On the Road to Potato Processing

On the Road to Potato Processing

The English potato terms used on an international level are not always the same from country to country. Therefore, please note that the terms ‘French Fries’ and ‘Chips’ in this brochure are used for:

And the term ‘Crisps’ is used for:

Contents

Introduction

As well as being grown for immediate consumption, potatoes are increasingly being used as a raw material by the processing industry. The grower should take into account the fact that customers are very particular about quality. The processing industry sets strict requirements because they have to produce a high-quality product on a cost-effective basis. Therefore, the processing industry sets strict criteria for tuber length, colour, fat content and dry matter content so that the French fries, crisps, granules and flakes meet well-defined standards. Potatoes serving as raw material for the processing industry must meet a number of requirements regarding the following quality characteristics:

- Size and shape of tubers
- Injuries and defects
- Dry matter content
- Colour

The quality is influenced by various external factors such as climate, type of soil, variety, crop management, harvesting and storage. The grower is able to positively influence these matters in order to guarantee the continuous supply of well matured, high-quality raw material to the processing industry.

1 Tuber characteristics determining quality

1.1 Size and shape of tubers

The external quality of potatoes is extremely important in the processing industry. Characteristics of particular interest are the shape, the occurrence of diseases on the skin, and the extent of external damages.

Size, shape and shallow eyes are important with regard to the appearance of the product and the influence on wastage during peeling.

- French fries producers prefer long-oval or long tubers with a size of ≥ 50 mm.
- For the production of crisps, round tubers are required with a size range of 40 - 60 mm.

1.2 Injuries and defects

Rough handling of the potatoes during harvesting and transportation causes internal bruising. The internal tissue cells crack and brown stains are formed in the tuber, which is an impediment to processing. Internal defects such as hollow or black heart are also undesirable.

One of the most important problems the industry often has to deal with is black spot. This blue to greyish-black discoloration in the tubers is more inclined to occur during transport and grading if the potatoes are not handled and stored in the proper way. As a result of tissue injury, chemical conversions take place, which after a day or two cause a dark discoloration. Therefore it is necessary to handle potatoes as carefully as possible to prevent black spot. In addition, potatoes should be heated to about 15ºC before grading. Some varieties are far more susceptible to black spot than others.

Almost all potato varieties are more or less susceptible to common scab. But this disease can be effectively controlled by keeping the soil moist, especially during the susceptible period of tuber initiation until about four weeks later.

1.3 Dry matter content

The term dry matter content means the mass fraction (%) that remains after the water fraction (%) has been removed by drying. The opposite term 'moisture content' is also used.

Both the processing efficiency and the quality of the finished product benefit from a high dry matter content. If the dry matter content is too low, the French fries or crisps will be too soft or too wet. In addition, more energy will be required, since more water must be evaporated. A high dry matter concentration results in a lower fat content. This lowers the processing costs and is better for the health of consumers. However, if the dry

matter content is too high, the French fries will be too hard and dry and the crisps will be too brittle. The dry matter content also partly determines the texture of both the fresh and the processed potato.

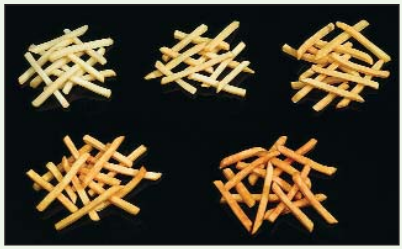
The requirements in respect of the dry matter content are determined by the end product:

- For the production of French fries, potatoes with a dry matter content of 20 - 24% are preferred.
- For the production of crisps, preference is given to potatoes with a dry matter content of 22 - 24%.
- For the flakes industry, potatoes with a rather high dry matter content (higher than 21%) are required.

1.4 Colour

1.4.1 Reducing sugars

The frying colour is an important criterion for potatoes destined for the French fries and crisps industry. The frying colour of the fried products is determined to a large extent by the reducing sugar content in the potatoes. The higher the content of reducing sugars the darker the frying colour. A dark frying colour results in a bitter taste, which is unacceptable in the production of French fries and crisps.



The requirements with regard to the content of reducing sugars depend on the end product:

- Of all processing industries, the crisps industry makes the highest demands on the content of reducing sugars; the reducing sugar content may not exceed 0.2 - 0.3% of the fresh weight.
- For the French fries industry the standard is less than 0.5% of the fresh weight.
- For flakes and granules used in snack production, the reducing sugar content should not exceed 0.3% of the fresh weight.

Another important aspect is colour distribution. Unevenness in colour distribution results in French fries with a brown colour at one end. The causes of this phenomenon are senescence after long storage and secondary growth. Some varieties are prone to the so called 'sugar ends' as a result of senescence after long storage. In extreme cases of secondary growth, starch is abstracted from the primary tuber. The abstraction starts at the heel-end of the potatoes and may lead to glassiness. Glassiness is when the potato tissue of a re-sprouted tuber, or the top end of a long tuber, looks watery-translucent when cut. It may even have a spongy texture. Glassy tubers can be sorted out by dipping the potatoes in a bath with a salt solution with a SG of 1,060 (153g NaCl/l water). The glassy potatoes will float and can easily be skimmed off.

1.4.2 Darkening

1.4.2.1 Non-enzymatic

During the production of potatoes a greyish hue sometimes develops. This occurs when a compound of iron and chlorogenic acid is oxidised due to the oxygen in the air. Once the French fries have been fried this discoloration is hardly noticeable, if it is at all. Yet this characteristic, closely linked with certain potato varieties, is considered to be a serious quality defect.

1.4.2.2 Enzymatic

Enzymatic darkening occurs when cells are damaged and enzymes and substrate are mixed, initiating all kinds of reactions. There are also reactions that cause brown and grey discolorations, due to the formation of a type of enzyme that affects tissue colour.

2 External factors influencing quality

When producing potatoes for processing the grower has three major aims: high yields, high quality and the lowest costs. While yields are expressed in tonnes per hectare, quality is expressed in terms of recovery, that is: the number of kg of processed product that are produced from 100 kg fresh potatoes. High yields are ensured when proper varieties are subjected to suitable growing conditions and are supplied with adequate amounts of inputs. The highest yields do not necessarily lead to the best quality because recovery depends on

high dry matter concentrations, homogeneous and relatively large tuber sizes, low amounts of black spot due to bruising, low reducing sugars and few defects. Well-matured crops have higher recoveries than crops harvested before maturity. Cost reduction results from the efficient use of land, labour and inputs such as water, fertilisers and crop protection chemicals. Crop management continuously takes these three factors into consideration to optimise the benefits of the crop.

2.1 Climatic conditions

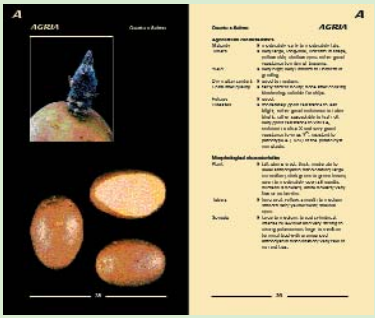
The production of dry matter and the dry matter concentration of potatoes are a result of photosynthesis and respiration. These processes are not only influenced by the physiologically determined factors of the plant, but also to a large extent by climatic conditions: radiation, day-length, and temperature. Daily radiation determines the growth and production (photosynthesis) of the crop. The temperature influences the efficiency of photosynthesis during the day and losses by respiration at night. At higher temperatures a greater proportion of the dry matter produced is allocated to the leaves. Temperature also determines the length of the growing season (ideally frost free but not too hot) and, as a consequence, the attainable yields. Day-length determines tuber initiation. The short day species of Solanum forms tubers earlier and matures earlier at shorter day-lengths. Both high temperatures and short days lead to lower tuber dry matter concentrations.

It is generally assumed that for the production of potatoes the optimum temperature is around 20ºC during the daytime and around 15ºC at night. Long days combined with relatively high temperatures tend to delay tuber initiation and stimulate haulm growth. This will result in an increased reducing sugar content. Experiments have shown that with day-lengths of 10, 14 and 18 hours the colour of French fries becomes progressively darker. This means that an increase in day-length corresponds with an increase in reducing sugar. This is in accordance with the evidence that varieties developed under long-day conditions improve in processing quality when grown under shorter-day conditions.

When the potato crop for processing is grown with high yields and high recovery in mind, the management should aim to match the available growing season and inputs with the requirement of the variety. When the growing season is too short to lead to high yields and high dry matter concentrations, or the variety is too late or too early, it is likely that profits will be reduced.

2.2 Variety

In determining the suitability of potatoes for the processing industry, internal and external quality plays an important role. Only varieties that meet special quality standards and can be processed on a cost-effective basis will qualify for the processing industry.



The 'Netherlands Catalogue of Potato Varieties' (a three-yearly publication by NIVAA) gives an indication of the suitability for processing of the varieties grown under Dutch conditions. In the catalogue, a selection is given of the most important Dutch potato varieties for the global potato sector. The various properties and qualities of each variety are stated clearly, for instance: dry matter content, shape of tubers, shallowness of eyes, size of tubers and internal bruising.

When selecting a variety for a particular environment it should be kept in mind that most varieties respond differently to temperature, day-length, availability of water and nutrients, planting patterns and the timing of haulm killing or harvest. Therefore it is advisable to test a number of varieties for a few years under local conditions to find out how to optimise management.

2.3 Crop Management

2.3.1 Planting density

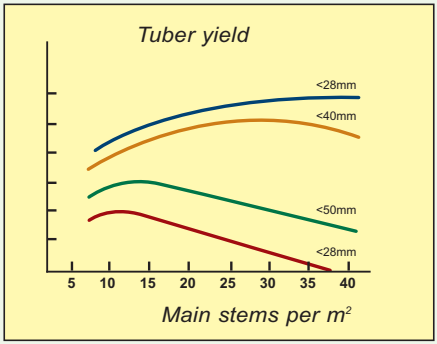
Potatoes grown as a raw material for French fries should be large, while those for crisps should be of medium size. The plant density affects both the total yield and the tuber size. In general, 12 -15 stems/metre^2 are sufficient to get a yield of 40 - 60 tonnes/ha, made up of a high proportion of large tubers. 30,000 - 50,000 plants/ha are required to produce a sufficiently high density of stems.

The exact number of plants per hectare is determined by variety, seed size, seed age, soil type and the end use of the crop. Larger seeds produce more stems, and well-sprouted tubers produce more stems than seed that is too young or too old.

Yield is determined by the amount of solar radiation the crop intercepts, so an early canopy closure increases production. Factors leading to early canopy closure include: higher plant densities, well pre-sprouted seed, planting depths that are not too deep, soil that is moist but not too cold, and a planting pattern where the distances between the rows are not too wide.

But while they increase yield, some of these factors may reduce quality due to the fact that high planting densities increase tuber numbers per square meter and reduce tuber size. Narrow distances between rows only allow smaller hills (ridges) and increase the risk of green tubers. Testing varieties and gaining experience with both varieties and management practices is of key importance in determining the best planting policy.

Trends in response to stem density, yield and tuber size are shown in the following graph. Lower plant densities increase tuber size (hence percentage recovery in the factory) but they may negatively influence tuber yield per hectare.



Relationship between number of main stems per m² and tuber yield in the various grades

(Source: H.P. Beukema/ D.E. van der Zaag).

All management by the grower should be aimed at reducing variability between tubers. Ideally, a potato crop for processing has tubers all of the same size and shape and with the same dry matter content between and within tubers. Reduction of variability in tubers is best achieved when variability in growing conditions is reduced by planting seed tubers of the same size at the same depth, with the same distances between tubers within the row, and providing an even distribution of fertilisers and moisture. Adequate hilling (ridging) with the aid of a rotary row-crop cultivator in heavy soils helps to ensure homogeneous conditions in the soil.

2.3.2 Fertiliser

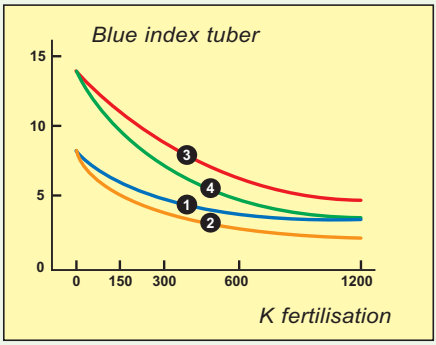
The establishment of good fertility and proper fertilisation with nitrogen, phosphate and potassium will have a positive effect on both the yield and the quality required.

Nitrogen is mobile in the soil and moves in the soil water. Therefore it can be applied throughout the season. Phosphorus and potassium are hardly mobile, being bound to the soil particles, and therefore have to be applied prior to planting and have to be well mixed through the soil.

By fertiliser application, the grower can influence the tuber dry matter concentration and the susceptibility to black spot. The processing industry demands a high dry matter content. However, a high dry matter content increases susceptibility to black spot and internal bruising.

When both nitrogen and potassium are applied in large quantities, they tend to reduce the tuber dry matter concentration and, consequently, the susceptibility to black spot. In this respect, the application of potassium chloride is beneficial in reducing black spot. However, under dry conditions this may lead to a somewhat lower yield. When using potassium chloride, this should be done well in advance of planting in order to avoid salinity problems. If black spot is a serious problem one might consider a crop rotation application on non-leaching soils. This is a method whereby all of the potassium that is required in a certain crop rotation period of e.g. three or four years is applied prior to planting the potato crop. This should be done well in advance of planting, during autumn or winter.

An excessive nitrogen application rate may adversely affect the colour and the non-enzymic blackening of the tuber. Moreover, a large quantity of nitrogen delays maturing of the crop resulting in a relatively low dry matter concentration and a relatively high nitrate content in the tuber. The dry matter concentration may drop so low, that the tubers cannot be used by the processing industry.



Effect of potassium fertilisation with K60 (kg K_20/ha) on the susceptibility to black spot after autumn and winter fertilisation on clay soils in the Northeast Polder (❶ resp. ❷) and S.W. Clay area (❸ resp. ❹) in the Netherlands

The quantities of nitrogen, phosphate and potassium fertiliser to be applied to the potato crop should preferably be based on a mineral analysis of the soil to determine the actual soil fertility prior to planting. Other issues to take into consideration are the soil type (risk of leaching or fixation), the previous crop and the lateness of the variety. Nitrogen is preferably given in more than one application. About half of the crop's needs are given at planting and the rest in one or more subsequent dressings. Laboratories that sample soils and crops advise how much should be applied during crop growth. The advantages of such monitoring are that yields and quality are manipulated continuously while the risks of leaching nitrogen are reduced.

As a guideline, the basic nutrient requirements of a potato crop yielding 30 tonnes/ha during growth are:

150 kg of N
60 kg of P_2O_5
350 kg of K_2O
30 kg of MgO
90 kg of CaO

(Source: H.P. Beukema / D.E. van der Zaag)

2.3.3 Irrigation

Water is of vital importance to crops. It is indispensable for the most elementary processes such as photosynthesis and transport of minerals in plant and soil. However only about 2% of the water needed by a crop is used for plant metabolic processes. The rest is transpired. The yield of a crop is determined to a large extent by the total amount of water that is available for the crop. With each litre of water transpired, the crop produces about 6 grams of dry matter.

Good moisture supply during the various growth stages is essential for the production of quality tubers. The moisture supply just before or during tuber initiation (that is, approximately three weeks after emergence) is of vital importance. More water increases the number of tubers and their size. More soil moisture at tuber initiation also reduces the occurrence of common scab.

Moist conditions during tuber initiation always result in a larger number of tubers, although dry conditions thereafter may lead to re-absorption of the smallest ones. Varieties which normally form many tubers may form too many in moist conditions. During tuber growth (bulking), a regular water supply prevents a decline in quality caused by growth cracks, secondary growth symptoms such as tuber deformation and glassiness and stem-end browning. If the conditions are dry during harvesting, particularly on heavier soils, irrigation can help prevent injuries caused by lifting the potatoes. Irregular water supply has a negative effect on the colour of the potatoes.

For proper irrigation, scheduling information is needed on the water holding capacity of the soil, which is lowest in coarse sand and fine clays. Water needs are greater when daily evapotranspiration (as measured and made available by meteostations) increases when the proportion of the soil covered with green leaves is higher.

2.3.4 Pest and disease control

Only a well-matured crop will finally meet the quality standards demanded by the processing industry. Diseases may lead to lower yield due to later canopy closure or to earlier dying off of the foliage. The quality may also be reduced as early crop death is associated with lower dry matter concentrations. Direct effects are caused by e.g. common scab or root knot nematodes that affect the skin and make thicker peeling necessary. Storage diseases such as silver scurf and Pythium may cause storage losses.

The two main measures to prevent diseases and pests are: a) the use of healthy and certified seed and b) hygienic measures such as crop rotation. Healthy seed reduces the risk of bacterial and virus diseases. A crop rotation, in which potatoes are not grown more frequently than once every four to six or more years, significantly reduces the risk of soil borne pests (nematodes) and fungi (Rhizoctonia and Verticillium). Once foliar pests (aphids) or diseases (Phytophthora infestans) are present, curative measures consist of regular spraying of the crops with appropriate chemicals. Weeds should be controlled throughout the season, preferably mechanically while hilling (ridging), but the use of herbicides may be necessary to avoid yield reduction and the build up of weed seeds in the soil.

When the crop nears maturity, haulm killing is often required to set the skin prior to harvest and to prevent diseases doing further harm.

2.4 Product handling

2.4.1 Harvesting

A crop should mature well. This will result in a relatively high dry matter content and a minimal reducing sugars content. This combination provides a relatively good frying quality. During harvesting, severe loss of quality may occur when potatoes are damaged during lifting. This causes subcutaneous discoloration, which should be prevented. The likelihood of internal bruising is greatest when the potatoes are lifted under dry conditions in cloddy soils.

To a certain extent damage can be rectified during harvesting by means of light irrigation just before the crop is lifted. Furthermore, the grower should try to keep soil on the web of the harvester for as long as possible, and the speed of the elevator chain should be adjusted to the driving speed (approximately a ratio one to one). In dry conditions it is useful to cover the spindles of the elevator chains with synthetic material or rubber. The dropping height of the potatoes should not exceed 40 cm during harvesting, unloading in the store and during grading. In places where potatoes drop down, soft materials and shock-absorbing mats can be used to prevent damage.

Because of their weight, the largest tubers are most liable to suffer damage. The risk of bruising increases when soil temperatures at harvest time are low. To prevent internal injury caused by harvesting, potatoes should not be lifted at soil temperatures below 12ºC. But if it is late in the season, attempts may have to be made to get the potatoes lifted, anyway. As a rule, harvesting at soil temperatures lower than 8ºC should be avoided whenever possible.

2.4.2 Handling

Bruises occur during storage as a result of the pressure that is put by one tuber on the other, causing the potatoes to flatten and be bruised. When the store is emptied, black spots in the tuber flesh can develop under these bruises. The incidence of bruising increases after dry seasons or as a result of too much ventilation.

In ware potatoes, black spot incidence often increases after a prolonged storage (six months or more). To prevent bruising in this situation, the storage height of the potatoes should be limited to 3.5 - 4 metres, and equipment where potatoes strike hard surfaces should be cushioned. However, when potatoes are stored in boxes, bruising usually does not occur, as the dropping height is minimal.

2.4.3 Storage

The potato is a living organism and, under favourable storage conditions, can be kept for long periods of time (7 - 9 months). However, during storage loss of weight, but also loss of quality may occur. Limiting these losses is a pre-requisite for the production of potatoes for processing.

When potatoes destined for the processing industry are stored, the following measures affecting quality, merit special attention:

- Ventilation
- Temperature control
- Application of sprout inhibitors
- Conditioning before delivery

2.4.3.1 Ventilation

To prevent weight loss, and consequently an increased susceptibility to black spot, the store should be ventilated as little as possible, and preferably at a high air humidity (RH >=92%). When this cannot be done, for instance in areas with very low outside temperatures or in very dry areas, artificial air humidification during ventilation can help to solve the problem.

2.4.3.2 Temperature

Storage losses caused by respiration and the occurrence of fungal or bacterial infection are smallest at storage temperatures of 3 - 5ºC. However at such low temperatures the development of reducing sugars, which negatively influences the fry colour, is stimulated. Therefore it is advisable to store potatoes that are intended for the processing industry at relatively high temperatures. For crisps production this should be at 7 - 10ºC and for the French fries and flakes industry, 6 - 7ºC.

Potatoes with a reducing sugar content that is too high (due to storage temperatures that are too low) can be reconditioned. To do this, they can be kept at a temperature of about 15ºC for a period of two to three weeks. This has the effect of breaking down the surplus of sugars by converting them to starch and by respiration. The results of this reconditioning can

vary, particularly after prolonged storage time. For example, prolonged storage decreases the effect of a reconditioning period, and senescent sweetening may occur. The effect of reconditioning is then even worse than if it had not been carried out, and should be avoided.

2.4.3.3 Sprout inhibitors

Sprout formation is minimal at a storage temperature of 3 - 4ºC. However, potatoes for the processing industry should be stored at higher temperatures to limit the formation of reducing sugars. Therefore measures to inhibit sprouting merit particular attention. The application of CIPC/IPC (Isopropyl 3-chloro-phenyl carbamate) is the method used most for this purpose. CIPC is effective when potatoes are stored at temperatures up to about 12ºC. A new development is the application of Carvone (a component of caraway seed) as a biological sprout inhibitor. Carvone is not only a sprout inhibitor, but it also has a positive effect on controlling various storage diseases and it even kills slugs.

2.4.3.4 Conditioning before delivery

Potatoes with a high dry matter content are more susceptible to black spot than potatoes with a low dry matter content. Heating the potatoes before size grading or delivering them will considerably decrease black spot susceptibility. Therefore, potatoes intended for the processing industry should be heated to at least 15ºC, before unloading out of the store. Potatoes with a high susceptibility to black spot should be heated to 18ºC. During the heating process the air temperature should not exceed 20ºC. It is wise to allocate at least three days to the heating process.

3 Methods of quality assessment

Only varieties that meet particular quality requirements are suitable for the potato processing industry. These requirements are comprehensive, varying from external size and shape, which is dependant on the destiny of the product (French fries or crisps), to the internal composition of the potato (e.g. dry matter or sugar content). A wide range of testing methods is available to measure these properties. These methods vary from simple visual inspections to advanced instrumental methods. Quality assessments will be done on raw material as well as on the end product.

For the raw material, particular aspects such as size, shape and the lack of defects like diseases, rot, bruising and dry matter and sugar content are of importance. Assessment of defects has to be done by visual quality inspection at the start of the production line. For the determination of the dry matter and sugar content a method is described under 3.1 and 3.2, respectively. The quality of the end product depends, among other things, on the buyer's specifications. The most important quality characteristics of the end product are described under 3.3.

3.1 Dry matter content

For the assessment of the dry matter content of raw material there is a simple and quick method based on the density of the potato tubers. This density can be obtained by determination of the tuber weight in tap water (W.I.W). The assessment of the dry matter content is based on the principle that there is a close relationship between the density of the potato tuber and the dry matter content of the potato tissue. In table 2, the figures of dry matter content corresponding with W.I.W. are given.

Determination of the weight in water of a potato sample

Table 2: Relation between the weight in water (w.i.w.), dry matter content (d.m.) and specific gravity (S.g.) of potatoes (IBVL Publication 247 B).

w.i.w.	d.m.	S.g.	w.i.w.	d.m.	S.g.	w.i.w.	d.m.	S.g.	w.i.w.	d.m.	S.g.	w.i.w.	d. m.	S.g.	w.i.w.	d. m.	S.g.
250	14,3	1.053	331	18,3	1.071	371	20,3	1.080	411	22,2	1.090	451	24,2	1.099	491	26,2	1.109
255	14,6	1.054	332	18,3	1.071	372	20,3	1.080	412	22,3	1.090	452	24,2	1.099	492	26,2	1.109
260	14,8	1.055	333	18,4	1.071	373	20,4	1.081	413	22,3	1.090	453	24,3	1.100	493	26,3	1.109
265	15,1	1.056	334	18,4	1.072	374	20,4	1.081	414	22,4	1.090	454	24,3	1.100	494	26,3	1.110
270	15,3	1.057	335	18,5	1.072	375	20,5	1.081	415	22,4	1.091	455	24,4	1.100	495	26,4	1.110
275	15,6	1.058	336	18,5	1.072	376	20,5	1.081	416	22,5	1.091	456	24,4	1.100	496	26,4	1.110
280	15,8	1.059	337	18,6	1.072	377	20,5	1.082	417	22,5	1.091	457	24,5	1.101	497	26,5	1.110
285	16,1	1.060	338	18,6	1.073	378	20,6	1.082	418	22,6	1.091	458	24,5	1.101	498	26,5	1.111
290	16,3	1.062	339	18,7	1.073	379	20,6	1.082	419	22,6	1.091	459	24,6	1.101	499	26,6	1.111
295	16,5	1.063	340	18,7	1.073	380	20,7	1.082	420	22,7	1.092	460	24,6	1.101	500	26,6	1.111
300	16,8	1.064															
301	16,8	1.064	341	18,8	1.073	381	20,7	1.082	421	22,7	1.092	461	24,7	1.102	505	26,8	1.112
302	16,9	1.064	342	18,8	1.073	382	20,8	1.083	422	22,8	1.092	462	24,7	1.102	510	27,1	1.114
303	16,9	1.065	343	18,9	1.074	383	20,8	1.083	423	22,8	1.092	463	24,8	1.102	515	27,3	1.115
304	17,0	1.065	344	18,9	1.074	384	20,9	1.083	424	22,9	1.093	464	24,8	1.102	520	27,6	1.116
305	17,0	1.065	345	19,0	1.074	385	20,9	1.083	425	23,9	1.093	465	24,9	1.103	525	27,8	1.117
306	17,1	1.065	346	19,0	1.074	386	21,0	1.084	426	23,0	1.093	466	24,9	1.103	530	27,1	1.119
307	17,1	1.065	347	19,1	1.075	387	21,0	1.084	427	23,0	1.093	467	25,0	1,103	535	28,3	1.120
308	17,2	1.066	348	19,1	1.075	388	21,1	1.084	428	23,1	1.094	468	25,0	1.103	540	28,6	1.121
309	17,2	1.066	349	19,2	1.075	389	21,1	1.084	429	23,1	1.094	469	25,1	1.104	545	28,8	1.122
310	17,3	1.066	350	19,2	1.075	390	21,2	1.085	430	23,2	1.094	470	25,1	1.104	550	29,1	1.124
311	17,3	1.066	351	19,3	1.076	391	21,2	1.085	431	23,2	1.094	471	25,2	1.104			
312	17,4	1.067	352	19,3	1.076	392	21,3	1.085	432	23,3	1.095	472	25,2	1.104			
313	17,4	1.067	353	19,4	1.076	393	21,3	1.085	433	23,3	1.095	473	25,3	1.104			
314	17,4	1.067	354	19,4	1.076	394	21,4	1.086	434	23,4	1.095	474	25,3	1.105			
315	17,5	1.067	355	19,5	1.076	395	21,4	1.086	435	23,4	1.095	475	25,4	1.105			
316	17,5	1.067	356	19,5	1.077	396	21,5	1.086	436	23,5	1.096	476	25,4	1.105			
317	17,6	1.068	357	19,6	1.077	397	21,5	1.086	437	23,5	1.096	477	25,5	1.105			
318	17,6	1.068	358	19,6	1.077	398	21,6	1.086	438	23,5	1.096	478	25,5	1.106			
319	17,7	1.068	359	19,7	1.077	399	21,6	1.087	439	23,6	1.096	479	25,6	1.106			
320	17,7	1.068	360	19,7	1.078	400	21,7	1.087	440	23,6	1.096	480	25,6	1.106			
321	17,8	1.069	361	19,8	1.078	401	21,7	1.087	441	23,7	1.097	481	25,7	1.106			
322	17,8	1.069	362	19,8	1.078	402	21,8	1.087	442	23,7	1.097	482	25,7	1.107			
323	17,9	1.069	363	19,9	1.078	403	21,8	1.088	443	23,8	1.097	483	258	1.107			
324	17,9	1.069	364	19,9	1.079	404	21,9	1.088	444	23,8	1.097	484	25,8	1.107			
325	18,0	1.070	365	20,0	1.079	405	21,9	1.088	445	23,9	1.098	485	25,9	1.107			
326	18,0	1.070	366	20,0	1.079	406	22,0	1.088	446	23,9	1.098	486	25,9	1.108			
327	18,1	1.070	367	20,1	1.079	407	22,0	1.089	447	24,0	1.098	487	26,0	1.108			
328	18,1	1.070	368	20,1	1.079	408	22,1	1.089	448	24,0	1.098	488	26,0	1.108			
329	18,2	1.070	369	20,2	1.080	409	22,1	1.089	449	24,1	1.099	489	26,1	1.108			
330	18,2	1.071	370	20,2	1.080	410	22,2	1.089	450	24,1	1.099	490	26,1	1.109			

The W.I.W. of potatoes can be determined by the following procedure:

- A representative sample of potatoes of over 5000 gram is taken from the lot. Scurfy and diseased tubers should not be included in the sample.
- The sample is washed with water, drained well and eventually dried with a cloth.
- In the air 5000 gram dry or 5050 gram wet potatoes (*a* gram) are weighed precisely to within one gram.
- The weight (*b* gram) of the potato sample is determined in tap water at a temperature of 8 - 12ºC.
- The W.I.W. can now be calculated with a formula, which is for dry potatoes: (5000 : *a*) x *b*, and for wet potatoes: (5050 : *a*) x *b*.

(Source: European Association for Potato Research, Methods of Assessment for Potatoes and Potato Products)

3.2 Reducing sugars content

The reducing sugar content of the tuber at harvest time depends on the maturity of the crop at the time of the haulm destruction. The reducing sugar content is higher as the potato crop has matured less. The reducing sugar content in potatoes and the colour of fried products are closely connected. The higher the reducing sugar content, the browner the colour.

To get a quick indication of the content of reducing sugars, glucose strips can be used. The potato is cut in two, and a glucose strip is placed on the freshly cut surfaces. The colour of the strip can be compared with the colour on the packing of the strips. This gives a quick visual indication of the glucose level. In addition, the strip can be put in a glucose indicator, thus giving a more exact indication of the dextrose content. The glucose strip only indicates the glucose content of the potato, not the fructose content. Reducing sugar content is often about twice the amount of the glucose content.

A more accurate assessment of reducing sugar content in relation to the frying colour can be obtained from frying sticks of French fries or slices from crisps. The sample sticks should be cut from the heart of the tubers. These sticks and slices are then fried for three minutes at 180ºC. After that, the colour of the fried product is compared with the standard colour charts. Rising values represent an increasingly darker colour and an inferior quality.

3.3 Endproduct

The assessment of the quality of the end product serves two tasks. Firstly, the information is necessary to check if the end product meets the quality specifications and, secondly, it performs a feed back control on the running process. The quality of the end product consists of health and food safety aspects and of properties concerning consumer appreciation, such as appearance, texture and taste. Measurements of health and food safety properties are merely instrumental methods, such as the measurements of the concentration on nutrients or the quantity of micro-organism. Standardised methods have to be used for these health and safety properties.

Aspects related to the appreciation of the product are tested merely by sensory analyses. Some aspects can also be measured instrumentally, but a straight relationship between the instrumental result and the human observation is often poor. Mostly the relationship is restricted to some correlation between the instrument and the human sensation.

The main aspects related to the appreciation are:

Appearance

The appearance consists of colour, size and length of the French fried sticks, also cracks, bubbles on the surface, defects and grey colour. Mostly, all these aspects have to tested by visual judgement. The accuracy of these determinations depends on the way these judgements are organised. They can be quite objective and accurate if the judgements are standardised. The colour of the end product, mainly the brown colour, depends on the sugar content of the potato. The colour of the fried product is compared with standard colour cards (see 3.2).

Taste

The taste of the end product will be tested by human observations. The taste of potato products is merely the determination of the lack of presence of off-flavours. Other taste aspects are strongly related to the texture. An aspect of high importance relating to taste is the fat content, which has to be measured instrumentally. In principle the fat content is measured by means of extraction of the fat out of the product with a solvent like petrol-ether.

Texture

Texture is a comprehensive property that consists of several aspects concerning different parts of the stick, such as the core or the crust of the stick. Terms used in the texture qualification of French fries are, for example, crispiness, mealiness, hardness, hollowness and heterogeneity. The crispiness of the French fries is determined by the characteristics of the crust, which is formed by the evaporation of water during the frying process. This makes water evaporation one of the most important texture-determining factors in the production process.

Principally texture can be measured instrumentally, but it is difficult to relate the forces for deformation of the product with the sensory qualifications. Only for some aspects, and with particular purposes, are instrumental texture measurements effective.

4 Food safety

Consumers are increasingly concerned about food safety. As a consequence governments are tightening regulations for the production and processing of food so as to prevent food-borne illnesses. Also large retailer chains make demands on food safety to their suppliers, obliging producers of food to follow strict regulations in order to avoid contamination of food with health threatening substances. They increasingly want to work with suppliers that are certified according to e.g. HACCP (Hazard Analysis Critical Control Points). HACCP is a system that has been adopted by the Codex Alimentarius Commission (an international food standard-setting organization) as the international standard for safe food. A supplier who wants to work according to HACCP has to make a stocktaking of hazards for food safety within his enterprise and has to indicate which preventive measures he is taking to avoid or to minimize these hazards. A correct registration of cultural practices, including fertilization and application of pesticides per potato field and per consignment of potatoes is part of HACCP.

An initiative of leading European food-retailers (EUREP - Euro-Retailer Produce Working group) is the EUREPGAP protocol. It sets out a framework for Good Agricultural Practice (GAP) on farms and it defines the minimum standards for the production of fresh food and vegetables, including potatoes, for these retail groups in Europe. A number of measures to ensure food safety are included in the protocol, and the use of HACCP is encouraged. The EUREPGAP protocol is the basis for certification of growers who want to produce fresh food and vegetables for EUREP-members.

Unwanted contamination of food products may be of physical, chemical or microbial origin. Microbial contamination is generally considered as the most dangerous one. Chemical contamination is often related to the use of pesticides. The main contaminations will be listed for the raw material, the potatoes, as well as for the processed product.

4.1 Raw material

Physical contamination

Examples of physical contamination are the presence of glass or wood splinters or small metal parts in the potato. Preventive measures include storage in a clean store, no broken wooden planks in storehouses, use of crack free lamps etc.

Chemical contamination

Any residues of pesticides that are not approved to be used on potatoes, or residues of approved pesticides that are too high, are considered as chemical contaminants. Safety periods after application of a pesticide should be adhered to. Excessive nitrate concentrations in the potatoes as a result of too high fertilizer application can be a reason for rejection of a consignment of potatoes by a processor. Other contaminants that are sometimes present in potatoes are mineral oil, fuel etc. Preventive measures: correct application of pesticides, appropriate partition between store house and machinery compartment, no use of mercury thermometers, protection of tubers from light etc.

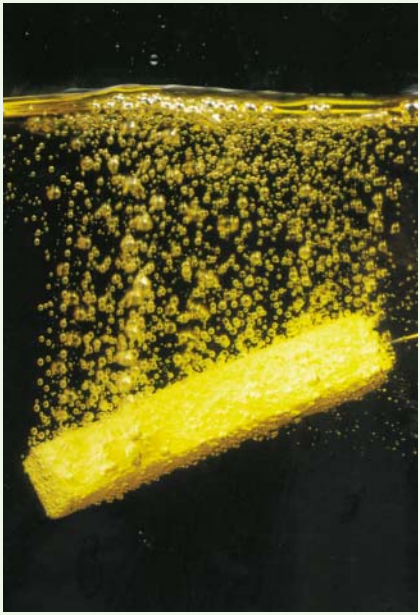
Microbial contamination

Microbial contamination of a dangerous nature will not normally be present in the raw material. However risks can be avoided by not using human faeces as manure and by not allowing animals such as rats, mice, cats and birds to be present in potato stores (wire netting in front of air inlets and outlets).

4.2 Processed product

Physical contamination

Physical contamination (by foreign material such as glass, wood, stones etc) coming in with the potatoes has to be removed in the process by grading, washing, and trimming. Although trimming is primarily focussing on quality inspection, it is also an important preventive step for removing any foreign material. Metal detection is seen industry-wide as a critical control point for metal. The general standard is to detect any metal that is larger than 2 mm in length. Other important control points are protection and registration of glass (e.g. lamps in the processing area) and a procedure to control materials (e.g. lubricants) during maintenance.



Chemical contamination
Strict procedures need to be met to avoid left-over cleaning residues after the cleaning of the processing area.

Microbial contamination
First, pest control by avoiding rats, mice, birds etc (close door policy) in the processing area and it's direct surrounding is needed to avoid microbial contamination. Secondly, the frying temperature in the fryer is often seen as crucial for killing any left over microbial contamination. In general these (pre-) frying temperatures are around 180°C. For dehydrated products (flakes, granules) it is essential to dry to at least 88% dry matter content. Over 12% moisture content can cause growth of fungi in the finished product.

General
Hygiene rules for all personnel and visitors needs to be in place to avoid microbial contamination (handwash at entrance), physical contamination (hairnets, no outside pockets on clothes to avoid foreign material falling into the productflow). Coding (date, time, production line etc) of bags and cartons is essential for good tracking and tracing of the finished product.

References

Beukema, H.P. / D.E. van der Zaag, Introduction to Potato Production, Wageningen, 1990, ISBN 90-220-0963-7

Burton, W.G., The Potato, Third Edition, Longman Group UK Limited, 1989, ISBN 0-582-46229-0

CPRO-DLO, 69th Descriptive List of Varieties of Field Crops 1994, Wageningen, 1994

European Association for Potato Research, Methods of Assessment for Potatoes and Potato Products, Wageningen

NIVAA, Netherlands Catalogue of Potato Varieties, The Hague, 1994

NIVAA, Professional Potato Growing, 'Planting', The Hague, 1994

Scheele, C. von, G. Sevensson & J. Rasmussen, 1937. Die Bestimmung des Stärkegehaltes und der Trockensubstanz der Kartoffel mit Hilfe des Specifizen Gewichts. landwirtschaftliches Versuch station 127: 67-96

Zaag, van der D.E., Potatoes and their Cultivation in The Netherlands, NIVAA, The Hague, 1992

Munsell Color Company Card for evaluation of French Fries

IBVL-colour Card for Evaluation of chips (crisps), developed by the Institute of Storage and Processing of Agricultural Produce

Colofon & Addresses

Second Edition
On the road to Potato Processing, first published by NIVAA in 1994, is comprehensively revised and updated for this second edition.

Editors
Mr. A.J. Haverkort (Plant Research International)
Mr. C.D. van Loon
Mr. P. van Eijck, Mr. F.P. Scheer, Mr. E.P.H.M. Schijvens, Mr. H. Uitslag (ATO DLO)
Mr. H.R. Baarveld (NIVAA)
Mrs. E.W.A. Campobello (NIVAA)
Mrs. S.R. Liefrink (NIVAA)
Mr. H.M.G. Peeten (NIVAA)

Photography
ATO-DLO
NIVAA

Design
Bernards/Visser communicatie BV, Leiden, The Netherlands

Printed
PlantijnCasparie, Den Haag, The Netherlands

Publisher
NIVAA
The Netherlands Consultative Potato Institute
Postbus 17337
2502 CH Den Haag
The Netherlands
Tel + 31 (0)70 312 30 00
Fax + 31 (0)70 312 30 01
info@potato.nl
www.potato.nl

2000eng2002

NIVAP
Postbus 17337
2502 CH Den Haag
The Netherlands
Tel + 31 (0)70 312 30 00
Fax + 31 (0)70 312 30 01
info@potato.nl
www.potato.nl