Project Report

Sustainable GB Potato Packaging - Supply Chain Report

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Preface

Together with the report *Life Cycle Assessment of Potato Starch Based Packaging – Strategic Industry Report*, this provides an assessment of the options for sustainable production of biodegradable packaging from GB-produced potato starch.

The British Potato Council became involved in and coordinated this one year Sustainable Technologies Initiative LINK project in order to bring leading researchers at PIRA International and Imperial College, London, together with representatives of the supply chain. A consortium including potato producers and processors were involved in the work, providing advice, information and guidance.

This work has demonstrated that supply of by-product potato starch recovered from potato processing operations is a viable alternative to starch produced under the EU subsidy system and imported, having advantages over this on three main counts:

Economic – this benefits both PotatoPak, the specialist company producing the packaging who played a lead role in the consortium, and the GB industry as a whole by increasing efficiency and adding value
Environmental – the Life Cycle Assessment has shown that potato starch based packaging has benefits over commonly used plastic-based alternatives, and GB-produced starch has benefits over imported
Properties – over the course of the project the properties of the finished packaging material have been improved, including the moisture-resistance and production cycle-time and therefore cost

Executive Summary

Biodegradable packaging concepts have been around for a number of years, but the uptake to date has been slow. Recent years have seen a resurgence in interest in these materials, apparent from the increasing number of options on the market and hence the increasing amount of competition.

The potato starch based packaging material produced by Potatopak is currently being produced and used commercially in limited quantities. The packaging was being manufactured from imported food grade starch but several possible alternative GB supply options had been identified prior to the project for GB based supply including:

- the use of potato starch that is produced as a by-product during potato processing
- potato starch from ‘waste’ whole potatoes, and
- using starch from potato crops grown in the UK specifically for starch

Each of these options was investigated during the course of the study together with the impact on the supply chain including manufacture.

The UK does not qualify for subsidies under the EU quota system and therefore it is unlikely that starch potatoes would be grown as a main crop in the UK due to the economics involved. It is possible that potatoes could be grown on set-aside as long as they did not enter the food stream but investment in a starch plant to remove and process the starch would still be required. Reform of the CAP will reduce the link between subsidies and production but this will not assist farmers in the UK.

Potatoes are currently graded for size and skin finish on the farm, then they are packed. Potatoes which do not meet the required size are ploughed back into the land. Figures from the British Potato Council indicate that 8% of the total ware crop does not meet size specifications. The potential to use these potatoes for starch production was investigated but the lack of infrastructure coupled with the fact that these potatoes would be widely dispersed across the country discount this as a viable option.

The best option identified in the study was the use of waste from the potato processing industry which produces waste starch as a result of potato processing operations. Whenever a cut is made in a potato, starch is released. The more cuts that are made, the more starch is released. The potential starch available in the UK has been estimated to be around 17,000 tonnes per annum, enough to fulfill future projections relating to the number of trays required.

A number of issues such as cost and mixing, cycle time, curing time and starch properties were highlighted during the course of the project as areas which require resolution if mass production is to be achieved where consistency of product and performance would be required. Trials were conducted during the course of the project with some success. Testing to date has shown that waste starch performs better as a raw material for packaging production than imported starch. Additional work now needs to be conducted in order to further the knowledge base regarding some of these areas.

The degradable nature of the packaging is an important differentiating factor as compared to more ‘traditional’ packaging. Potatopak trays have currently not been certified under any of the biodegradable/compostable certification schemes and therefore do not outwardly display any logo. The use of a logo would help to improve sorting efficiencies in terms of both the household and at the back of supermarkets where currently packaging and perishable goods are separated for disposal.

The effect of the trays in a dry recyclables waste stream was investigated through a trial at a MRF (Materials Reclamation/Recovery Facility). This trial indicated that the majority of trays entering the facility ended up in the residue stream. However it should be noted that the trays used were dry and unused. Further trials should be conducted to investigate the behaviour of wetter trays as they may stick to recyclables preventing efficient sorting by sticking to packs preventing them from being blown into the correct stream.

Supply chain issues

1 Introduction

Packaging is a wide ranging, diverse sector and with sales of around $400bn pa[1] is one of the world's largest manufacturing sectors. In the UK, the industry has an annual turnover of £9billion and over 130,000 employees[2]. Competition within the industry is intense and pressures to evaluate and improve performance are particularly acute.

Whilst biodegradable packaging concepts have been around for a number of years, the uptake to date has been slow. However in recent years there has been increased interest in these technologies. There are several reasons for this, some of which are listed below:

- Increased media attention relating to sustainable development and environmental issues in particular have heightened public awareness.
- A change in consumer attitudes towards what they eat and a rise in the amount of 'organic' foods available has opened up potential markets.
- The publication of the UK Government's Waste Strategy 2000 highlighted the problems and potential crisis that the UK faces in terms of waste disposal issues. 28 million tonnes of municipal waste are produced annually in England each year of which almost 80% is sent to landfill sites. Household waste in England is growing at a rate of 3% annually – faster than the growth in GDP[3].
- The EU Packaging and Packaging Waste Directive (94/62/EC) introduced producer responsibility, sets targets for the recovery and recycling of packaging waste and sets out minimisation and recovery criteria for packaging.

There are a number of biodegradable materials currently on the market a few of which are included in the table below:

TABLE 1: SELECTION OF BIODEGRADABLE MATERIALS CURRENTLY ON THE MARKET

Material	Company	Type of material/source	Type of packaging
Alginsulate	Research team from Austria	Algae (brown seaweed)	Burger type boxes
APACK	APACK	Starch	Trays
Biophan	Trespaphan	PLA - polylactic acid	Film
Biopol	Metabolix	PHAs polyhydroxyalkanoates	Films, containers, trays etc
Compak	Compak (Packaging) Ltd	Vegetable oil	Trays
Earthshell	Earthshell Corporation	Potatoes, corn, wheat, rice, tapioca	Hinged lid containers, sandwich wraps
ECOLOJU	Mitsubishi Plastics	PLA	Film
	FARDIS	Starch based	Bags, cups
Lactron	Kanebo Gohsen Ltd	PLA from cornstarch	Trays, fast food packaging etc

1 The Packaging Manufacturing Industry Annual Report 2, The Packaging Federation
2 The Packaging Federation
3 Waste Not, Want Not – A Strategy for tackling the waste problem in England, The Strategy Unit, November 2002

Lacty	Shimadzu	PLA	
Mater-Bi	Novamont SpA	Corn, wheat and potato starch	Films for dry food, thermoformed trays, packing systems, foamed items, yoghurt cups, bags, liners
NatureFlex	Suface Specialities	Wood Pulp	Film
NatureWorks PLA	Cargill Dow	Fermentation of starch eg corn starch	Containers and films
Nodax	Procter & Gamble	PHA	Films, Flexible packaging
Potatopak	Potatopak	Potato starch	Trays, plates

The number and variety of biodegradable materials provides some indication of the competitive nature of the market. Ultimately, to be successful, Potatopak will need to either compete directly in terms of cost and performance or provide added value in some other form.

Potato starch packaging

The potato starch based packaging material produced by Potatopak, is being produced and used commercially in limited quantities. At the start of the project, the packaging was being manufactured from imported food grade starch. However several possible alternative GB supply options had already been identified including

a) the use of potato starch that is produced as a by-product during potato processing
b) potato starch from ‘waste’ whole potatoes, and
c) using starch from crops grown specifically for starch.

This project focused on identifying the opportunities, challenges and key actions facing the non-food starch supply chain if it is to deliver sustainable economic, environmental and social benefits through packaging produced from potato starch. The methodology employed is outlined in Appendix 1 of this report.

Potatoes – the raw material

Potatoes are cultivated worldwide, except in the lowland tropics. Table 2 shows potato production in the main EU Member States compared to World production in 2002. After cereals the tubers provide the main source of carbohydrate in the European diet and secondary uses include the production of starch and dextrose, industrial alcohol by fermentation and spirits. The paper and board industries are the largest non-food starch using sector, using approximately 60% of the total industrial starch. Potatoes are grown specifically for starch in several EU countries. The starch is obtained by industrial wet milling, refining and drying.

TABLE 2: POTATO PRODUCTION 2002

Country	Area Harvested (Ha)	Potato Production (t)
Austria	23,200	695,000
Belgium – Luxembourg	65,000	2,700,000
Denmark	39,000	1,600,000
Finland	29,600	719,200
France	170,000	6,700,000
Germany	284,000	10,975,000
Greece	45,600	880,000
Ireland	13,900	400,000
Italy	80,000	2,000,000
Netherlands	160,500	7,225,000
Portugal	80,000	1,200,000
Spain	109,800	3,062,000
Sweden	31,495	950,000
United Kingdom	166,000	6,650,000
EU (15)	1,298,095	45,756,200
World	19,256,031	307,886,519

FAOSTAT 2002

Potato processing

Potatoes are processed in the UK by a number of different companies including household names such as McCains, Walkers and Golden Wonder as well as less well known companies such as Cheviot Foods Ltd and Seabrook Potato Crisps Ltd. For a more complete list of processors, see Appendix 2. Table 3 below shows the tonnage of potatoes being processed in the UK providing an indication as to the size of the industry.

TABLE 3: ESTIMATED TONNAGE OF RAW POTATOES USED FOR PROCESSING IN THE UK

	1997/98 '000 tonnes	1998/99 '000 tonnes	1999/00 '000 tonnes	2000/01 '000 tonnes	2001/02 '000 tonnes
Canned/dehydrated/other					
Home grown	93	82	156	144	137
Imported*	3	3	1	4	3
Crisped					
Home grown	713	725	669	515	638
Imported*	5	7	15	151	26
Frozen or Chilled					
Home grown	1053	1112	1151	918	1033
Imported*	59	65	55	326	104
Total UK Grown Usage	1859	1919	1976	1576	1807
Total UK Production	7147	6448	7114	6288	6663
Total Processed in UK	**26%**	**29.5%**	**27.8%**	**25.1%**	**27.1%**

*Imports of raw potatoes used for processing in the UK
Source: British Potato Council, Potato Statistics in Great Britain 1998-2002

The GB potato industry currently produces around 17,000t p.a. starch as a by-product[45]. This currently has low value but could have added value by being used as a raw material for packaging. According to the British Potato Council, an additional 400,000t of potato waste results from processing and fresh packing operations. A further 1.2 million tonnes produced on farms do not enter the food chain as they do not meet customer specifications.

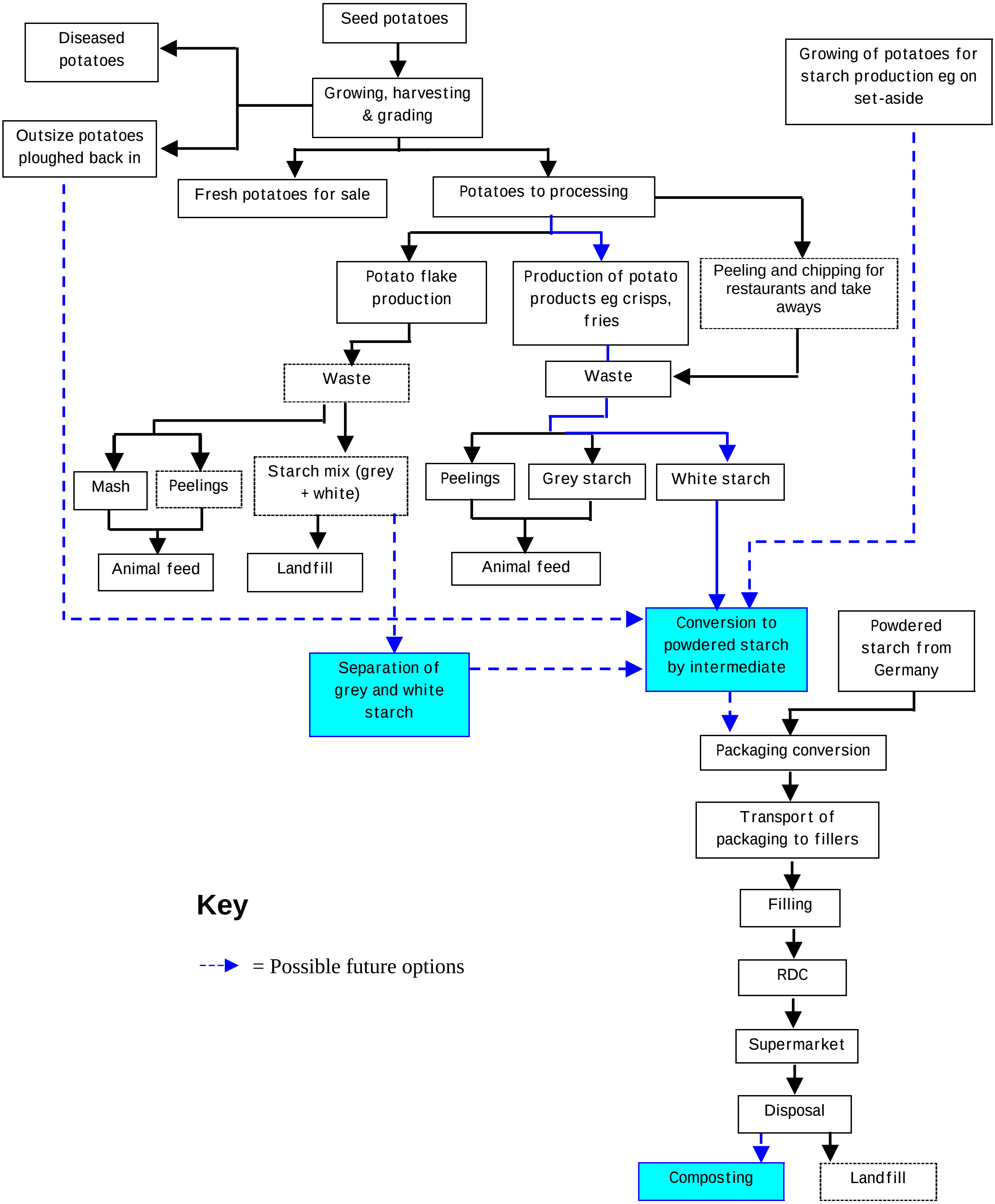
2 The Potato Packaging Supply Chain

As with most packaging supply chains, the potato packaging supply chain consists of raw materials supply, conversion, distribution of packaging to the filler, packing and filling, distribution of the packed product, selling and disposal of the packaging by the final user. This is shown diagrammatically in Figure 1.

4

5[5] Estimate provided by Stadex Industries

FIGURE 1: POTATO PACKAGING SUPPLY CHAIN



Key

---▶ = Possible future options

2.1 Raw materials

As already mentioned, at the start of the project food grade starch was being imported from Germany where potatoes are grown commercially as an industrial non-food crop.

However a number of potential options for GB supply were identified. These included:

- Growing potatoes specifically for starch
- Use of outsize potatoes
- Use of waste starch from the potato processing industry.

Each of these options are investigated below:

Growing potatoes for starch

The options available are:

1) to grow potatoes as a main crop
2) to grow as an additional non food crop on set-aside land

Figures from the British Potato Council estimate that there is approximately 50,000ha of land available which could potentially be used to grow potatoes.

1) Potatoes as a main crop

Potatoes are grown on the continent specifically for starch production. The EU provides subsidies to producers and manufacturers of starch through the starch quota system. Because of the direct competition between potato starch and maize starch in the market, in order to maintain equilibrium, starch potatoes are linked within the CAP to the Common Market Organisation of the cereals. Therefore calculations are based per tonne of starch (1.6 tonnes of maize = 1 tonne of maize starch = 1 tonne of potato starch).

The minimum price of potato starch has been cut by 15% over 2 years but from 2001/2002 is set at €178.31/tonne. This is based on the cereal intervention price of €101.31/tonne, and it is set at 110% of this figure ie €101.31 x 1.1 x 1.6 = €178.31/tonne of starch. The intervention price for cereals has been decreased in the McSharry and Agenda 2000 reforms with partial compensation for the farmers in the form of direct income support. Likewise starch potato growers get a direct income support of €110.54/tonne of starch contained in potatoes delivered to potato starch manufacturers.

To compensate the potato starch industry for shorter campaigns – ie idle factories for part of the year, and fewer by-product revenues than in the maize starch industry - an equilibrium premium is paid directly to the starch manufacturers of €22.25/tonne of starch provided they pay producers the minimum price for potatoes.

Starch potatoes are not easily distinguished from ware potatoes, therefore the subsidies for potato starch are not given per hectare but per tonne of starch delivered to the factory. Consequently the system is not limited by fixing a maximum area as with cereals, but by means of starch production quotas. The direct income payments are made only in respect of the quantity of potatoes covered by a cultivation contract between the potato producer and the starch manufacturer within the limit of the quota allocated to that undertaking.

Starch quotas are based on historic production and when they were introduced the UK had no history of starch production for industrial use. Hence the UK has no quota.

In May 2002 the starch quotas were fixed for another three years, ie marketing years 2002/3, 2003/4, 2004/5. In 2004 they are up for a regular 3-year evaluation, and the Commission must submit a report on quota allocation to the Council by September 2004, together with proposals which will take account of possible changes in the cereal and potato starch markets. This report will form the basis for future Council decisions on quota allocation. In 2004 the accession of 10 Central and Eastern European countries is expected, some of which have starch quotas: Poland 114,985, Czech Republic 33,660, Latvia 5,778, Lithuania 1211, Slovakia 700 and Estonia 250 tonnes per year. Quotas for EU countries are shown in Table 4. The quota for Spain has never been used.[6]

TABLE 4: STARCH QUOTAS

	Starch quotas, tonnes		
Country	1995/6 to 1999/00	2000/01	2001/02 to 2004/5
Germany	696,271	676,680	656,298
Netherlands	538,307	523,161	507,403
France	281,516	273,595	265,354
Denmark	178,460	173,439	168,215
Sweden	63,900	63,001	62,066
Finland	54,750	53,980	53,178
Austria	49,100	48,409	47,691
Spain	2,000	1,972	1,943
EU Total	1,864,304	1,814,237	1,762,148

In the past it has been suggested that the UK should try to negotiate a change and receive a quota. However, it seems unlikely that this approach will be taken as it goes against current thinking of relying on market forces. Potatoes could in principle be grown in the UK just for the starch with no subsidy, but potatoes grown for food are a high value crop with good margins[7]. Indeed, it is interesting to note that, despite subsidies, some Dutch growers are actually pulling out of starch production because of pest and disease problems as this means that the crop cannot be grown to its full yield potential.

Potatoes grown under this quota system tend to be specific varieties which have a higher dry matter content than ware potatoes. The dry matter content of ‘starch’ potatoes is approximately 26%, compared to approximately 22% for food varieties.

The potato varieties currently grown in the UK are very specific and are grown for particular qualities such as skin finish. Table 5 below shows provisional figures for total plantings in 2003 by variety.

[6] Information on starch quotas from conversation and email communication with W. de Zeeuw, Director of Corporate Public Affairs, AVEBE

[7] Conversation with Sarah Hugo, GIFNFC

TABLE 5: TOTAL POTATO PLANTINGS IN 2003 BY VARIETY (HECTARES) PROVISIONAL

Variety	England 2003	Scotland 2003	Wales 2003	Great Britain 2003	Great Britain 2002	% change 2003 on 2002
First Earlies						
Dundrod	345			345	513	-33%
Maris Bard	1483	166	16	1664	2227	-25%
Minerva	27		28	56	128	-56%
Pentland Javelin	127	91		218	378	-42%
Premiere	1793	240	105	2138	2461	-13%
Rocket	96	131	19	245	287	-15%
Winston	140	93	52	284	244	+16%
Other First Earlies	253	175	29	457	700	-35%
Total First Earlies	**4263**	**895**	**249**	**5407**	**6937**	**-22.1%**
Second Earlies						
Carlingford	448	214	13	676	460	+47%
Charlotte	880	473	8	1362	1631	-17%
Estima	9363	1262	214	10840	15769	-31%
Fambo	405	0	3	409	677	-40%
Marfona	3369	397	115	3880	5475	-29%
Maris Peer	4062	1616	109	5787	4625	+25%
Nadine	3020	1633	155	4808	7348	-35%
Nicola	581	694	0	1275	1573	-19%
Saxon	794	1512	0	2306	2773	-17%
Victoria	424	14	20	457		
Wilja	1205	253	22	1480	1898	-22%
Other Second Early	129	472	6	607	441	+38%
Total Second	24680	8540	666	33886	42670	-20.6%
Total Earlies	**28943**	**9435**	**915**	**39293**	**49607**	**-20.8%**
Maincrop						
Accord	447	1	45	493	n.a.	
Ambo	433	57	1	491	608	-19%
Cara	1341	829	14	2184	4913	-56%
Cultra	254	909	0	1163	1303	-11%
Desiree	3139	1773	14	4926	5168	-5%
Fianna	532	5		537	365	+47%
Hermes	3066	920	0	3986	4552	-12%
King Edward	2872	708	9	3590	3673	-2%
Lady Rosetta	5592	286	66	5944	6030	-1%
Maris Piper	24433	4728	113	29275	28451	+3%
Morene	726	105		831	851	-2%
Osprey	166	1220	0	1386	n.a	
Pentland Dell	4821	585	49	5455	6171	-12%
Romano	1512	262	44	1818	1537	+18%
Russet Burbank	2624	280	40	2944	3070	-4%
Sante	1581	185		1766	2860	-38%
Saturna	4813	437	10	5259	5013	+5%
Shepody	1410	210		1619	1781	-9%
Other Maincrop	6312	2638	196	9147	12712	-28%
Total Maincrop	**66074**	**16138**	**602**	**82814**	**89057**	**-7%**
Total All Varieties	**95017**	**25573**	**1517**	**122107**	**138664**	**-11.9%**

The reductions in the total plantings in 2003 were a result of growers in GB cutting back production as a result of oversupply which led to very low prices for two years running.

On 26 June 2003, the EU Agricultural Council agreed fundamental reform of the Common Agricultural Policy. In principle all the major farm subsidies will be replaced by a new single farm payment to promote a more market oriented, sustainable agriculture. Member States will be able to introduce this payment from January 2005, but may, if they wish, delay this until 2007 under certain conditions. This should greatly simplify the CAP and in general will break the link between subsidies and production. However, Member States may choose to maintain a limited link between subsidy and production to avoid abandonment of production.

With respect to starch potatoes, the current policy provides for a direct payment of €110.54 to growers of starch potatoes. In the future, 40% of this payment will be included in the single farm payment, on the basis of the historical deliveries to the industry. The remainder will be maintained as a crop specific payment for starch potatoes. The minimum price will be maintained, so will the production refund for starch.

2) Set-aside land

Prior to the Common Agricultural Policy (CAP) Reform of 26 June 2003, under the Arable Area Payments Scheme (AAPS) of the CAP, all significant producers of cereals were required to set-aside a minimum 10% of their land in order to be eligible for arable area payments. This was referred to as ‘obligatory’ set-aside. Further land could then be set-aside on a voluntary basis. The main objective of set-aside was to control the surplus production of cereals in the EU.

Under the CAP reform agreement set-aside is maintained, based on the amount of land a farmer had in compulsory set-aside in the simplified payment reference period. This land is covered by the same payment system, but subsidy is only paid if the land is kept in set-aside, although rotation is allowed.

Farmers can grow specified crops for approved industrial purposes on set-aside land and still receive the annual set-aside payment. In the UK, the main crops grown on set-aside land are industrial oilseeds and energy crops but it is theoretically possible to grow potatoes on set-aside land. The explanatory guide to the Arable Area Payments Scheme in Part II lists crops which can be grown on set-aside land for use in the manufacture of certain end products, which are not for human or animal consumption. Potatoes are allowed provided they are grown for the manufacture of some types of packaging. The packaging is defined by customs nomenclature codes and conversations with DEFRA suggest that Potatopak trays would fall within the codes.

It is likely that if a grower intended to grow potatoes for this purpose it would be necessary to liaise with the Rural Payments Agency (which deals with the enforcement of non food crops on set-aside), DEFRA and potato processors. The administrative arrangements could then be established to ensure there was no diversion of potatoes or products to food use. It would be necessary to ensure that no by-product from starch production went for human or animal consumption or that it was below the value of the primary product ie starch.

The rate that farmers are paid for set-aside land is currently €371.07 per hectare. Given a yield per hectare for maincrop potatoes of 49.2t/ha[8], this would in effect provide a subsidy of €7.5 per tonne. However, this separate subsidy will end from 2005 and will be included in the new single payment.

Outgrade potatoes

Potatoes are currently graded for size and skin finish on the farm when they are packed. Potatoes which do not meet the required size are ploughed back into the land. 1998 figures indicate that 8% of the total ware crop (equating to approximately 480,000 tonnes) did not meet size specification which is particularly important for the processing and prepack markets. The cost of this wastage to the industry is in the region of £24million.[9]

[8] British Potato Council, Potato Statistics in Great Britain 1998 - 2002
[9] British Potato Council Crop Wastage Survey 1998

Starch production from specifically grown or outgrade potatoes

To release starch from potatoes grown specifically for starch production or from outgrades, the potatoes would need to undergo rigorous processing to release the starch. The box below outlines the individual processes necessary to harvest the starch.

*Industrial Potato Starch Production**

Cleaning and Washing

Fresh potatoes are carefully cleaned before starch extraction as soil and dirt not removed in the washing station give problems later. Loose soil and stones are removed on rotating screens before the potatoes are deposited in the store.

Potatoes are flumed by water in channels, passing a stone trap which relies on the difference in density between stones and potatoes, to the washing drum, where the potatoes are vigorously rubbed against each other to remove fungi, rotten areas, skin and dirt. A high standard of washing improves refining because many impurities are similar to starch in density and size, so washing the potatoes is the only way to get rid of them. Clean water is used in the final high-pressure spray.

Rasping (grinding)

Rasping is the first step in starch extraction. All the potato cells have to be opened to release the starch granules, The slurry obtained can be considered as a mixture of pulp (cell walls), fruit juice and starch. With modern high speed raspers, rasping is a one pass operation.

Sulphur dioxide gas or sodium bisulphite solution is added to prevent discoloration which would otherwise occur when the sugars and proteins in the cell juice react with oxygen.

Extraction

Powerful washing using the undiluted potato juice extracts the starch granules from the open cells. Rotating conical sieves made from stainless steel with long perforations 125 microns wide are used to separate the starch granules and juice from the cell wall material (pulp).

Concentration of starch milk

The crude starch milk (starch and juice) is concentrated on a series of hydrocyclones. To save rinsing water, this is a countercurrent operation with fresh water added only at the last stage. The different densities of the starch, cell wall (fibres), water, soil and sand causing separation.

TABLE 6: DENSITIES

	Density g/ml
Starch	1.55
Cell walls (fibres)	1.05
Water	1.00
Sand, soil	>2.0

Fibres, which just float, are carried away with the overflow. However, any soil, sand, fungi etc are of equal or greater density than the starch and so cannot be separated by centrifugal force.

Drying and sifting
Most of the water is removed from the starch on a rotating vacuum filter and the dewatered filter cake is dried in a stream of hot air in a flash dryer. The dried starch and drying air are separated on cyclones and the starch is cooled in a stream of cold air. The cooled, dried starch is screened on cyclone screens ready for storage, packing or bulk delivery. The starch yield in a modern process is close to 96% of the granular starch in the raw material.

*Information sourced from International Starch Institute, Denmark (www.starch.dk/isi/starch/tm5www-potato.htm)

The UK currently has no infrastructure to process potatoes for starch production although some capacity may exist at the peelers/chippers who produce chips for the restaurant industry.

Information from the International Starch Institute in Denmark indicates that the current price for a plant capable of processing 45tonnes/hour of potatoes with 18% granular starch content into 8.1 tonnes of starch per hour is approximately £3million. This would be a medium size factory – the typical output of factories in Denmark is more than 20 tonnes per hour. Usually such a plant would run continuously for 6 months of the year (September to February), and the rest of the year is used for maintenance. In a year this would produce approximately 35,000 tonnes of starch, considerably in excess of the projected requirements for starch trays in the UK in the near future ie the total for both organic and conventional fruit and vegetables. Added to this investment would be the costs associated with growing potatoes for starch where applicable, labour, energy and transport of the potatoes from farm to factory (assuming use of set-aside/outgrade potatoes etc as raw material). Costs vary but, as an example, for a factory based in the Cambridgeshire area estimates have been given of £5 per tonne for potatoes from a local source or £15 per tonne for potatoes from Shropshire. The costs associated with growing starch potatoes in the UK which are shown below are the result of a trial planting carried out by Greenvale.

TABLE 7: STARCH POTATO YIELDS

Variety	Field acres planted	Yield/tonnes	Av. Yield per acre
Elkana	32	457	14.5
Elise	34	550	16.4

Total field acres planted 66
Total tonnes produced 1007
Average yield tonnes/acre 15.26

TABLE 8: COSTS

	£
Average cost ex field per acre	1170
Average cost/tonne	76.72
Average store cost/tonne	18.00
Gas application per tonne	2.50
Haulage field to store	6.50
Cost per tonne ex store	103.72

Notes:

- The starch varieties yielded poorly against main crop where Maris Piper yielded 25 tonnes per acre in the same growing period and on similar soil

- Dry matter percentages in both varieties were higher than the main crop at 29.5 and 30%. The main crop averaged 22%
- The above crop is in store and will be processed early 2004
- Haulage costs from the store to the factory are similar to that from field to store.

A report prepared in 1982 for the Potato Marketing Board[10] indicated it would not be economic to run a starch production factory without price support. At that time the maximum price that it would be possible to pay the growers without price support would have been £10 per tonne.

The position is not likely to have changed significantly as potato growers in the starch producing countries of the EU continue to receive a subsidy and hence can deliver at a lower cost. In addition, the investment in such a plant is significant and it would be necessary to ensure there was a market for the remainder of the starch produced which was not used for starch trays.

Estimates for the amount of starch produced from potatoes are shown below:
Food potato – 7 tonnes potatoes = 1 tonne of starch
Starch potato – 5 tonnes of potato = 1 tonne starch

Waste from the potato processing industry

An alternative to growing potatoes specifically for starch is to utilise waste from the potato processing industry. The potato processing industry including for example, McCain's which produces chips, Greenvale producing potato flake and Walkers producing crisps, together with peeling and chipping companies producing chips for the restaurant and take away business, all produce waste starch as a result of potato processing.

Different varieties of potato are used throughout the processing industry but they are fairly specific for the different applications. McCain's for example use Pentland Dell, Russett Burbank, Maris
Piper, Maurine and Premier. PAS Grantham use Maris Piper, Estima, Yukon Gold, Astrix, Fiana, Maurine, Pentland Dell, Cara and Premier.

The processing of potatoes produces distinct waste types from different points within the system. These wastes can be split into:

- Peel, skins, slivers and nubbins
- white (or free) starch
- grey (or gelatinised) starch (containing washed peel, soil and fibre)
- mash (from potato flake processing).

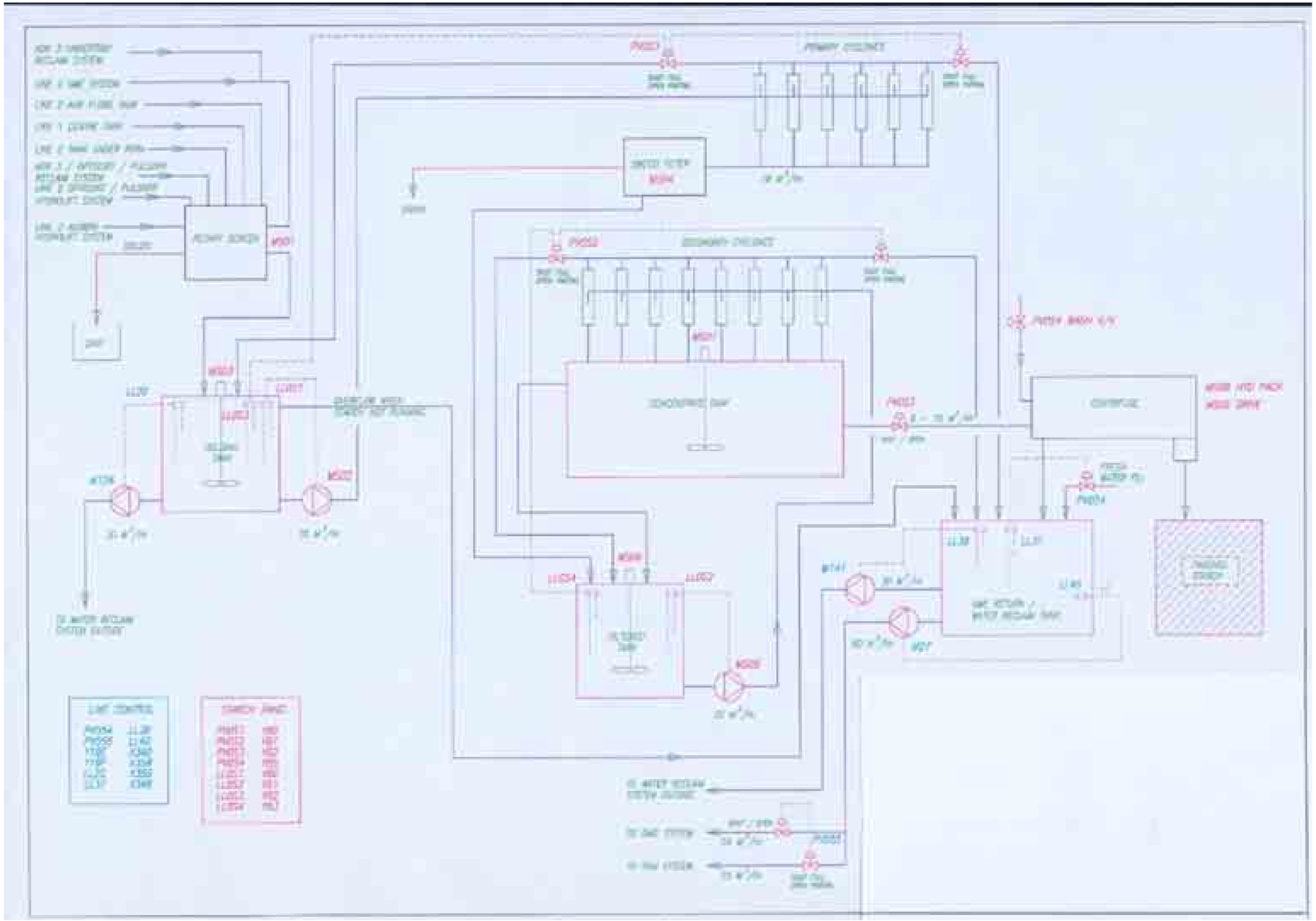
[10] The Potential use of UK Potatoes for the production of starch and starch derivatives. Laurence Gould Consultants Ltd. Dec 1982

The peeling of the potatoes is carried out by either mechanical or steam peeling. Mechanical peeling is carried out by abrasion and is used, for example by Walkers and Golden Wonder. In steam peeling, used for example by McCains and Greenvale, the potatoes are placed in a steam chamber for up to four seconds. The outer layer of the potatoes (4-5mm) is heated to above 62-65^{o}C which results in the skin in effect being blown off. The heating of the potato bursts the starch cells in this "outer halo" which become soluble and dissolve in the potato juice making them subsequently difficult to separate. Once in this state the starch is often known as grey or gelatinised starch. Undamaged starch is known as white starch and is insoluble making it easy to separate. It is this white starch which has most value in terms of potential packaging applications due to its colour and consistency.

Once the potatoes are peeled, they are sliced. As cuts are made in the potato, white starch is released. The more cuts that are made, the more starch is released. Hence waste starch production from potato processing activities will be much greater from crisp manufacturers such as Walkers and KP than from chip manufacturers. Slivers (which are too small to be made, for example, into chips) and nubbins which are rejects, perhaps because of an eye or mark, are disposed of along with the peel. However there is potential to macerate and centrifuge these wastes and release the starch. It has been estimated that one company, Garden Isle, produces approximately 10,000t of slivers and nubbins per annum equating to approximately 1,500t of starch.

A schematic diagram of the starch recovery at a processing plant is shown in figure 2.

FIGURE 2: SCHEMATIC OF STARCH PLANT



Waste such as peel, skins and mash from the potato processing industry is often used in animal feed. Pre foot and mouth, many processors were able to sell their waste for this purpose. However currently, the market has collapsed and some processors are having to pay for it to be removed. Costs depend on the type of waste and the quality. Companies which separate the white starch from the grey starch using a system comprising of hydrocyclones, filters and centrifuges can sell on the recovered white starch as a by-product to the starch processing industry.

The potential volume of white starch currently available in the UK is estimated to be approximately 17,000 tonnes per annum[11] enough to fulfill future projections relating to the number of trays required.

Increasing environmental pressures to prevent waste water contamination, through the EU Urban Waste Water Treatment Directive (91/271/EEC)[12], have resulted in an increasing number of potato processing operations installing plant to recover the waste starch[13].

2.2 Conversion of waste starch by an intermediary

White starch recovered from the processing industry contains approximately 55% solids. At this level the starch is not stable and micro-organisms are able to use the available water. Intermediate companies such as Stadex Industries are able to further dry this starch to 18-20% moisture. At this level microbes are unable to utilise the water as it is locked up within the starch granule. Starch is typically processed within 4 days (depending on weather conditions) to stabilise and prevent colonisation by micro-organisms.

To maintain a reliable source of supply from this route, the starch processing industry itself needs a reliable source of material. This has been shown to be the case during the lifetime of the project with the closure of the Oldham site of Stadex Industries. The closure was due to the diversion of the waste starch from one of the Walkers sites to another use. Machinery from Oldham was dismantled and moved to the remaining site at Wrexham but costs involved in rebuilding have prevented this machinery from running again to date. However, provided tonnages of 60-80t per week could be guaranteed, it would be possible to restart production at Wrexham.

The machinery at Oldham subjected the starch to a washing process (removing fibre, sugars etc) prior to drying. This produced a very consistent product – the 905 starch. Machinery in place at the Wrexham site sieves rather than washes the starch producing a less consistent end product, PD890.

[11] Personal conversation, Terry Davies, Stadex

[12] Definition from 97/271/EEC - 'urban waste water' means domestic waste water or the mixture of domestic waste water with industrial waste water and/or run-off rain water

[13] This Directive was adopted by member states in May 1991 and transposed into legislation across the UK by the end of January 1995. Its objective is to protect the environment from the adverse effects of sewage discharges. It sets treatment levels on the basis of sizes of sewage discharges and the sensitivity of waters receiving the discharges. By the end of 1998 the UK had stopped all disposal of the sewage sludge left over from treatment processes at sea or to other surface waters in accordance with its requirements.

2.3 Packaging production

Trays, cups and plates made from potato starch are produced by Potatopak Limited using compression forming techniques. Potatopak produces a range of trays for different applications using a range of ingredients from a given ‘basket’, for example, the apple tray for organic apples has 7 added ingredients, the chip tray only 4.

Production is small scale and various issues were identified throughout the course of the project which required resolution if mass production was to be achieved. Some of these have been addressed within the scope of the project, some will require further research/action outside of the project. The issues identified at the start of the project include:

Issues:
- Cost of the trays compared to ‘traditional’ alternatives. Imported starch vs GB starch
- Hand mixing of batches
- Cycle time
- Curing time
- Browning of cut stems packed in Potatopak trays and softening of trays.

2.3.1 Cost

Cost is an important factor if Potatopak is to persuade retailers to increase the use of their pack. Retailers are generally working with small margins and look to save costs wherever possible. The Potatopak trays are currently approximately 2 times more expensive than the alternative EPS trays. It is therefore imperative that some of the cost of production is removed from the system.

Costs arise in three main areas:
- Raw materials
- Energy
- Labour.

Raw materials

Potato starch is the main ingredient of the process with other ingredients being added depending on the mix being made. At the outset of the project, imported food grade starch was being used. This has the advantage that it would not cause harm if ingested accidentally. However it carries a premium in terms of price. Starch from the processing industry is classed as industrial grade starch.

The different categories of starch are outlined below:
A: Food grade starch
B: Animal feed
C: Industrial Grade

The differences between the categories relate to the number of viable micro-organisms present. It is likely, in the case of the Potatopak trays that the temperature achieved during the forming of the trays destroys any microbes that may be present. However this has not been tested.

Starch obtained from the GB potato processing industry is available much more cheaply than the imported starch. Trials conducted with Stadex 905 starch produced at the Oldham site provided very promising results. However the PD890 starch, produced at the Wrexham plant has produced a less consistent and weaker product. This is likely to be the result of the different treatment process used (sieving instead of washing) rather than issues with the starch itself. The PD890 had a moisture content of approximately 17% compared to 18.5% for 905 and this resulted in it being necessary to add more water to the production mix created at Potatopak. This may have caused the inconsistencies noted. However, moisture contents frequently vary by ±1% and this may be typical of the variation that Potatopak will have to control.

Potatopak is also investigating ‘wasteless’ moulds. Currently some mixture is ejected from the moulds during the forming process and whilst some of this is reground and reused, some is inevitably wasted. By using ‘wasteless’ moulds, less material is required at initial dosing, reducing the overall amount of raw material and energy required for production.

Currently 1 tonne of starch can be used to make approximately 43,000 trays and the maximum output would be 425,000 trays per month if all machines were running with the same tray.

Imported vs GB starch

Trials have been conducted using starch recovered from the processing industry and further refined by Stadex Industries. The starch used for the trials, the ‘905’ starch has resulted in a significant decrease in the curing time down to the point where trays can be packed almost directly after forming. Trays produced from this starch also have improved moisture resistance and more flexibility.

The reasons for this improvement are unclear however potato starch rheology is influenced by:

- Amylose:amylopectin ratios – if the amylose content is too low it is not possible to make a viable product, quality is also poor – amylose affects viscosity and amylopectin affects strength
- The degree of crystallinity in the highly branched amylopectin
- Phosphate content
- Granule size distribution.

Starch properties can change between varieties and also can be influenced by site/season. Added to this, starch properties can change with time in storage as the starch starts to be broken down to provide carbon for respiration, sprouting etc, adding to the existing variation.

For example, data has been published on variation in composition and properties between three potato genotypes grown at two different sites and in two different years.[14] Differences in the chemical compositions of the granules were investigated using blue values of the starch iodine complexes as indicators of amylose contents, and from phosphorus contents. Several physical properties were measured including granule size and viscosity.

[14] Morrison I et al, J.Sci Food Agric 81 p319-328, 2000

The differences between apparent blue values of the complexes, which was used as an indicator of amylose content were significant between genotypes, but not between sites and years. However, the phosphorus contents of the starch samples were strongly affected by the genotype. For 86Q35(8), Glamis and Record, the three potato varieties, the mean phosphorus contents over both sites and over both years, were 1.06 ± 0.17, 0.53 ± 0.06 and 0.66 ± 0.08g/kg starch. The phosphorus contents were also influenced by site, with the Ormskirk samples having significantly higher phosphorus contents than the Mylnefield samples, but the effect of the year was less significant, (see table 9).

TABLE 9: APPARENT BLUE VALUES AND PHOSPHORUS CONTENT OF THE THREE POTATO VARIETIES

	86Q 35(8)				Glamis				Record			
	M/96	O/96	M/97	O/97	M/96	O/96	M/97	O/97	M/96	O/96	M/97	O/97
Apparent blue value	0.36	0.36	0.41	0.45	0.40	0.41	0.34	0.39	0.37	0.41	0.37	0.33
Phosphorus, g/kg	0.84	1.18	1.06	1.22	0.49	0.61	0.55	0.55	0.59	0.70	0.76	0.64

M grown at Mylnefield, O grown at Ormskirk
96 grown in 1996, 97 grown in 1997

Particle size of the starch granules was determined by the Coulter counter for 1996. There were no significant differences between the sites for any of the genotypes but there were significant differences between the genotypes themselves. The mean modal diameter for 86Q35(8) was approximately 32µm, for Glamis 35µm and for Record 40µm.

A Rapid Visco Analyser was used to measure viscosity. Peak viscosities were strongly influenced by genotype, site and year. Also differences in the hot paste viscosity values for genotype, site and year were all highly significant. Final viscosities were also significantly different.

Final viscosity values are essential when choosing a particular genotype when either high or low viscosity is required. These viscosity profiles provide evidence of considerable variation between genotypes, sites and years and also between sites and years for the same genotype.

These results demonstrate some of the differences in amylopectin, phosphate content and granule structure – all of which affect starch viscosity. If potatoes were to be grown for potato starch for trays then consideration would need to be given to genotype not only to optimise starch content but also viscosity and manufacturing parameters.

Trials have also been conducted with a hydrophobic starch with a cross linking agent from Biocomposites Centre. Unfortunately initial results were not promising. The starch trialled was hydrophobic but the method used to make the modification also introduces some element of water-sensitivity into the product. By using aqueous alkali as the 'solvent' for the modification, the starch is pre-gelatinised, its granular structure is lost and the starch molecules become more sensitive to water (but also to hydrophobising reagents). When the modification is made, hydrophobicity is introduced but it appears not to a large enough extent to overcome the water sensitivity that's also induced[15].

[15] Information from Biocomposites Centre

Energy

Energy is a huge cost to the business. The production of the trays involves the release of large quantities of steam. This is currently released to atmosphere within the factory. There is a possibility that this steam could be utilised in some way and Potatopak is investigating the possibility of conducting an energy audit. Utilisation of the steam would also improve the climate within the warehouse which has an influence on curing time.

The use of solar panels on the factory roof was also investigated but this will only deliver single phase electricity, not the three phase required to run the machines.

Labour

Tray production requires a minimum of two people and frequently three are being used on some shift patterns. However, it is possible to significantly increase production and utilise more machines, when there is sufficient demand, and still use the same number of people, reducing the labour costs per tray.

2.3.2 Hand mixing of batches

To date mixing of batches has been carried out in relatively small quantities with ingredients being manually added by skilled staff in a set sequence. Manual mixing allows adjustments to be made to the mix to account for any inconsistencies that may occur. Inconsistencies are noticed in the mixes made by different staff even when set procedures relating to quantities and sequence are followed.

It is recognised that automatic mixing and dosing would be required for a larger scale operation. This has been considered and investigations relating to rheology and viscosity of the mix have been undertaken. To date these trials have not determined any differences.

2.3.3 Cycle time

Another issue for the production of trays is the cycle time ie the time from injection of the mix to ejection of the tray. This depends on the specific mix being used, for example:

- Trays for organic apple trays - 140 seconds
- Trays for other apples - 60-70 seconds
- Trays for outside catering - 50 seconds.

Reduction in the cycle time would allow increases in production efficiency. However cycling too quickly makes the trays brittle. The mix cannot be heated up prior to entering the moulds as it gelatinises in the pumps.

As a comparison, the cycle time and speed of production for similar trays made from traditional plastics are shown in table 10 below.

TABLE 10: SPEED OF PRODUCTION

Material	Cycle time	Speed
EPS	9 or 12 up, cycle time 3.5-4 seconds	125-150/min
APET	Dependent on depth of tray	~ 200/min

It is estimated that to have a fully automatic plant for producing Potatopak trays with automatic mixing, producing approximately 300 trays per minute with automated packing etc would cost in the region of $5m, an enormous investment.

2.3.4 Curing

'Curing' is the process by which the trays reach equilibrium once ejected from the moulds. Forming trays with imported starch requires a curing time of between 18-36 hours during which time the trays typically gain approximately 6g. This is an essential part of the process but adds an additional manual handling step to the production process and takes up considerable space.

The curing time of the trays produced using the Stadex 905 starch was dramatically reduced with trays being packed within 15-20 minutes after production. This occurred during the summer months when humidity within the factory was reduced due to increased ventilation though doorways and higher external temperatures. This is a huge step forward in terms of production.

On the basis of these results, a budget has been made available to purchase controlled air extraction and climate control within the factory.

2.3.5 Performance

Whilst Potatopak trays have some unique features, most prominently their biodegradability, they are competing for market share with more traditional forms of packaging.

In relation to EPS trays, for example, Potatopak trays tend to be more brittle and have lower moisture resistance. Some simple tests were carried out on a small sample of trays by Pira International and the results obtained are shown in Appendix 3.

Packaging requirements are normally outlined in a packaging specification document allowing users to ascertain 'Fitness for Purpose'. Demands from consumers requiring longer shelf life products with fewer preservatives have placed much higher demands on the packaging itself. Composite packaging, for example, has increased in prominence due to the ability to achieve these performance requirements with thinner materials.

The properties associated with some common single material packaging plastics are shown in tables 11 and 12 below.

TABLE 11: PROPERTIES OF SOME COMMON PACKAGING PLASTICS

Plastic	Properties
EPS sheet	Can be folded up to 180^{o} without breaking – tough Moisture resistance - high Moisture barrier – low to intermediate (depends on foam density)
APET	Stiff, strong Moisture barrier – moderate Gas barrier – moderate
PVC	Stiff, strong Moisure barrier – good Gas barrier – moderate

TABLE 12: OXYGEN PERMEABILITY AND MOISTURE PERMEABILITY OF SOME COMMON PLASTICS[16]

Plastic	Oxygen permeability cc/m^2.d.atm for 25µ film	Moisture permeability g/m^2.d for 25µ film 38^{o}C/90%rh
LDPE	6500-8500	15-20
PET	100-150	15-20
PS	4500-6000	70-150

2.4 Distribution

The amount of product being packed by individual packers is relatively small. Packaging is bought in bulk by Produce Packaging who sell it on in smaller volumes to the individual packers.

Due to the quantities of Potatopak trays currently being sold, transport to the distributer (Produce Packaging) is on an ad hoc basis, fitting in around other deliveries (use of back loading etc). If volumes were to increase significantly, Potatopak would need to arrange for full articulated vehicle loads to be sent to Produce Packaging in Kent. The associated costs would be approximately £350.00 per full load with a full load containing approximately 750,000 trays.

However Potatopak trays do offer a significant space saving over EPS trays, although this is not at present optimised as Potatopak are using a standard carton to hold the trays rather than a bespoke one.

The carton currently being used measures 485x317x300mm and holds 250 of the 4 apple trays.

The EPS trays from Italy are packed 700 into a large plastic bag which measures approx 1200x340x600mm.

TABLE 13: DIMENSIONS OF TRAYS:

Tray	Thickness	Dimensions
Potatopak	2.5mm	162 x 142 x 25mm
EPS	5mm	170 x 150 x 35mm

From the information it can be calculated that the EPS trays occupy approximately twice the volume of the Potatopak trays (350cc compared to 184cc) (see Appendix 4 for calculations). This is confirmed by the fact that the trays are of similar dimensions and the EPS tray is about 5mm thick and the Potatopak tray 2.5mm thick.

2.5 Potential Market

Currently Potatopak trays are used for outdoor events and for some organic ranges of produce. Table 14 provides an estimate of the current total market potential, in terms of fresh produce, for Potatopak trays given restrictions such as range of trays available. Table 15 provides future market potential if some of the current issues were resolved.

[16] Fundamentals of Packaging Technology, Walter Soroka

TABLE 14: CURRENT MARKET POTENTIAL

Sector	Organic / annum*	Conventional/annum*	PotatoPak Tray type	Notes
Top fruit / citrus (apples, pears, oranges and lemons)	4,000,000	0	4 and 6 ridge trays	Limitations • Cost • Market for citrus limited by an occasional reaction of the tray and the citrus peel resulting in trays becoming soggy
Soft Fruit (strawberries etc)	0	0		• No product available
Stone Fruit (plums, peaches etc)	20,000	0	4 and 6 ridge trays, 4 domed trays	• Limited due to high percentage of moisture given off by stone fruit leading to 'soggy' trays • Delicate nature of stone fruit can lead to bruising if not adequately protected
Salads (tomato)	0	0		• No suitable tray available
Vegetables (courgette, baby sweet corn, mange tout etc)	0	0		• No suitable tray • Issue relating to cut stems browning due to reaction with raw material component

* estimates *Source: Produce Packaging*

TABLE 15: FUTURE POTENTIAL

Sector	Organic/ annum*	Conventional / annum*	PotatoPak Tray type	Notes
Top fruit / citrus (apples, pears, oranges and lemons)	6,000,000	15,000,000 to 20,000,000	4 and 6 ridge trays	Takes into account • reduced costs • manufacturing output increases • reaction of trays with peel overcome
Soft Fruit (strawberries etc)	4,000,000	80,000,000		• Automatic packing important in this market • Would require ability to be lidded • Requires clarity similar to A-PET
Stone Fruit (plums, peaches etc)	1,500,000	35,000,000 to 40,000,000	4 and 6 ridge trays, 4 domed trays	Based on • Improved moisture resistance • Increased protection offered by material (eg properties similar to EPS)
Salads (tomato)	30,000,000	80,000,000 to 90,000,000		Would require: • Punnet for automatic packing

				lines taking standard weights of tomato, 250g, 500g and 1kg • Flat trays required for vine tomato and large tomato packs • Clear material for conventional product
Vegetables (courgette, baby sweet corn, mange tout etc)	30,000,000	70,000,000 to 90,000,000		Requires • Range of trays • Issues of browning must be overcome • Issue relating to cut stems browning due to reaction with raw material component must be overcome

*estimates *Source Produce Packaging*

These figures indicate the huge potential market available within the fruit and vegetable sector.

2.6 Retail

One of the major issues for Potatopak is to encourage uptake of the trays by the retailers. There has been some success to date with trays being used for some of the organic range within Sainsbury's supermarkets, specifically four apple trays.

One of the advantages of using a compostable packaging (including trays, films and labels) for fruit and vegetables is that out of date produce from the back of store need not be separated from the packaging prior to disposal, increasing efficiencies. 'Traditional' packaging must be separated from organic material.

Some of the issues preventing further roll out include:

Cost. Potatopak trays are currently almost twice the cost of the traditional alternative (EPS)

Tray design. The current tray design is not suitable for all types of fruit and vegetables, for example, punnets for cherry tomatoes and clear trays

Differentiation. Supermarkets and major brand holders wish to have a clearly differentiated pack, for example, by colour or printing. Colour could be added to trays without much additional cost but changing moulds for different designs would be a significant additional cost in terms of manufacture. However, costs would be increaed in terms of distribution for both colour and design as a greater range of trays would need to be held in stock at any one time.

Assuming uptake throughout the fruit and vegetable sector, approximately 400million packs would be required per annum. This number of trays could in principle be met by the amount of waste starch currently available. However there are two potential issues relating to the utilisation of waste starch. Firstly, Potatopak would be solely reliant upon the waste starch able to be purchased by Stadex Industries and, as has recently been demonstrated with the withdrawal of waste starch supplies from Walkers and the closure of the Stadex Oldham plant, this could prove to be problematic. Secondly, in the last two years, particularly in the United States, it has been reported that processed potato consumption has fallen by 5% per annum in the last two years due to several factors including lower carbohydrate intake caused by such publicity as the Atkins Diet and obesity issues. If this trend is followed in the UK, there could be a corresponding reduction in waste starch availability.

2.7 Waste Disposal

Historically the UK has relied heavily on landfilling for waste disposal. However, a shortage of suitable sites together with increased regulation and legislation means that alternative methods of disposal, including the development of composting as a means of waste treatment will have to be considered.

Packaging, due to its high visibility and 'throw away' characteristics is perceived to be a major part of the waste stream yet it accounts for only approximately 7% of waste sent for landfilling[17]. It is therefore a prime target for consumer concern, environmental NGO's and legislation.

2.7.1 Legislation - Packaging and Packaging Waste Directive.

The Packaging and Packaging Waste Directive came into force in 1994 and imposes obligations, including recovery and recycling targets, which all Member States must meet. However it does not include any prescriptive elements defining how to achieve compliance. As such, distinct systems have been developed in each of the Member States, many based on national legislation already in place.

In the UK, a system of shared responsibility across the supply chain has been developed. The amount of material a company is obligated for depends on

- the recovery and recycling targets for that year. [These have recently been revised and new targets set for 2004-2008. The new targets are set out in table 16]
- the amount of packaging that they handle
- the activity or activities they perform (supplier of raw materials, converter, packer/filler, seller or importer).

[17] Waste Management Factsheet, INCPEN

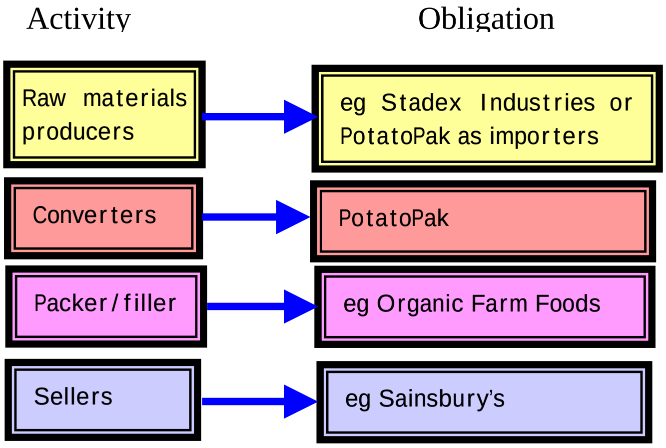
TABLE 16: PACKAGING RECOVERY AND RECYCLING BUSINESS TARGETS (%)

	2004	2005	2006	2007	2008
Paper	65	66	68	69	70
Glass	49	55	61	66	71
Aluminium	26	28	30.5	33	35.5
Steel	52.5	55	58	60	61.5
Plastic	21.5	22	22.5	23	23.5
Wood	18	19	20	20.5	21
Overall recovery	63	65	67	69	70
Minimum amount of recovery to be achieved through recycling	94%	94%	94%	95%	95%

Source: Defra[18]

The change from overall targets to material specific targets is a result of the review of the EU Packaging and Packaging Waste Directive. The increased targets will prove to be a huge challenge for the UK.

In terms of the potato packaging supply chain the system of shared responsibility could mean, for example:



PRN's (Packaging Recovery Notes) or PERN's (Packaging Export Recovery Notes) are purchased to prove that a company's obligated tonnage has been recovered thereby proving compliance with the Regulations. There has been some argument at EU level that biodegradable plastics should not be included within a company's obligated tonnage. This has not been resolved to date and biodegradable packaging is treated alongside other packaging. There are no material specific PRN's for biodegradable/compostable material.

Further information outlining how a company's obligation is calculated under the Packaging Regulation can be found in Appendix 5.

In 1998, the Packaging (Essential Requirements) Regulations were introduced[19]. These implement the single market requirements (Heavy Metal Limits and Essential Requirements) of the EU Packaging and Packaging Waste Directive and require packer/fillers, brand owners or importers to demonstrate compliance. To comply, packaging must be minimised and recoverable at the end of its life by at least one of the following mechanisms:

- Material recycling
- Incineration with energy recovery

[18] Defra News Release 485/03 20 November 2003
[19] Recently been amended and published as The Packaging (Essential Requirements) Regulations 2003. S.I. 20031941

- Biodegradation / composting.

CEN, the European Standards Committee has produced a number of Standards under mandate from the EU (although not all have been harmonised). The full list of standards applicable under the Essential Requirements is shown in Appendix 6. For a pack to meet the requirements for biodegradable/compostable it must comply with BS EN 13432:2000 "Requirements for packaging recoverable through composting and biodegradation". As yet the Potatopak tray has not been tested to this standard putting it at a potential competitive disadvantage compared to some of the other biodegradable materials available.

The Heavy Metals Limits which apply to cadmium, mercury, lead and hexavalent chromium state that total by weight of these heavy metals should not exceed 100ppm.

2.7.2 Legislation – The Landfill Directive

The Landfill Directive was implemented in England and Wales by means of the Landfill (England and Wales) Regulations 2002[20] which came into force on 15 June 2002. The Directive aims to prevent, or reduce as far as possible, the negative effects of landfill.

In terms of waste going to landfill, the Directive requires that:

- Biodegradable waste will be progressively diverted away from landfill
- The pre-treatment of wastes (composted or digested) prior to landfilling will become a requirement.

Compared to industrial and commercial waste, which together came to 71 million tonnes in 2000/01, the municipal waste stream is relatively small. But the municipal fraction is trailing behind in terms of recycling and recovery. In addition to this, about 60% of municipal household waste is biodegradable, and therefore a major contributor to the production of the greenhouse gas methane, when landfilled.

For these reasons, the Landfill Directive focuses on reducing the impact of municipal waste. Because the UK is so dependent on landfill, it has been allowed an extra four years to meet European targets, leading to the following goals based on the weight of biodegradable municipal waste (BMW) landfilled in 1995:

- Reduce BMW landfilled to 75% of 1995 level by 2010
- Reduce BMW landfilled to 50% of 1995 level by 2013
- Reduce BMW landfilled to 35% of 1995 level by 2020[21]

In addition, the Government's Waste Strategy 2000, set the following timetable, focusing specifically on recycling and composting:

- Increase recycling/composting of household waste to 25% by 2005
- Increase recycling/composting of household waste to 30% by 2010
- Increase recycling/composting of household waste to 33% by 2015.

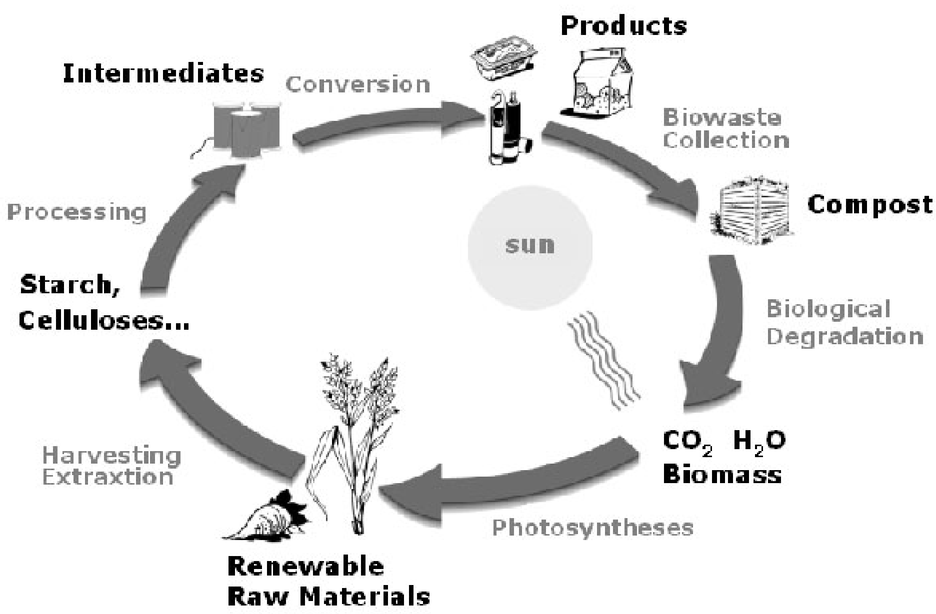
The government hopes that recycling-focused legislation such as the Packaging Waste Directive will help to achieve these goals. The Landfill Tax rate is set at £13.00 per tonne increasing by £1 per tonne per annum. There are plans to increase the Landfill Tax by £3 per tonne per year from 2005/06. Then, the government hopes, composting, recycling and incineration will together eventually "crowd out" landfill.

[20] SI 2002/1559
[21] Waste not, want not, A strategy for tackling the waste problem in England, Strategy Unit, November 2002

2.7.3 Composting.

Composting is defined as the biological decomposition of organic materials by microorganisms under controlled, aerobic, conditions to a relatively stable humus-like material called compost[22]. This is shown diagrammatically below.

FIGURE 3: THE COMPOST CYCLE



Source: http://www.ibaw.org/eng/seiten/disposal_frameset.html

Currently, the infrastructure for handling compostable material and particularly biodegradable packaging waste in the UK is underdeveloped. Composting is a very marginal business and commercial composting sites are able to obtain adequate amounts of clean green waste to produce high quality end products and are therefore unwilling to contaminate this with packaging waste. Local authorities are beginning to actively encourage home composting (in association with WRAP[23]) to reduce the quantity of household organic waste requiring collection. The Potatopak trays will degrade in 7 days by the action of moisture and micro-organisms[24] but a mechanism of easily identifying the trays as compostable is required.

There are several schemes already in existence using logos to indicate biodegradability/ compostability and some of these are outlined below:

Kassel Scheme

The Kassel project was a pilot project set up by IBAW (International Biodegradable Polymers Association & Working Groups) in the German city of Kassel in May 2001 in order to determine consumer acceptance and whether consumers are able to sort this type of material into biobins. The logo below was developed from the IBAW symbol to enable packaging to be identifiable as biodegradable/compostable. All packaging using this symbol was certified by DIN Certco Institute, Berlin as compostable.

kompostierbar

[22] www.compostinfo.com/tutorial/Glossary.htm
[23] Waste Resources Action Programme
[24] Report from Orrtec (Organic and Resource Recovery Technology), 14 December 2000

The UK Compost Association recently announced the launch of the UK's first Compostable packaging Certification Scheme which is a co-parnership agreement between Din Certco and the Composting Association[25]. The scheme enables certification to the DIN V 54900, BS EN 13432 and ASTM D 6400 standards and uses the following logo.

In order to achieve certification, materials, intermediates and additives are exhaustively tested in four different areas:

- Chemical test (for heavy metals)
- Complete biodegradation
- Disintegration under compost conditions
- Ecological test (plant toxicity)

OK Compost

The OK Compost mark from AIB-Vinçotte International is a conformity mark for goods, products and materials which are compostable in industrial plants. It guarantees complete disintegration and biodegradation with no negative influence on the quality of the compost.

Compostable Logo

The Biodegradable Products Institute (BPI) and the US Composting Council (USCC) run a joint program to certify and identify (via a logo) plastic products that will biodegrade and compost satisfactorily in actively managed compost facilities. The "Compostable Logo" is awarded to those plastic products that conform to the American Society for Testing and Materials (ASTM) Standard D6400-99 "Standard Specifications for Compostable Plastics".

[25] http://www.compost.org.uk/dsp_news_detail.cfm?id=159

The use of a logo would also improve efficiencies of sorting not only in the household but also at the back of supermarkets. Cleanaway is trialling the removal of compostable waste from the back door of supermarkets using 120litre wheelie bins with starch based liners. Currently the separation of organic material such as fruit and vegetables from packaging is not very efficient and compostable waste is often contaminated. Sorting on arrival at a composting site would be impossible hence the material is shredded, composted and then screened at the end of the process to remove inorganic material. The use of biodegradable/compostable material would allow complete packs to be disposed of without the need for opening packs and separating the packaging.

Composting is also now complicated by the Animal By-Products Regulations which require material which has been in contact with animal products to be disposed of within an in-vessel composting facility. Although animal products are collected separately, all of the material collected from Sainsbury's is disposed off within an in-vessel composting facility due to the Animal By-Products Regulations[26].

There are between 3-10 in-vessel composters in the UK at present and approximately 120 open windrow systems. It is likely that there will be an increase in the number of in-vessel composting facilities over the next few years but progress has been slow as many organisations were awaiting the Animal By-Products Regulations before investing. If all of the biodegradable material currently going to landfill is to be absorbed, there needs to be a 10 fold increase in the amount of composting facilities currently available.

Collection of dry recyclables by local authorities

Many local authorities now collect dry recyclables including plastic bottles, glass, paper, steel and aluminium cans separately from general MSW. These dry recyclables are then separated in a MRF[27] using techniques such as air knives, infrared light sources and magnets. The separated materials are then sold on for recycling.

A trial was conducted at a MRF to investigate the behaviour of dry mix Potatopak trays should they enter this waste stream. However, it must be noted that the trays used in the trial were unused which may affect overall performance in the MRF. A report from the trial outlining methodology and results is included in Appendix 7 but in summary, the majority of the trays ended up in the residue stream wich is send for landfilling. A small proportion may find their way into the paper stream but could be removed by trained staff.

Wet trays which end up in the dry recyclables stream may cause greater problems in the MRF preventing efficient sorting by sticking to bottles, cans etc which would then be too heavy to be blown into the correct stream. Contaminated materials would then be sent for landfilling.

It is possible that a logo such as those discussed above may help in domestic source separation, particularly if promoted nationally.

3 Conclusions

Potatopak trays are made from potato starch, a readily available renewable raw material. Once made the trays will fully degrade through the action of water and micro-organisms, providing a viable alternative to more traditional plastic based trays. Other types of starch such as maize, tapioca and sweet potato have previously been trialled but the technical drivers are for the use of potato starch as the raw material.

[26] The Animal By-Products Regulations 2003. SI 1482
[27] Materials Recycling/Reclamation Facility

Until recently, Potatopak was sourcing raw material (potato starch) from continental Europe where potatoes are grown specifically for starch production under a quota system with the aid of subsidies from the EU. The starch produced is food grade starch. Alternative sources which have been investigated are

- Waste starch from the potato processing industry
- Potato starch from waste whole potatoes, and
- Starch from crops grown specifically for starch.

GB has never had a potato starch industry and as such would not be eligible for any subsidies from the EU if crops were grown specifically for starch production. The reform of the CAP with the payment of a single payment is meant to break the link between subsidies and production. From 2005, there will be no separate subsidy for set-aside land and 40% of the subsidy for potato growers will be incorporated into the single farm payment. However, the remainder will be maintained as a crop specific payment for starch potatoes. Despite subsidies, some growers on the continent have given up production of starch potatoes because of inefficiencies caused by pests and diseases.

Alongside this, there is no infrastructure in place to extract starch from potatoes, except for potential spare capacity at peelers and chippers. However the infrastructure in place is not designed to efficiently remove starch. This would mean that further investment would be required in order to be able to macerate the potato to release all of the available starch. A further issue is that the source of the potatoes (whether waste whole potatoes or from crops grown on set-aside) would be incredibly disparate creating high transportation costs. It is therefore unlikely that potatoes could be grown economically in the UK for the production of starch.

However starch is currently available as a waste from the potato processing industry. Starch is released when cuts are made in the potato and this starch can be separated out of the potato juices using a system of centrifuges and hydrocyclones. Further drying of this starch increases stability of the material preventing colonisation by micro-organisms. This waste was previously sold to the animal feed industry but higher returns can be made when sold for alternative uses, such as packaging.

Testing to date has shown that waste starch from the processing industry performs better as a raw material for packaging production than starch from the starch production industry in continental Europe. Some testing of viscosity of the mix has been conducted but no conclusive results have yet been obtained. It is important to carry out further testing in order to obtain specifications for incoming raw materials in order to allow consistent product to be manufactured and automated mixing to become viable.

The potato packaging industry is still in its infancy and costs are one of the main issues. Costs need to be reduced in order for Potatopak trays to compete successfully outside of niche markets which are currently purchasing the trays for their biodegradability/compostability. Increased production at Potatopak will reduce costs as the proportion of labour costs per tray will decrease. In addition, the use of starches such as 905 from Stadex will reduce the curing time and hence handling and storage costs.

One of the problems faced by Potatopak in terms of increasing market share is that whilst there is no infrastructure for widespread collection of compostable materials, the market is likely to be limited particularly whilst there is a cost differential between the Potatopak trays and more ‘traditional’ packaging such as EPS. However on the positive side, more waste must be diverted from landfills in the future in order to comply with the Landfill Directive. Local authorities will be looking to increase diversion of waste at source, for example, by home composting and also by source separation of materials being collected. Identification of the trays as compostable will therefore be important. This also links into testing to recognised standards in order to compete with other biodegradable/compostable materials. More and more biodegradable materials are gaining accreditation which is likely to put Potatopak at a disadvantage when looking for new markets.

The small scale trial at the MRF demonstrated that dry Potatopak trays are most likely to be sorted into the residue streams. Any material ending up in the paper streams is unlikely to be an issue as it would be such a low proportion of the overall material. Trials were not conducted with wet/damp trays, which may cause sorting problems within the MRF itself, and should be conducted in the future to investigate any issues.

Further promotion of the tray and its advantages in terms of biodegradability and production from a sustainable source should also encourage sales and it will be important that as “full and coherent story” is presented (such as the information from the LCA) in order to maximise the effect.

Appendices
Appendix 1

Methodology
Introduction and objectives

The objectives of the supply chain analysis were to:

- Identify the current and future issues, at the different stages in this supply chain, that require actions in order to deliver a competitively priced, environmentally and economically sustainable end product produced from GB potato starch.
- Produce and test hypotheses that will improve the efficiency of the supply chain, particularly at the point of manufacture
- Establish practical and cost-effective baseline specifications for formulation, processing and distribution and waste handling of potato starch products at each stage of the supply chain and compile these into a series of supply chain reports
- Assess the future impact of market drivers to provide a strategic overview of the sustainable economic, environmental and social benefits and quantify the longer term opportunities to be gained from the production of potato starch packaging.

Resolution of these objectives was met through a number of discrete but inter-related tasks and these are outlined below.

Task 1: Analysis of environmental and market forces
Much information relating to the opportunities and constraints associated with the use of GB sourced potato starch is held at various points throughout the supply chain. The first task was therefore to identify and collate this information. This was carried out through a desk based study and discussions (either in the form of telephone conversations or visits) with the various supply chain partners. Where necessary, information was also sourced from individuals outside of the supply chain such as legislators and waste disposal organisations.

The issues identified were compiled in the form of a STEEP (Social, Technical, Economic, Environmental and Political) analysis. The results of which are outlined in the tables below.

Social

Driver	Implication
A positive perception of the term 'biodegradable'	Consumers with a positive perception of 'biodegradable' are often aware of environmental issues and are likely to buy organic foods thereby creating a niche market for these products. The organic market also currently attracts a price premium allowing the higher cost trays to be used
A negative perception of the term 'biodegradable'	'Biodegradable' is sometimes perceived as inferior. Consumers with this attitude will reject products in this type of packaging
Advertising/media	Advertising and the media often feed on novel ideas
Changing demographics	More single households and more women working lead to a need for products to be sold in convenient formats in terms of both portion size and ease of use
Change in shopping behaviour from daily to weekly or monthly trips	This change in behaviour increases the pressure on packs to provide a longer shelf life for products
Labelling	Packaging capable of being composted should be clearly marked to avoid confusion[28] and to allow convenient source separation

Technological

Driver	Implication
Threats from other degradable materials	Biopolymers such as Cargill Dow's Nature Works PLA and UCB Films' NatureFlex NE[29] offer greater flexibility in terms of barrier performance
Automation	To move to a mass market will require an increase in production automation. To achieve this will require either • Consistent raw material to allow automation of the mixing process or • Production technology to be tolerant enough to cope with variability
Efficient production	The issues of time in mould and curing time will need to be addressed as current systems are not conducive to mass production
Production of starch from potato crop	In order to utilise outsize potatoes or potatoes grown as an industrial crop would mean investment in machinery for releasing and recovering the starch
Automated filling	To realise the full market potential, the trays would have to be capable of being handled on automated filling lines
Pack performance	Competition within the packaging industry is intense and packs are expected to be fit for purpose. This may be, for example, in terms of shelf filling convenience in the supermarket or product protection issues.
Pack options	There is a huge variety of current packaging options for different applications. Will PotatoPak be able to meet this range of performance and aesthetic requirements (eg transparent strawberry punnets with lids)?

[28] Is everything in the garden really all that (shade of) rosy? Terry Robins, Packaging News, March 2003
[29] Wood film that fades to nothing, Packaging News , March 2003

Economic

Driver	Implication
Cost relating to competing trays	PotatoPak 4 apple trays are currently more expensive that plastic alternatives. This will limit market potential in the short term. Bringing the price down is not viable at present, even if production costs can be reduced. This is likely to mean a concentration in niche markets or where added value can be claimed.
Cost associated with recovering starch from processing	Where the required machinery is not yet in place, this will mean investment
Cost associated with alternative starch supply	The starch quota system in place in Europe means that some farmers are paid a subsidy for growing potatoes as an industrial crop. There is no quota system in place in the UK and therefore no subsidy available.
Cost of recovering starch from industrial crops	The capital investment required to recover starch from industrial crops in the UK would be huge
Food Contact issues	Plastic materials can have food contact issues, eg migration into the food causing tainting. PotatoPak products are excluded from the terms of EC Directive 90/128/EEC as they are based on natural starch as opposed to modified starch. PotatoPak trays are also in compliance with the general requirement of SI 1523 (1987) that no substances harmful to the health of the consumer can be transferred to foodstuffs[30]

Environmental

Driver	Implication
Biodegradable	Packaging is the biggest source of plastic waste (60%)[31]. Over 60% of litter found on beaches in 1999 was plastic which is persistent in the environment[32]. PotatoPak trays will degrade in 7 days
Use of compostable materials may reduce the amount of waste being sent to landfill in the long term.	This will ultimately depend on the facilities available to allow convenient composting
Transportation	Starch is currently transported from Germany. A source of starch from within the UK will reduce the environmental burden of raw material transportation
Resource issues relating to alternatives	PotatoPak trays use a renewable resource as a raw material. Alternative, 'conventional' packs use non renewable resources
Labelling	The potential for contamination of different waste streams is a concern. This may be addressed by the use of a common marking system for biodegradable/compostable products.
UK Farming	Potato production from starch could provide new markets and income for UK agriculture – supporting rural, environmental and society.

[30] Communication from Dr A Irvine, Pira International, 20 December 2000
[31] Waste Strategy 2000
[32] Plastics In the environment – Environment Agency

Political

Driver	Implication
Legislation	UK must meet legislative targets in terms of the Landfill Directive requiring a decrease in the amount of biodegradable material sent to landfill and the Packaging and Packaging Waste Directive requiring packaging to be minimised and recoverable at the end of its life
Emerging policy	One of the emerging policy areas in the EU is Integrated Product Policy which aims to minimise the environmental impact of products over their whole life cycle
CAP	Review of CAP leaves many issues relating to industry crop production uncertain at this time.

The information gathered was used to inform further tasks such as scenario development and supply chain workshop discussions.

Task 2: Current supply chain
Information obtained from discussions with supply chain partners was used to map the current supply chain. From this, three scenarios were developed with the aim of examining both short and long term requirements.

The scenarios used are outlined below:
Short Term (Scenario 1) (< 1 year)
An increased proportion of the total organic top and stone fruit and vegetable market is packed in Potatopak trays. This is estimated to require approx 5 million trays.

Medium Term (Scenario 2) (1 – 3 years)
A significant proportion of the total organic fruit and vegetable market is packed in Potatopak trays, requiring approximately 71.5 million trays. Potatopak trays are beginning to be exported.

Long Term (Scenario 3) (3 – 5 years)
Potatopak is less reliant on the fruit and vegetable market and has encroached into other market areas to add business diversification. The volume of trays required equates to 400 million plus. There is also increasing penetration into the export market.

Task 3: Constraints and opportunities impacting the supply chain
A supply chain workshop was held during which the supply chain partners were asked to identify the key themes and interactions from each of the scenarios presented. The participants were then asked to vote on the five issues which they considered to be most important, giving a five to the most important issue and one to the least important.

The aggregated results for each of the scenarios are given below:

Scenario 1

Issues	Total
Cost	74
Competitors activities / EPS retaliation etc	45
Potential issue with microbial growth on tray	34
Differentiation between major multiples	27
Competition with other starch / biodegradable trays	20
Shelf life extension adding value - competitive materials	16

Scenario 2

Issues	Total
Cost	69
Change in culture to achieve composting	32
Investment required to produce 72m trays	26
Supply and demand of starch due to increased value of starch waste	23
Potato availability - where grown, stored, processed, transport costs	22
Convenience	17
Product diversity (range of trays)	10
Advertising / coherent sales story	9
Currently don't pay for waste disposal by weight / volume	8
Consolidatiion of multiples	4
Less organic / stronger green lobby on continent	2

Scenario 3

Issues	Total
Greater competition from other degradable materials	49
'Copy cat' manufacturers with cheaper imports	44
Genuine bioplastic alternatives	30
Matching technical performance	30
Appearance / transparency	25
Capital investments for processing	11
Capital investment in starch production	8
5 year oil price prediction	3
Dark greens - organic pack to go with organic product	2
Fall in potato production (because of fall in demand for processed products)	2

Task 4: Determination of actions

Three supply chain groups were established to discuss and further explore the issues identified and highlighted during the supply chain workshop. The members of each group are set out below:

Supply chain group 1 – members

Organisation	Attendees
Biocomposites Centre	Dr Paul Fowler
Greenvale*	Robert Ash
Imperial College	Bill Hillier
PAS Grantham	Syd Clark
Potatopak	Toby Matthews
Stadex	Dr Terry Davies
Pira International	Michael Sturges, Richard Roberts, Carolynn Royce

* Unable to attend

Supply chain group 2 – members

Organisation	Attendees
Cleanaway	David Nicholson, Vicky Woods
Fresh Produce Consortium*	Douglas Henderson
Imperial College	Dr Richard Murphy
Organic Farm Foods*	Dave Holbourn
Potatopak	Toby Matthews
Produce Packaging	Mark Tierney
Pira International	Michael Sturges, Richard Roberts, Carolynn Royce

* Unable to attend

Supply chain group 3 - members

Organisation	Attendees
British Potato Council	Dr Mike Storey, Mark Anderson, Guy Gagen, Rihab Hussein
Pira International	Michael Sturges, Richard Roberts, Carolynn Royce
Potatopak	Toby Matthews
Potato Processors Association*	Richard Harris
Town and Country Communications	Steve Wellbeloved

* Unable to attend

The issues particularly pertinent to each group were identified from the ranking tables.

Supply chain group 1 - issues

	Issues
Costs	• What can be done to control the costs, by whom? • What proportion of potatopak tray costs are raw material, what proportion labour etc?
Investment	• What would be required? • By whom?
Technical	• Can anything be done with the peelings etc to utilise this waste more effectively? • Why is Walkers/McCain's starch better than pure starch from Germany? • Are there performance spec's – what are the critical properties of the starch, when will spec's be drawn up by?

Supply chain group 2 – issues

	Issues
Requirements	• What are the key requirements for the trays – they meet the requirements for organic apples, why not others?
Multiples	• Do we know what multiples want? • Differentiation – colours, shapes, personalisation – will this affect labeling for composting?
Post consumer	• What happens to post consumer and back door waste? • What do the local councils want – eg reduction in biodegradable material going to landfill? How are they going to achieve this?
Composting	• What facilities are currently available for composting? • What facilities will there be in the future?

Supply chain group 3 – issues

	Issues
Competitors	• Do they know all of their competitors and what they are up to?
Farmers	• Benefits to farmers? • CAP?
Story	• How do we build the story?

Appendix 2

Potato processors

Company	Location
Axgro Foods Ltd	West Butterwick, Nr Scunthorpe
Bridge Farm	Maghull, Liverpool
Cavaghan & Gray Group	Sweetbank, Markinch
CBA Enterprises Ltd	Manchester
Cheviot Foods Ltd	Amble, Morpeth
Country Chef Ltd	Scunthorpe
Farm House Potato Bakers Ltd	Bridlington
Frito-lay Trading GmbH	Leicester
Garden isle Frozen Foods Ltd	Wisbech
Ginsters	Callington
Golden Wonder Ltd	Market Harborough
HCC Tinsley & Son Ltd	Peterborough
HJ Heinz Frozen & Chilled Foods Ltd	North Walsham
HL Foods Ltd	Spalding
Highlander Snacks Ltd	Bathgate
Hitchen Foods PLC	Wigan
James Abbey & Son (Vegetables) Ltd	Warrington
KP Foods Group	Billingham
Kettle Foods Ltd	Norwich
Kitchen Range Foods Limited	Huntingdon
Kolak Snack Foods Ltd	
McCain Foods (GB) Ltd	Scarborough
Parripak Foods Ltd	Shefford
PAS (Grantham) Ltd	Grantham
RF Brookes Ltd	Newport
Seabrook Potato Crisps Ltd	Bradford
Sirhowy Valley Foods Ltd	Cwnfelinfach
Swancote Foods Ltd	Telford
The Snack Factory Ltd	Skelmersdale
Unilever Ice Cream & Frozen Food	Lowestoft
WA Baxter & Sons Ltd	Fochabers
Waldersey Farms Ltd	Downham Market
Warrell Morton & Co Ltd	Braintree

Source: British Potato Council

Appendix 3

Tests comparing flexibility / brittleness

Two tests were carried out to compare the flexibility and brittleness of Potatopak trays with Apack and EPS trays. Two unused trays provided by Potatopak were compared with Potatopak, Apack and EPS 4 apple trays purchased from Sainsbury's.

The tests carried out were:

- **Puncture based on Defence Standard 81/75-1 (1987).**
  The sample to be tested was clamped between metal plates in which there was a 25mm diameter hole. A 3mm radius probe was pushed through the centre of the exposed sample. The test speed was 250mm/min. The maximum load and extension were recorded.
- **Three point bending based on ASTM test procedure D790.**
  A sample 25mm wide and approximately 120mm long was cut from the base of each tray. The sample was supported on narrow beams with a span of 85mm and loaded at the centre of the span at 5mm/min. The load at maximum deflection, when the sample fractured, was recorded.

The results are summarised in the following tables

Table 1: Puncture test

Tray	Max force (N)	Extension at maximum force (mm)
Potatopak - unused - used	22.0 29.0	3.0 3.0
Apack	41.5	3.4
EPS	24.7	6.7

Table 2: Three point bending

Tray	Max load (N)	Deflection at failure (mm)
Potatopak - unused - used	4.5 6.4	7.7 8.6
Apack	4.5	16.0
EPS	4.2	15.8

The results indicate that although the load at failure is similar when the trays are subjected to bending, the EPS and Apack trays are capable of greater deflection before failure. The Apack tray also has greater puncture resistance. In the case of the Apack tray this is related to the fact that the tray is manufactured with a film lining the inside of the tray.

Although there have been no reports of damage in distribution, there has been a suggestion that some Potatopak trays have been damaged before packing. When packing is manual, this is not a problem, but with automatic packing this could be an issue. Also these results should be borne in mind when development work is carried out on the trays, such as that to improve resistance to moisture from cut stems/moist fruit etc, ensuring that the brittleness does not become significantly worse.

Appendix 4

Volume calculations

Carton volume = 485 x 317 x 300mm = 4.6×10^4 cc = 250 trays
Bag volume = 1200 x 340 x 600mm = 2.4×10^5 cc = 700 trays

Approximate space required:
Potatopak = 184cc per trays
EPS = 350cc per tray

Appendix 5

Calculating your obligation

To be obligated a company must:

- Have a turnover of greater than £2million
- Perform activities within the packaging chain
- Own the packaging which they handle
- Supply packaging onto the next stage in the chain or the final user
- Handle more than 50 tonnes of packaging (based on the tonnage of packaging handled over the previous year).

A company meeting all of the above criteria is obligated under the Regulations. The amount of the obligation is determined by three components:

The amount of packaging handled

Total amount
Material types

The activity performed

Activity	Obligation
Raw material producer	6%
Converter	9%
Packer/filler	37%
Seller	48%
Importer	Rolled up obligation of all activities performed outside of the UK

The UK recovery and recycling targets

See main report, table 16

The recovery obligation = tonnage of packaging handled in the previous year x activity x UK recovery target
The material specific recycling obligation = tonnage of packaging handled for each material x activity x UK recycling target

To provide evidence of compliance with the Regulations, companies must purchase PRN's (packaging recovery notes), or have PRN's purchased on their behalf by a compliance scheme, for the amount of obligated packaging that they handle. PRN's are issued by accredited reprocessors who recover and recycle packaging and are approved by the Environment Agency, SEPA or EHS.

PRN's are subject to market forces and therefore price fluctuations. The table below shows the price ranges for March and April 2003.

Table 1: PRN prices

	March 2003 £ per PRN/tonne of material	**April 2003** £ per PRN/tonne of material
Glass	13-18	10-15
Paper	10-15	9-13
Aluminium	18-22	12-16
Steel	13-16	10-15
Plastics	14-18	9-21
Mixed (energy recovery)	12-15	10-12
Wood (recovery)	12-15	8-12

Appendix 6

The Packaging (Essential Requirements) Regulations

These Regulations require that no packaging may be placed on the UK market unless the packaging fulfils the Essential Requirements and the Heavy Metal concentration limits.

The Essential Requirements are:

- Packaging must be minimal subject to safety, hygiene and acceptance for the packed product and for the consumer
- Noxious or hazardous substances in packaging must be minimised in emissions, ash or leachate from incineration or landfill
- Packaging must be recoverable through at least one of
  - Material recycling
  - Incineration with energy recovery
  - Composting or biodegradation.

The requirement to comply with these Regulations lies with the brand owners, packer/fillers or importers.

CEN standards:

- EN 13427:2000, Packaging - Requirements for the use of European Standards in the field of packaging and packaging waste
- EN 13428:2000, Packaging – Requirements specific to manufacturing and composition – Prevention by source reduction
- EN 13429:2000, Packaging – Reuse
- EN 13430:2000, Packaging – Requirements for packaging recoverable by material recycling
- EN 13431:2000, Packaging – Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior caloric value
- EN 13432:2000, Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging.

Appendix 7

PotatoPak biodegradable packaging
Test run through Cleanaway's Materials Recycling Facility
Rainham Essex December 2003

Partners

PIRA International – Martin Kay, Carolynn Royce
Potato-pak – Toby Mathews
Cleanaway Ltd – David Nicholson, Victoria Woods

Introduction

The 'Potato-pak' food packaging materials are potato starch based and suitable for storage and presentation of a range of foods at supermarket and other retail outlets. The aim of this trial was to determine the impact of the biodegradable packaging material on a Materials Recycling Facility (MRF) should the public confuse the material and place it with the collection of dry recyclable packaging including paper and plastic, rather than a collection of compostable material for example garden trimmings and kitchen scraps.

The dry-mix potato-pak packaging was used in the trial, the total packaging material fed into the MRF = 96 kg, comprising of 14 kg complete trays and 82 kg broken trays.

Results

Material collected from the various output lines of the MRF:

MRF stream	Mass g			Proportion of input (%)
	Smaller than 30 mm	30 mm – 100 mm	Full trays	
Residue	85,751 (estimated)	0	0	89.3
Paper fraction	0 (estimated)	613	0	0.6
Non-compliant paper	200 (estimated)	136	0	0.4
Heavy air knife fraction	0	3,100 (collected estimated 33 % retrieval rate implies actual throughput of) 9,300	0	9.7
Total	85,951	10,049	0	100 %

The majority of the packaging used in the trial was already part broken, however it may be noted that of the full trays included in the trial all were damaged and/or broken during the rigorous materials handling process employed by the MRF.

Many trays were broken during the first stage, the bag splitter, where revolving teeth are designed to tear open the bags of recyclable materials and spread the items evenly onto a conveyor. The items are taken into the primary sorting cabin, where an initial sort removes large pieces of cardboard and the polythene bags for recycling.

Trommel screen

The material stream then passes into the trommel screen (see below), which is designed to separate paper from everything else. Here the fines, items smaller than 30 mm such as bottle tops, are removed from the material stream as residue. The trial demonstrated that the majority of the broken fragments of the packaging were removed by the trommel as residue at this stage. Estimates suggest approximately 89 % of the original material fed into the MRF came out as residue.

Paper sorting cabin

A small proportion of the trays (0.6 %) found their way into the high quality paper stream.

The remainder of the material stream passes by an air-knife, designed to separate the lighter pieces of paper and plastic from the heavier metal and plastic materials. During the trial the air knife, only approximately 0.4 %, picked up surprisingly few trays.

Following the air knife the material stream passes by a succession of sorting technology designed to separate, ferrous and non-ferrous metals and PET and HDPE plastics. No trays were picked up by any of these separating technologies.

The majority of the trays that were not emitted as residue and travelled through the MRF came out at the heavy end of the non-compliant stream (9.7 %). This material does not have any final sorting at this stage but is sold globally and may be expected to have an additional sorting abroad.

Conclusions

Should the potato-pak packaging be confused with plastic wrapping or other recyclable material by members of the public and subsequently placed in a dry-recycling collection then the results from this trial suggest that the majority of the trays (89%) would be separated as residue and be taken to landfill.

The trays that find their way into the paper stream (0.6%) could be removed by trained sorting staff. However should a small proportion pass through the system and be included in the baled paper product, the high pressure employed by the baling equipment would crush the trays. The crumbled material may then predominantly disappear as dust or, should some remain in the bale, being organic in nature, the small proportion of potato-pak trays anticipated would not contaminate the saleable product above the currently acceptable limit of less than 2%.

The trays that pass through the trommel screen predominantly pass by all the separation technology to come out as heavy, non-compliant paper (10%). This stream does not currently have a secondary sorting at the Rainham MRF. Therefore the trays would not be pulled out by sorting staff but will continue to the baler and considered to be contamination. The shelf life of the bales could be several weeks, in which time the crushed trays are likely to have either soaked up liquid contamination from other materials and disintegrated, or been crushed to a dry powder and again disintegrated.

In summary, with the current anticipated volume of potato-pak trays in circulation it is unlikely that their inclusion in the dry-recyclable collection will affect the quality of the finished bales that are sold onto the re-processors. However promotion of their biodegradability and/or compostability and perhaps clear labelling, could help to ensure that the public do not confuse the material with other recyclable packaging destined for the MRF. Should the material arrive at the MRF it will predominantly be separated in the initial stages of the process as residue and sent to landfill.

Diagramatical map of the material flows through the MRF