector can evolve, it is nearly impossible to envisage a more sustainable world energy supply without any role for biomass at all.

A large benefit not directly stemming from the increase in available agricultural land is a decrease in pressure on scarce water resources. Meat production is a very large water user world-wide. Millstone and Lang estimate the water use of beef production at 250 m^3 per kg and furthermore state that 1 kg of beef requires one thousand times as much water as 1 kg of cereal (Millstone and Lang, 2003). In their recent publication "Water – More Nutrition per Drop", The Stockholm International Water Institute estimates that the production of 1 kg of grain-fed beef requires 5-40 times as much water as 1 kg of cereal, whilst admitting that their estimate for the water use of beef is rather low (SIWI-IWMI, 2004). In the same publication they describe the current water use in food production as “not environmentally sustainable” and “undermining its own resource base and threatening the resilience of ecosystems”.

An extreme scenario as presented here would have enormous impacts on the anticipated growth of the meat sector, as it should have. The impacts are the greatest for the intensive meat producing sectors. One cannot continue the current intensive ways of producing meat if the production of feed crops is discontinued. It should be pointed out, however, that the whole area currently used as permanent pastures is left as is. This means that on a smaller scale than before, cattle farming will still exist and beef and mutton would continue to be available albeit in smaller quantities. The picture for pigs and poultry looks quite different as pigs and poultry are almost exclusively produced intensively and are not kept on pastures. Some pig farming using residues from the food industry as feed might be conceivable, but on the whole these sectors would face a dramatic decrease. It must be noted that such developments would change the whole meat sector world-wide and would require a very powerful driving force as well as a long time-scale. Consumers in the current market are unlikely to suddenly stop buying meat at the scale described and so producers are unlikely to stop producing it. Whether consumers in the future will – voluntarily, through price effects or for any other reason – adopt consumption patterns that will lead to reductions in meat production of any significance remains to be seen.

In contrast, it is difficult to see how a significantly large area could be made available for biomass production without the proposed reduction in feed crop production. It is questionable whether much of the land currently used as pastures could be used for growing biomass. Quite often pastures are in areas that are too steep, too cold, too dry, without the necessary infrastructure, etc. to use them for anything but pasture. Using areas that are currently already forested areas seems even more outrageous as the relatively small area of managed forest has its own uses (mainly paper and construction wood) but the not-managed forests and woodlands are often of enormous importance for the preservation of nature (such as tropical forests).

6.3.4 Conclusions

This section clearly shows the interrelationships between food, feed, raw materials and energy from crops. From the calculations presented it is clear that in case of a large-scale transition from meat protein to plant protein the decrease in land needed for feed crops is the largest change in world agriculture. Not only does this change offset any increases in protein production for NPFs, but it also provides an enormous amount of land that can be used for any purpose, as it currently is high-quality cropland.

Our simplified calculations show a biomass potential of one fourth of the current energy use without the detrimental effects that such an increase of biomass use would have if no concurrent reduction in meat production were to take place. There are many benefits conceivably related to a change such as we have presented, in terms of freshwater use, acidification, energy gained (from reductions in fertiliser production, transport etc.) and possibly health effects. Although further study on such benefits is required they are a first but clear indication of how the transitions to more sustainable food, water and energy production – hitherto studied in separation – seem to be inextricably intertwined.

6.4 ACTOR COMMITMENT[4]

Chapter 5 divided the actors who are important for the prospects of NPFs into two main categories, namely (1) the "proximate" decision makers in industry and government, and (2) the members of society who participate in the market and in the political processes. This distinction is highly relevant for the question of how the future of NPFs will be decided when important related issues are on the agenda. The answer is not only dependent on the content but also the timing of decisions. Based on these distinctions, this section will discuss how the initiators of a new technology may gain the commitment of other actors.

Both companies and consumers are sometimes depicted as being "conservative". In view of the meaning of such a term, however, it should be added that it is usually not very wise for companies or consumers to change the course of their behaviour too easily or too often. At the level of an individual company or consumer, the process of behavioural adaptation is not gradual and continuous, as often argued in the innovation literature, but instead it is highly discontinuous (Tyre and Orlikowski, 1994). Hence, for a decision to change an important procedure or habit there are in fact only relatively brief windows of opportunity (see Chapter 1). The conditions that may contribute to the opening of a window are, in general terms, the following:

- implications of another change (e.g. a change in personal relations),

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- aftermath of events that function as interruptions (e.g. food scares, special offers),
- a threshold of gradually increased dissatisfaction (e.g. growing distrust).

These conditions are particularly relevant when initiators of a new technology want to induce changes in the behaviour of companies or consumers. Section 4.3, it will be recalled, focused on the replacement of meat by meat substitutes and specified a number of successive stages in consumer behaviour, which are variants of these conditions. As mentioned in Chapter 1, the multiple stream model of organizational decision making has demonstrated the importance of distinguishing between factors that contribute to the opening of a window of opportunity and factors that increase the chances that the open window will be used in a particular way (Kingdon, 1984). For example, a food scare may temporarily create a window of opportunity for a decision to replace meat by an alternative, but this motivation may not be enough for a lasting behavioural change.

Similarly, the prospects of NPFs may partly depend on the degree to which decision makers in industry and government see them at a certain moment as a solution to sustainability issues, such as the reduction of ecological impacts and as the need to destine more cropland to grow biomass for energy production. As a rule, their decisions on these topics are to a certain extent steered by their anticipations of consumer response in the market and citizen response in the political process. This applies in particular to industries where environmental performance seems to play an important role in the public's perception, such as food and retail. In these cases, there may be strong pressures on government officials to tighten regulations and on companies to do more than what is formally required.

Business strategies

Whether entrepreneurs are interested in the ecological advantages of NPFs depends in part on their specific market. Those companies that are competing in a cost-driven commodity market with largely undifferentiated products, such as oil, grain and meat, will enjoy few financial incentives for achieving environmental or moral performance beyond compliance (Miles and Covin, 2000). In these markets, the price may be the primary marketing variable that differentiates suppliers. They will only be interested in NPFs as far as there are options to produce cheap proteins for multiple purposes.

Other companies may seek to take advantage of the pressure on them and their competitors by incorporating ecological issues into their product or process improvements. The incentives for them to do so may include strategic advantages over their competitors, cost savings, or price premiums for higher quality products. This will require that entrepreneurs can legitimise the inclusion of ecological issues as an integral aspect of corporate identity and that they have enough resources ("discretionary slack") for innovation (Reinhardt, 1998; Sharma, 2000). Generally, this is more likely when price is not the primary basis of competition, when differences between products in a product class are perceived to be significant, when companies are forced to continually improve their products, and when innovations are defensible against imitation by competitors.

Companies that are interested in the ecological advantage of NPFs may use this issue as a selling point in their marketing strategy. Accordingly, they have to choose special signals to gain attention from quality-sensitive customers. This can be done, for example, by bundling information on sustainability issues with product quality information (De Boer, 2003). The resulting quality signals can be transmitted in many forms. Within information economics, it is assumed that the unobservable quality of certain products, such as durables, can be signalled in the form of high prices when customers understand that it is in the economic self-interest of the company to honour its claims about quality (Kirmani and Rao, 2000).

The literature on business strategy and the environment (Peattie, 2001) shows, however, that companies in well-established markets may be reluctant to highlight the relative benefits of a more sustainable product, because they themselves often produce and sell also the conventional brands for which full disclosure would be potentially disadvantageous. Companies may even collectively decide not to compete with each other on a sustainability issue to protect their industry's image and avoid additional costs. Whether the initiators of a new technology will gain the commitment of companies, therefore, depends on the pressure of other actors who may emphasize the relevance of the issue.

Market power

One of the ways in which members of society can influence the decisions of an entrepreneur is by using their market power. Through their participation in the market consumers can specify with their spending that they want a particular type of products. By accepting certain products and rejecting others, consumers can sometimes take sides in moral or political conflicts. In general, however, they do not have much market power over the production process. As Lindblom (2001) notices, their behaviour may affect proximate decisions on what is to be made, but generally not on where and how.

In the case of food, there are still links between types of product and methods of production. Some well-known examples of consumer influence on the ups and downs of production methods involve organic agriculture, genetic modification, and issues of animal welfare. However, market research has shown large differences between consumers in the strength of their motivation to include, for example, ecological or moral considerations into their purchasing decisions (Roberts, 1996). The following examples show that consumers are often dealing with mixed motives, which may or may not be consistent:

- Consumers who buy foods produced in an ecologically sound manner may primarily be motivated by considerations related to their personal health, which happen to be consistent with ecological considerations (Wandel and Bugge, 1997).
- Consumers who are well aware of the ethical nature of purchase decisions may not change their buying pattern as long as that would be inconsistent with their loyalty to a particular taste, brand or supplier (Newholm, 2000).

Consumers are often accused of paying less attention to ecological or moral criteria when they are in a shop than when they are in a non-commercial situation, but these examples indicate that it is unrealistic to expect that they will simply signal all their preferences through their purchases in the market. As participants in the market, consumers will not ordinarily be focussed on ecological or moral issues and they are often not informed about processing and production methods.

Moreover, if the only merits of a product seem to be that it is considered preferable from an ecological or moral point of view, many consumers might not be fully convinced that they should search for that product and pay a premium price for it. In order to create more value for these consumers, both the design and the marketing of a product should be addressed to all the product attributes that they consider relevant, such as functional and esthetical features, together with distinctive environmental and moral advantages (Meyer, 2001; Peattie, 2001). Depending on the product category (e.g. luxuries or necessities) and the market segment the product is aimed at, this strategy might imply that the product's environmental and moral advantage is presented as one of its self-evident qualities rather than as its main selling point.

In other words, the claim that NPFs have an ecological and moral advantage compared to meat should be only one of its merits in the perception of consumers. As has been said in Chapter 4, consumer-driven product development should not be based on the assumption that consumers will like a product just because of its ecological or moral advantage. Moreover, it is important that this advantage will not be destroyed by any associations between NPFs and controversial processing and production methods. Section 5.2 noted that the wish for more natural ways of food production kept returning with the progress of industrialisation. Those consumers, in particular, who are highly motivated to include ecological or moral considerations into their purchasing decisions may also be highly motivated to scrutinize the naturalness of processing and production methods. Therefore, any ecological and moral claim should be consistent with the overall characteristics of the product.

Issue linking

Another way in which members of society may influence proximate decisions is through their participation in political processes, such as voting or supporting non-governmental organizations (NGOs). In this context, they may be more inclined to take ecological and moral considerations into account than through their participation in the market. Although specific issues, such as climate change and biodiversity, may rise to favour or fall from grace from time to time, their underlying themes will often come back, just as the wish for more natural foods (Lindblom, 2001). This enables individuals and groups to become "political entrepreneurs" who invest resources with the aim to couple a particular solution to a problem. Their activities, as well as factors such as public opinion and public campaigns, may result in the opening of a policy window.

For the opening of a window in the case of NPFs it will matter whether this type of products can be linked with issues such as mentioned in Table 6-4. These linkages (and maybe others) can make it attractive for decision makers in industry and government to consider NPFs as a potential solution to one or more problems on which they have to make decisions. The open window creates opportunities for action inspired by initiatives inside and possibly also outside the organization.

Whether and how the window will be used depends on the position of NPFs on the shortlist of the specialists involved. What the specialists need at such a moment is a viable alternative that they can offer to policymakers. The alternative should be technically feasible and acceptable in terms of relevant values. If the alternative has not been worked out yet, the chances of success will decrease. Table 6-4 gives an indication of the linkages with other issues that may increase the chances of NPFs as cheap proteins and as quality products, respectively. As noted in Chapter 4, the appealing arguments for consumers to reduce meat consumption will be different for various (niche) consumer segments. Notably, the table is just the result of opinions, but it is a tool that can be elaborated in the future.

For instance, the notion that NPFs are essentially plant based may be attractive from various points of view. This notion may appeal to many consumers who have ambivalent feelings towards meat or towards novel meat products, such as meat with a functional property. A recent Canadian study (West *et al.*, 2002) showed that many consumers appeared willing to purchase and to pay a price premium for functional foods, particularly if the functional property, such as anti-cancer substances, were added to foods derived from plants. Consumers were less receptive to a functional property incorporated in a meat product. Although these examples are just hypothetical, they indicate that consumers may have more flexible notions about qualities of plant-based foods than about those of animal-based foods.

Table 6-4. Potential impacts of various issues on the opening of policy windows and the prospects of NPFs as cheap bulk proteins or high-quality specialty products.

Linkages of NPFs with other issues	**Contribution to window opening**	**NPFs' prospects as cheap proteins**	**NPFs' prospects as quality products**
Sustainable food supply at national level	+		
Sustainable food supply at European and global level	+		
North-South issues	+		
Landscape protection	+		
Promotion of biomass	+	+	
Resistance against the treatment of animals	+	+	+
Increasing meat prices	+	+	+
Leaning towards ready meals		+	
Resistance against genetic modification			+
Food safety			+
Prevention of human illness/promotion of human health (e.g. functional foods)			+

In sum, a company's decision on NPFs will be governed by strategic and political circumstances, such as the ripeness of certain issues, at the time the options are contemplated. These circumstances, in turn, will generally depend on its own capabilities, its position in the industry in which it competes, the economic situation of this industry and the industry's public image. Whether an issue is ripe will be influenced, on the one hand, by technological innovations related to sustainability ideals and, on the other hand, by public campaigns that emphasize the ills of an industry. In this relation, the role of NGOs should not be underestimated.

Several issues have been mentioned that may influence the opening of policy windows and the prospects of NPFs as cheap bulk proteins or high-quality specialty products. The main message of this section is that the linkages that may facilitate opening a window of opportunity are often different from the linkages that may improve the market success of a particular product segment (specialty or bulk).

6.5 ACTOR FEEDBACK[5]

6.5.1 Introduction

In the development, market introduction, promotion and support of NPFs a number of different groups of actors are involved. They comprise not only scientific and industrial organisations, but also governmental and non-governmental organisations. Feedback from these actors is indispensable in order to be able to broaden and strengthen the societal basis for the introduction of NPFs and, if required, adjust the research to emerging societal and technological issues. Furthermore, feedback is required for identifying topics missing in the present programme or missing links to other societal issues. The latter is indispensable for developing a follow-up programme.

In order to get feedback, representatives of groups of actors have been interviewed. In these interviews these representatives were asked to give their opinions on enhancing the sustainability of food systems, in particular the meat chain. In addition, they were confronted with the aims and (preliminary) results of the PROFETAS programme and the upcoming ideas for a successor programme. As a start, interviews have been held with policymakers from two groups of actors, i.e. Dutch governmental and non-governmental organisations. The governmental organisations comprised the Ministry of Agriculture, Nature and Food Quality, the Ministry of Economic Affairs and the Ministry of Spatial Planning, Housing and the Environment. In addition, Prof. R. Rabbinge, a Dutch senator, has been interviewed. The non-governmental organisations comprised Friends of the Earth (in Dutch: Milieudefensie), Society of Nature and Environment (in Dutch: Natuur & Milieu), World Wide Fund for Nature (WWF) and the Dutch Consumer Union (in Dutch: Consumentenbond).

6.5.2 Necessity of reducing meat consumption

Sustainability of food systems and developments to improve their sustainability are regarded to be important issues by all organisations. More specifically, the high environmental impact of present meat supply systems

[5] Johan M. Vereijken & Harry Aiking

is acknowledged. This impact is thought to be due to the high (indirect) use of resources such as energy, land and freshwater, and the use of polluting chemicals such as pesticides and fertilisers. Taking into account the finite character of the resources, the transition from meat to plant proteins is seen as being inevitable.

In addition to reducing the environmental impacts of meat production, it is expected that securing global future protein supply requires a reduction of meat consumption. However, the Dutch governmental organisations, in particular the Ministry of Agriculture, Nature and Food Quality, stress the point that in the Netherlands neither the per capita meat consumption is rising, nor the number of inhabitants is growing strongly. So in the Netherlands, and probably also in the rest of the European Union, future protein supply is not a high priority item. However, in other parts of the world, especially in rapidly industrialising countries such as China and India rising meat consumption (due to an increase in both consumption per capita and in number of inhabitants) will probably result in a global protein shortage. Of course, this will affect world-wide protein supply chains. In particular, this will create problems for protein supply in developing countries. For instance, in these countries the pressure to produce protein for global use at the expense of production for regional or local use may increase due to rising global protein prices. Therefore, problems associated with increasing global meat consumption clearly have a North-South dimension.

Furthermore, a reduction in global protein supply may result in changes in flows of proteins to Europe. For instance, to feed its animals, Europe is a major importer of soy protein from countries such as the USA and Brazil. Rising prices of soy proteins may therefore result in a decrease of this import. To cope with this, the European production of protein-rich crops, which is relatively low at this moment, may increase. The European policy is still directed towards self-sufficiency. However, some policymakers expect that this will become less and less important because of the globalisation of feed and food supply. Based on this train of thought, neither the Netherlands nor the European Union is seen as being the "problem owner" with respect to securing protein supply. However, the Ministries, and in this case particularly the Ministry of Agriculture, Nature and Food Quality, assume they have a role in raising the awareness that a problem is coming up.

6.5.3 Ways to reduce the environmental impact of meat consumption

To reduce the environmental impact of meat production, European non-governmental organisations generally promote the consumption of organic meat or simply a reduction in meat consumption. The latter could be enhanced by higher prices for meat, but it is generally felt that just taxing meat is not the way to go. In their opinion, a better way would be internalising environmental costs into the price of meat (see also the arguments presented in Section 5.4).

A technological way to reduce the environmental impact of meat production is by so-called precision farming: during cultivation of fodder crops resources such as nutrients, water and pesticides are used only as required in a particular spot of the field, in the right amounts and on the right parts of the plants. The sustainability of meat produced by this kind of farming is expected to be better than that of organic meat. Other technological ways that have been mentioned are feedback coupling in chains (e.g. just-in-time production) or by lateral integration between different production chains (coupling of chains in such a way that by-products from one chain are available at the right moment and amount for use as inputs in another chain). Of course, another technological option is the incorporation of plant proteins in meat products.

With respect to the PROFETAS programme all interviewees agreed that the introduction of NPFs, provided that they are successful among consumers, will result in reducing meat consumption and, hence, in the associated environmental impact.

6.5.4 Barriers

Technological and societal

The main bottlenecks in introducing NPFs are not considered to be technological. The (non-technological) actors expect that technology can provide the necessary tools to develop NPFs that meet consumer demands. However, it is generally agreed that present meat substitutes – though on the rise – are not very successful in the market and, hence, not in reducing meat consumption. Other products that better agree with present trends should be developed. For instance, products that align with trends towards so-called "grazing" (more eating moments a day), towards exotic eating habits (eating of foreign foods) and towards healthy products (reduction of risk for diseases).

According to all organisations the main bottleneck is the consumer's attitude. They regard the consumer to be "conservative" with respect to willingness to change consumption behaviour. Furthermore, all stressed that in general the consumer does not want to pay for more environmentally friendly products though the consumer says so (the citizen – consumer dilemma). However, times may be changing. For instance, consumer concerns for animal welfare are increasing and may be one of the driving forces to reduce meat consumption.

Legislative

Most organisations expect that new and previously underestimated legislative rules might hamper the introduction of NPFs. Specifically it was mentioned that the Novel Food Regulation of the European Union could be an obstacle, because it is a rather expensive and time-consuming procedure. Furthermore, specific agreements regarding land use and agricultural produce in the framework of the World Trade Organisation and/or the European Union might constitute obstacles. The Ministries agreed that the government should ease legislative obstacles in order to facilitate the development of NPFs. It is suggested that a way of doing this might be to direct legislation more towards goals and less towards means or instruments.

6.5.5 Opposition

In the opinion of the actors, opposition against the introduction of NPFs might come from the part of the agro-lobby that is involved in meat production. In particular, the Netherlands is an important meat producing and exporting country. So, in the short term opposition could be large in the Netherlands, but in the long term meat producers might get involved in the production of NPFs. Furthermore, the Netherlands is an important producer of food and home country to many large food companies. So the Netherlands might even take the lead in introducing NPFs.

6.5.6 Introducing Novel Protein Foods into the market

Consumer aspects

All organisations agreed that NPFs can significantly contribute to the sustainability and security of future protein supply. However, to achieve a large consumption will be difficult because, as already pointed out, consumers are “conservative” and not considered willing to abandon meat consumption. To be successful, NPFs should not be too expensive compared to meat. The Dutch Consumer Union stressed that consumers do seem to accept higher prices for increased animal welfare and sustainability, provided they know what they pay for. However, the price difference may not be too large and clear information about the background should be available to the consumer.

In addition to sustainability, health aspects may be an issue. For instance, the fat content and composition (saturated versus unsaturated fat) can be adjusted much more easily in man-made products such as NPFs than in meat. This kind of health aspects may enhance the acceptability of NPFs by the consumer. In addition, consumers are willing to pay for specific health claims as is evident from the price difference between low fat spreads with and without added plant sterols. When informed that NPFs are overall healthier than meat this might also enhance consumer acceptability.

Initiative

According to most organisations, the initiative to introduce NPFs on the market should come from industry, particularly large food companies. The latter have the marketing facilities, know-how and power to introduce real new food concepts such as NPFs. This is required because according to the interviewees the consumer is, as already mentioned, “conservative” with respect to food choice and therefore has to be tempted to buy NPFs. To this end, these products should not be marketed as meat substitutes but given a unique image. They should not be directed towards vegetarians or to other idealist groups. Instead “they should have a trendy image”. In line with this reasoning, most organisations feel that NPFs should initially be marketed as a speciality. However, to have a substantial effect on either or both the environment and protein supply, it is agreed that NPFs should become a commodity.

Support

It is generally stated that the government should play a role in the introduction of NPFs by facilitating their introduction. Not by subsidising them, but by other means. A covenant covering the whole chain from primary producers to retailers could be helpful in this respect. In addition, support may come from non-governmental organisations. However, care should be taken, because some consumers associate some of these organisations with activists.

6.5.7 Relation to other transitions

Governmental initiatives

In the fourth National Environmental Policy Plan four transition programmes are outlined. The transition from meat to plant protein consumption by introducing NPFs, the focus of the PROFETAS programme, is regarded to have links to three of these four transition programmes:

- Sustainable agriculture
- Biodiversity
- Energy

The link to sustainable agriculture is obvious: a sustainable cultivation of protein-rich crops, the starting material of NPFs, will contribute to enhancing the sustainability of NPFs. Furthermore, the environmental impact of sustainable agriculture will be decreased by the reduction of meat production in favour of the more environmentally friendly NPF production.

The link to biodiversity is also clear-cut: rising meat consumption threatens biodiversity, because it will result in higher usage of natural resources such as land and freshwater. Furthermore, rising meat production threatens biodiversity by the resulting increased levels of air, water and soil pollution.

One of the topics within the transition programme "Energy" is the use of biomass to produce energy in a sustainable way. The production of biomass implies the production of proteins, a component too valuable to convert into energy. Usage of this protein to produce NPFs will contribute to enhancement of the economics of biomass utilisation. Vice versa, the biomass produced by the production of plant proteins can be used to produce energy and in this way contribute to the overall economy of NPF production.

Non-governmental initiatives

The World Wide Fund for Nature has recently started projects directed at the reduction of freshwater usage. Because meat production requires much more water than plant protein production does, the relation to the PROFETAS programme is evident.

6.5.8 Conclusions

In line with the PROFETAS programme, all organisations state that the environmental impact of the present meat supply is high and should be reduced. Furthermore, it is agreed that rising meat consumption is most likely to result in a shortage in future protein supply. However, in the Netherlands reduction of meat consumption does not have a high priority yet. The ministries stress that with respect to future protein supply, neither the Netherlands nor the European Union is the problem owner.

The organisations indicated that there are several ways to reduce meat consumption. The introduction of NPFs will, provided they are successful among consumers, certainly contribute to this reduction. However, this introduction will be difficult because the consumer is felt to be "conservative" with respect to food choice. In order to deal with this obstacle the initiative to introduce NPFs should come from large companies because they have the means to tempt the consumer. In line with this argument, most organisations feel that NPFs should initially be marketed as a specialty.

With respect to the follow-up programme of PROFETAS, most actors advised placing the transition of meat to plant proteins in a global context and addressing the North-South dimension. Furthermore, links should be established to other transition programmes.

In conclusion, the organisations agree with the aims and ideas of the PROFETAS programme. However, developing NPFs to be consumed on a large scale is not an easy task. In a follow-up programme more emphasis should be on the global context of the meat to plant protein transition as well as on links to the other three transitions.

6.6 CONCLUSIONS [6]

The results of the PROFETAS programme should be seen in the context of an evolving global food economy, which will increasingly recognize the advantages of crop-based solutions. For various reasons, decision makers in industry are exploring options for a cross-fertilisation between food disciplines and areas such as biotechnology and information technology. Generally, large companies seek greater economies of scale for global and highly flexible supply chains. New technologies will increase the possibilities for product differentiation and improve responsiveness to customer demand. Clearly, consumers and society in general will influence the direction of these developments, but there are several major areas of uncertainty in which the future of the sector remains open. In many countries, for example, there is uncertainty about the public's willingness to pay for environmental quality and about the possibility that specific areas of technology will be implemented and accepted.

Protein-rich foods are playing an essential part in the pursuit of a food economy that contributes to sustainability and health. The results of PROFETAS clearly indicate that a societal transition from meat to plant protein is indispensable towards the achievement of sustainability. However, how such a transition may be realised – in particular with regard to social and technological aspects – is yet unclear. A requisite, but in itself insufficient condition for this leap towards a more sustainable food production is to convince the consumer, as can be seen from Section 6.4. Since Western European consumers tend to be more susceptible to arguments regarding their health than to sustainability arguments, the more feasible approach seems to be human health, targeting issues such as obesity, circulatory disease and food safety. In other countries, however, it may be crucial to link a diet shift with culinary traditions.

[6] Harry Aiking, Joop de Boer & Johan M. Vereijken

Due to the approach of global sustainability from a European perspective, the initial PROFETAS focus has been on pea as a model crop. In Western Europe, however, human consumption of pulses has been declining for centuries (Smil, 2001: 36). Globally, soy is the most abundant pulse crop, but due to climatic requirements, cultivation of soy is taking place almost exclusively in the Americas and in Asia. The main product is oil for human consumption. 95% of the remaining cakes, which are high in protein, is primarily used in livestock feed. A small, but culturally and historically significant, amount of soy is used to produce protein-rich products such as tofu, tempeh and miso, which are primarily consumed in Asia.

Climate and soil determine to a large extent which crops can be grown efficiently and where, as can be seen from our crop growth modelling research in Section 3.4. Whether pea-derived NPFs will be the products of choice for a transition in Europe remains to be seen. Alternatively, it seems likely that soy-derived NPFs may be a successful option in Asia. Not only would this option also abolish much transportation, but also it is likely that soy would appeal more to Asian consumers than peas, due to its long-standing historical and cultural familiarity. The Americas may constitute an intermediate case. At any rate, it is evident that local production and consumption coupling has huge environmental advantages due to transport reduction. Consequently, in different parts of the world different crops are likely to be used for NPFs production.

A partial diet shift in Western Europe and other OECD countries may function as a social and technological model for producers and consumers in other parts of the world. This applies to both the "eat less meat" option as the "eat more plant-based protein" option. One of the notions behind PROFETAS was that scientific innovation might take place in Europe, for example, and then diffuse to other regions (Herok, 2003). Although Europe, and particularly north-western Europe, has often been characterised as a meat eating continent, such a transition is not altogether unlikely. Currently a trend towards a more vegetarian lifestyle seems to be slowly emerging here, which seems to have been shaped by an endless string of animal-related food safety incidents. These incidents have upset Western consumers in particular because health-consciousness and protection of animal welfare are on the rise. Interestingly, the concept of sustainability itself has not emerged as a key issue valued by many Western consumers, as it may be too remote from their daily lives.

In contrast, in developing countries food security (Gupta, 2004) is valued over both food safety and sustainability. Furthermore, it is in the rapidly industrialising countries, in particular, where most of the world's population and/or economic growth is taking place. In China, for example, a moderate population growth is coupled with a high economic growth and, thus, leading to a booming meat demand. On the one hand, China is experiencing meat production shortages and, on the other hand, massive pollution in the central provinces, such as Sichuan, in which most of the production is concentrated (Sicular, 1985; Ke Binsheng, 2005). Geissler (1999) argued that in China a (nutrition) transition is presently taking place from soy to pork rather than the other way around and, in this respect, she concluded that in China "nutritional policies to promote the consumption of soyabean are unlikely to be effective in the context of an increasingly free and global market." India is a case in itself (1) because its rapidly expanding population is expected to outnumber the Chinese within the next few decades and (2) due to its vegetarian background, which is already showing some cracks, maybe as a result of increasing affluence. In summary, it is clear that regional approaches and intercontinental cooperation will be indispensable to achieve a worldwide protein transition towards sustainability.

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