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Conference Papers

Store Design and Operations

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The 21st Century markets will demand a continuous supply of competitively priced potatoes with an ever higher quality, using minimum, if any, chemicals. The potato industry can meet these demands, but must increasingly pay attention to details in both the design and operation of its stores.

Below are some of the major issues which, if understood and followed, should enable growers to offer a quality of product able to meet the demands of all potential markets.

BASIC PARAMETERS

Typical storage periods

In a normal year the temperate British Isles climate allows potatoes to be held until mid March using only outside air and a controller which can blow the crop during any cool (but not frosty) period. However the predicted upwards trends in temperature through global warming will reduce this 'ambient' storage period. Outside these winter months it is essential to use refrigeration. A well designed and operated refrigerated store will be able to turn out marketable tubers right through from one harvest to the next, possibly even without sprout suppressants.

Unfortunately, however good the store and its management there will always be a slight loss of quality as the natural ageing processes take place - seldom does a period in store improve the product. The aim of the store manager should therefore be to minimise deterioration in quality.

Temperatures. The correct storage temperatures are now determined by market and variety. Potatoes for the 'fresh' table market are usually stored at 4 - 6C, but possibly down to 3C if chemical sprout suppressants are not used. Process potatoes will normally be stored at 8 - 10C to prevent production of reducing sugars which darken the product when fried, but will need artificial sprout suppressants. All new stores should be designed to hold crop as low as 2C.

Humidity. Table potatoes need to be firm to the feel when marketed, the firmness being determined by the amount of water lost during the storage period. Water loss is minimised by maintaining high humidity throughout the storage period. Modern stores should be capable of reducing the water loss to 4% or less of the original tuber weight. To achieve this the ideal store air humidity should be 95 - 98%. Fully saturated (100% humidity) air is not desirable, as it can wet the surface of the tuber and promote storage diseases and possibly even sprouting.

Carbon Dioxide. The quality of many fruit and vegetable crops is enhanced if stored under high levels of CO_2 combined with low oxygen. This is not the case with potatoes, increased levels of carbon dioxide can be detrimental, promoting sprouting and effectively shortening storage life. Even the small amount of CO_2 produced as the potatoes respire during the season can build to unacceptable levels up in a well sealed modern store, so it is always wise to ventilate periodically in stores with few natural leaks.

Airflow and distribution; bulk stores. The primary purpose of ventilation in bulk stores is to remove heat produced by respiration, and if not refrigerated, to take in as much cold (but not frosty) air as possible to keep the heap cool. Modern bulk stores should also have the facility to recirculate air occasionally within the heap, to even out temperatures. The major disadvantage of blowing air through potatoes is that it tends also to remove moisture from the tubers. The rate at which moisture is removed will depend on how long the heap is blown, whilst the reduction in temperature depends on the amount of air blown through. Store designs in the British Isles have evolved to have high powered fans, delivering 1.2 - 2.8 m^3/min (40 - 100 cubic feet per minute) per tonne of crop, which rapidly removes heat but takes out little moisture. These airflows suit our cool, damp maritime climate. Storage systems in other countries with different climates, such as mainland Europe and N America, use different airflow regimes which best suit their climates. This should be taken into account before importing packaged storage systems from beyond the British Isles.

Airflow and distribution; box stores. Airflow technology in a box store is different from that in bulk stores. In a box store the objective is to have high rates of internal air movement to prevent the air in the building from 'layering' - where warm air naturally rises. If the air is not recirculated properly the boxes and thus the tubers near the roof can often be 5 degC or more warmer than at the floor, making any close temperature control of the crop impossible. The fan system in a box store should create the internal circulation to prevent layering, as well as ability to draw in cool ambient air or distribute cold air from the fridge chillers.

In the normal type of box store the potatoes cannot be ventilated in the same way as in bulk. It is not possible to force air through the crop in the box, unless special boxes are used and these are stacked to form closed ducts so the air is forced through. The only air movement in a box is generated by the tubers themselves. Those in the middle of the box warm slightly as they respire, warming the air around them; this warmed air rises through the box and draws in cool air through the base. Thus in a box store the objective should be to keep the air round each box at just below the designated storage temperature, so that the tubers can draw it in if they begin to warm. In practice the middle of a box will always be slightly warmer than the store air, and this must be taken into account when setting controls. The fan rate in box stores is usually based on the volume of air the building, and not in the amount of crop within. Typically fans are sized to circulate the air in the building 15 - 25 times per hour. In basic stores they run continuously, but with good automatic temperature controllers which sense the onset of layering, can run periodically.

Compatibility with other crops. Some small producers tend to try to use their store to capacity by filling any spare space with other crops. This is not good practice, as few other crops store well in the conditions best for potatoes, and multi-product storage usually results in none of the crops achieving class I marketing status.

CURING DRYING AND SPROUT SUPPRESSANTS

Curing. This is the process of allowing the crop to warm up after loading to heal surface cuts and abrasions. In bulk stores this tends to be done to the whole heap as a single batch, which means that in prolonged harvests there is a considerable difference in the lengths of treatment. In box stores where the building can be subdivided, or another shed is available, each of the different liftings can be stored initially in a 'warm' curing environment before moving into the main store for cooling.

Drying. This is becoming an increasingly significant part of the storage operation in the wetter areas of the British Isles, especially in wet, late harvests. In a bulk store the crop can be force ventilated in a similar way to grain drying. As explained above, it is impossible in normal box stores to force drying air through a box of wet crop. Techniques have been therefore been developed where batches of boxes are grouped tightly together and sheeted to form a closed unit which can be force ventilated with a high volume fan. As in curing, this is usually done in an area separate from the main store, and the boxes moved into the store after they are dry.

Sprout suppressants. The hot fog applied sprout suppressants can be difficult to distribute evenly in box stores, even with good air movement. This has been exacerbated in the UK, following a number of store fires caused by electric sparks igniting the hot carrier vapour, resulting in a reluctance to run any electrical equipment in the store including fans, to assist distribution. It is possible to remove this danger by adopting 'flameproof' technology but at a considerable cost.

Also the hot vapour re-crystallises, and soaks into porous surfaces such as boxes and the concrete in the store. Once absorbed it impossible to clean out. Therefore any store which has been fogged with sprout suppressant must be regarded as unsuitable for seed or subsequent use for an 'organic' crop.

BOX DESIGN

The British Standard sets out the strength requirements of a box for stacking 4, 6 or 8 high without risk of collapse through failure. The Standard does not cover any other aspects of box design and will not guarantee that a box to the Standard has good airflow or minimises damage to the tubers.

STORE STRUCTURES

Dimensions. Most UK box stores are based on 'clearspan' framed structures with a minimum eaves height to fit a 6 or 8 high stack of BS rated boxes The building height should be determined by the clearance under the frame braces at the side of the building, which should allow the top box to be put up without hitting the frame. Do not specify on the nominal eaves height, which is based on wall and not frame height.

With modern air movement systems there is little restriction on the width or length of a storage building.

Floor. In a box store the floor must be as level as possible so that the box columns stand vertically and there is no risk of their tilting over. There is a trend amongst some UK growers to have single piece floors without individual slabs and expansion joints, in the belief that significant damage to the tubers in the box occurs each time the forklift bumps across an expansion joint.

Insulation. Good insulation is essential to the correct store performance. In an ambient store the level of insulation and sealing from air leakage can determine how long into the spring the store will hold. In a refrigerated store the insulation and sealing levels will determine how long the fridge plant runs, which in turn will determine how much water is drawn from the crop. The normal levels of insulation will have a conductivity value ("U" value) of 0•4 W/m^2degC, equivalent to about 100mm of foamed plastic board. As insulation value is quoted in terms of conductivity, the lower the "U" value, the better the insulant, for example a "U" of 0•4 is twice as good as "U" 0•8. Many types of insulation are available, but the two most commonly used in crop stores are either foamed plastic board or spray on foam. The board is available in a number of materials, but it is essential that only boards made of closed cell foams are used, as open cell foams will readily absorb water from condensing moisture, however well surface sealed, and once wet will have little insulation value. Many new build stores are clad with composite panels, which consist of a foam board sandwiched between metal sheets. This form of construction gives both the weather cladding and insulation in one. All rigid board insulants must be sealed at all joints to minimise air leakage into the building. Existing buildings are often best treated with spray on foam, which both insulates and seals the structure.

One important issue is that of fire. Certain types of foam are both highly inflammable and produce noxious gasses if burning. Most manufacturers will give the fire resistance rating, normally quoted in terms of 'class 0', 'class 1' etc. It is recommended that the insulant fire specification is checked with both the local buildings inspectorate and your insurer. There have been examples in UK of insurers not accepting any naked foam sheet, insisting that it is fully faced with a non flammable material.

Doors. The main loading doors can form a major source of heat and air leakage into a store. It is recommended that the doors are highly insulated and can be tightly sealed when closed. It is usual to have the main loading doors sealed up once the store is full and to have a small personnel door for management access.

Subdivision. Some growers find it beneficial to be able to subdivide large stores. This might be to run different varieties or markets at their optimum conditions, or to contain the space being cooled as the season progresses and the store is emptied. The best type of temporary insulated divider is an insulating curtain, which has a number of fixing points in the store.

VENTILATION AND COOLING PLANT

Ventilation. The ventilation system should keep the crop conditions as even as possible with the minimum of fan power. It is always essential to use high efficiency fans, as the waste heat from the motors adds to the cooling load on the refrigeration, which in turn takes moisture from the crop.

Most systems incorporate louvres, and these can be critical in ensuring that store conditions are maintained. When closed they should form an airtight, insulated seal, and should open fully to avoid restricting the fan. The farm storage industry has developed its own designs of louvre, which often outperform cheaper versions brought in from the industrial air conditioning trade.

In most modern stores the roof apex forms a clear space to blow air over the tops of the boxes; even in large stores discharge ducting should not be needed if there is a good 'air throw' from the ventilation unit. If however the store is a conversion from a barn with lattice roof trusses, distribution ducting must be used.

Cooling plant. Whilst fridge plant removes heat from the store air it also removes humidity in the form of condensation on the coils. The amount of humidity removed will depend on coil surface temperature, the lower it is relative to the store air, the more moisture it will remove. To keep this temperature difference to a minimum will need a coil with a very large surface area; a large area coil which needs only to run at 1degC or less than the store will remove little humidity, and should keep the store humidity at the recommended 95+% without recourse to artificial humidification. Unfortunately, for the same refrigeration power these coils are significantly more expensive than the smaller face area coils used in the industrial air conditioning trade. These latter whilst cheap to install, will cost heavily in terms of lost crop value.

Fridge coils can easily be fitted in existing ambient cooled stores to convert to a refrigerated store. The coils need not be fitted into the air mixing box; a number of UK stores work quite well with the coil bank mounted in the roof so that the circulating air picks up the cold air discharge from the mixer box fans.

Maintaining/adding humidity. If the above rules on fridge coil selection are followed there should be no need to humidify artificially in Western European conditions. Adding humidity can be costly and harmful, as little of the water evaporates, the remainder dropping onto the floor or crop; it is best avoided by good design.

AUTOMATION AND MONITORING

Ambient stores. An automatic 'air mixing box' will significantly help the length of the storage season. The automatic sensing of inside and outside temperatures allow all periods of cooler outside air to be used, irrespective of when or for how long these happen. When setting up mixing box controls it must be remembered that the fans will add up to ½ degC, and you will need another ½ deg to do any effective cooling. Setting the control temperature too close will merely result in the fans running excessively.

Refrigerated stores. In many ways automation is simpler, as the fridge coils have a simple thermostat and the fans might be controlled to run only if there is a temperature difference between different areas of the store.

Sensors. The critical part of any controller or recorder will be the sensors. The controller will rely on temperatures sensed by a number of probes. If these are wrongly placed or faulty the controller will not make the correct actions, and the monitor could show that all is well when there is a problem. Unless the controller allows for the lack of response, control probes should not be buried in the boxes, although monitoring probes can be buried to show actual tuber temperatures in the mass.

In bulk stores the control probes should be buried at least 600mm into the heap, as this will be the hottest part of the stack.

In some of the simpler systems where the probes can be unplugged when the store is empty, it is essential to have all the probes plugged back in to run the store, as a missing probe can be interpreted as a hot spot by the controller.

Calibration and checking. At the end of each season the probes should be checked to see that they all give the correct readings. To do this they can be placed all together in a bucket of sand or water, together with an accurate thermometer. This test will show both whether the probes all agree, and whether all are reading the correct temperature.

The dangers of automation. The critical factor to remember in any automatic system is that it is an adjunct to your management, and not a replacement. The human feel, nose and eyes are far better in detecting things going wrong than the most sophisticated controller. The store should be inspected as a minimum, daily when it is first pulling down and every few days after that.

BOX STORE LOADING

Many of the advantages of box storage can be lost if box loading is not well thought through.

One major advantage is that the crop can be presized into the various market grades, and these stored separately. This will require a high capacity intake grader, fitted with proper screens, as well as good inspection to ensure that minimal rubbish is being stored.

Damage is also an important factor, especially when filling boxes. If possible filling should be via a gentle descent elevator with automatic control, so that the box is not overfilled. The fillers which tilt the box onto a conveyor, whilst giving the required gentle fill, are now not liked in UK by the safety authorities as technically a person can be trapped as the box drops.

Whenever possible clods should be removed, because they will dry during storage and hard sharp clods can cause considerable damage as the box is transported or tipped.

Irrigation - Scheduling for the Future

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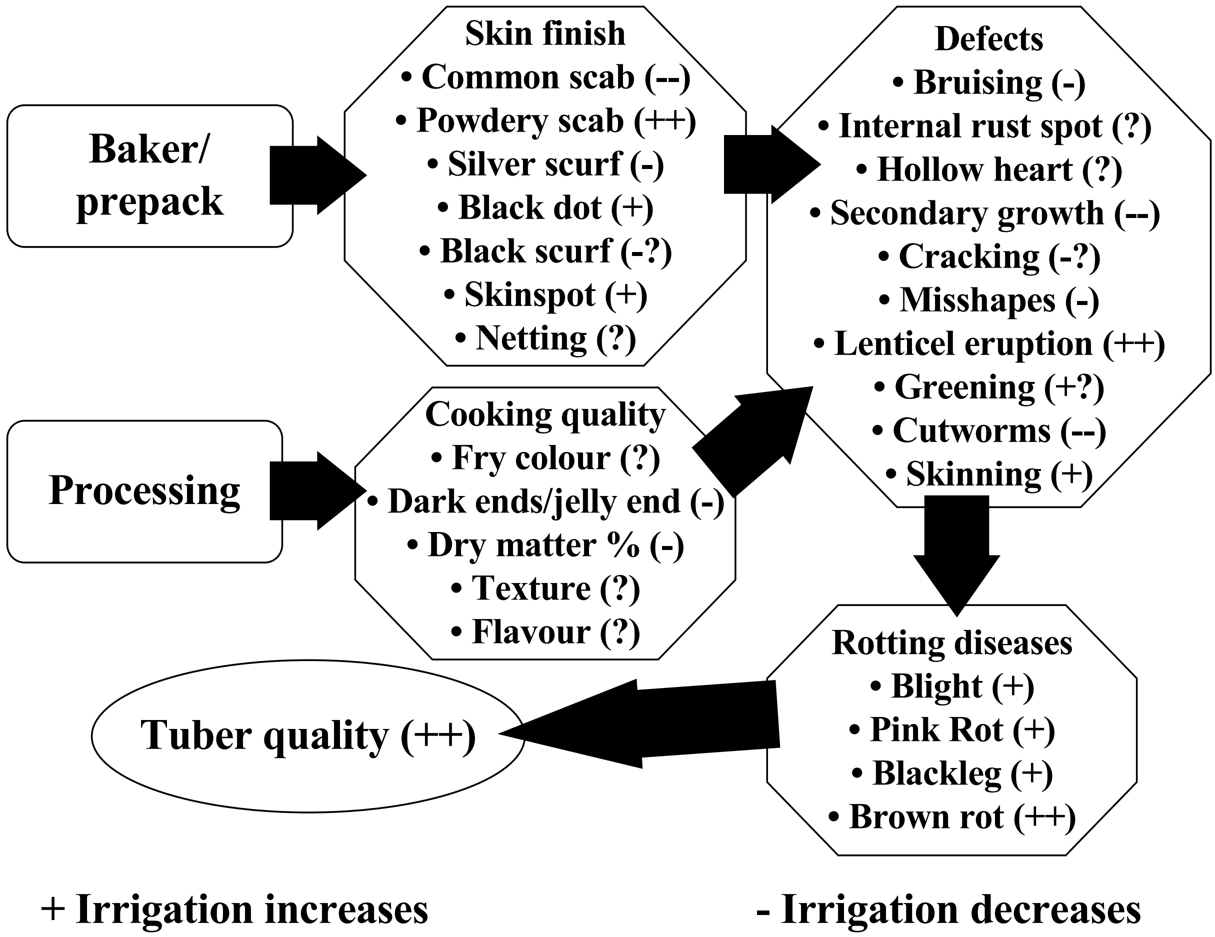
In order to achieve the potential yield of potato crops, most growers need to supplement water from rainfall and soil supplies with use of irrigation. In climates like Ireland, where rainfall is usually high and cloud cover reduces the amount of sun reaching the crop, the requirement for irrigation may be low. However, there are benefits associated with irrigation that go beyond preventing yield loss during drought periods. If irrigation is to be used efficiently, it requires the application of the minimum amount of water consistent with the achievement of potential yield and desired quality.

The potato crop's requirement for water is determined by the prevailing meteorological conditions and the amount of leaf covering the ground. Meeting this requirement means taking water out of the soil. Soil water supply is affected by both soil factors (texture, structure, stoniness and organic matter) and the rooting characteristics (depth and density) of the variety being grown. However, the condition of the soil profile is a major influence on the rate and depth of rooting of the crop and hence its access to soil water. Cloddy conditions in the upper soil horizons prevent effective water uptake by reducing the rate at which roots grow, and can be a significant factor in restricting growth especially early in the season on heavy soils. Few potato soils are over bedrock which confine rooting, but compaction in the profile can change the effective soil depth on all soils, light and heavy. The use of most implements, particularly rotary cultivators and destoners, when soils are too wet, will cause compaction which will delay root extension or even prevent penetration into the subsoil. As a result crop access to soil water will be delayed or reduced. Varieties differ markedly in their rooting characteristics, but given the opportunity most will root to at least 70-80 cm and varieties such as Cara beyond 100 cm. However, in practice many crops do not achieve these depths because soil conditions restrict rooting. It is not uncommon to 'lose' access to 20-30 mm of soil water through this effect, thereby increasing the need for irrigation. The consequence is an increased and unnecessary requirement for irrigation, which cannot completely remove the effect of the compaction, and sometimes makes it worse by creating waterlogged areas in the field. In seasons where there is moderate, evenly-spaced rainfall, crops grown without compaction can yield close to similar crops grown with irrigation. With compaction, especially where it is shallow, potato crops yield poorly. The target for minimizing the need for irrigation is clear: to create as deep a root system as possible, and the key is the quality of the soil conditions into which the crop is planted.

A measure of the efficiency of irrigation is to establish whether the increase in yield from watering matches the quantities of water applied. In both practice and experiments there is often a huge discrepancy, and inaccurate scheduling is a major contributor. Crops not suffering from water stress produce around 6 t/ha of tuber yield for each 25 mm of water used by the plant, so that if 100 mm (4″) were applied as irrigation and used by the crop, the response to irrigation should be 6 x 4 x 85 % = 20 t/ha (assuming 15 % loss during application). The contribution from rainfall and soil supplies even in sandy soils would be 135 mm in an extremely dry summer such as 2000 giving a total of 20 + 32 = 52 t/ha. In many cases, this type of analysis leads to the conclusion that more water was applied than was necessary, since the yield is frequently less than expected purely from the irrigation applied. Growers should aim to maximize their application efficiency by paying attention to the set-up of irrigators, including maintaining the correct pressure at the reel and selecting the right nozzle size for the lane width, application amount and crop cover to avoid variation in application across the field and eroding the soil from ridges. Applications of irrigation exceeding 30 mm are to be avoided as this may result in restrictions to growth caused by temporary waterlogging, physical damage to both soil and canopy and lead to quality defects such as erupted lenticels.

Tuber quality covers areas such as skin finish, defects and processing quality. The target quality of the end product influences irrigation scheduling recommendations:



Considerable time has been spent by researchers investigating the effect of irrigation on skin blemishing diseases owing to the importance attached to this attribute by the multiple retailers. It is well established that keeping the soil moist around the tubers when they are forming is the key to reducing common scab severity. The critical period for scab control begins at the onset of tuber initiation when tubers are only 2-3 mm in diameter and lasts for 3-5 weeks depending on the tubers' rate of growth and susceptibility. The key to effective common scab control is to have crops emerging over as short a period as possible, starting irrigation if the soil is dry when any tubers are seen, and continuing until the last tubers become resistant to infection. In commercial crops this can mean 3-5 small (12-15 mm) applications over a period of 4-6 weeks in the absence of rain. The area of potatoes being irrigated must be adjusted to match the capacity of the irrigation system. When the demand on the system increases, it may be tempting to stop irrigating some crops after 2-3 weeks rather than completing the susceptible phase of 4 weeks. However, scab can still form at the rose end of the tuber making the sample rejectable. In some cases, ceasing irrigation prematurely once started can result in more common scab than not irrigating at all. In many seasons in Ireland, the major financial benefit from irrigation would come from reducing the severity of common scab on samples destined for pre-packing rather than preventing loss of yield.

If powdery scab is present on either seed or in the soil, then this disease can be increased by large fluctuations in soil moisture during the period following tuber initiation. Cold soil temperatures and low oxygen concentration as a result of waterlogging delays suberization of lenticels, thereby increasing the susceptibility to infection by both forms of scab. Irrigation can decrease silver scurf but black dot may be increased. The latter disease is becoming an increasing problem for growers and packers. Persistent leaf wetness is needed for successful infection by blight, but whilst irrigation can maintain a higher humidity within the canopy compared with unirrigated crops, most leaf surfaces are dry within 30 minutes of irrigating. However, once infected, plants may liberate sporangia which can be washed down from diseased foliage by irrigation and can infect tubers through lenticels, eyes or growth cracks. Irrigation may also create conditions more favourable for bacterial activity, e.g. blackleg, pink and brown rot.

Tuber dry matter percentage is influenced by soil water status, and consequently can be manipulated by withholding irrigation at critical periods, although the effects are often only temporary, and can be small if the soil remains wet for a prolonged period after burning off. However, dry matter percentage may not be a good indicator of cooking quality, and irrigation does not have consistent effects on the texture or flavour of potatoes. Susceptibility to bruising may be altered if the tubers are turgid rather than dehydrated at harvest. Fry colour is generally unaffected by timing or quantity of irrigation, except where excess is applied. Defects such as growth cracking and internal rust spot are generally thought to occur in response to fluctuating water stress, therefore the use of irrigation scheduling to maintain the crop adequately supplied with water throughout the season will help minimize these problems.

The EU-15 potato market and the outlook for 2000/01

by Guy Faulkner, Agra Europe (London) Ltd.

1) The wider context

Ware potato growing is the single major arable enterprise which is completely outside the EU's Common Agricultural Policy. Growers in the 15 EU countries deliver an annual 35-40 million tonnes of a product which gives very good value for money for the consumer at a cost of virtually zero to the taxpayer. Only the starch potato industry, which utilises around 8mt of special varieties annually, benefits from EU support but is subject to strict quota control.

Because the ware industry is subject to the forces of supply and demand, production is static. Over the 27 years from 1973 to 2000, the practice of growing potatoes for feeding to livestock tailed off while the starch industry expanded to reach a peak in 1996. But the dominant trend has been a huge expansion of the processing industry and in most countries there has also been a revolution in fresh potato grading, marketing and retailing. The real increase in value has been beyond the farm gate.

EU-12 arable crop comparisons, 1973 and 2000

	2000	% change	1973
Cereals			
Area (million ha)	33.602	- 8.4	36.678
Yield (t/ha)	5.82	+75.8	3.31
Prod. (million tonnes)	195.633	**+61.0**	121.538
Oilseeds			
Area (million ha)	5.205	+420.0	1.001
Yield (t/ha)	2.57	+73.6	1.48
Prod. (million tonnes)	13.369	**+804.5**	1.478
Sugar beet			
Area (million ha)	1.685	- 5.2	1.777
Yield (t/ha)	9.23	+63.7	5.64
Prod. (million tonnes)	16.766	**+60.9**	10.422
Potatoes			
Area (million ha)	1.263	-39.9	2.100
Yield (t/ha)	36.5	+58.7	23.0
Prod. (million tonnes)	46.071	**- 4.0**	48.000

Notes: Oilseeds = Rape, sunflower, soya beans. Sugar yield and production in tonnes white sugar. **Sources**: Eurostat; ZMP; COCERAL; F.O. Licht GmbH; Agra Europe (London) Ltd.

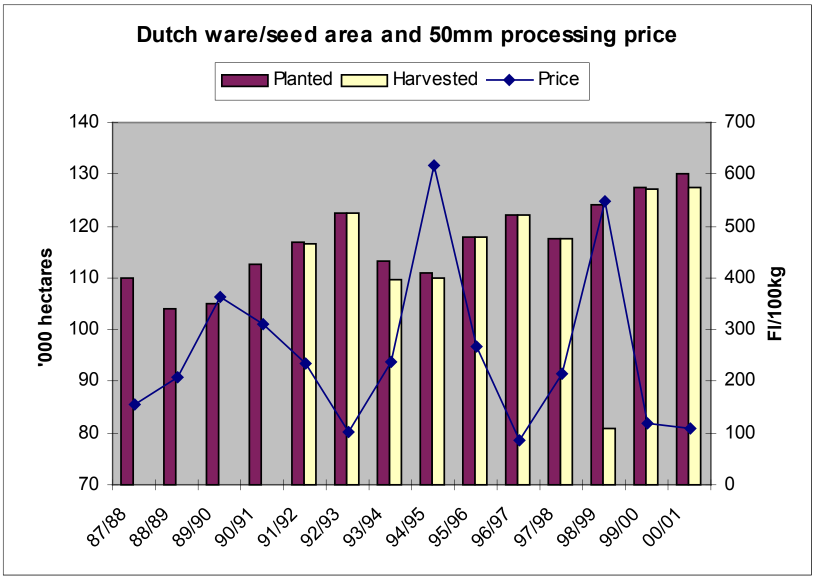
CAP crop development has contrasted with the ware potato trend. Cereals, oilseeds and sugar beet have been subject to cast iron market intervention. Growers and their bank managers have been secure in the knowledge that the EU was obliged to purchase these products at prices which were fixed in advance at levels which, in the past at least, guaranteed a good profit.

CAP policymakers were however unable to cope with the productivity gains which arable farmers were able to make. Over the 27 years, average yields have increased by 50-75% while there has been little change in cereal and sugar beet plantings but a spectacular rise for oilseeds, stimulated largely by the world supply shortages in the 1970s and the EU's situation of being deficient in supplies of protein feeds and vegetable oils.

Production of CAP commodities quickly moved into surplus. Because of the high internal support prices, subsidies were necessary if these surpluses were to be exported, leading not just to the WTO restrictions but also to the highly bureaucratic supply controls for the CAP crops. The arable support regime now costs an annual 18 000 million euros for the EU-15 with the sugar regime costing a further 1 900 million euros.

A wonderful illustration of the effects of the CAP is provided by the Cambridge University report on farming in the eastern counties of England. Sugar beet growers do best in high yield seasons, while potato growers do best in shortage seasons.

Because ware potato growers have to answer to the market, plantings have been cut by 38% over the 27 years and any surpluses in bumper crop years are disposed of mainly by feeding to livestock. Even in these surplus years, the sum total of any national aids across the EU must be less than 50 million euros and in most years the cost is zero.

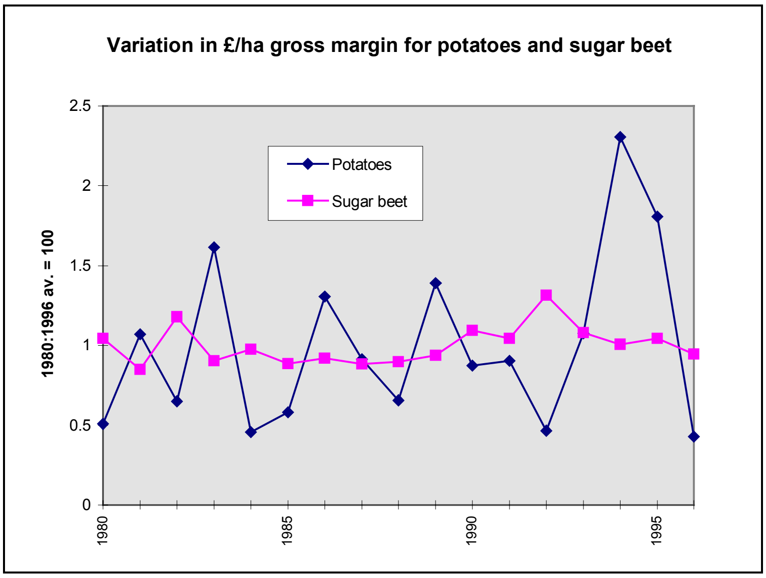


2) Seasonal fluctuations in plantings

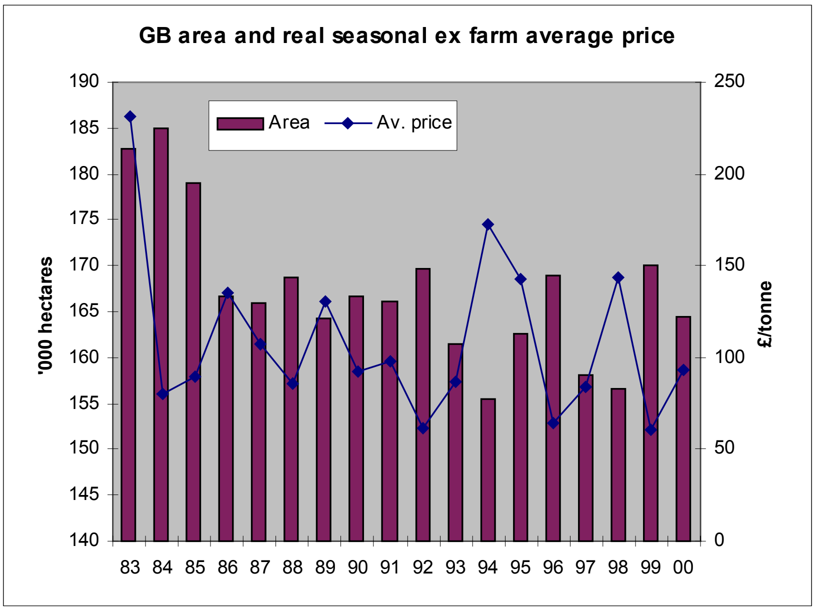
Because ware potato production is market-driven, prices fluctuate very widely from year to year, and the peaks and troughs are the exact inverse of the peaks and troughs in potato plantings. Farmers respond to high prices by planting more and cut back after a season of very low returns.

The attached chart takes the Dutch ware and seed planted and harvested areas and relates them to the average Rotterdam price quotation for 50mm Binte for processing, to provide a crude price indicator. Dutch ware and seed plantings peaked in 1987, 1992, 1996 and in 2000. The rise in 1998 was non-cyclical and due to a starch industry contraction; some starch growers switching to ware production. The effect was however confounded by the 1998 harvest losses.

The Dutch chart clearly shows the opposing price trend. The 50mm Rotterdam average price peaked in 1989/90, 1994/95 and again in 1998/99.



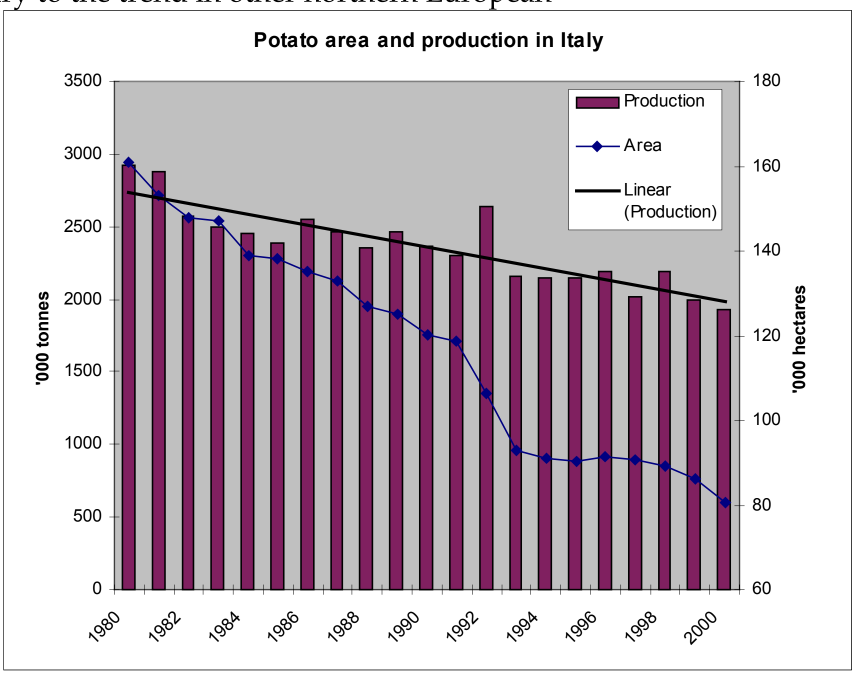
The Dutch and Belgian potato industries are unique in that they have been expanding over the long term, a trend which has been driven by the processing industry, although their reliance on Bintje makes them sensitive to the glassy tuber problem and the low-lying heavy soils in the Netherlands are sensitive to wet weather at harvest. In most other countries, plantings have been declining, although yield increases have sustained production.



The second chart takes the example of the area grown by British farmers according to the June census and takes the average ex farm price for the season calculated by the British Potato Council (formerly the PMB). Because of the downward trend, it is more difficult to make sense of the cyclical peaks and troughs.

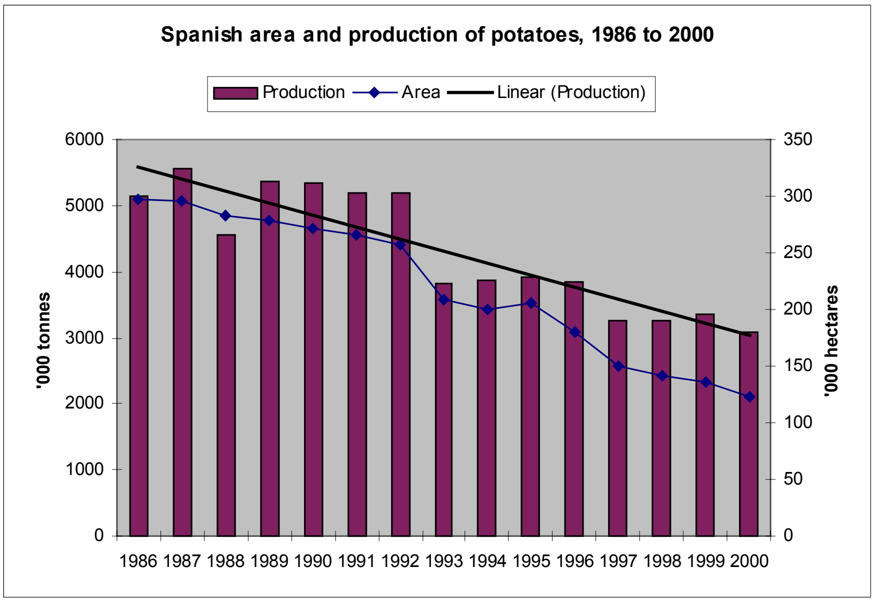
The seasonal prices shown have been adjusted for inflation on the basis of 1999 = 100. 1983 was a clear price peak but it took two successive seasons of poor prices to precipitate a savage cut in plantings. Trends in the late 1980s were not very pronounced but a series of dry summers enabled farmers to get away with continued increases in plantings. 1992 was however a wet growing year and the bumper yield produced a heavy surplus for feeding to livestock. Since then, however, the GB market has settled down to a clear four-year cycle from trough to trough. Plantings surged in 1999, because the increasing strength of sterling against the euro resulted in very poor returns for the CAP arable crops, while potato markets everywhere were benefiting from the Dutch harvest shortfall. But the euro plunged in value early this year, further depressing CAP crop returns, and the sharper decline in British and Irish plantings this year - quite contrary to the trend in other northern European countries - is something of a puzzle.

Both plantings and production have also declined over the long term in Italy and even more sharply in Spain. The chart sets out the position for Italy, according to ISTAT figures. In Italy the seasonal variation appears to be less than in more northerly producing countries; only the 1992 and 1998



crops showed a marked departure from the linear trend.
The long term decline is surely due to the switch in consumption away from fresh potatoes towards the consumption of processed products. The new processing plants have been sited in the central EU producing countries where rainfall is ideal for potato growing and yields are highest.

Spain is an example of an industry in serious decline. Spanish growers planted almost 300 000 hectares of potatoes in 1986, when they joined the Community. But by this year the area had more than halved - to 122 600ha - and output has fallen by more than 2 million tonnes to just over 3mt.This decline is illustrated in the following chart.



3) Other factors affecting area

Most of us here today are only interested in the market for fresh ware potatoes and for processed products for human consumption. But in Germany, for example, many more potatoes are planted for industrial uses (Starch, alcohol and feed) than for ware. The 2000 totals are estimated at 173 906ha for industry, 20 361ha early ware potatoes and 110 318ha maincrop ware.

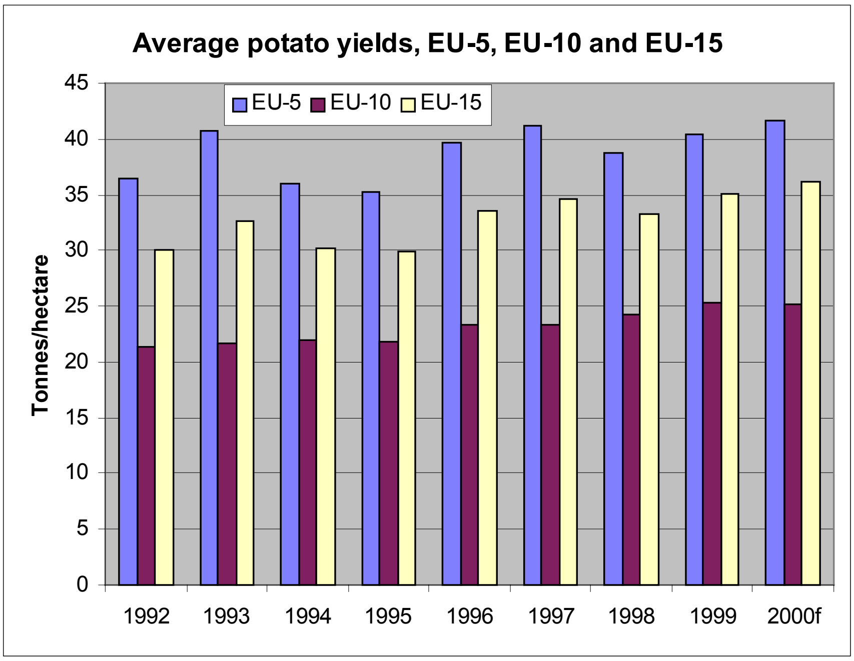
For most countries, it is very difficult to isolate ware production statistics from those published for total production. Only the French Ministry of Agriculture does a thorough job, publishing separate area, yield and production statistics for earlies, seed, maincrop ware and starch. But there is the complication here that the Ministry maincrop estimate differs from that published by the interprofessional committee CNIPT. The Dutch provide separate area - but not yield or production - figures for seed, and also provide complete starch industry figures. Britain and Italy do not routinely separate seed from ware.

4) The yield trend

Average yields of potatoes also fluctuate from year to year but the long term trend is clearly upwards, in all countries. In the dry summers of 1989, 1990 and 1991, the EU-15 average had been below 28 tonnes/hectare. It rose to 30.1 t/ha in 1992, when both Italy and the UK achieved their peak yields, but the EU-15 average was significantly higher in 1993 (32.7 t/ha) before easing back in 1994 and 1995 and surging again in 1996. A high level has been sustained since then: a new record level was achieved in 1999, and yet another this year.

Average yield of all potatoes in the seven major EU producing countries (tonnes/hectare)									
	2000f	**1999**	**1998**	**1997**	**1996**	**1995**	**1994**	**1993**	**1992**
Germany	**42.5**	37.5	38.1	38.4	39.0	31.4	33.0	39.3	30.2
Neths.	45.2	45.8	41.5	44.3	43.5	41.0	41.7	**46.3**	40.9
UK	36.9	40.1	39.3	42.9	40.7	37.4	40.0	41.5	**43.2**
France	39.2	37.9	36.8	**39.4**	35.8	33.6	33.2	35.6	36.3
Belgium	46.7	44.4	40.7	**45.8**	40.8	37.6	31.9	44.2	41.2
Spain	**25.3**	23.8	22.9	20.6	21.4	19.0	19.2	18.4	20.1
Italy	24.0	23.2	24.6	22.3	24.0	23.8	23.6	23.2	**24.9**
EU-15 av	**36.1**	34.6	33.3	34.3	33.6	29.9	30.2	32.7	30.1

The most spectacular performer this year has been Germany, whose likely yield average of 42.5 tonnes/hectare sets a new record by a very considerable margin. Dutch yields peaked in 1993, while French and Belgian yields peaked in 1997. 1996/97 was a season of heavy surplus but in many countries the average yield was higher in 1997 than it was in 1996. As Germany alone accounts for around 25% of the EU potato harvest, it has the dominant influence on the average yield, and is largely reponsible for this year's EU record.



The figures for the seven major producing countries set out in the table refer to all potatoes, and again there is the category problem. Of these countries, Germany, the Netherlands and France have substantial starch potato industries, where the growers' aim is to achieve the maximum possible yield. The Dutch also have by far the largest seed potato industry in the EU, but they only publish yield figures for ware and seed combined. Countries also vary in their percentages of early potato varieties, which sacrifice yield for early maturity. Italian early potato production now accounts for 20-25% of the total crop.

A curious feature of potato growing in the EU is that average yields also tend to move in 4- to 5-year cycles (see chart). I have absolutely no explanation for this.

5) Outlook for 2000/01

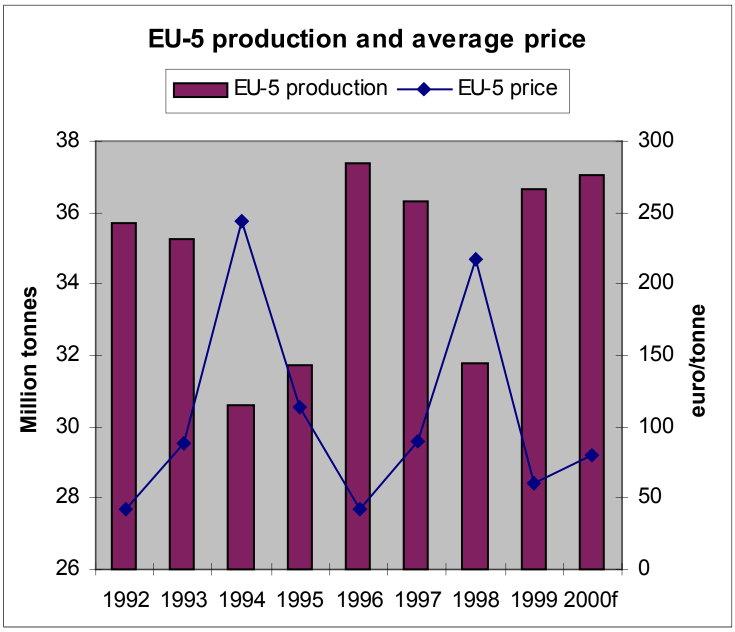
Ware potato prices are determined solely by supply and demand, although spot prices reflect the current state of the market and take no account of unsold stocks. Seasonal average prices however show a strong relationship with the tonnage of marketable production.

The market in the five centrally located producing countries (Germany, the Netherlands, the UK, France and Belgium) is quite clearly operating on a four-year cycle. The average price shown in the chart on the following page is a simple mathematical average in euro/tonne of the main quotations in each of the countries, with a forecast for 2000/01 being based on an extrapolation of the trend up to November 28.

The smallest harvest was produced in 1994, and the figure of 30.61mt for these countries over-stated the true position, because the Dutch estimate was not reduced to take account of the more than 20% wastage due to the glassy tuber problem. Not surprisingly, this season shows the highest price

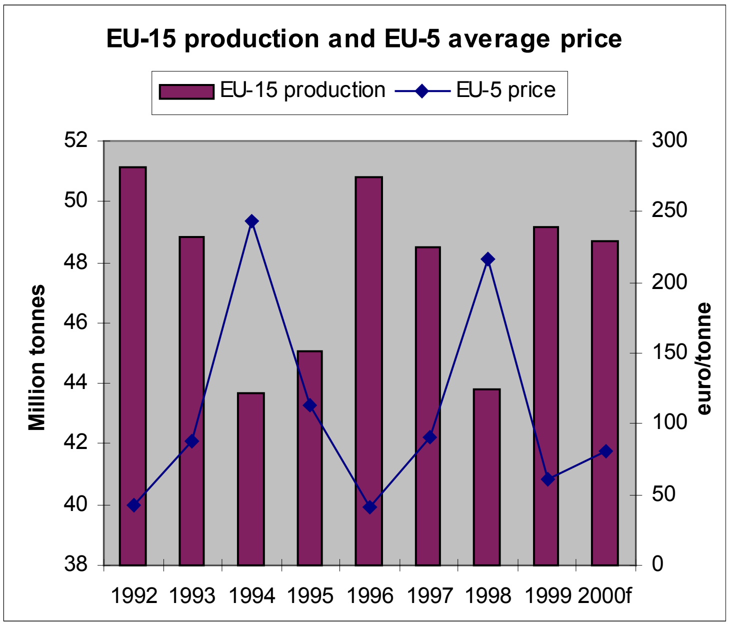
The next price peak was in 1998 as a result of the Dutch harvest disaster. Although the EU-5 harvest was unchanged on 1995, producers benefited from much higher prices in 1998/99 because the harvest in the remaining 10 countries was only 12.1mt compared with 13.3mt in 1995 and the five countries were able to increase their exports.

This is apparent from the second chart, which relates the EU-5 average price to total EU potato production. The total EU harvest was significantly smaller in 1998 than in 1995.



The same effect is apparent this year. Assuming that most of the unlifted area in the British Isles and in the Netherlands, France and Belgium is successfully harvested, the EU-5 harvest is actually larger than last year, due to the bumper German crop and increases in the Netherlands, France and Belgium more than outweighing the GB shortfall. But because of the continuing contraction in the remaining ten countries, the EU-15 harvest is down and this is allowing a small lift in prices.

Although this year's total harvest of 48.7 million tonnes is only slightly down on last year's 49.2mt crop, which resulted in prices falling through the season to rock bottom levels, I believe that there could be some limited price rises in the New Year, because this year's surplus will be largely confined to Germany. While German exports of processing potatoes will undoubtedly rise in response to demand from Britain, Germany does not grow the right varieties



for the British packing market and the top quality samples being demanded by British retailers are difficult to find, because German standards for skin finish are not as stringent. Export outlets in East Europe or non-food outlets may well have to be found for substantial tonnages of the German harvest.

6) The longer term outlook

Returns from CAP arable crops remain very poor, particularly in the UK because of the strength of sterling against the euro. It remains a puzzle to me why UK potato plantings were cut by 7.4% this year and farmers switched land back into wheat, while northern Continental growers, who did not suffer from the sterling effect, cut plantings by less than 2%.

There will surely be a large variation in planting trends next year. German farmers will have had their fingers burned this season. In 1997, following the glutted 1996 season, they reduced plantings by 9.6% or 32 200ha, although a quota-induced contraction of the starch potato area was partly responsible. Next year a 5% reduction is surely on the cards.

The Dutch industry is far from happy with returns this season. Plantings have remained at close to 180 000ha for the past four seasons but a second successive season of poor returns might prompt a small cutback, possibly of around 2%. The Belgian industry has also shown itself to be resilient to low prices and a 2% cutback is also likely here. French production is more cyclical and a 3% reduction is probable.

It is interesting to note that the two high-priced seasons in the mid- and late-1990s were both precipitated by developments in the Netherlands. This year it is the British and Irish harvesting problems which are mitigating the influence of the huge German crop. It is reasonable to expect a recovery in potato plantings in both the UK and Ireland. The overall effect could be a 2.7% cutback, to 1.314.7m ha.

The ideal EU-15 potato harvest, which would ensure satisfactory supplies to consumers and processors while providing a reasonable and sustainable return to growers, is 46-47 million tonnes in total or 37.5-38.5mt ware (assuming 8.5mt are

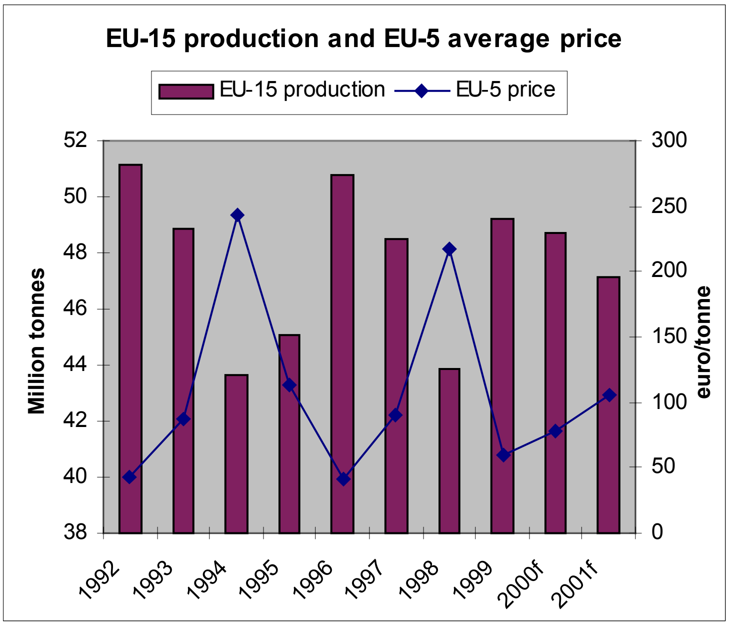
EU area, yield, production and price of potatoes by country grouping, 1991 to forecast 2001

	Area ('000 hectares)			Yield (tonnes/ha)			Production ('000t)			EU-5 price
	EU-5	**EU-10**	**EU-15**	**EU-5**	**EU-10**	**EU-15**	**EU-5**	**EU-10**	**EU-15**	**euro/t**
1991	928.1	730.0	1 658.1	33.6	19.3	27.3	31 174	14 096	45 270	n.a.
1992	976.9	722.0	1 698.9	36.5	21.4	30.1	35 680	15 476	51 156	42.1
1993	867.6	626.0	1 493.6	40.7	21.7	32.7	35 264	13 591	48 855	87.6
1994	850.1	594.8	1 444.9	36.0	21.9	30.2	30 610	13 050	43 660	244.1
1995	899.6	609.0	1 508.6	35.3	21.8	29.9	31 746	13 297	45 043	113.1
1996	941.5	572.9	1 514.4	39.7	23.4	33.6	37 410	13 409	50 818	41.5
1997	882.0	518.8	1 400.8	41.2	23.3	34.6	36 321	12 100	48 421	90.0
1998	817.8	498.3	1 316.1	38.8	24.3	33.3	31 754	12 086	43 840	217.0
1999	905.5	494.8	1 400.3	40.5	25.3	35.1	36 679	12 512	49 191	60.3
2000	887.3	463.9	1 351.3	41.7	25.2	36.1	37 035	11 690	48 725	78?
2001f	*867.2*	*447.5*	*1 314.7*	*41.5*	*25.0*	*35.9*	*35 988*	*11 188*	*47 176*	*105?*

Note: EU-5 = Germany, Neths., UK, France, Belgium. Agra Europe forecasts for 2000 and estimates for 1999 where official data not available.

produced for starch manufacture).

It can be seen from the table that over the past decade the EU-15 crop has been like Goldilocks' porridge: it has either been too large or too small, never just right. Growers need an average return of €100-130/tonne to provide a sustainable return and only the 1995/96 season came near to this. In some seasons the average price exceeds €200/t but this is only achieved on the back of a market shortage. This hits consumption and the effect extends into the first half of the following season.



If we are correct in our area forecast, then the EU-15 average yield needs to be 35-35.7 tonnes/hectare to achieve this harvest level. The problem in recent years has been the rapid technical improvements being implemented by growers. From a yield level of around 30 t/ha in the first half of the 1990s, yields surged upwards in the second half.

Of course it is anybody's guess what yields might be because it is impossible to predict what the climate will do. There could be another glassy tuber problem and a three-week summer drought, which occurred in three successive years from 1989 to 1991, can never be ruled out. Many more growers are now equipped with irrigation, but a drought could still knock 1-2 t/ha off the EU average, removing 1.3-2.6mt of potential production. On the other hand, growing conditions could be ideal and a third successive yield record could be set.

Companies have to engage in forward planning in the face of these uncertainties. My feeling is however that there is a good chance of the 2001 EU potato harvest being closer to the ideal level and for growers to benefit from a more significant lift in returns.

Freeze-Chilling of Mashed Potato

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SUMMARY

Freeze-chilling is an emerging technology which offers logistic and other benefits in ready-meal production, distribution and retailing. Freeze-chilling involves freezing and frozen storage, followed by chilling and chilled storage. Tests at The National Food Centre have indicated that mashed potato is a suitable food for freeze-chilling; however, level of centrifugal drip, and also loss of adhesiveness need to be controlled. Follow-on tests indicated that guar or xanthan gums, and also rapid freezing rates, largely overcome these deficiencies. Supplementing with encapsulated vitamin C was found useful for maintaining the vitamin C status of freeze-chilled mashed potato. The use of Good Manufacturing Practice (GMP), and Hazard Analysis of Critical Control Point (HACCP) is imperative in the production, distribution and retailing of freeze-chilled foods. General food labelling requirements should also be adhered to.

INTRODUCTION

The prepared consumer foods sector in Ireland is showing sustained and dynamic growth (1, 2) with exports increasing from £1,189 million in 1999 to £1,281 million in 2000 (2). Ready-meals are a significant component of the prepared consumer foods sector. Mashed potato is a ready-meal component, and is often a stand alone item in its own right, e.g. potato á la crème. Freeze-chilling is an emerging technology with potential for ready-meal production and distribution. The tests reported here investigated the freeze-chilling of mashed potato as a route to extending the 'chilled' shelf life of this product. Instant mashed potato was used as a model food, and tests are also ongoing on mash from the cultivars Rooster, Golden Wonder and Maris Piper.

FREEZE-CHILLING

Chilled foods (4°C) often command a premium in the market place as consumers perceive them as fresh. However, they have a short shelf life, perhaps only 5-days, depending on the product. Freeze-chilling offers the possibility of greatly increased shelf life and involves freezing and frozen storage followed by thawing and then retailing at chill storage temperatures. Freeze-chilling offers logistic and other advantages. For example, **(i)** foods can be prepared in bulk, then frozen and stored at deep freeze temperatures until required. Some, or all of the batch can then be thawed as necessary; **(ii)** freeze-chilling enables "chilled" foods to reach distant markets in that product can be shipped deep-frozen and then thawed when it reaches its destination prior to retail display; **(iii)** freeze-chilling can reduce the level of product recalls as it enables routine microbiological tests to be completed before the product is released from the factory.

Only certain foods are suitable for freeze-chilling. First and foremost they must be suitable for freezing and must not suffer significant structural damage; they should give zero or minimal drip on thawing. Factors which maintain product quality, such as rapid freezing, may be essential for some products. Freeze-chilling has particular application to more complex foods such as ready-meals or ready-meal components. However, all of the meal components must be freeze-thaw stable, including sauces and gravies. This may require the use of functional ingredients, such as hydrocolloids and cryoprotectants.

MATERIALS AND METHODS

Potato samples

Mashed potato made from reconstituted potato flakes (Erin Food Ltd) was used as a model food and was prepared according to the manufacturer's instructions (3). Mashed potato from Rooster was prepared following boiling the potatoes for about

20 minutes. Samples (500g) were placed in plastic boxes prior to applying a range of process treatments (see below) and the surface was covered with cling film to prevent moisture loss.

Process treatments

The samples were subjected to four process treatments as follows:

(i) **Freeze-chill:** Blast frozen at -35°C (2.5 hours); stored at -25°C for 1 week; thawed overnight at 4°C; held in chilled storage at 4°C for 5 days.

(ii) **Freeze:** Blast frozen at -35°C (2.5 hours); stored at -25°C for 1 week; thawed overnight at 4°C.

(iii) **Chill:** Chill storage at 4°C for 5 days.

(iv) **Fresh:** Cooked and tested on the same day.

Thawing took place in a chill room at 4°C overnight.

Test procedures

The samples of mash were tested for moisture and vitamin C contents, softness (by penetrometer), adhesiveness (by penetrometer removal), colour (Hunter colour meter), centrifugal drip, and taste panel preference. Details of the procedures have been published (3).

Other treatments/tests

Additional tests were conducted on freeze-chilled mashed potato as follows: **(i)** the effects of different freezing rates; **(ii)** the use of hydrocolloids/cryoprotectants for controlling drip loss; **(iii)** the use of encapsulation as a tool for maintaining vitamin C content. Brief details of procedures relating to these are given in the Results and Discussion section below.

RESULTS AND DISCUSSION

Effect of freeze-chilling

Freeze-chilled *instant mashed potato* was less soft, less adhesive, less white, had a lower vitamin C content, and a higher centrifugal drip loss than freshly prepared samples (Table 1). However, these differences were not reflected in taste panel response in that the freeze-chilled and fresh samples got the same mean rank score (Table 3). The freeze-only sample was the most preferred which agrees with the findings for Rooster mash (Table 3). Inspection of the data in Table 1 indicates that the freezing step of the freeze-chill process, and also the freeze-only treatment, resulted in a level of damage to the cell/starch structure in that the mash lost adhesivesness and had more free water on centrifugation. This can be overcome, to an extent, by using hydrocolloids/cryoprotectants (see below). The chill component of the freeze-chill

Table 1: Effect of process treatments on a range of quality parameters for instant mashed potato.

Test	Freeze-chill	Freeze	Chill	Fresh
Penetrometer value (N)[1]	7.27	6.33	6.05	4.68
Adhesiveness (N)[1]	0.87	1.08	2.75	2.60
Colour (L/b)[2]	3.80	3.92	4.28	4.10
Centrifugal drip (g/100g)	22.6	23.1	0.8	0.6
Vitamin C (mg/100g)[3]	11.8	19.8	11.2	21.2

[1]N = Newtons (low values indicate softness)
[2]White/yellow ratio
[3]Potato samples supplemented with vitamin C

process, and also the chill-only treatment, resulted in a loss of vitamin C; this effect has been found by other authors (4) for a range of vegetables that were cooked and then chilled. This finding prompted the use of encapsulation (see below) as a tool for maintaining the vitamin C status of freeze-chilled mashed potato. It should be noted that the vitamin C content of the instant mashed potato in the current tests (Table 1) was boosted by adding vitamin C; i.e. the instant mash ex-pack had a very low vitamin C content.

The pattern in the data for *freeze-chilling mash from Rooster* (Table 2) was similar in respect to adhesiveness and centrifugal drip, but different for penetrometer value and colour, to that obtained for instant mashed potato. Freeze-chilling and freezing gave a softer Rooster mash than chill-only and fresh, while the chill-only sample gave the whitest mash (Table 2).

Table 2: Effect of process treatments on a range of quality parameters for mashed potato from the cultivar Rooster

Test	Freeze-chill	Freeze	Chill	Fresh
Penetrometer value (N)[1]	3.03	3.37	5.19	4.32
Adhesiveness (N)[1]	0.72	0.98	2.53	2.32
Colour (L/b)[1]	3.87	3.86	4.30	3.67
Centrifugal drip (g/100g)	30.8	23.4	2.8	1.9
Vitamin C (mg/100g)[2]	1.0	1.8	0.8	4.0

[1]See footnotes in Table 1
[2]Mash not supplemented with vitamin C

Table 3: Taste panel preference scores (rank means)[1, 2, 3] for mashed potato samples

Treatment	Instant mash	Rooster mash
Freeze-chill	2.69	2.71
Freeze	2.12	2.11
Chill	2.49	2.93
Fresh	2.69	2.24

[1]Low values indicate the preferred samples
[2]Best possible score = 1; worst possible score = 4
[3]Means for 75 tasters (instant mash) and 45 tasters (Rooster mash)

Taste panels indicated a preference for frozen and fresh Rooster mash in comparison with the freeze-chilled and chilled samples (Table 3). These data suggest that the freeze-only treatment imparted desirable characteristics to the mash which was liked by the panellists; this effect seems to be negated by the follow-on chill step of the freeze-chill process. Full details of these tests have been published (3, 5).

Effect of rate of freezing and thawing

Tests were carried out on instant mashed potato to study the effect of different freezing and thawing rates on product quality, and especially on centrifugal drip loss. Fast freezing was conducted using cold nitrogen gas at -30, -60 or -90°C using a CM2000 cryogenic freezer supplied by Air Products plc; the corresponding centrifugal drip (CD) losses were 21, 18 and 12% respectively. An unfrozen chilled sample had a CD value of 0.65%. These data show that very rapid freezing is beneficial for the freezing of freeze-chilled mashed potato as it reduces CD values. However, quality improvement should be balanced against the higher cost of rapid freezing. The different rates of thawing had no influence on the quality parameters of the instant mashed potato. Full details of these tests are being prepared for publication (6).

Effect of hydrocolloids/cryoprotectants

A range of hydrocolloids/cryoprotectants was added as functional ingredients to potato puree (cultivar Rooster), prior to blast freezing, to study their effect on the level of centrifugal drip post-thawing. The levels of inclusions (as % weight/weight) were: xanthan and guar gums at 0.1%; carrageenan, pectin and lupin albumin at 0.5%; sodium caseinate 1%; whey protein concentrate 4%. Xanthan and guar gums gave major reductions in drip loss (Table 4) compared with the other treatments; however, they received the lowest sensory scores. It should be noted that all purees were tasted without the inclusion of milk, butter or seasoning. Future tests will focus on the inclusion of xanthan and guar gums (at different rates) in freeze-chilled mashed potato with added milk, butter and seasoning. The complete details of these tests have been published (7).

Table 4: Effect of hydrocolloids/cryoprotectants on the centrifugal drip loss (%) from blast frozen (and then thawed) potato puree

Ingredient	Centrifugal drip loss (%)
Xanthan gum	2.1
Guar gum	4.4
Carrageenan	12.5
Lupin albumin	14.4
Whey protein concentrate	16.9
Pectin	18.0
None **(control)**	19.6
Sodium caseinate	20.8

Effect of encapsulation on vitamin C status

Encapsulated ('cocooned' in a fat melting at 50°C) vitamin C (EVC 50) was compared with an equivalent amount of ordinary vitamin C as supplements in instant mashed potato subjected to freeze-chilling and freeze-only treatments. The supplements were added post cooking/cooling but before subjecting the samples to the process treatments. Encapsulation protected the vitamin C in freeze-chilled mash resulting in a value which was 70% higher than that in the freeze-chilled sample with ordinary vitamin C. The results of these tests have been published (8).

Table 5: Vitamin C content (mg/100g) of instant mashed potato supplemented with ordinary and encapsulated vitamin C, and subjected to freeze-chill and freeze-only treatments

	Fresh mash[2]	Frozen mash[2]	Freeze-chilled mash[2]
Added[1] vitamin C	18.8	16.4	7.9
Added[1] encapsulated vitamin C	20.8	18.1	13.4

[1]Added post-cooking/cooling, but prior to freezing
[2]Tested after microwave heating

SAFETY AND LABELLING OF FREEZE-CHILLED FOODS

The use of Good Manufacturing Practice (GMP) and Hazard Analysis of Critical Control Point (HACCP) is imperative in the production, distribution and retailing of freeze-chilled foods. Particular attention should be focused on the thawing step, and careful temperature control should be exercised. General food labelling requirements should be adhered to in the case of freeze-chilled foods, and the statement '*previously frozen*' should be included on the pack for reasons of consumer information and product liability. A use-by date should also be employed and this label should be attached at the start of the thawing process. A facts sheet (9) on *Freeze-Chilling of Food* and a manual on *Managing the Cold Chain for Quality and Safety* (10) are available from The National Food Centre.

CONCLUSIONS

- Freeze-chilling is an emerging technology which offers logistic and other benefits in ready-meal production, distribution and retailing.

- Mashed potato, as a stand alone product, or as a component of a ready-meal is a suitable food for freeze-chilling.

- Guar, or xanthan gum additions, and also very fast freezing, have potential for reducing centrifugal drip, and increasing the adhesiveness of freeze-chilled mashed potato.

- Encapsulated vitamin C, added as a supplement to mashed potato, is much better retained under freeze-chill conditions than is ordinary vitamin C.

- Tests are continuing at The National Food Centre on the freeze-chilling of mashed potato in order to pinpoint the best combinations of cultivar, functional ingredients and freeze-thaw conditions.

ACKNOWLEDGEMENTS

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