CHAPTER 7

TRANSITION FEASIBILITY AND IMPLICATIONS FOR STAKEHOLDERS

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7.1 INTRODUCTION

Taken together, the research projects that constitute PROFETAS have developed a comprehensive approach to assess whether and how a transition of protein production and consumption may contribute to a more sustainable system of protein supply. The common object of study was the triple hypothesis that a shift in the Western diet from meat protein to plant proteins is (1) environmentally more sustainable than present trends, (2) technologically feasible, and (3) socially desirable. In the design and evaluation of alternative protein chains the focus was on NPFs and consumer preferences were given a predominant role. For the comparative analyses, the entire protein chain served as a starting point to measure differences between the NPF sector and the intensive livestock sector in the Netherlands and the EU. Given the global nature of the concept of sustainability, environmental, economic and social issues were studied in the context of global development. In addition, several emerging options were pointed out from the general perspective of a future biobased economy.

No matter how comprehensive, studies of this sort inevitably show strengths and weaknesses. One of the PROFETAS' strong points is the toolbox principle it adopted. According to this principle, developing the methodology and the tools now to facilitate problem solving in the future is far superior to trying to solve presently perceived future problems. Another strong point is the programme's multidisciplinary character and its embedding in more than one university. This multifaceted setting paved the way for a flexible organizational structure with various linkages to representatives from science, government, industry and, to a lesser degree, NGOs. From the very beginning, the organization was especially designed to

ensure outcomes that may assist policymakers from both government and industry with relevant tools and arguments.

An evident weakness is the programme's dependency on pragmatic choices, boundary conditions and other explicit assumptions. The main cause is that whereas the meat chain has been optimised for hundreds of years, the plant-based NPF chain is still in its infancy. Hence, the initial choices were made to focus the projects and to get them started. Methodologically, PROFETAS is very much a product of systems analysis, a tool that approaches complex issues, such as sustainable food production, by constantly making trade-offs between the analyst's workload (reduced by disregarding non-core issues) and the output's realistic portrayal (reduced by each simplification). In fact, it is the most flexible and robust research strategy that can be devised in this type of studies.

Surprisingly, some of the most remarkable insights PROFETAS delivered refer to a number of choices from the programme's very beginning, which have been put in a different light. For instance, it was decided at the outset to study the global food system from a national (Dutch) and European perspective. This seemed a logical choice, because – as far as we are aware – the Netherlands is the only country in the world with an explicit policy on “transition management” towards improved sustainability. An implicit assumption may also have been that developed countries are setting the global consumption standard. Although the latter may still be true at present, it has become clear that in rapidly developing countries such as China and Brazil the incentives to achieve a protein transition are not just different, but also likely to be much stronger. As a consequence, it may become more fruitful to look from the international context towards the EU and the Netherlands than the other way around.

In other words, it may primarily be global environmental and societal changes that contribute to the opening of a policy window for a diet shift, both in the Netherlands and elsewhere. However, whether the open window will be used in a particular way, may also depend on decisions by policymakers from government and industry at the national level. Although the Netherlands as a country is far from representative with respect to agriculture and with respect to freshwater availability, it may significantly contribute to the development of alternative protein chains. Against this background, the rest of this chapter is devoted to discuss the insights and tools PROFETAS delivered, as well as related options and arguments.

7.2 ENVIRONMENTAL SUSTAINABILITY

7.2.1 Insights and tools delivered by PROFETAS

In a highly simplified form, a production system may be called sustainable if it can be maintained at a certain “quality” in the long run. The quality may be evaluated by monitoring trends in a number of indicators, which are supposed to reflect complex and sometimes poorly understood phenomena. Thus, in order to describe environmental sustainability in relation to alternative protein chains, in PROFETAS three approaches were chosen. This multi-method strategy is based on the notion that the mutual relationships of their findings may shed light on different aspects of a complex phenomenon. In theory, these findings may either converge and validate one another, or they may highlight complementary aspects of the phenomenon, or they may show scientifically interesting divergences. In each of the approaches, two model protein chains (i.e. the pork chain and the pea-based NPF chain) were used to analyse the consecutive stages associated with a certain amount of human protein consumption.

First, in the *environmental* approach a tool was developed to find a systematic way to select the substances and processes that are relevant for a comparison of pork and pea-derived NPFs. The option chosen is to start off from the reliance of human society on the benefits that the environment provides and, therefore, to focus on ecosystem services. For using ecosystem services as the theoretical basis, it is possible to provide transparent criteria for a comparative study of alternative protein food options. In addition to its more solid theoretical foundation, the method displays – as intended – several advantages over established tools such as LCA, including the focus on effects rather than on emissions, applicability to virtual products and the inclusion of location-dependent parameters such as climate and soil properties.

Second, in the *economic* approach a model linking economy and environment was developed, which yielded the view that the problems related to pork production in the Netherlands and the European Union are not only local but also global, as a result of large-scale imports of feed. It was concluded that for global environmental sustainability a local (European) transition in itself will be insufficient, because the current centres of growing economies plus growing meat consumption are to be found in Asia and South America. Whether it is profitable to continue local pork production for economic reasons is partly dependent on the environmental standards set by governmental policymakers. In this respect, the model parameters illustrated that – under the present circumstances – the political

role of citizens who support more stringent environmental standards might be greater than their economic role as consumers when they make trade-offs between the prices of pork and NPFs.

Third, the *ecological* approach argued that for developing a coherent *set* of indicators no framework turned out to be available, which (1) links pressures to environmental consequences, and (2) focuses on how each of the indicators can contribute to the problem solving logic required to answer questions of environmental sustainability. Rather, the existing frameworks take a one-dimensional perspective. Therefore, causal networks were recommended, describing how individual indicators are interrelated, thus providing a more complete, holistic picture of what is happening in the environment. In short, process knowledge provides insight into cause-and-effect networks and is put forward to guide the selection of appropriate indicator sets.

Together, irrespective of the approach, a clear consensus was provided (1) that NPFs are environmentally more sustainable than pork and (2) that the most important impacts are due to tampering with (a) land use and the cycling of (b) water, (c) carbon and (d) nitrogen, leading to biodiversity loss, climate change, eutrophication and acidification (Chapter 2).

7.2.2 Further insights and tools required

Given the convergent results concerning the relative advantages of NPFs, the question emerges whether this information will be enough for policymakers who want to choose between alternative protein chains. As we shall see in greater detail later, policymakers should try to avoid suboptimal solutions and that makes it important for them to start with a comparative analysis of a large number of options. Presently, the environmental assessment tool is limited to the agricultural production phase. After extension to the rest of the production and consumption chain the method should be generalised beyond comparing just protein food options. In view of the increasing relevance of linkages between transitions, it should be extended sufficiently to become a tool to assess the environmental sustainability of transitions in general.

Because a large part of the environmental impact of the pork chain takes place outside Western Europe, it is important to also look at the global dimension. Reducing this environmental impact in developing countries of Asia and South America by shifting to a more plant protein centred consumption pattern in Western Europe may have important economic repercussions in those developing countries. In turn, this may or may not cause negative environmental impacts there, depending on what alternative livelihood strategies will be developed to compensate reduced feed crop

exports to Western Europe. So North-South issues clearly require further study.

7.3 TECHNOLOGICAL FEASIBILITY

7.3.1 Insights and tools delivered by PROFETAS

Six projects aimed at assessing aspects of the technological feasibility of pea-derived NPFs were performed in PROFETAS. Two of them were directed at aspects concerning primary production of peas and two at aspects concerning processing of peas to NPFs. In addition, in one project a tool is being developed to optimise the NPF chain. Last but not least, in one project the options for the non-protein fractions were studied.

In the *breeding* project it was shown that between different varieties there is a large variation in protein composition. This variability can be exploited in classical breeding programmes to obtain pea varieties that are optimised towards NPF production. Furthermore, a tool has been developed for genetic modification of pea and other legumes. Its application will enable selective removal of certain storage proteins (which affect texture formation) and of certain enzymes (which affect flavour compounds) in order to improve the quality of the raw material. As an alternative, genetic modification may be used in R&D for screening the effects of alterations in protein and flavour composition. Such an approach will speed up classical breeding while field crops are kept GM free.

In the *cultivation* project, a crop growth model has been developed that predicts yield of peas and pea protein as a function of genotype and environmental variables (such as solar radiation, temperature and rainfall). The model is generic; it can be extended to any arable crop. The model can be used to optimise production (e.g. with respect to resource use efficiency such as water) or to define the characteristics a variety should have for a given environment. An important insight resulting from this project is that using varieties with a high protein content cannot increase the protein yield per hectare. To achieve the latter, other traits (e.g. plant architecture to sustain leaf area duration during the grain filling period) should also be changed. Furthermore, attention was drawn to agronomic aspects, such as resistance to lodging and soil-borne diseases, which indicate that peas may not be the best choice to function as starting material for NPF production.

The *texture formation* studies yielded new insights into a process that is of prime importance in texture formation, i.e. heat-induced gelling behaviour of pea proteins. This behaviour was shown to be affected by the protein

composition and by the rate of cooling during processing. This implies that a range of textures can be produced (a) by varying the protein composition by selecting appropriate pea varieties and (b) by varying the processing parameters. This provides basic tools to food technologists to direct the texture of pea-based NPFs towards consumer demands. Comparative studies using soy and pea proteins led to the insight that despite similarities between proteins on the molecular level, their gelling behaviour may be different. On the one hand, this could mean that a large range of textures can be made using a limited set of proteins. On the other hand, this observation likely sets limits to the interchangeability of proteins.

Protein-flavour interactions studies using model volatile flavour compounds provided information on the amounts of flavour compounds associated with the pea proteins under various conditions. They also showed that the interactions with flavour compounds differ per type of pea protein. So again, varying protein composition or process parameters offers possibilities to tune the flavour of NPFs. Furthermore, it was shown that saponins, not only present in peas but also in numerous other legumes (including soy) are responsible for a bitter taste. This bitterness may be reduced by heating, thus providing a technological tool to adjust taste. It was also found that in pea protein preparations “off-flavours” seem to be present that are derived from fat oxidation. Similar “off-flavours” have been found in other plant protein preparations too; very well known examples are soy protein preparations.

The project on *chain design* will not be completed before 2006. Tools developed in this project are expected to be useful in the design of food chains to optimise these chains either towards a single goal (such as product quality, costs, or environmental load), or even towards multiple goals. Preliminary results are that the cost price of NPFs could be less than or at least comparable to that of pork. Comparison of the environmental load by using exergy analysis showed that an NPF chain is more efficient than a pork chain only if the non-protein fractions of pea seeds (mainly starch) are put to use.

Options for the non-protein fractions were investigated in a project added later to study the feasibility of plant-derived NPFs from a different perspective. A tool was developed to assess different protein crops on the potential uses of the non-protein fractions. Only bulk fractions were distinguished and evaluated on their suitability to be used as food, feed, stock and biofuel. The conclusion was drawn that – at present – oil crops may be at an advantage, because the oil fractions have better application perspectives than other non-protein fractions. Interestingly, a transition from intensive meat production to NPF production from any crop would lead to a shortage of soy oil for food applications, rather than to a surplus of this non-

protein fraction. If it is assumed that all *intensive* livestock farming disappears and only grass-fed and other extensive meat production would remain, then this shift – irrespective of the crop (pea or soy) – would release an enormous area (over 300 million ha) of highly productive land for other uses. For example, if used to grow biomass, this would be sufficient to cover approximately 25% of the current world energy demand.

7.3.2 Further insights and tools required

The research on technological feasibility has focussed primarily on basic problems and on issues that needed to be solved before products could be designed. With respect to processing some important insights and tools are still missing. For instance, neither have texturisation processes been studied, nor have products (or product concepts) actually been made. Such research is indispensable to allow a consumer-oriented development of NPFs. At present it is still unknown whether more traditional texturing processes such as extrusion can deliver the range of textures desired by consumers. It may well be that novel techniques have to be deployed and further developed, such as techniques based on phase separation. Furthermore, in actual NPFs other components (e.g. hydrocolloids, fats) will be present. No information is available about the effects of such components on the texture and flavour of the NPFs. With respect to flavour, stakeholders from industry have indicated that starting materials for NPF production should preferably be free from “off-flavours”. The prevention of formation of such compounds or ways to remove them should be investigated. A lot of knowledge on this subject is already available from research on soy proteins.

Missing insights with respect to the use of the newly developed protocol to genetically modify peas include, among others, its effectiveness and efficiency as well as its effects on cultivation. These effects not only include those relevant for NPF processing (e.g. effects of protein composition on texture and flavour) but also those relevant for primary production. Questions have to be answered regarding the effects of the modification on for example (a) germination power of the seeds, (b) viability of the modified peas in the field and (c) an eventual yield penalty for total protein content because of the modification. Furthermore, the applicability of this new protocol to modify crops other than peas needs to be further explored.

To exploit the interesting possibilities offered by the crop growth model, it has to be validated and to be extended to crops other than peas. Then it can be a powerful tool in identifying differences among various crops in resource use efficiency for e.g. biomass and protein production, hence in contributing to a sustainable primary production of raw materials for NPFs.

In summary, quite a lot of research is still required to actually develop and produce NPFs that meet consumer preferences. In addition to the technological issues discussed above, the project on chain design will most likely result not just in answering questions but also in raising others. Furthermore, options for the non-protein fractions should be detailed by means of scenario studies, with particular attention for the projected shortage of soy oil for food applications. Finally, the issue of the crops to be used for NPF production is still open. As argued in Section 6.2, even in Europe peas may not be the preferred crop for NPF production. More research concerning crop choice is required.

7.4 SOCIAL DESIRABILITY

7.4.1 Insights and tools delivered by PROFETAS

In addition to sustainability – which is an evident societal preference – societal desirability was studied in PROFETAS with respect to (1) the behaviour and preferences of consumers and (2) the food-related political and economic developments of the next decades. The underlying notion of this work was that the desirability of a diet shift is in proportion to its fitting in with the behavioural patterns of current and future generations. In addition, it was argued that a lack of fit would create less serious problems if mitigating measures can be taken.

Based on a long-term view on behaviour, the potential for a diet shift in relation to socio-cultural changes was examined. A newly developed analytical framework sorts insights on influences on behaviour into a logical order. Its cascade-like structure embodies the view that a long-term development will create opportunities for food choices that match its general direction, whereas it will put constraints on others. The analysis of long-term changes indicated that there is a favourable socio-cultural context for decisions that make consumers and producers less dependent on meat proteins. One of the most salient results of this work, however, is the contrast between, on the one hand, a series of impressive changes in dietary choices over the last few centuries and particularly over the last few decades and, on the other hand, the observation that an individual will not easily change his or her food preferences from one day to the next. This contrast underlines the value of the analytical framework in combination with small-scale consumer research.

By using currently available meat substitutes as a model to analyse consumer behaviour and food choices, it was possible to develop several

tools that may guide NPF product development. It appears that the currently available meat substitutes will not become popular without additional measures. Analysis of consumers and consumption behaviour with respect to meat and meat substitutes provided insights such as (a) non-vegetarian consumers of meat substitutes are not impressed by environmental arguments, (b) only a small group of consumers is open to completely new products due to so-called “neophobia”, (c) consumers would like more information on usage and preparation of meat substitutes and on ingredients used.

Consumer sensory preferences were analysed and their translation into product characteristics was attempted, yielding insights such as (a) attention should be paid to satiating properties of NPFs, which are related to protein content, (b) most people want soft, smooth or crispy meat substitutes to have a seasoned, meat-like flavour and a brown colour, (c) meat substitutes should have the same place in the dish as meat. Other than originally anticipated, the latter results clearly show that people want NPFs to have meat-like characteristics. They confirm the notion that people will habitually look for what is familiar when they are trying to make sense of something, such as an invitation to try a product. The retrospective character of sense making can explain why non-vegetarian consumers keep relying on distinctions drawn in the past and why they evaluate meat substitutes by using meat-based criteria.

The selection environment in which NPFs have to survive is partly dependent on their positioning in the market, for example as cheap (bulk) proteins or as quality products (specialties). The prospects of the new products may also depend on linkages with other issues, such as increasing meat prices or health promotion. These prospects are not only dependent on consumer responses in a potential usage situation, but also on processes at the level of markets and public institutions. Given the fact that technology development takes place in a changing and malleable world, the stakeholders of a new technology may opt to monitor and influence its selection environment. PROFETAS applied some advanced tools such as policy analysis and econometric modelling, as well as a skilled examination of the rules of international institutions with regard to novel foods.

In a political analysis it was investigated how politics and public policy affect the possibilities of a diet shift. As expected, it appeared that governmental policy does not have many direct influences on food choices (i.e. the proportion of meat vs. plant proteins in the nation’s diet), but mostly indirect influences. These influences demonstrate that production and consumption are, at least partially, facilitated by a political “infrastructure”, implicitly favouring certain products or production processes over others. To uncover indirect influences, it was analysed how current food practices have developed in the Netherlands since 1850 (i.e. when the physician G.J.

Mulder brought up the issue of proteins and the societal effects of the lack of proteins in most people's diets). Given the current sustainability-related issues, the political infrastructure still seems to favour the option of more protein production and consumption, although that option is not actively promoted by governmental action. From a sustainability perspective, however, it may be desirable to have a political infrastructure that favours a more divergent food system with different approaches to food. This would mean, for example, that the option of producing more plant protein does not necessarily get more emphasis than the option of simply "eating less meat".

Two complementary econometric analyses studied agricultural production and consumption and the patterns exhibited (by adaptations to the existing GEMAT model), and institutional arrangements affecting agricultural production and trade (adapting the GTAP model), respectively. It was shown that a protein transition results in a decrease of environmental pressure on land under all scenarios (GTAP) and that the potential is even larger (GEMAT). Though crucially important to the feasibility of a transition, interestingly, the two models employed disagree on future meat price development. From GTAP a price decrease may be inferred, but from GEMAT a price increase. The underlying cause of this disagreement is the implicit assumption, deeply embedded in the models, to what extent agricultural efficiency will continue to increase in the future. These results show the added value of employing two complementary models.

A study of institutional aspects provided the insight that even though international institutions (such as the EU and the WTO) may provide both incentives and barriers for the introduction, marketing and promotion of NPFs, on balance the barriers exceed the incentives. Since these barriers (primarily intended to resist protectionist practices in international trade) cannot be circumvented, a successful introduction and marketing of NPFs should be taking them into proper account. In short, it is easier to start from already authorised foods and ingredients than to start from foods and ingredients that still need to be authorised, especially in Europe if they are GM crop derived. For the promotion of NPFs not too much should be expected from traditional government instruments such as taxes (on meat) and subsidies (on NPFs). Subsidies have already lost their appeal in most EU countries for purely domestic reasons, plus they are heavily restricted by EU regulations concerning state aid and the single market. If NPFs are to become a success, it should primarily be through private, commercial means and action. International institutions can protect and support commercial interests, however, through the international protection of intellectual property rights.

7.4.2 Further insights and tools required

Each of the tools has provided relevant information about opportunities and barriers for NPFs, but, under the present conditions of uncertainty, none could lead to conclusive answers. For example, one of the drawbacks of consumer research is that the currently available meat substitutes are, in fact, sold in a niche market and that they are almost twice as expensive as the cheapest meats. In order to improve the relevance of consumer research (sensory research, in particular), actual pea-derived NPF products – in the form of cheap protein products or as quality products – are indispensable. Since such products are not available yet, they should be crafted for this purpose. These products could also be used in assessing the relation between sensory properties of NPFs and their physical characteristics, a very difficult field of research, but of great importance for consumer-oriented product development. Evidently, it is important for product developers to realize that “the average consumer” does not exist. Subsequently, it is important to realize that different NPFs will have to be developed to fulfil the needs of different consumer groups.

All of the tools may seriously be influenced by the use of pre-conceptions in thinking about the future. The role of pre-conceptions is particularly great when questions have to be answered about the social desirability of policy options. It was shown that pre-conceptions lead to hidden assumptions that blur the arguments for or against an option. For instance, one of the pre-conceptions defined a diet shift primarily as an opportunity to develop products with a larger profit margin than meat. In contrast, it may be more sensible to develop plant protein ingredients that can serve as a low price alternative to meat protein ingredients. Another example is the implicit assumption mentioned above that meat prices will continue to decrease in the future, in consequence of continuing agricultural efficiency. Probably, policymakers may show wisdom by expecting that the meat prices will not decrease but increase as a result of changes in the world market and agro-ecological constraints on production. In fact, it seems inevitable that the present growth of spending power in China will put the world market prices of meat and feed under pressure. In addition, it should be emphasized that not too much should be expected of traditional government instruments such as taxes and subsidies. Although the latter are effective tools, their application is fraught with political difficulties.

Although the various tools to analyse the social desirability of a diet shift have not identified strong arguments against it, a critical reflection on the results may lead to the conclusion that the corresponding PROFETAS hypothesis deserves some more stringent tests than the arguments that have been described. In addition to the limitations mentioned above, it should be

noted that the present analyses might have overstated the importance of agriculture to the political and economic processes in modern society. Other linkages, in particular to non-food issues, may have been overlooked or underestimated.

It is clear that health issues – which have not been directly studied in PROFETAS – require further attention. For example, it has emerged recently that *intensive* production of poultry and pigs in close proximity with people may play an important role in the adaptation of originally poultry-specific viruses via pigs to human beings as suitable hosts (Pilcher, 2004; Chen *et al.*, 2004). Under such conditions – primarily extant in South East Asia – new viruses are frequently spawned. It seems more and more likely that recent incidents such as with SARS and avian influenza are correlated with the intensive meat production there, and that the frequency of such incidents will continue to rise in parallel in the future. Apart from animal welfare issues, this health aspect, in itself, seems a good reason to reduce intensive meat production in general, and that of poultry and pigs in particular, at least under conditions such as in South East Asia, which is globally an important producing and exporting area.

7.5 TRANSITION FEASIBILITY

7.5.1 Insights delivered by PROFETAS

From PROFETAS the conclusion emerges that there are several sound reasons that support the triple hypothesis. That is, a shift in the Western diet from meat proteins to plant-derived protein products appears to be (1) environmentally more sustainable than present trends, (2) technologically feasible, and (3) socially desirable. Interestingly, the citizen generally seems to consider sustainability to be socially desirable, but the consumer does not like the taste of present meat substitutes. Nevertheless, the main evidence is in support of a transition to make food production and consumption more sustainable. Given the aims of PROFETAS, the programme has not included specialized transitions research. Nevertheless, many insights have been generated on the protein transition and on its linkages with the energy and freshwater transitions. These insights are described below.

First, it has become clear that the protein transition is a necessity at the global level. Without it, food production and sustainability are on a collision course. From time to time, there will be signals, alarming reports or dramatic events, which may contribute to the opening of a policy window. If the window opens, however, the market system will not simply guarantee that

the most sustainable alternative technology will win. Market failures, but also government failures, may result in the selection of a suboptimal solution.

Second, study of the technological feasibility has revealed a number of options, but also some gaps in the required knowledge, such as the preferred crop for NPF production. Although many criteria for such a crop have been established (such as low fertiliser requirement, high protein yield, and preferably already part of the established food system), a more conclusive choice cannot be made yet, for criteria in other areas (such as concerning the non-protein fraction) have not yet fully materialised. Presently, the top choice in Europe may be rapeseed or pea yet, but in Asia it will probably be soy.

Third is the insight that the protein, energy and freshwater transitions are inextricably intertwined and that all parts of the crop or seed – protein and non-protein – should be considered one combined chain. Although the former, in particular, is a novel insight, both the former and the latter views fit in nicely with the present trend towards a biobased economy, aiming to derive food and feed, chemicals and other non-food materials, and energy from plant crops in the most efficient way.

Fourth, there is support from various actors, although this depends on linkages with other issues. Feedback from Dutch governmental actors and NGOs revealed enthusiasm for a protein transition, however, they are not inclined to initiate one themselves. In contrast, they do feel committed towards an energy transition. For most Western consumers, sustainability or the environment is not an incentive for food choice, however, health is. Due to a number of meat crises and other food scares, health and animal welfare are valued as increasingly important issues by Western consumers. In fact, sales of meat substitutes are increasing every year and they are being bought and eaten by non-vegetarian consumers.

In conclusion, several trends in different areas (protein, biofuel, water saving), on different geographic levels (local to global; western to developing countries) and concerning different actors (consumer, government, industry, NGOs) have been identified by PROFETAS, which – taken together – may lead towards a protein transition. A major step is raising the awareness that all these trends are linked up and cannot be seen in isolation. So a major achievement of PROFETAS is the insight to propose bringing together all these different actors, all with their own agendas and multiform aims. This is, we believe, the true definition of a societal transition.

7.5.2 Further insights and tools required

For pragmatic reasons, in PROFETAS many boundary conditions were assumed, such as the focus on the Western consumer and the focus on peas. At this stage, it seems timely to start focusing the attention on how – and where – a protein transition may be achieved in a dynamic, multiform society. Alternative options such as deriving proteins from algae should be investigated, as well as the feasibility of reducing the present protein overconsumption in Western countries (the “eating less protein” option). More direct research on transitions seems in order. The latter requires better insight into the role of explicit as well as implicit pre-conceptions in thinking about the future. In this respect, the use of multi-method strategies appears to be indispensable. Multi-method strategies may not only validate each other or specify complementary aspects of a complex phenomenon, but they may also show interesting divergences.

PROFETAS has shown several divergences that are extremely important for further research into transitions. Some examples are:

- The divergence between pre-conceptions that see a diet shift primarily as an opportunity to develop products with a larger profit margin than meat and pre-conceptions about developing plant based products that can serve as a low price alternative to meat protein ingredients.
- The contrast in the studies of consumer behaviour between, on the one hand, a series of impressive changes in dietary choices over the last few centuries and decades and, on the other hand, the observation that an individual will not easily change his or her food preferences from one day to the next.
- The assumption that meat prices will continue to decrease in the future, in consequence of continuing agricultural efficiency, versus the assumption that meat prices will increase as a result of changes in the world market and agro-ecological constraints on production. In spite of historical trends, it seems inevitable that the strong increase in meat consumption in countries such as China will put the world market prices of meat and feed under pressure.

Further research may be necessary into historical transitions, as well as into future general trends in global society. With respect to the latter, developing a number of contrasting visions of a potential global future is often considered helpful. In order to arrive at a robust transition strategy, these visions can be confronted with desirable options for protein food development. Such an approach should not be too general, for example, by focussing on aggregated parameters such as the growth rate of the world economy. More specific factors, such as global public health, should be an explicit part of the picture. So does taking geographic and cultural

inhomogeneities into account, which clearly requires international cooperation.

7.6 GOVERNMENTAL POLICY OPTIONS

For the purpose of Dutch and European policy making, it can be argued that protein sustainability is a medium to long-term issue on a global scale. In the not too distant future, intensive meat production worldwide should be discontinued, or at least strongly reduced. In practice, the notion of an approaching collision between current food production and sustainability means that imminent disturbances of the protein production chain will let themselves be known to policymakers through all kinds of signals. Obviously, some of the weak signals could be a gradual rise of meat and feed prices. Stronger signals may include human and animal health incidents, such as with SARS and avian influenza, which are probably correlated with intensive meat production.

Against the background of irregular signals that vary in strength, governmental policymakers may have to manage at least three emerging goals:

- The first goal is to detect and interpret the signals correctly and to attribute them without delay to the relevant disturbances of the protein production chain. The BSE case has shown that a delay might have disastrous consequences on the controllability of the whole policy making process.
- The second goal is to minimize any negative effects that the disturbances may have on society. For instance, it may be wise to be prepared for a large-scale vaccination campaign.
- The third goal is to prevent the opportunity to take action getting lost as a result of counteracting processes that favour suboptimal solutions. That is, solutions that are suboptimal from the perspective of long-term sustainability objectives, not aimed at the root of the problem, such as temporary bans on certain types of meat.

The prevention of suboptimal solutions may require that governmental policymakers take action to correct market failures, for example, where private actors do not take full responsibility for the societal consequences of their activities. However, suboptimal solutions may also result from government failures, such as subsidies given to the wrong group or at the wrong moment. Moreover, the various linkages between the protein transition and other transitions on different levels of scale will seriously complicate any attempt to apply straightforward forms of strategic planning.

The least a robust policy should entail is an open mind to problem solving. For governmental policymakers it would be wise to avoid fixation on one particular technological option. In contrast, this might involve a decision to actively stimulate a *range* of divergent potential solutions to be developed, for example, by supporting research in the pre-competitive stage of technology development. This may especially be necessary where private parties have difficulties in making sense of the linkages between transitions, i.e. protein, energy and water. This approach would entail:

- Slighting the mental barriers between thinking about food, energy and water policy, or about natural resources in general.
- Trying to identify links with specific other policies, such as with the fight against obesity, the aims for renewable energy (such as the EU Biomass Action Plan) and the aims to promote organic farming.
- Considering alternatives such as NPFs as sustainable successors to animal products (such as pork) with regard to export of products and know-how and considering incentives to R&D in that area.

In combination with an open-minded approach, it is extremely important that governmental policymakers pay attention to the selection environment in which newly developed NPFs have to survive. Governmental policymakers can do a lot to prevent suboptimal solutions by monitoring and influencing the selection environment NPFs are facing. Some points in need of attention are the following:

- Initiating removal of national, EU and international (WTO) institutional barriers to the introduction of NPFs on the market.
- Increasing the transparency of the food chain in order to enable citizens and consumers to make sound choices.
- Continuing and internationally promoting “green” thinking by acknowledging the role of plants for improving sustainability.

In fact, the presently emerging trend towards a “biobased economy” is a first step toward the latter. In addition to deriving materials and energy from plant crops in combination, by the same token, food can be added to the list because crops are the ultimate renewables, degradable and all, and particularly sustainable if little fertiliser is required (such as with nitrogen-fixing protein crops).

European (EU) policymakers are in much the same boat as their Dutch counterparts, where they have to deal with global environmental changes. The goals for biofuels and organic farming are easily linked to the protein transition. In addition, recovering the presently lacking self-sufficiency in protein rich feed crops may be an incentive for EU policy towards striving for sustainability by means of a protein transition. This may be even more so in view of the expected increase in demands (and consequently, competition) for protein rich feed crops by industrialising countries such as China. An

additional incentive may be provided by the potential savings on freshwater use by agriculture, given the rising need expressed by the World Water Forum.

7.7 INDUSTRIAL POLICY OPTIONS

For industrial policymakers an important question will be whether or not they want to be among the first movers in the market of new protein products. A company's decision on this topic will be governed by strategic and political circumstances at the time the options are contemplated, such as the ripeness of an issue. These circumstances depend on its own capabilities, its position in the industry, the economic situation of this industry and the industry's public image. The ripeness of an issue will in particular be influenced by the technological state-of-the-art (including innovative power), by the durability of the issue (a trend or a hype), by public opinions (including campaigns that emphasize the "ills" of an industry), and by linkages that improve the market success of a particular product segment.

In view of the many potential linkages between a protein transition and other transitions, it should be emphasized that developing alternatives to an established technology may require many innovations and that these will not occur automatically as the outcome of a linear process. The currently predominating policy of multinational companies seems to be rather risk-averse by doing R&D themselves only on a moderate scale and, when deemed necessary, strategically buying emerging small companies with innovative products. The progress of small companies may be highly dependent on the relational context in which an innovation is located, such as the other innovations on which it builds, the status of the actors that own competing innovations, and the underlying community of experts involved in its elaboration. In addition, many chance factors may affect the content and the timing of innovation decisions.

Accordingly, the prospects of NPFs may depend on many initiatives. As a start, they may entail:

- Implementing "green" thinking in policies towards stepwise innovation and stepwise improving sustainability.
- Slighting the mental barriers between thinking about raw materials, energy and water. Integral thinking is a cornerstone of the emerging "biobased economy".
- Considering plant-derived alternatives as sustainable successors to animal products with regard to export of products and of know-how, and increasing R&D in that area.

This way of thinking coincides very well with parts of the mission statements of many companies: to create innovative products that promote a sustainable future.

Next to contributing to a sustainable future, NPFs could also meet another important issue for industry: making profit. Preliminary PROFETAS calculations indicate that cost price of NPFs could be lower or at least comparable to that of pork. Furthermore, meat prices are expected to increase. This increase will be higher than the increase in the cost of plant proteins because of the low conversion factor of plant protein to meat protein. Hence the gap between the costs of NPFs and meat will become bigger, thereby increasing the profit margin. Furthermore, NPFs are directed towards a growing market. Among others, the increase will evidently depend on the extent to which the products meet consumer demands and preferences, not only with respect to sensory properties but also to other issues such as health and animal welfare. This will be discussed in Section 7.8.

Those industrial policymakers who want to be among the first movers on the NPF market may start thinking about questions such as:

- Which markets are the most interesting options, specialty or bulk, which products and how to position the products on the market?
- What are the preferences of the different consumer groups and which ones can be translated to product characteristics?
- What techniques are required to produce the desired products?
- Which proteins or, even more basic, which crops seem feasible where?
- What chains should be developed and optimised, and with whom?

This sounds partly like revisiting technological projects of PROFETAS and indeed it is, but now on the level of actual and competitive products, rather than on the level PROFETAS was directed at, i.e. the development of a toolkit on a basic, pre-competitive level. However, to answer the questions asked above in a science-based way and to provide a sound base for future NPF development, further pre-competitive research on technological issues is still required. A number of subjects for such research have been discussed for example in Section 7.3.

In addition to technological issues, questions should be addressed such as:

- Cooperation with what other parties is useful (e.g. for optimal use of the crop)?
- How may a protein transition spread across the world (e.g. which countries are best suited for introducing and testing NPFs)?
- What may be the side effects of a protein transition (e.g. with respect to the North-South divide)?

- What trends in other areas (transport, technologies, lifestyles) may be relevant?

For smaller companies it may pay to closely watch the emerging trend towards a “biobased economy” and start thinking about strategic alliances. As long as innovation is not “directed” by larger companies (cf. transition “management” as proposed by the Dutch government), niches for innovative products will open, be it plant-derived protein foods or products made from the non-protein fraction of crops, products for saving water and/or energy, or others.

7.8 CONSUMERS AND OTHER STAKEHOLDERS

The consequences of a protein transition will affect many stakeholders, such as consumers, retailers, farmers and NGOs. Without addressing each of these groups individually, the present section intends to sketch the most pertinent implications. What consumers should ideally do in the context of a protein transition may boil down to (a) eating one third less protein (the average Dutch over-consumption), (b) replacing one third by plant-derived proteins, and (c) replacing the remaining third by extensively produced meat (such as most beef and lamb). Although in the Netherlands intensively produced pork converts much food industry waste in a sustainable way, globally this is not a representative example. Theoretically, the proposed threefold option has both environmental and health benefits. In practice, few consumers will be convinced immediately, but they may do so in the long run.

At present, the environmental benefits may not appeal to many consumers. The well-known activist storyline of “global nature” under threat and in need of protection from a global community has become too simplistic. Modern Westerners do not tend to think in terms of one big environment that is the same for everyone. They want credible solutions that give them the feeling that they are “doing the right thing.” In contrast, the fact that many people are no longer aware of the animal origin of meat indicates that there is an increasing indifference toward the origins of proteins. At first sight, this seems to open possibilities for NPFs. Some producers might be tempted to change the protein chain in a way that does not have to be noticed by the people who are eating it, which may create a substantial shift from meat to plant protein foods without much consumer involvement.

On second thought, however, a low-involvement approach may not be the optimal strategy to pursue more sustainable food choices. If people are no longer aware of meat’s animal origin, they will also be less inclined to

pay attention to animal welfare. This may have negative consequences for attempts to stimulate sustainable agriculture by promoting high quality meat from well-treated animals or by simply eating less meat. An additional reason to not opt for a low-involvement approach refers to the societal value conflicts that are expected in many technology-related areas. In Europe, the recent example of genetically modified food has shown that a low-involvement approach may backfire if people get the impression that they are part of a “hidden” transition. Therefore, it is essential that all the people concerned are mindful of any transitions of food production methods.

One of the ways to involve people is a discussion on personal health aspects, which have many links to the protein transition. In contrast to plant-derived diets, meaty diets generally contain more saturated fats – associated with heart and coronary disease – and are sometimes associated with overconsumption of calories – leading to obesity. NPFs may not only exert a beneficial effect on health indirectly, via these relationships, but maybe also directly. That plant proteins may provide such an effect is indicated, for example, by the claim approved by the American Food and Drug Administration: “Diets low in saturated fat and cholesterol that include 25 grams of soy protein a day may reduce risk of heart disease” (FDA claim 21 CFR 101.82, October 1999). Proteins from crops other than soy seem to exert the same protective effect, according to the FDA, though this protective effect does not go unchallenged. Last but not least, NPFs are complex foods for which the amount of calories can be set via the choice of ingredients, which may be an important tool in view of the increase in obesity. Admittedly, certain plant-derived foods may generate more allergies than meat, but this affects a minority of people compared to the stifling incidence of heart and coronary disease, let alone the downright epidemic incidence of obesity (800 million people afflicted worldwide).

Public health aspects, such as food safety, add to personal health aspects perceived by consumers. Due to recent meat crises, both with chemical contaminants (such as dioxins, antibiotics, growth hormones) and pathogenic microbes (such as foot-and-mouth disease, avian influenza) European consumers are rather keen on food safety. Other aspects – such as the proposed relationship between intensive pork and poultry production in South East Asia and the increasing outbreaks of avian influenza – may not be topics consumers think about when they are shopping for food, but reminders of these issues may gradually induce “green” thinking by acknowledging the role of plants for improving their quality of life.

7.9 CONCLUSIONS

Environmental sustainability

The preceding chapters and sections have once again made it crystal-clear how large the environmental burden of meat production is. Conservatively estimated, it requires a 3-10 fold larger agricultural area and energy input and produces 3-10 fold more eutrophication than the production of plant protein. Not only does meat production bring about over 60 fold more acidification, but it also appropriates 30-40 fold more of the dwindling freshwater resources. In addition, it produces a lot more pollution by pesticides, heavy metals and antibiotics. As an entirely novel finding, PROFETAS has clearly demonstrated that the protein transition is coupled inseparably to two other societal transitions, namely those towards sustainable energy production and towards sustainable water use (Section 6.3). The freshwater link is evident from the resource difference indicated above. The energy production link primarily regards the release of agricultural area, which is freed for biomass production. Furthermore, the considerable proportion (60-80%) of non-protein biomass released as a by-product during NPF production may be utilised very efficiently for energy production. An evident case of win-win-win, with a triple environmental gain due to combined savings on protein, energy and water (Section 6.3).

Technological feasibility

Concerning technological feasibility many questions have been answered, both in primary production, processing and chain development. Generic as well as dedicated tools have been developed or are under development. Among the generic tools is the crop growth model (which still has to be validated) and the model for chain design (which is still under development). Applied knowledge concerning flavour-binding properties of pea proteins should be rated among the specialised tools. As might be expected, in addition to answers, many new questions have been raised as well (see Chapter 3). These concern, among others, the way in which process and ingredient selection may fulfil consumer wishes for NPFs within certain target groups (Sections 3.2, 3.3 and 6.4). This puts forward three major challenges: how to obtain a wide range of textures by using plant proteins, how these textures are affected by ingredients other than proteins and how to obtain the desired flavour? Next to questions regarding processing, also questions with respect to primary production remain to be answered. These questions concern among others the extent to which protein composition may be manipulated without affecting the viability of the plant in the field, and which crops are the most suitable to yield raw materials with the desired specifications (Section 6.2). Another major issue is the extent to which new

developments in molecular biology and breeding may affect the suitability of crops for NPF production.

Societal desirability

From the sustainability perspective, the societal desirability has been established beyond doubt, particularly concerning resource and pollution aspects (land, water and energy uses, and their implications for biodiversity loss and climate change). Furthermore, increased availability of plant protein based foods will undoubtedly make an important contribution to food protein security, which is presently under increasing pressure from world-wide increasing meat consumption. Doubtlessly, such a transition will have a significant impact on North-South relationships and the poverty issue in the world (Section 6.5). Concerning societal desirability it has also become apparent that different actors can hold different interests and opinions here (Section 6.4). It has been clearly established that the consumer is the player who holds the key to a short-term protein transition and that Western consumers currently rate health above sustainability. For consumer-oriented product development, much more interaction is necessary between product developers and various user groups, such as consumers leaning towards health, convenience or culinary traditions.

Developing countries

Although PROFETAS was originally designed from the Western perspective, it has become clear that in developing countries the incentives to achieve a protein transition are not just different (Section 6.6), but generally much stronger (Section 6.5). In China, for example, meat production generates pressure by its inability to meet the national demand on top of the pressure generated by severe local pollution. Crops tailored to climatic (Section 6.2) and cultural (Section 6.6) characteristics are available. It can be concluded that, although the developed countries are primarily responsible for the unbalanced meat consumption referred to earlier, it is primarily the developing countries that are confronted with the effects (see Section 2.5). The latter, therefore, may experience stronger and more direct incentives to strive for a protein transition. However, the required technological expertise may be available in developed countries mainly. At any rate, if mineral oil and meat prices continue to rise, particularly in developing countries there will be opportunities for the onset of a combined protein plus biomass transition. Since the majority of the developing countries are particularly short of freshwater resources, the additional implicit water conservation will be considered an important bonus.

Facilitating transitions

In PROFETAS, neither transitions, nor their feasibility have been studied directly. Rather, insights and tools have been developed to facilitate a potential transition from meat protein to plant-derived protein products in the near future. These have been summarised in the present chapter. For the reasons outlined above we feel that a protein transition – reducing intensive livestock farming and cultivation of feed crops – is not just beneficial to the environment, but also more sustainable, most certainly socially desirable, and in the long run inevitable. It is yet unclear whether NPFs will be able to replace meat, to what extent, on what scale internationally, and how rapidly. When the window of opportunity opens, however, it will be crucial to have the technology available for more sustainable alternatives.

Facilitating a transition does not seem easy. However, it is interesting to note that – while exclusively working on an approach to make protein production and consumption more sustainable – the PROFETAS research community has yielded an integrated solution for various global problems far beyond its original scope. In addition to promising much more sustainable protein production – directly contributing to biodiversity and resource conservation and probably indirectly to animal welfare and human health – PROFETAS simultaneously indicated realistic options to produce a significant amount of biomass for sustainable energy production, and to save an immense volume of freshwater. This suggests that integral thinking combined with an even further extension of the disciplines involved (including health aspects, in particular) may be a promising avenue to meet the foreseeable challenges of the next few decades.

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