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The Food Supply Chain and Innovation: a Case Study of Potatoes



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and Andrew Flynn



**THE FOOD SUPPLY CHAIN AND INNOVATION:
A CASE STUDY OF POTATOES**

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ABSTRACT

The food consumption and production system in the UK is undergoing constant transformation in relation to technology, production methods, economic structure and relationships between key organisations and institutions. The dynamic nature of the food system is powered by changes in regulations, shifts in consumption patterns, economic competition between processors and supermarkets, and pressures from international competitors in the light of growing global food sourcing. The changes that take place within the food system may have implications upon the actors within the food system but also upon the sustainability of the food system in general. This paper explores innovations in the food consumption and production systems in the UK using the case study of potatoes. The paper presents a mapping of potato supply chains and explores inputs and outputs of the systems, as these have important implications for the sustainability of the food system. The paper establishes linkages between technological innovation and the sustainability of the potato production and consumption system.

Keywords: *Food system, food supply chain, innovation, potato*

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1. INTRODUCTION

In narrative terms, the food system consists of distinct economic stages of agricultural production, industrial processing, marketing or retailing and consumption. The food system must be viewed through a lens of corporate structure, which does not map directly on to economic stages of the food system (Fine et al, 1996). For example, the corporate structure may cover two to three economic stages such as agricultural growing, industrial processing and retailing (vertical integration), and may span across different industrial sectors at one economic stage, such as retailing of food and other domestic goods (horizontal integration). In understanding the food system we therefore need to be aware of the way in which corporate structures will potentially impact upon the processes of innovation and sustainability.

The modern food system is characterised as an increasingly complicated system with highly industrialised processes oriented towards mass production and consumption. Production methods and consumption patterns have been internationalised, and the financing and marketing of foods have been monopolised and internationally integrated (Fine et al, 1996). Globalisation of food markets and the reduction of trade barriers have led to global competition at all stages of the food supply chain.

The UK government, non-profit organisations, consumer groups, media and general public are increasingly concerned about the possible effects of the food system upon society, the rural economy and the environment. Concerns are raised around issues of the eating habits of the nation and the link between food and health; about safety of the food, which are eaten, and the environmental impacts of food production, including a desire for organic production and lower input farming; and higher animal welfare standards (MAFF, 1999a). Moreover, the food production and distribution processes present a number of environmental challenges, especially in relation to waste disposal, energy use, air pollution, water degradation and a decrease in bio-diversity (Werner and Bammert, 2001).

Sustainable consumption and production is becoming a major topic of interest (Fuchs and Lorek, 2002; Jackson, 2003). Not surprisingly, economic aspect of sustainability, which is reflected in the contribution that the food system makes toward national and world economies, is well known. For example, in 2002, nearly 300,000 enterprises were

engaged in agricultural and fishing business, food manufacturing, catering, retail and wholesale of food in the UK. The UK agriculture and fishing, food manufacturing and retail employed around 1.6 million people (Fenn, 2002a; 2002b). However, environmental and social aspects of sustainability of the food system are less well explored and documented. This paper is set out to remedy the gap by providing a framework to defining the food system that will allow us to explore the interrelationships between social, environmental and economic aspects of the system. The paper is an early output of a project “Technological transformations in food consumption and production systems”, which is funded by Economic Social Research Council and runs from January 2003 till June 2005.

Green et al (2001) identify four “dynamics” that affect sustainability in food consumption and production, including:

- changes to environmental context of food production and distribution;
- changes in economic development;
- changes in household consumption patterns; and
- changes in technologies.

Amongst these dynamics, the effects of technology in the food system upon the sustainability are the least examined (Weaver et al, 2000). Moreover, it is important to include the entire food system when considering innovation strategies. An innovation in one part of the food system can lead to innovation in the other part of the food system, or can affect relations between organisations that belong to different parts of the food system. A radical technological innovation may cause social or cultural change for consumers, communities and organisations in the food system. Therefore, the most appropriate way of investigating sustainability implications of innovation in relation to food is via applying systems approach.

Systems approach to the food production and consumption, which we adopt in this research, allows us to analyse comprehensively processes of agricultural production, processing of agricultural products, distribution of food (such as food wholesale, retail and food services) and food consumption. Food system also includes other important processes that are crucial to its functioning such as waste disposal and manufacture of packaging, equipments and the like.

Viewing the food supply chain as a system is useful in two respects. First, it would help us to understand the effect of technological innovations, evaluate different strategies for sustainable transformation, and investigate the implications of innovations in the food system for sustainability. The effects of innovations may be confined to one aspect of the system (e.g. agriculture), but may and, perhaps, are more likely to have knock-on effects elsewhere in the system. For example, the popularity of microwavable food products led to the invention of microwavable chips. Second, to explore the impact of innovation within the food system, supply chain approach demonstrates a holistic, system-wide perspective. In this way we can evaluate different strategies for sustainable transformation and investigate the implications for sustainability of innovations in the food system.

A further output from the project will be identifying policy implications for the UK and the EU in relation to strategies for promoting sustainability in the food system. The project uses case studies of different food types (chicken, fish, potato, tomato and yogurt) and examines the claims for sustainability and strategies for transformation both of different foods and of the whole food consumption and production system in the UK.

Potatoes were chosen as for this research due to significance of this vegetable product in the UK consumption and production. Firstly, potatoes represent vegetables and fruit sector, which is one of the most important sectors of the UK food system, accounting for 27% of the entire UK food market (Fenn, 2002a). Within vegetables and fruit sector, potatoes are the single largest product, accounting for 9% of the entire vegetables and fruit sales in the UK in value terms (see Table 1). Moreover, potatoes are a very important food product in Europe as a whole; they are the second most important crop in Europe after wheat (Hoekstra, 2003). Secondly, potatoes play an important role in the food system in terms of domestic consumption and expenditure. According to the National Food Survey in 2000, household expenditure on potatoes amounts to 4.6% of the entire household expenditure on food and drink in the UK (MAFF, 2001). Thirdly, domestic potato producers dominate both the fresh and processed UK potato market. The potato supply chain is a good example of a food supply chain with clear system boundaries, which is defined by a limited number of growers, packers, processors and retailers; due to dominance of domestic producers. Moreover, the potato supply chain

mainly sources from domestic market, therefore the system boundaries are confined within the UK.

Table 1: Volume of retail sales of various food products in UK in 1998-2001

	1998		1999		2000		2001	
	£M	'000t	£M	'000t	£M	'000t	£M	'000t
Meat and meat products	11,699	4,176	11,944	4,306	12,316	4,284	12,145	4,258
Beef and veal	1,601	859	1,622	934	1,752	914	1,688	901
Mutton and lamb	746	381	774	387	802	396	740	341
Pork	818	827	729	834	760	798	739	833
Poultry meat	2,360	1,649	2,400	1,696	2,630	1,707	2,710	1,713
- domestic production		1,545		1,525		1,513		1,565
- plus imports		316		349		355		345
- less exports		197		187		174		186
Bacon and ham	1,670	460	1,700	455	1,700	469	1,710	470
Other meat products**	3,978	-	4,073	-	4,299	-	4,494	-
Fruit and vegetables	11,684	6,886	12,049	6,817	12,082	6,906	12,524	6,940
Fresh vegetables	4,579	-	4,592	-	4,633	-	4,671	-
Fresh fruit	2,673	-	2,726	-	2,772	-	2,819	-
Fresh potatoes	1,170	-	1,148	-	1,111	-	1,099	-
Other fresh vegetables	2,254	-	2,255	-	2,294	-	2,324	-

Source: Fenn, 2002a and 2002b; Baxter, 2003

*excluding drinks and confectionery

** sausages, tinned meats, ready meals, delicatessen products, savoury products, etc.

The overall aim of this research project is to investigate the changes that are taking place within food consumption and production system and to critically assess the implications of technological innovations for the sustainability of the food system. The objectives of the research projects are to:

- identify technologies that are crucial for determining sustainability of the food consumption and production system;
- investigate the implications of technological innovations for sustainability of the food consumption and production systems;
- identify to what extent the key actors promoting technological change recognise the sustainability and system implications of their actions;
- review strategies for consumption and production and their effects on sustainability of the food system.

Our objectives within this paper are more specific, and they are to explore patterns of potato consumption and production in the UK; to map the supply potato supply chain; to identify areas of technological innovations within the supply chain; and to explore conventional and organic strategies for potato consumption and production. The main body of the paper is thus consists of five parts. First, a methodology section highlights

the supply chain approach and methods for data collection and analysis. Second, the paper reviews the economic structure of the potato supply chain and focuses on conventional potato production and consumption as well as the organic production of potatoes. Third, the paper presents a mapping of the potato supply chain, and its inputs and outputs that are crucial for the sustainability of the food system. Four, the paper summarises key innovations within the potato supply chain. Five, it discusses the key changes that are taking place within potato production and consumption system and their implications for sustainability. Finally, the conclusions present the results of the study and mapping exercise and identify areas for further research in the project.

2. METHODOLOGY

This section describes methodological approaches adopted for this research. Here we outline perspectives on supply chain, innovation, case study approach, and describe data collection process.

2.1 The supply chain approach

The research adopts a food supply chain approach to the study of the food system. The food supply chain is a system of stages, which represent particular sequence of economic activities, through which resources and materials flow downstream for the production of goods and the provision of services for ultimate consumption by the consumer. Moreover, the food supply chain is perceived as a network of organisations that have primary economic, but also social relationships with each other that enable the functioning of the supply chain to produce goods and services. Significantly, these relationships will also have environmental consequences.

An important feature in any system-based assessment is a clear definition of the system boundaries (Heller and Keoleian, 2003). The food supply chain consists of the following stages: origin of resource, agricultural production, primary processing, further processing, final manufacturing, wholesale, retail, food service and domestic consumption. For a more comprehensive systemic view of the flow of materials and resources, innovation processes and their implications for sustainability of the food system, the boundaries of the food system need to be extended beyond to include suppliers of equipment and materials such as packaging and feed, as well as the process

of waste disposal. Finally, the research also covers regulators and policies makers that have influence on the food supply chain.

Two types of production strategies are examined for each food product, i.e. the conventional supply chain and the organic supply chain. First, both strategies are well established and therefore open to analysis. Second, both strategies are the focus of much discussion, often being counter-posed with one another in public policy debate and commentary on the food system. Third, through comparisons of these two strategies it will help us to bring out more clearly the role of key actors, their relationships and how they affect the sustainability of the food system.

2.2 Innovation

Innovation normally includes all stages of new economic activity including the

“search for discovery, experimentation, development, imitation and adoption of new products, new processes and new organisational set-ups” (Dosi, 1988, p. 222 cited in Murphy and Gouldson, 2000).

Innovation can be a technological change, which may involve product innovation and process innovation, or organisational change, which involve new managerial techniques, or a social innovation (Schubert and Sadlacek, 2002). Innovations can be classified as radical, which imply discontinuous change and the introduction of new technologies, or incremental, which refer to the gradual improvement of existing technologies and techniques (Murphy and Gouldson, 2000).

Innovation in the food industry is seen as a combination of technological innovation with organisational innovation, it occurs throughout the entire food system, including production, harvesting, primary and secondary processing, manufacturing and distribution (Earle, 1997). It is evident that innovations in the food system are primarily targeted at improving economic performance of food producers and retailers. The most popular way to innovations that are taking place within the food system are new food product development (Stewart-Knox and Mitchell, 2003). Within the food system, common areas of technological and organisational innovations include the following (Earle, 1997):

- Food ingredients and food processing;
- Formulated foods and food manufacturing;
- Fresh foods and distribution;
- Packaging;
- Retailing;
- Food qualities, including nutrition and safety.

The growing attention of researchers is focussed on environmental innovations (Vellinga and Herb, 1999; Dewick and Miozzo, 2002; Butter, 2002). Dewick and Miozzo (2002) define environmental innovation as the use of production equipment, techniques and procedures, and products and product delivery mechanisms that are sustainable, because they conserve energy and natural resources, minimise the environmental impact or footprint of human activity and protect the natural environment. Huber (2003) argues that environmental innovation may include any kind of innovation – technological, economic, legal, institutional, organisational and behavioural. The benefit of environmental innovation is an improvement of environmental quality and reduction in resource use.

Butter (2002) defines three types of environmental innovations:

- 1) Optimisation of existing products. This type of innovation focuses on improving existing products, processes or infrastructures. The main objective is to modify systems which already have a commercial use. The efficiency of the system is increased by making slight modifications only.
- 2) System re-design. This type of innovation partly changes (redesigns) the actual design of existing products, processes or infrastructures. Specific features of the systems are changed, although the system concept remains largely unchanged.
- 3) Functional innovations. More far-reaching improvements can be achieved by departing from the system concept and by developing new systems which perform the same function better. This can result in radical change as to how the function is fulfilled.

System innovations are sometimes referred to as transitions (Faber et al, 2003). System changes are driven by a combination of social, economic and technological concerns and opportunities. In the past, some system changes occurred as a result of scientific

and technological development through their progressive adoption to replace existing systems and have also occurred as a result of technical and institutional innovations inspired by social problems. It is often argued that in order to achieve more sustainable society, important changes in production and consumption system will be required (Vellinga and Herb, 1999).

Butter (2002) defines green system innovation by the following characteristics:

- Functional changes with a jump in efficiency. System innovations are focussed on the development of new ways to fulfil a social need and lead to a jump in eco-efficiency.
- Constellation of innovations. System innovations are a cluster of aligned individual innovations, comprising technological, institutional and organisational changes.
- Multi-actor process. System innovations are the result of a combined effort of a large number of economic actors, which are connected to each other along and across the value chain.
- New guiding principles and set of goals. A system innovation results in new heuristics, goals, experiences and interests on the part of the actors.
- Long-term changes on micro and meso level. System innovations will lead to changes in organisations, changes of regimes and will be long term processes of change.

2.3 Case study approach

The research is based on a case study approach. Robson (1993, p. 5) defines case study research as

“... a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real context using multiple sources of evidence”.

The case study approach has several advantages that correspond to the objectives of this research project, including:

- A case study approach enables development of detailed knowledge about a particular phenomenon (Robson, 1993). One of the objectives of this project is to investigate

how food production and consumption system operates and how it affects the sustainability.

- A case study helps to understand the complexity of a single case and its activity within a defined set of circumstances (Stake, 1995). The food production and consumption system relates to the sustainability through its input and outputs.
- A case study approach is often employed, when the boundaries between a phenomenon and context are not clearly evident (Yin, 1993). The relationship between the food consumption and production system and sustainability is not clearly evident.
- A case study approach is an empirical inquiry, which investigates a contemporary phenomenon within its real-life context (Yin, 1994). The objective of the research project is to study current food consumption and production system in the UK.
- A case study relies on collection of evidence (Robson, 1993), and employs data collection methods such as questionnaires, observations, interviews and documentary analysis (Robson; 1993; Saunders et al, 2000). This research project therefore utilises secondary data collection method (analysis of documents and reports) and primary data collection method (interviews).

One of the major drawbacks of case study approach is a difficulty in drawing generalisations from a case study to the entire phenomenon. The extent to which we can draw generalisations from a case study depends upon the purpose of the case study. Stake (1998) makes distinctions between intrinsic and instrumental case studies. Intrinsic case study is undertaken because one wants better understanding of this particular case, while instrumental case represents a particular problem and provide an insight to an issue or helps refinement of theory. The choice of an instrumental case of food products is made to advance our understanding of food production and consumption systems and sustainability. Because we would like to increase the viability of our approach, we are pursuing a collective case study approach, which is an instrumental case study extended to several cases.

As Patton (1990) pointed out selecting of the case studies within an instrumental collective case study depends upon understanding of a phenomenon. Food production and consumption is a complex system which produces various food products starting from vegetable production, animal production, fish production and functional food

production. These production systems vary in their in production methods, character of innovations and environmental impacts. The project chose to study several food products such as tomatoes, yogurt, potatoes, chicken and fish. The choice of these particular food products has been made because they represent the variety of production systems within the UK. In this paper we are looking at the case study of potato production and consumption in the UK and details of its particular characteristics are discussed below.

2.4 Data collection methods

The primary methodology adopted by this case study is a qualitative approach (Robson, 1993; Denzin and Lincoln, 2000; Silverman, 2000). The data collection methods employed in this research include in-depth interviews with key persons in the food supply chain; analysis of secondary data such as market reports produced by consultants and trade associations. The key person (a representative of a key organisation) interview approach was chosen to provide data on organisations they represented, issues and problems that relate to processes within the supply chain. The organisations that were selected for the data collection represent important stages and processes within the food supply chain. The key persons within those organisations were chosen on the grounds of their relevance to the project. Initially, we approached trade associations, as these were able to provide the insight into the structure of the food supply chain and act as gatekeepers to their members (see Table 2).

The data collection process aims to cover all stages of the potato supply chain along with the processes, which are essential for the functioning of the system such as suppliers, waste disposal and regulators. The data collection process aims to involve not only economic actors within each stage, but also non-profit organisations which influence the technological development within the system. The research primarily targets data collection in the UK potato supply chain; however some of the data collection processes are limited to regional scale (Cardiff), while others relate to EU level. One of the objectives of this research is to investigate the organisational structure of the supply chain, and there is a limited number of organisations involved in the supply chain in a particular geographical region.

Table 2: Data collection

Supply chain stage	Informants	Date collection methods	Geographical scale
Origin of resource	- NGOs - Seed companies	- Interviews, Reports - Interviews	- UK - UK - UK
Agricultural production	- Farmers - Agricultural companies - Trade associations	- Interviews - Interviews - Interviews, Reports	- UK - UK - UK
Primary processing	- Packers - Processing companies - Trade associations	- Interviews - Interviews, Survey - Interviews, Reports	- UK, International - UK - UK
Further processing	- Processing companies - Trade associations	- Interviews, Survey - Interviews	- UK, International - UK
Further processing	- Processing companies - Trade associations	- Interviews, Survey - Interviews	- UK, International - UK
Final manufacturing	- Processing companies - Trade associations	- Interviews, Survey - Interviews	- UK - UK
Wholesale	- Merchants - Wholesalers	- Interviews - Interviews	- UK - UK
Retail	- Large supermarkets - Other supermarkets - Green grocers	- Interviews, Reports - Interviews, Reports - Interviews	- UK - UK - UK - UK
Food service	- Fast food restaurants - Takeaways - Restaurants - Catering companies - Public procurement: NHS, Defence, Schools, Criminal Justice System	- Interviews, Reports - Interviews - Interviews - Interviews - Interviews, Reports	- UK - Cardiff - Cardiff - UK - UK
Consumers	- Consumer associations	- Interviews, Reports	- UK
Waste disposal	- Waste companies - Trade associations	- Interviews, Reports - Interviews	- UK, Cardiff - UK - UK
Suppliers	- Equipment provider - Packaging providers	- Interviews, Reports - Interviews, Reports	- UK - UK
Regulators and Policy Makers	- UK agencies - EU agencies	- Interviews, Reports - Interviews, Reports	- UK - EU

3. ECONOMIC STRUCTURE OF THE POTATO SUPPLY CHAIN

3.1 Industrial structure and key organisations

In terms of industrial structure, the potato supply chain is represented by a relatively large number of potato growers; a smaller number of packers and merchants; and a very small number of processors. Potato growers are becoming fewer in number but larger in the area they operate on. For example, in Great Britain a number of potato growers decreased from 6,886 growers in 2000 to 5,685 in 2002. In 2002, some 229 potato growers, that is 4% of the entire population of potato growers in the GB, each with planting areas of 100 hectares and over, occupied c. 46,000 of planting land, which equates to 33% of the entire potato planting area in GB (British Potato Council, 2003a). The number of merchants and packers also declined from 1,030 in 2000 and 864 in 2001 (Fenn, 2002a). There were only 55 enterprises engaged in processing and preserving of potatoes in 2002. These are mainly large enterprises with turnover above £1 million, among which are McCain Food (GB) Ltd, Birds Eye Wall's Ltd, H J Heinz Company Ltd, and Fisher Food Ltd (Fenn, 2002a).

There are three important organisations which influence the operations of British potato production; these are British Potato Council (BPC), Potato Processors Association and National Farmers' Union. BPC was established by the Potato Industry Development Council Order 1997 on 1st July 1997. BPC is an industrial body which is funded by levy payments from its members. The membership of the BPC includes the majority of potato growers and potato processors. The BPC also actively interfaces with Fresh Produce Consortium, Potato Processors Association, British Potato Marketing Association, National Federation of Fish Fryers and major retailers. The main activities of BPC include the funding of research and development, the collection and dissemination of market information, and the promotion of potatoes in the UK and abroad.

The Potato Processors Association (PPA) was established in 1969, when the potato processing industry including crisping, dehydration and later freezing grew in importance. At the end of the 1960s, the potato market in the UK was tightly controlled by the Potato Marketing Board, which protected the interests of potato growers and ensured supplies and price levels, while the rest of Europe had a free market. The reason for the establishment of the PPA was a willingness of potato processors to protect their

interests and lobby the Government in order to reduce prices for potatoes, which is the main cost of production for the potato processors.

The National Farmers' Union (NFU) represents farmers and growers of England and Wales. Its central objective is to promote successful and socially responsible agriculture and horticulture, while ensuring the long term viability of rural communities. The NFU was founded in 1908 and is financed by members' subscriptions. The NFU is the largest farming organisation in the UK, representing around three quarters of the full time commercial farmers of England and Wales (NFU, 2003).

3.2 Conventional potato production and consumption

Potato production in the UK has been fairly stable over the last ten years (see Table 3). In 2002, an area of 159,000 hectares was planted with potatoes, and of which main crop occupied 146,000 hectares and only 13,000 hectares were dedicated to early crop. In 2002, approximately 6,375,000 tonnes of potatoes were harvested in the UK, which were worth £463 million (MAFF, 2003). Imports of potatoes to the UK constitute c. 20% of the domestic production. The major suppliers of potatoes from abroad are France, Germany, Israel, the Netherlands, Egypt, Spain and Cyprus. The UK mainly imports new potatoes and salad varieties from the Middle East (Tambe, 2002).

Table 3: Domestic production, imports and exports of potatoes in the UK during 1990-2002

Year	Area harvested for potatoes, ha	Production of potatoes, thousand tonnes	Seed production, thousand tonnes	Potato imports, thousand tonnes	Potato export, thousand tonnes
1990	117,100	6,467	536	-	-
1991	177,000	6,267	544	-	-
1992	180,000	7,814	545	-	-
1993	170,086	7,072	510	990	221
1994	163,568	6,542	478	1,120	337
1995	171,000	6,404	487	1,202	346
1996	177,400	7,228	511	1,049	282
1997	165,900	7,128	449	1,031	362
1998	164,100	6,422	437	1,194	375
1999	177,600	7,131	446	1,105	339
2000	166,000	6,636	452	1,185	369
2001	166,000	6,498	380	1,533	350
2002e	159,000	6,375	399	1,284	363

Source: Baxter, 2003; Global Potato News, 2003; MAFF, 1998a, 2003.

Note: e-estimated

The majority of harvested potatoes are sold on the fresh produce market, however, over 2 million tonnes of potatoes (which equals to c. 30% of the UK annual harvest) are sent for processing. Within potato processing industry, the production of frozen and chilled potato products has steadily increased over the last decade (see Table 4). The market for canned and dehydrated potatoes has remained remarkably stable during this time. These market developments are explained further below.

Table 4: Production of processed potatoes in the UK during 1992-2001

Year	Total, thousand tonnes	Canned/Dehydrated/Other, thousand tonnes	Crisped, thousand tonnes	Frozen or Chilled, thousand tonnes
1992	1,743	146	697	900
1993	1,814	153	697	964
1994	1,829	172	645	1,011
1995	1,899	181	685	1,033
1996	1,991	188	701	1,102
1997	1,925	96	718	1,112
1998	1,994	85	732	1,177
1999	2,046	157	684	1,206
2000	2,058	148	666	1,244
2001	1,940	140	664	1,137

Source: British Potato Council, 2002

The UK potato market is not only supplied by domestic potato processors, but also by potato processors from abroad (see Table 5). Within the last ten years, the imports of processed potato products has more than doubled. The majority of imports are frozen and chilled potatoes.

Table 5: Imports of processed potatoes into Great Britain during 1993-2002

June/May Season	Total, thousand tonnes	Canned/Dehydrated/Other, thousand tonnes	Crisped, thousand tonnes	Frozen or Chilled, thousand tonnes
1992/93	559	53	172	374
1993/94	775	64	201	509
1994/95	705	101	216	388
1995/96	659	122	201	336
1996/97	1,076	160	179	737
1997/98	1,061	103	163	795
1998/99	1,040	90	141	809
1999/2000	1,091	183	159	748
2000/2001	1,106	117	127	862
2001/2002e	1,274	201	164	909

Source: British Potato Council, 2003b

Note: e-estimated.

One of the major reasons for the expansion of potato processing is an opportunity to create value during potato processing and extract considerable profits. For example an

average retail price of fresh pre-packed potatoes is 50 pence per kg, while an average retail price of crisps is £5.20 per kg (see Table 6).

Table 6: Average retail prices for potatoes and potato products in GB in 2003

Potatoes and potato products	Average retail price (£ per kg) in August 2003
Total pre-packed potatoes	0.50
Pre-packed New	0.68
Pre-packed Main crop	0.37
Pre-packed Baking	0.65
Total loose potatoes	0.50
Loose New	0.49
Loose Main crop inc. Baking	0.52
Total Frozen	0.92
Frozen Chips	0.9
Frozen Potato Products	1.7
Chilled Potatoes	2.4
Canned Potatoes	0.5
Crisps	5.2

Source: British Potato Council, 2003c

3.3 Frozen and chilled potato production and consumption

Currently, almost 58% of all processed potatoes are frozen or chilled products (Fenn, 2002a). The UK frozen potato market is the largest in Europe and was estimated at £415 million in 2002 (see Table 7). In the UK, potatoes are consumed in the large quantities compared to other European countries. In 1999, UK per capita consumption of potatoes and potato products was 111 kg, while in Finland it was 70 kg, France 67 kg, Germany 78 kg, Holland 84 kg and Sweden 53 kg (Barker, 2001).

Table 7: Retail sales of frozen potatoes in the UK during 1996-2002

	1996	1997	1998	1999	2000	2001	2002
Total household expenditure on frozen foods, £ million	4,427	4,658	4,866	4,994	5,089	5,164	5,243
Retail sales of frozen potato products, £ million	334	360	379	398	392	400	415
Share of potato products in total frozen food sector, %	7.5	7.7	7.7	7.9	7.7	7.7	7.9

Source: Barker, 2001; Tucker, 2003

Even though the production of potatoes has slightly decreased during 1992 and 2002 (see Table 3), there is a distinct change in the pattern of potato consumption by the nation as the consumption of fresh potatoes has decreased, but the consumption of

processed potatoes has increased substantially (see Table 8). According to the National Food Survey household consumption¹ of fresh potatoes over the period 1990-2000 has decreased by almost 30%, while the consumption of processed potatoes over the same period has increased by 51% (MAFF, 2001).

Table 8: Potatoes moving into human consumption in Great Britain during 1974-2001, kg/head/year*

Year	Household consumption of fresh potatoes in GB, grams per person per week	Household consumption of processed potatoes in GB, grams per person per week	Human consumption of potatoes, kg/head/year	Raw potatoes for human consumption, kg/head/year	Processed potatoes for human consumption, kg/head/year
1974	1304	71	-	-	-
1980	1163	86	-	-	-
1985	1162	117	-	-	-
1990	996	135	102	67.6	34.1
1991	959	141	99	63.0	35.8
1992	901	167	106	64.8	41.3
1993	875	178	113	71.2	41.5
1994	812	185	106	63.9	42.0
1995	803	188	102	59.3	42.3
1996	805	205	107	34.4	44.3
1997	745	196	103	59.9	43.1
1998	715	200	113	57.8	45.5
1999	673	199	113	60.6	52.6
2000	707	202	112	61.8	50.2
2001			110	55.89	54.35

Source: British Potato Council, 2002, MAFF, 1991-1997, 1998b, 1999b, 2000

* including wastage in distribution

The growth of processed potatoes is due mainly to the increased consumption of crisps and frozen chips. Frozen chips and potatoes are very popular products in the UK. For example, according to National Food Survey in 2000, 78% of female housewives purchased frozen chips and potatoes, which were also popular most amongst people aged 35-44 and with the working class. In Scotland more people eat frozen chips and potatoes than in Greater London, where they are least favoured (MAFF, 2001; Barker, 2001). 21% of people say chips are their favourite potato dish (British Potato Council, 2003d). Chips are consumed in large quantities not only at home but also outside the home. According to research conducted by the BPC, over 70% of the UK population eat fish and chips more than once every six months. Just fewer than 50% eat once a month and 14% of all adults enjoy fish and chips once or twice a week (British Potato Council, 2003d).

¹ Household consumption refers to household foods, i.e. foods brought into the home.

The growth areas within frozen potato market are microwavable chips, frozen roast potatoes and children's shapes (Barker, 2001). Frozen foods have been available in the UK since the 1940s and 1950s. However, substantial growth of the frozen food consumption in the UK took place in the 1980s and 1990s, which is related to the increased ownership of freezers and microwaves, as well as shift in demand for more convenience foods. In 1979, only 40% of the UK households had a freezer but this increased to 83% by 1991. In 2000, 91% of households in the UK had a fridge-freezer or deep-freezer. Penetration has remained at around 90% since 1997. Microwave ownership has increased rapidly in the 1990s. In 1989, 43% of households had a microwave but, by 2000, household penetration had reached 80% (Barker, 2001).

Retail sales of frozen potato products are dominated by the large supermarket chains. According to the Expenditure and Food Survey in 2002, large supermarket chains account for 87% of the UK household expenditure on potato products (DEFRA, 2003). According to Baker (2001), in recent years, most supermarkets have increased the shelf space for frozen foods and most of the smaller grocers and retailers cannot compete with the supermarkets on product range. Tesco is the leading supplier of frozen foods amongst the grocery multiples, followed by J Sainsbury PLC, Waitrose Ltd, and Marks and Spencer PLC (see Table 9).

Table 9: Selected leading frozen food suppliers by number of multiple grocery and freezer outlets in 2000

Tesco	656
Safeway	476
Sainsbury's	405
ASDA	232
Marks and Spencer	296
Waitrose	137
Iceland	760
Farm Foods	238

Source: Barker, 2001

The review of the modern potato production and consumption in the UK shows that processed food, especially frozen food, are increasing in their significance and this is related to changes in household storage and cooking technology, e.g. the rise of freezers and microwaves. The system for potato production and consumption is therefore significantly dependant upon technological advances throughout the system, from the stages of food processing to the stages of distribution and household consumption.

3.4 Organic potatoes

Organic potatoes are grown on a much smaller scale than conventional potatoes, however in recent years, the harvest of organic potatoes has grown year on year (see Table 10). Organic potato growers in the UK are supplied with organic potato seed from home and abroad, and potato packers are beginning to play an increasingly important role in supplying organic growers with organic seed. There are different potato varieties popular with organic growers and conventional growers due to different agricultural techniques such as limited use of fertilisers and pesticides in organic growing, and the necessity to rely on natural resistance of organic potatoes to disease and pests. According to the EU regulation, only 100% organic seed should be used for growing of organic potatoes since 2004 (Soil Association, 2002).

Table 10: Organic potato supplies and disposals in GB*

	1998/1999	1999/2000	2000/2001
Supplies, tonnes			
Home crop	22,775	28,750	52,025
Imports	15,000	16,000	16,000
Total	37,775	44,750	68,025
Disposals, tonnes			
Retail sales**	27,703	26,824	27,349
Direct sales	1,000	1,000	2,000
Processing/Catering	1,500	3,000	5,000
Seed	3,450	6,243	6,900
Field leaving & waste	4,372	5,750	11,903
Not accounted for	250	1,933	14,873
Total, tonnes	37,775	44,750	53,152

Source: British Potato Council, 2001

* Data based on best industry estimates

** Data for April to March periods.

A quarter of the organic potato market depend on imports of potatoes from abroad, mainly from Austria, Israel, Egypt, Italy and Netherlands (British Potato Council, 2001). Countries that export organic potatoes to the UK are similar to those countries that export conventional potatoes (see Section 3.2 of this paper). The notable exception is Austria, which has a higher developed organic sector. The retail sale of fresh organic potatoes is now well established, with supermarkets occupying the largest share of the market. However, industrial processing of organic potatoes and the manufacture of ready meals have been slow to take off, and therefore organic growers who produce crops below fresh sale standards unlike conventional producers, do not have alternative outlets, which leads to large amounts of wastage in organic potato production.

Table 10 above shows that domestic production of organic potatoes has more than doubled in two years, while imports of organic potatoes and retail sales stayed the same. The statistics for organic potatoes shows that about 15 thousand tonnes of potatoes are not accounted for in 2000/2001 and when combined with 12 thousand tonnes of potatoes left on field and wasted, we suddenly see where the increase of domestically grown potatoes might end up. According to an interview with organic potato grower in the UK, about 50% of harvested organic potatoes are considered as waste, as they are rejected by packers on the grounds of quality, size, colour and disease. Moreover, if potatoes are rejected by the retailer, they may be sold for cheaper to other outlets, but may go to stock feed. Therefore, potentially 15 thousand tonnes of oversupply of organic potatoes in 2000/2001 went to stock feed.

According to the British Potato Council (2001) the main factors that could limit the growth of organic potato products include:

- High price of organic produce in comparison to conventional produce. This could be too high for some consumers regardless of their feelings on health and safety issues. The average retail price of organic potatoes in September 2001 was £0.70 per kilo, while for conventional potatoes it was £0.50 per kilo gram.
- Demand for organic potatoes is greater than the home market can supply, therefore there is a continued dependency on imported potatoes. Food miles do not add to the attractiveness of imported potatoes, because consumers may prefer local produce, and therefore they might shift to local conventional production.
- Organic production has difficulties in controlling disease in potatoes, such as blight and consumers' perception of quality, particularly appearance, may lead them to discount organics.
- There is a limited choice for potatoes both of product range and sizes of packaging and in processed form. There is an increased demand for fast, convenient food in processed form, but organic potato processing is limited due to the high costs of the raw materials.
- High levels of wastage in the field and retail outlets. High degree of rejection by supermarket standards of organic potatoes leads to large quantities of waste in organic potato production.

In addition to these reasons, a representative of the British potato industry pointed out in the interview that industrial food processing of organic potatoes is not popular due to technical reasons associated with the difficulty to ensure steady supply of organic potatoes throughout the year. The problem is in storage of organic potatoes, which is a cold storage, and is recognised to be less successful than a long-term storage provided with the use of CIPC (Chlorpropham), which suppresses sprouting of potatoes in store. Regulations prevent the use of artificial chemicals such as CIPC during the storage of organic potatoes, which puts them into disadvantage in terms of industrial processing.

3.5 Summary

There are two distinct strategies for the production and consumption of potatoes in the UK. First, there is conventional potato production and consumption, which is dominated by high agricultural production outputs, extensive international trade, high levels of industrial processing, retail sales and a high volume of household consumption. Within conventional potato production and consumption, frozen potato production and consumption is a distinct sub-strategy, which is highly reliant upon technological innovations (such as microwaves and freezers) and the dissemination of their outcomes throughout the supply chain, starting from processing, distribution and household consumption. For instance, the increase in consumption of processed potatoes has led to changes in the varieties of potatoes that are grown. Structurally, the conventional potato production and consumption system is in the hands of few large potato processors and potatoes are mainly distributed through the few large supermarket chains. Second, there is the organic potato production and consumption system, which is characterised by small agricultural outputs, minor industrial processing, small but growing international trade, mainly imports, and where retail is once again dominated by large supermarket chains. Structurally, organic potato production is oriented towards small-sized potato growers, a small number of leading organic packers, and distributed through a few large supermarket chains. Organic potato production and consumption is significantly dependent upon agricultural techniques for its existence.

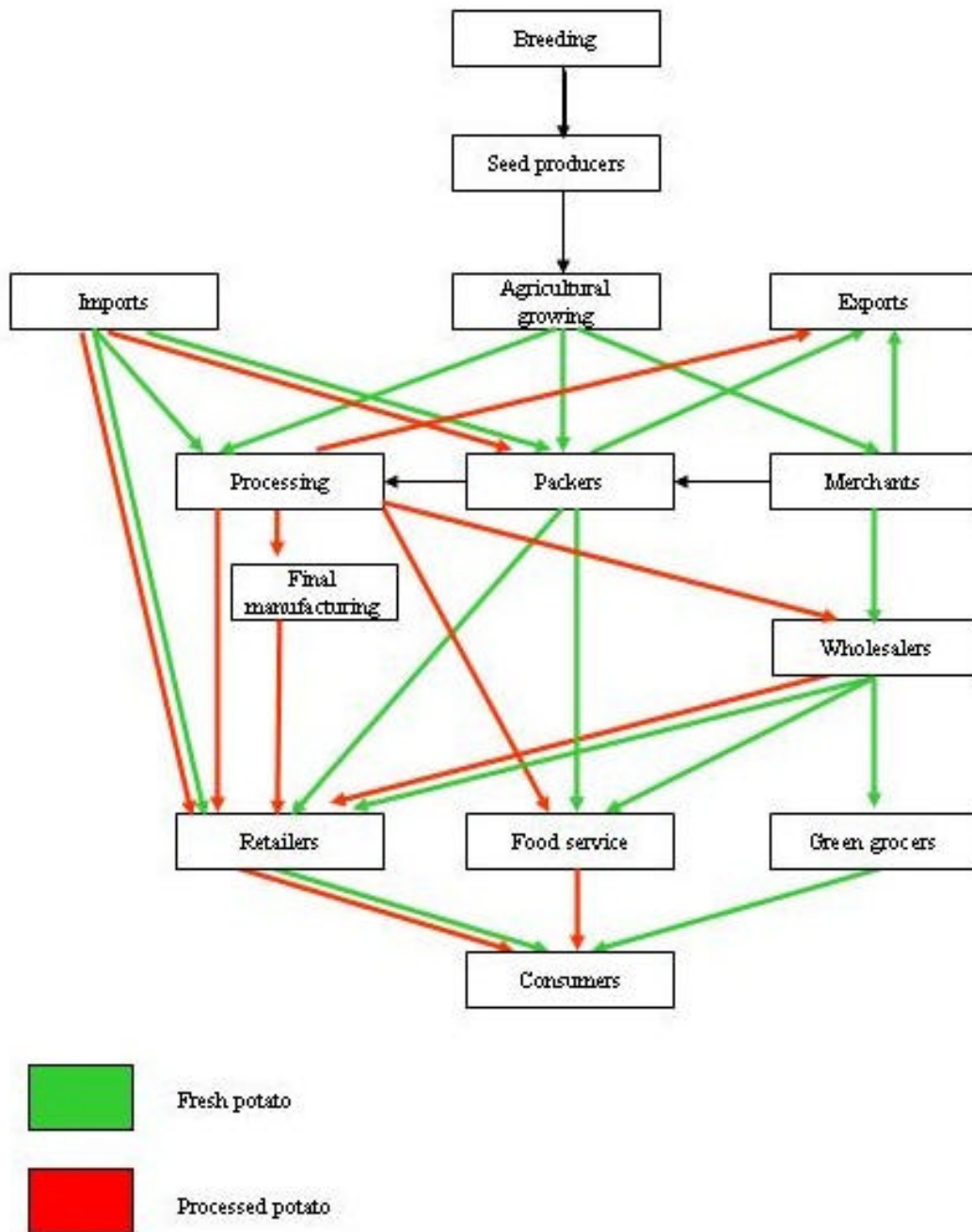
4. MAPPING THE SUPPLY CHAIN

This section presents recent attempts to map the conventional potato supply chain. The mapping exercise was based on a literature review and empirical research and aims to

illustrate the sequence of stages in the supply chain, to identify the variety of linkages between the stages, and to establish the flow of materials and resources for the production of potato products and provision of services. The mapping exercise has significantly improved understanding of the supply chain, and has helped to model the data collection strategy and proved to be a useful tool in generating new ideas and hypotheses. Based on recent findings, the map of the conventional potato supply chain is presented in Figure 1 and consists of the following stages:

- Breeding – the process of developing new varieties of potatoes.
- Seed selection – the stage where potato seeds are selected and improved for better potato production. Potato seeds are produced and later supplied to the farms.
- Agricultural growing/farming – the stage where potatoes grow from seed to the stage of their harvesting. Potatoes are gathered and then transported to the distribution or processing stage.
- Merchants – are engaged in exports and imports, supply for processing, packing and wholesale of potatoes at the stages of distribution.
- Packing – the stage when potatoes are cleaned, graded, weighed, packed and priced and later supplied to retailers. This stage refers to either primary processing or commonly distribution stages of the supply chain.
- Processing – the stage of value adding, such as peeling, pre-cooking, cooking, seasoning, preparation of various products.
- Final manufacturing – the stage for value adding leading to chilled production, where potatoes are used as ingredients for the preparation of soups, ready meals, salads, etc.
- Wholesale – the stage at which wholesalers acquire potatoes and potato products and distribute them amongst retailers and market outlets.
- Green grocery sale – the stage of retail through green-grocers, who are supplied by the wholesalers.
- Retail – includes supermarkets and other outlets, except for green-grocers.
- Food service – includes fast food service, restaurants, takeaways, work canteens, etc.
- Consumption – refers to household consumption of potatoes and potato products, including purchasing, storing, cooking, consuming and disposing of food.

Figure 1: The conventional potato supply chain



The material input and environmental outputs of the potato supply chain are presented in Figure 2. The stages within the potato supply chain can be grouped according to similarities in the nature of their activities into four processes:

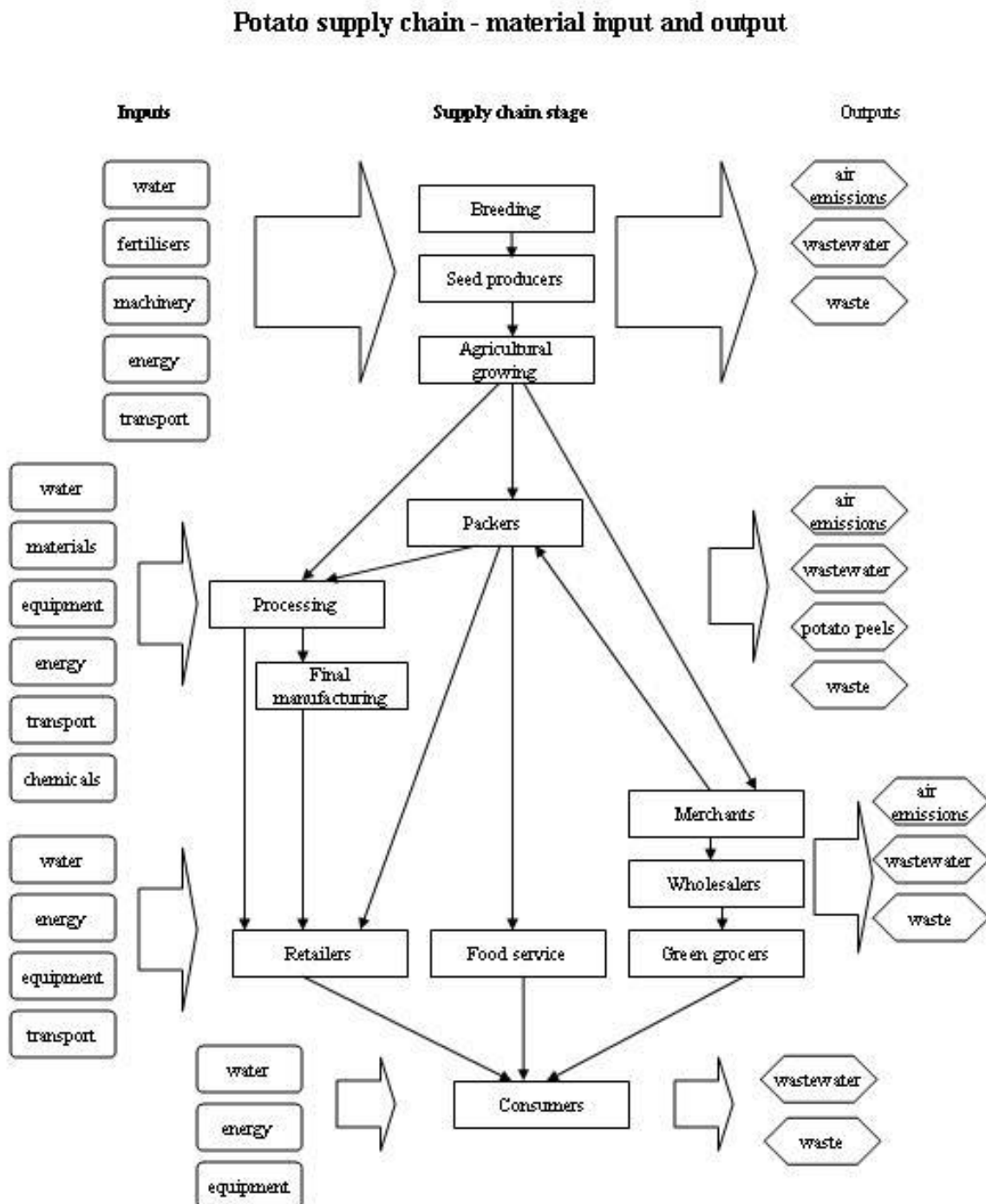
- 1) *Agricultural production*, which unites the stages of Breeding, Seed Production, Agricultural Growing which have major inputs such as water, fertilisers, machinery, energy and transport and major outputs of air emissions, wastewater and waste.

- 2) *Industrial processing*, which unites the stages of Packing, Processing and Final Manufacturing with major inputs such as water, material (packing), equipment, energy and transport and major outputs of air emissions, wastewater and waste.
- 3) *Distribution*, which unites the stages of Merchandising, Wholesale, Retail, and Food Service with major inputs of water, energy, equipment and transport and major outputs of air emissions, wastewater and waste.
- 4) *Domestic consumption* which has major inputs of water, energy and equipment and major outputs of waste.

The major material inputs at the stage of agricultural production include the supply of water, fertilisers, agricultural machinery, energy and transport. Despite developments in breeding, potato is still susceptible to a large number of diseases and pests, and as a result potato production is one of the heaviest users of chemicals inputs for crop growing (Hoekstra, 2003). The major environmental outputs during this stage are air pollution, wastewater emission, land degradation and waste generation.

During the stage of potato processing the major material inputs are water, energy, materials for packaging and the like, chemicals, processing equipment and transport. Processing of potatoes involves freezing, and from this stage on, involves large energy inputs for the storage of frozen or chilled potato products. Therefore, industrial processing of potatoes is very energy and water intensive. Moreover, packaging is a very important part of processing, which greatly contributes to waste generation during the latter stages of the supply chain. The major environmental outputs of the industrial potato processing include air pollution, wastewater emission and waste generation.

Figure 2: Inputs and outputs in the conventional potato supply chain



A process of distribution has various inputs such as water, energy, equipment and transport. Distribution is highly energy intensive, because it involves display and storage of large quantities of frozen and chilled potato products. Environmental outputs are similar to the previous processes of the potato supply chain.

These quantifiable inputs and outputs are crucial for defining the environmental sustainability of potato production and consumption system. The level of environmental sustainability of the potato production and consumption system depends on production and consumption strategy. Conventional strategy, which incorporates freezing and chilling of potatoes, is highly resource intensive and has significant environmental impacts. Organic strategy is very inconsistent throughout the supply chain, organic strategy applies to seed production, agricultural growing, storage; neither industrial processing nor distribution have any resemblance with the principles of organic production. Organic strategy strives to be less resource intensive and less environmentally harmful, but in fact is very marginal and inconsistent.

Technological design, efficiency and organisation of processes in the supply chain that consume these material inputs define the quality and volume of outputs. Changes that we are seeking to identify within the supply chain should be of technological as well as organisational merit such as changing patterns or nature of linkages or relationships between economic actors in the supply chain or within the economic units themselves.

5. INNOVATIONS IN THE POTATO SUPPLY CHAIN

Innovations within the potato supply chain have taken place in three major areas:

- 1) Agricultural developments. Potatoes have entered the organised food production and consumption system since 5,000 BC, when it was domesticated in Peru.
- 2) Processing. The early development of potato production and consumption system is full of major process innovations at the stages of agricultural production and food storage and processing.
- 3) Organisation of the supply chain. The organisational change such as creation of organised industry for processing potatoes has been a great leap in the development of potato production and consumption system.

The chronology of key technological innovations within the potato system is summarised in Table 11. Technological innovations that are related to production and consumption of potatoes are taking place at every stage of the potato supply chain. At the stage of breeding, many new varieties are developed every year, though very few will make it the market. Due to differences in agricultural techniques for growing conventional and organic potatoes different potatoes varieties are required for both productions. In relation to organic potatoes, seed producers try to enhance the quality of potatoes varieties to make them more resistant to diseases and pests. However, it takes about 10 years from the invention of a new variety for it to see commercial success on the food market, due to the long period of testing at all stages of the supply chain.

Table 11: Chronology of key innovations in the potato supply chain

Date of innovation	Type of innovation	Product vs. Process development	Supply chain stage	Degree of dispersion effects along the supply chain
5000 BC	Domestication of potatoes in Peru and Bolivia	Major process development	Agricultural growing	Major effect on supply of potatoes for consumption
2500 BC	Creation of new varieties of potatoes through natural cross-fertilization.	Process and product development	Breeding	Effect upon all stages of the supply chain downstream
2500 BC	“Freeze-dry the tubers” - technique for preservation of potatoes for long-term storage developed in Peru. This potato product is called <i>chuño</i>	Process and product development	Agricultural growing (harvesting) and storage (transportation)	Effect on supply of potatoes for consumption
2500 BC	Creation of a foot plough.	Process development	Agricultural growing	Effect upon all the stages of the supply chain downstream
2500 BC	System of regular crop rotation developed by Inca	Process development	Agricultural growing	Effect upon all stages of the supply chain downstream
1560-80s	Potatoes brought to Europe	Geographical expansion	Establishment of new supply chain in Europe	Novelty to the diet of Europe
1600-1700	Potato is established as a field crop around Europe	Diffusion of the potatoes	All supply chain stages	All supply chain stages
1870-80s	Development of new varieties of potatoes: Irish Cobbler and the Green Mountain	Product development	Breeding	Effect upon all stages of the supply chain downstream
1903	Development of new variety of Russet potatoes, which later became the most used variety in US	Product development	Breeding	Effect upon all stages of the supply chain downstream
1920s	Invention of processing technologies	Process development	Processing	Effect upon all stages of the supply chain upstream and downstream

Source: Kiple and Ornelas, 2000

The current key innovations in the potato supply chain are summarised in Table 12. A general pattern of technological change within the potato supply chain indicates a shift from major process development to minor product development. For example, the first new varieties of potatoes were introduced in 2,500 BC using cross fertilisation techniques, which could be seen as a major process development. Currently, new varieties of potatoes are introduced using the same or more advanced techniques and these innovations could be considered as minor product developments.

Table 12: Current key areas for innovation in the conventional potato supply chain

Supply chain stage	Description	Product vs. Process development	Possible effect on sustainability
Seed selection	Development of new potato varieties	Product development	Increased diversity of potatoes
Agricultural growing	Improved fertilisers and irrigation	Product development	Increased or decreased environmental impacts
Packing	New packaging	Product development	Increased or decreased environmental impacts
Processing	New machinery for chilling and freezing	Product and process development	Energy efficiency
Final manufacturing	New product development	Product development	Impacts on energy use, packaging supplies, waste generation, food miles
Retail	New storage and distribution techniques	Organisational and logistic change	Effects upstream on other economic actors within the supply chain
Food service	New product development	Product development	Impacts on energy use, packaging supplies and waste generation

At the moment, product development is more significant for the supply chain than process development. Examples of products developments include the introduction of: new potato varieties, new types of fertilisers, new potato products, such as microwavable chips, and new ready meal such as chilled mashed potatoes. All this product development bring inevitable changes to process development, as they lead to alterations in processing cycles, parts and modifications of technology.

Over time, leading innovators have moved from earlier stages in the supply chain to latter stages. Although innovations are taking place at every stage of the potato supply chain, it is noticeable that technological changes in processing and distribution stages have greater effects upon the supply chain as a whole.

It is possible to explore the implications of innovation within the food system in a number of ways, but two that are particularly helpful include time and space. Technological changes within the potato supply chain have significant implications for the dimension of “time”, i.e. the duration of movement of materials within the supply

chain. Typically, this will involve shortening the duration of one or more stages of the supply chain such as a reduction for storage, processing, transportation of products to retailers (which leads to fresher products for consumers and faster movement of the materials along the supply chain).

The effect of innovation within the dimension of “space”, i.e. the sourcing of materials for the consumption and production of potatoes, is largely witnessed by an increasing degree of globalisation of the supply chain. Seeds may be produced and imported from one country, grown and harvested in another country, and possibly processed and consumed in a third country. Moreover, food related technologies are widely exchanged between nations in the form of new products or new processes.

6. DIFFUSION OF TECHNOLOGIES AND THEIR IMPACTS

There are several trends that are taking place within the potato supply chain, including:

- Specialisation of potato varieties for specific markets.
- Niche marketing, i.e. organic potatoes.

These trends not only define the current state of the potato supply chain, but also have significant implications for sustainability of the food system. These trends represent a mixture of socio-technological developments within the food supply chain, which are described below.

6.1 Specialisation by varieties

In the case of potato varieties, the most popular variety of potato planted today in Great Britain is Maris Piper, which is a main crop variety and it accounted for almost one quarter of the total planted area of potatoes in Great Britain in 2003. Estima, which is an early crop variety, is the second most popular variety grown and accounted for 8.8% of the total planted area of potatoes, Lady Rosetta is the third (4.8%), closely followed by Maris Peers (4.7%) (British Potato Council, 2003e). As the number of uses to which potatoes are put has increased, so a specialisation of varieties has emerged. For example, there are certain potato varieties, which are more suitable for boiling, others for frying, and others are more likely to end up in salads.

However, it is a potato that has a number of uses that is favoured by British growers. Maris Piper, which is popular variety used for home cooking and by chip fryers, is the most planted potato variety; hence this could indicate that the most popular processing of potatoes in Britain is chip frying. According to the information from British Potato Council, Maris Piper is considered to produce the higher quality chips than other potato varieties. However, Maris Piper is very susceptible to diseases and pests, therefore is very rarely grown extensively in organic production. Maris Piper exists only in the form of a conventional potato.

This variety travels through all channels and stages of the potato supply chain: Maris Piper is sold pre-packed as a fresh produce in large supermarkets and other retail outlets; it is industrially processed into frozen chips and other products; and used in fish fryer shops and other food service units. Finally, household consumers have a variety of Maris Piper products to choose from a variety of retail and food service outlets.

The life cycle of a potato variety is relatively long; they achieve a stage of commercial success after 10 years of their initial invention. Varieties are promoted not only by seed companies, but by packers and industrial processors as well. Packers sometimes subcontract potato growers and supply them with particular varieties and later on sell the crop to a supermarket. The supermarkets have a list of preferred potato varieties and this list is regularly updated, but it is difficult to convince the supermarkets to include new potato varieties into their lists. Another reason for the popularity of certain potato varieties is dependent upon the patent cost and duration of a patent protection. A lot of potato varieties in the organic potato growing scene are fairly few, which were developed after organic potato market started to grow and the price for these varieties is relatively high. Whereas, some varieties, especially conventional varieties have been on the market for 10-15 years and recently have come out of patenting protection and reduced in price.

Large potato processors sub-contract potato growers, because the production of complex processed foods leads to increased requirements for consistency in variety, quality, shape and size of raw material. Improved agricultural techniques and use of fertilisers ensures the fulfilment of these requirements. Therefore, specialisation of potato processors for production of certain potato products leads to specialisation of growers for production of certain potato varieties. For example, certain varieties of

potatoes are preferred for crisping potatoes, other varieties are preferred for chipping and further varieties are best for sale on the fresh market.

A strict specialisation of sub-contracted potato growers by variety is likely to increase returns of the potato growers, but also puts limitations on their opportunities to make sales to alternative markets, if their specialised potato variety should underperform. The reason for that lies in structural characteristics of the potato industry, i.e. there are only few large potato processors who are after specific quality and quantity of potatoes, and that specific potato varieties could be efficiently used only for specific processing techniques. So in case of underperformance of the crop in a certain year, specialised potato growers could not only lose the contracted processor, but could also fail to sell it on wholesale market and end up selling the entire crop for cheap animal feed. This situation therefore puts potato growers under enormous pressure to perform at their best and to establish long-term relationships with their customers. Thus, the specialisation in potato varieties favours large potato growers, while small potato growers are ceasing to exist.

6.2 Organic production

Organic production is growing throughout Europe. Since the 1970s and 1980s there has been a growth in the number of organic potato producers. Organic potato production is highly regulated as all organic producers are certified by a certification body² and follow regulations for organic production. Minimum standards are set by the European Union and interpreted by the UK Register of Organic Food Standards which is a part of the Department for Environment, Food and Rural Affairs (Organic Centre Wales, 2003). Organic potato growing in the UK started to develop on commercial scale in 1990s.

Major supermarkets now sell organic ranges of fresh vegetables and meats and organic food is mainly sold through the network of major supermarkets. However, only 1% of the entire retail sales comprises of organic foods. Organic producers claim that as the market demands for higher quality products, supermarkets pay increasing attention to

² Organic producers must register with one of the organic certification bodies: Soil Association, The Biodynamic Agricultural Association, CMi Certification Ltd, Organic Farmers & Growers Ltd and Organic Food Federation, which are private companies, licensed by the UK Government to enforce organic standards (Organic Centre Wales, 2003).

the cosmetic appearance of the foods which greatly affects the competitiveness of organic producers. Since organic producers discourage the use of certain fertilisers, their potatoes may have blemishes in their appearance when compared to conventional produce, which affects their presentation value which consumers and supermarkets seek.

Organic producers often claim to have special philosophy or ethics in the way they conduct business operations. Although it might be true, the majority of organic produce sold not through organic shops or local shops, but through large supermarket chains. Organic packers not only source from domestic producers, but seek for organic potatoes abroad. In terms of marketing, organic potatoes are very similar to conventional potatoes and only at the stage of agricultural growing that the differences in the system could be observed, such as differences in growing techniques. Organic potatoes are not popular with potato processors, and there are no as such organic potato processors on the market.

Another aspect of organic potato supply chain is the adoption of organic market by mainstream conventional operators. For example, large seed producers, who deal with conventional seed, have recently started to deal with organic seed. Similarly, some potato packers, who primarily deal with conventional potatoes, have also moved on to organic potato market and now also pack organic potatoes for their customers. Some potato processors, who process conventional potatoes, are looking into producing products from organic potatoes. Therefore, the functioning of organic potato supply chain is highly dependent upon the operators in conventional potato supply chain.

7. CONCLUSIONS

The analysis of UK potato supply chain shows that it is affected by several major trends, which include the following:

- The potato supply chain is becoming more integrated.
- The potato supply chain is increasingly competitive and dominated by small number of large retailers.
- The potato market is increasingly globalised, potatoes are traded in fresh and processed form with countries of Europe, Middle East and North Africa.

- Technological development leads to a greater number of new food products and consumer now have greater choice of products.
- Food consumption pattern have changed within the last 20 years leading to consumption of more processed foods.
- Industrialised potato production and consumption is a dominant strategy, while organic potato production is a niche strategy.

The potato supply chain is becoming more integrated. The potato supply chain is becoming more efficient and organised, more and more growers have stopped growing speculatively and now know for whom they are growing and what requirements they have to meet. Large potato growers are more often subcontracted by large packers and potato processors. The feedback of information upstream the supply chain is improving and here the role of packers is increasing in strengthening the supply chain. Packers are beginning to act as active integrators of the supply chain; they contract farmers, often supply them with seed and later buy their harvest and sell it to a designed retailer. Packers are linking seed production, agricultural growing with retailing.

Increasingly large supermarket chains are becoming more powerful, taking up almost 80% of the entire fresh potato market. British manufacturers have to compete harder for the place on shelves of a few large supermarket chains such as Tesco, Sainsbury and Asda. Consumer demands for fresh and cheap food expose British food producers to price competition from foreign counterparts, while British retailers exert considerable pressures upon manufacturers, which are also felt in the area of innovation.

Another important characteristic of the modern potato supply chain is its expansion in terms of the geography of supply, due to seasonality of potato growing in the UK, so that a lot of potatoes are imported from Mediterranean countries, so that new potatoes are always on the supermarket shelves. The globalisation of potato market leads to greater use of transport in food production. Potato seeds could be imported from Europe, grown in the UK, later potatoes could be exported in fresh or processed form. The increased used of transport in food production and consumption systems leads to greater energy use (Garnett, 2003)

The potato supply chain has experienced rapid changes in terms of potato varieties grown and potato products developed. The potato supply chain has a shorter life cycle

than some other agricultural products. For instance, it could take 2 years from a plantation of potato seed to the consumption by a final potato product. The situation is different with orchards, for example, it takes 10 to 15 years to replace an apple tree (Hodgson, 2003). This allows the potato supply chain to adapt to the changing demands of the consumers for potato varieties.

Technological innovations in the potato supply chain take place at each stage: seed production, agricultural growing, processing and marketing. However, these innovations are largely incremental product developments. New product development is playing an important role in restructuring the potato supply chain. Therefore, specialist chains are formed. However, these specialist chains are highly dependent upon the limited number of specialised clients. For instance, if the grower of crisping potatoes fails to meet the specifications of a potato crisper, the grower has limited economic alternatives for disposal of his or her harvest.

The dominant strategy for the consumption and production of potatoes is clearly industrialised. More and more potatoes in UK are consumed in processed form whether at home or outside of home. This industrialised strategy does not show any signs of slowing down, however new strategies are beginning to show in sharper relief, for example organic potato production. Major differences between conventional and organic potato supply chains are as follows:

- Organic potato production is clearly marginal production in comparison to conventional potato production.
- Procedures for handling organic potatoes at the stages of seed production, agricultural growing and storage are distinctly different from those in conventional potato production, and these procedures are documented and regulated by legislation.
- Organic potato production is in the hands of small to medium size organic growers, while conventional potato production has a range of growers from small and medium size growers to large size growers.
- Organic potatoes are less popular with food processors than conventional potatoes.

An organic strategy for the potato consumption and production system exists from seed production to processing of organic ready meals and organic crisps; however the distribution stage is very much dependent upon the prevailing industrialised system, i.e.

supermarkets. Another feature of organic production is that many conventional seed producers and conventional potato processors also have interests in organic potato production. Therefore, we can see that major economic actors within the potato supply chain are diversifying and developing two parallel strategies for production (conventional and organic).

It is very difficult to access whether organic packers - those who pack and sell organic produce - are radically different in their business strategies from conventional packers. Since the former also import organic produce from abroad, adding to the food miles of products, use similar packaging, because they supply the same supermarkets as the conventional packers, dispose of their waste in a similar fashion as conventional packers and use similar sorts of machinery. Further research is to be undertaken in the area of technological innovations in food supply chain and their effects upon the sustainability of the system.

Issues that might have potentially significant implications for the sustainability of the potato supply chain and need further investigation include: a) consolidation of potato growers, packers and processors; and b) value adding and development of complex foods that use potatoes. The project is undertaking further work on evaluating sustainability of the food system, development of sustainability indicators and collection of data for sustainability assessment. Similar research, utilising same methodological approach, is undertaken to investigate technological changes and sustainability in the chicken supply chain in the UK.

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