The Quality of Potato for Processing and Consumption

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ABSTRACT

Potatoes are destined both for cooking in households and for food processing (chips, French fries, dehydrated products) as well as starch and alcohol production. The requirements of industries, regarding the chemical composition and quality of raw material vary, depending on the destination of the finished product. The technological value of potato is determined by a variety of features required by a particular industry. The properties and components of potato tubers affect the technological process, the yield and quality of the finished product. The nutritive value depends on the chemical composition of the product, including the presence of toxic compounds hazardous to human health. Potato cultivars have a great impact both on the technological value of potato destined for industrial use and on the quality of potatoes destined for human consumption. However, a number of factors determining the technological value of potato tubers can be influenced by human actions (fertilization, use of pesticides, planting and harvest dates, irrigation, storage conditions, etc.) and the environment (location of the field, weather and soil conditions).

Keywords: potato, technological value, processing, nutrition quality

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INTRODUCTION

The world production of potatoes has increased by 5% in the last decade and in 2007 it amounted to 320 million tonnes. About 50% of the total amount is used for direct consumption, while the other half is destined for industrial processing, including food products, starch and ethanol production and also kept on farms for planting and animal feed (Rembeza 2007; Rocznik statystyczny GUS 2007; Prońska-Białczyk 2008). The destination of potato tubers varies from country to country. Potato starch manufacturing in Europe accounts for 21% of the total production of agricultural produce, including corn, wheat and potato (Lewandowicz et al. 2008). This accounts for 5% of the use of these raw materials in the world production of starch. Ethanol from potatoes is primarily made in Central Europe (Prońska-Białczyk 2008). The largest producer of potato products is the United States. The Netherlands is the leading European country in French fries production, with annually 2.8 million tonnes of potatoes being destined for French fries manufacturing. This makes the Netherlands, next to the US and Canada, a world leader in French fries production. Great Britain is the largest producer of chips in Europe. Germany is the largest manufacturer of potato dehydrated products (Lisińska 2004). In Poland, a six-fold increase in potato products manufacturing has been noted in the last 15 years (from 115,000 tonnes in 1992 to 950,000 tonnes in 2007), and further increases in the production of chips and dehydrated potato products are expected in the forthcoming future (Lisińska 2004; Rembeza 2007).

In most countries, potato production is mainly demand-dependent, therefore, the quality of potatoes must meet certain standards, depending on their destination.

THE TECHNOLOGICAL VALUE OF POTATO

The technological value of potatoes, a term used in Central and East Europe (Leszczyński 2008), refers to a number of features (external and internal) determining their suitability for processing. The external features include: the size and shape of potato tubers, the depth and the number of hollows (called eyes), blemishes and thickness of the skin. The chemical composition and the features of potato flesh are internal characteristics of potato tubers. The technological value of potato refers to the quality of the potatoes destined for industrial processing.
A potato cultivar plays a major role in determining the technological value of potato, although a wide variety of factors may have an impact on potato suitability for processing. These include environmental factors (location of potato fields, weather and soil conditions) and cultivation methods (fertilizer rates, irrigation, pesticide treatments, planting and harvesting dates). The differences in the chemical composition of potato tubers grown in various locations result from differentiated environmental conditions, especially the weather and soil types (Lisińska and Leszczyński 1989; Cieślak 1995; Frydecka-Mazureczyk and Górska 1996; Hass and Plate 1996; Gould 1999; Lutomirska 1999; Agblor and Scanlon 2002).

The agrotechnical treatments can influence both the yield and the technological value of potatoes destined for processing (Kolbe et al. 1995; Ghuska 1999; Mazureczyk and Lis 1999; Mochanacki and Kolpak 1999; Proshba-Bielski and Mydlarski 1999; Thybo et al. 2001; Jarych 2007). Both the yield and the chemical composition of potato tubers are, to a large extent, dependent on nitrogen rates (Leszczyński and Lisińska 1988; Bélanger et al. 2002; Hass et al. 2007b).

High N rates are likely to reduce starch content (Mozolewski 1997; Ghuska 1999; Mozolewski 2003; Jarych 2007; Trawczyński 2008), and increase reducing sugars (Talburt and Smith 1987; Ghuska 1999; Kumar et al. 2004; Putz 2004; Jarych 2007) and nitrates (Grassert et al. 1984; Claasen et al. 1993; Mozolewski 2003; Jarych 2007; Trawczyński 2008) Besides, they affect potato susceptibility to discoloration (Talburt and Smith 1987; Lisińska and Leszczyński 1989; Mozolewski 2003; Wang-Pruski and Nowak 2004; Jarych 2007). When mineral fertilizer rates are high, some elements are accumulated in the soil, since they are not fully utilised by the plants. As a result, the proportion between the minerals is disturbed and their availability to the plants is also impaired (Lisińska and Leszczyński 1989; Leszczyński 2002b).

The losses due to pest and weed infestation or potato diseases can be prevented by the use of such chemicals as: insecticides, fungicides and herbicides. The differences in the quality of potato yields resulting from the use of pesticides are likely due to different responses of the metabolic processes in plants to the chemical treatments, aimed at reducing pest and weed infestation and invasion of potato plants by diseases. When the pesticides are applied appropriately (dates and rates), their concentrations in potato tubers are low (Leszczyński 2002a, 2002b). However, the use of fungicides and sprout inhibitors in storage houses results in higher accumulation of these substances, especially in the potato skin, but they are removed in the peeling process (Leszczyński 2002a; Ezekiell and Singh 2007).

Planting and harvesting dates are important factors affecting the chemical composition of potato tubers destined for processing (Talburt and Smith 1987; Lisińska and Leszczyński 1989; Gould 1999). The chemical composition of mature potato tubers is stable since their skin has a well-developed protective layer, and for this reason, they are suitable for long-term storage before processing. The growing season of late potato cultivars is long (140-160 days), therefore, under the weather conditions that prevail in Central and Eastern Europe, it may happen that potatoes remain in the field unharvested until the soil temperature falls below 8°C (in mid-September). Temperatures <8°C at harvest time and throughout storage reduce the technological value of potato tubers (used in chips factory), due to increasing reducing sugar content (Lisińska and Leszczyński 1989). However, there are potato cultivars suitable for so-called “cold storage”, which are resistant to the accumulation of reducing sugars under such conditions (Putz 2004; Grudzińska 2007; Czerko and Górska 2008).

Table 1 shows the effects of some properties of the raw material on the yield and quality of potato starch due to processing.

Table 1. Effect of raw material properties on the yield and quality of starch during processing.

<table>
<thead>
<tr>
<th>Properties of raw material</th>
<th>Stage of processing</th>
<th>Yield/quality of starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>mechanical damages, diseases, etc.</td>
<td>hydro-transport, washing operations</td>
<td>yield decreasing</td>
</tr>
<tr>
<td>potatoes too small</td>
<td>dewatering system</td>
<td>yield decreasing</td>
</tr>
<tr>
<td>deep eyes (oil)</td>
<td>tubers rasping (rasp damage)</td>
<td>increasing of specks in starch</td>
</tr>
<tr>
<td>darkening of raw tubers (enzymatic)</td>
<td>tubers rasping and next stages (creating of dark pigment)</td>
<td>grey starch without gloss</td>
</tr>
<tr>
<td>the content of insoluble non-starch substances</td>
<td>tubers rasping (higher quantity of potato pulp)</td>
<td>starch losses</td>
</tr>
<tr>
<td>soluble substances (foam creating)</td>
<td>separation (surface pressure decreasing, foam creation)</td>
<td>starch losses</td>
</tr>
<tr>
<td>small potato granules (smaller than 15-20 μm)</td>
<td>-separation (small granules remain together with fiber in a pulp or are loss with foam)</td>
<td>-starch losses</td>
</tr>
<tr>
<td></td>
<td>-drying (separating of granules with air in cyclone)</td>
<td>-starch losses, mat and cream starch</td>
</tr>
</tbody>
</table>

Potato tubers for starch production

Starch is the only component of the potato dry matter that is considered significant in starch plants. The other constituents are treated as by-products or wastes. For this reason, potatoes destined for starch production must contain at least 15% of starch (Leszczyński 2000a). Processing of the potatoes low in starch is almost as expensive as that of the potatoes high in starch, but the yield is incomparably better with the use of the latter.

Taking these factors into account, it may happen that the same potato cultivar grown in one region can be suitable for manufacturing of certain products and absolutely unacceptable when grown elsewhere, due to the variations in the qualitative features and chemical composition.

Potatoes for the food industry

The requirements of food manufacturers have always been the strictest of all the industries processing potatoes (Górska 2005; Lisińska 2006) and the standards have been steadily increasing in the last decades. This is mainly due to the advances in potato processing technologies and competition on the markets regarding such potato products as: French fries, chips, flakes, granulate and potato grit.

The quality standards that have to be met by the raw material destined for food manufacturing can be divided into two groups: general (common for all industry branches) and specific (strictly connected with a type of the finished product). General quality criteria for potatoes destined for food industry comprise both the external and internal features that can be seen after cutting a potato. Good quality potatoes are healthy, mature, with no blemishes and hollow-hearted tubers, regular in shape and uniform in size, with a

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Table 1. Effect of raw material properties on the yield and quality of starch during processing.
small number of shallow hollows (eyes), undamaged, un-
-frozen, over-chilled or greenish potato flesh (Talburt and
Smith 1987; Lisinska and Leszczyński 1989; Zgorska and
Frydecka-Mazurczyk 2002).

Apart from the general criteria, also varietal factors
have to be determined in the case of potatoes destined for
food industry. These include: skin smoothness and thickness,
natural flesh colour, susceptibility to discoloration of raw
potatoes and after cooking, dry matter and starch content,
reducing sugar content immediately after harvest and during
storage, limited ability to increase the quantity of reducing
sugars due to storage at low temperatures (about 4°C)
(Lisinska and Leszczyński 1989; Zgorska and Frydecka-
Mazurczyk 2002; Zgorska 2003). There is a wide array of potato products available to the
consumer in food stores and restaurants and the assortment
depends on their popularity in a given country. In Germany,
for example, the most popular are dehydrated products and
those which are manufactured with the use of dehydrated
potato, e.g. dumplings, potato pancakes, etc. In the UK, the
most popular are fried potato products, manufactured both
from raw and dehydrated potatoes, like chips and French
fries. The requirements concerning potato cultivars selected
for the production of chips, French fries and dried products
vary, depending on the technologies used for their manu-
facturing and, therefore, need individual approach and dis-
cussion.

Potatoes for chips production

Potatoes destined for chips production should not only meet
general quality criteria, but it is extremely important they
are suitable for long-term storage, since industrial proces-
sing is performed for the whole year, excluding short
breaks for maintenance works, in Europe usually in July.
The potato cultivars are selected in such a way that high
quality raw material is available throughout a year.

It is important that potatoes selected for chips produc-
tion are round or oval in shape and from 40 to 75 mm in
size. As for the internal traits, the content design should be
as follows: 21–25% of dry matter, 16–20% of starch and
below 0.25% of reducing sugars. A uniform distribution of
reducing sugars in the tuber cross-section is of particular
importance. Potato tubers accumulating reducing sugars
around the vascular system (ring) or in the stem end and at
the bud end are unacceptable for processing (Zgorska and
Susceptibility of potato flesh to enzymatic discoloration is
also important, but to a lesser degree, since the entire tech-
nological process, from potato peeling to packaging of the
finished product does not take longer than half an hour. Sus-
cceptibility of potato flesh to chemical discoloration can be
neglected, since the fried product dried to the moisture con-
tent <2% and containing 33–39% of fat can by no means
turn gray.

Table 2 shows the effects of some raw material charac-
teristics on the yields and quality of potato chips.

Potatoes for French fries production

Potatoes for French fries production must be oblong or oval
in shape size ≥70 mm. The cross-section diameter is stan-
dardized with regard to the potato cultivar. Due to these re-
strictions, only a few potato cultivars out of many registered
in different countries of Central and East Europe can be
used for French fries manufacturing (Zgorska 2003; Lisin-
ska 2006).

As for the internal traits, the following requirements
must be met: 20–23% of dry matter, 15–18% of starch and
below 0.3% of reducing sugar content (Zgorska 2003; Lisinska
2006; Hasse et al. 2007). It is worth noting that
distribution of reducing sugars in potato tubers is of great
significance because of the so-called “sugar-end” effect
(brown ends of French fries) resulting from Maillard’s reaction is likely to appear only in the finished product, that
is after the second cycle of frying (Sowokinos et al. 2000).
Another dangerous effect is the occurrence of grey colour in
French fries during storage, resulting from potato tuber sus-
cceptibility to chemical discoloration. Potato tubers can turn
greyish after cooking. This phenomenon is called after-
cooking darkening. It results from non-enzymatic oxidation
of the complexes formed due to a combination of phenols,
mainly chlorogenic acid, and iron in the presence of atmos-
pheric oxygen (Lisinska and Leszczyński 1989). Suscepti-
bility of potato flesh to discoloration should be as low as
possible, since the technological process is much longer
than that of chips manufacturing and, for this reason, the
potatoes cut into strips are more prone to enzymatic dis-
coloration prior to blanching (enzyme inactivation).

Table 3 shows the effects of some raw material charac-
teristics on French fries yields and quality.

Potatoes for granulate and flakes production

The requirements for the raw material destined for the pro-
duction of dehydrated potato products (flakes, granulate)
from cooked potatoes vary significantly from the standards
that have to be met by the raw material selected for manu-
facturing of dehydrated potato products from uncooked po-
tatoes (dice, slices or grit), especially regarding dry matter

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### Table 2 Effect of raw material properties on the yield and quality of chips.

<table>
<thead>
<tr>
<th>Properties of raw material</th>
<th>Stage of processing</th>
<th>Yield / quality of chips</th>
</tr>
</thead>
<tbody>
<tr>
<td>size of tubers, shape regularity, eyes deepness, thickness of skin</td>
<td>tubers washing, cleaning and cutting</td>
<td>yield decreasing</td>
</tr>
<tr>
<td>mechanical damage, internal damages of tubers</td>
<td>tubers washing, cleaning and cutting, chips selection</td>
<td>yield decreasing, discolouring of chips</td>
</tr>
<tr>
<td>too low dry matter and starch contents</td>
<td>frying</td>
<td>yield decreasing, increasing of oil consumption, oily, not crispy chips</td>
</tr>
<tr>
<td>too high dry matter and starch contents</td>
<td>frying</td>
<td>too hard, granity chips</td>
</tr>
<tr>
<td>too high content of reducing sugars</td>
<td>longer time of blanching</td>
<td>increasing of oil consumption, oily not crispy chips</td>
</tr>
</tbody>
</table>

### Table 3 Effect of raw material properties on the yield and quality of French fries.

<table>
<thead>
<tr>
<th>Properties of raw material</th>
<th>Stage of processing</th>
<th>Yield / quality of French fries</th>
</tr>
</thead>
<tbody>
<tr>
<td>size of tubers, shape regularity, eyes deepness, thickness of skin</td>
<td>tubers washing, cleaning and cutting</td>
<td>yield decreasing</td>
</tr>
<tr>
<td>mechanical damage, hollow hearts and other internal damages of tubers</td>
<td>tubers washing, cleaning and cutting, optical selection (cutting of dark ends)</td>
<td>yield decreasing, too short French fries (II category)</td>
</tr>
<tr>
<td>too low or too high content of dry matter and starch</td>
<td>second stage of frying</td>
<td>too hard (or too soft) texture of French fries (too hard surface of French fries, inside broken and greasy)</td>
</tr>
<tr>
<td>too high content of reducing sugars or their not regular distribution – “sugar end”</td>
<td>blanching, frying of I and II stage</td>
<td>discoloured French fries, brown ends of ready products</td>
</tr>
<tr>
<td>increased tuber susceptibility on chemical darkening</td>
<td>frozen French fries</td>
<td>grey French fries surface</td>
</tr>
</tbody>
</table>

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and starch content. The present article demonstrates the data for the production of dehydrated potato products from cooked potatoes.

Potatoes for dehydrated products (mashed potatoes) manufacturing, in addition to the requirements for general characteristics, must also possess such traits that make them suitable for long-term storage at 6–8°C, causing no reductions in the technological value.

Potato tubers destined for the production of dehydrated products are preferably round or oval in shape and 40–75 mm in size. As for the internal traits, the following requirements must be met: 20–25% of dry matter, 15–19% of starch and below 0.5% of reducing sugars (preferably < 0.3%) content. The flesh of potato tubers destined for dehydrated products manufacturing should be susceptible to enzymatic and chemical discoloration (Lisieńska and Leszczyński 1989; Zagórski 2005; Lisieńska 2006).

Table 4 shows the effects of some traits of the raw material on the yields and quality of dehydrated products made from cooked potatoes.

### THE NUTRITIVE VALUE OF POTATO

The quality of potatoes destined for human consumption as well as processing is determined by certain external and internal traits and also sensory properties. Another important quality factor is their nutritional value and low content of any anti-nutrients.

#### Sensory properties of potatoes

The external quality of potato tubers is determined by: the appearance of skin (firmness, discoloration, cracks, greenish), depth and number of eyes, and regularity in shape. The internal quality of potato is determined by the colour of flesh, its susceptibility to enzymatic and chemical discoloration, internal quality of potato is determined by the colour of flesh, its susceptibility to enzymatic and chemical discoloration, hollow heart and brown spots (Leszczyński 1994, 2000a, 2000b).

The perception of sensory properties (flavour, aroma, colour and texture) is subjective and depends on consumers’ preferences and likenings. However, no potatoes with off-flavour or odor, dark or mushy will be acceptable. The texture of cooked potatoes (disintegration, compactness, mealiness, granularity, and moisture/dry matter content) determines the utilization design of potatoes, which is as follows:

- **Type A** – suitable for salads – firm tubers, easy to cut, “moist”, of smooth and delicate texture of flesh;
- **Type B** – waxy – suitable for table use (boiling and mashing) – fairly firm tubers, delicate texture of flesh;
- **Type C** – mealy – fairly firm tubers, prone to disintegration in cooking, dry, with fairly smooth texture of flesh;
- **Type D** – very mealy or dry – prone to disintegration in cooking, slough when boiled, with coarse texture of flesh.

Many potato varieties exhibit combined features of two types mentioned before and these are assigned to the following types: AB, BC and CD.

#### The nutritional value of potatoes

The nutritional value of potatoes has been studied extensively (Leszczyński 2000b; Hasse 2007; Pęksa 2008). Potatoes are the mainstay in many diets since they are very nutritious and contribute significantly to the good health. Potatoes are rich in complex carbohydrates, providing energy for physical activity, and proteins (Table 5). They are available all year round and have become very popular mainly due to the fact that they provide useful amounts of dietary fiber, vitamins (C, B₁, B₂, PP, B₆) and mineral nutrients (K, Mg, Fe, Cu, Zn, P).

Vitamin C present in potatoes (10-30 mg/100 g) (Leszczyński 2000b; Rydel and Lisieńska 2007; Pęksa 2005) is not only valued as an antioxidant, but it also enhances iron availability to human body. Potassium (about 380 mg/100 g of potato) plays an important role in ionic and water management in human body. Dietary fiber of potato containing non-starch polysaccharides (NSP), such as cellulose, hemicelluloses, lignin and pectin (Kita 2002; Golubowska 2005; Lisieńska and Golubowska 2005), improves bowel movements and increases the volume of digesta in the small intestine by increasing water binding capacity (WBC) and forming appetite satiety compositions, at the same time reducing the energy value of food (insoluble fraction of fiber). Fiber soluble in water is capable of capturing toxic compounds, e.g. bacteria or ions of heavy metals (Gawęcki 2004).

Consumption of 250-300 g of potatoes provides 7.5% of the daily intake of energy and 7-8% of protein, 6-11% of carbohydrates, 14-19% of vitamin B₁, 20% of vitamin PP,

<table>
<thead>
<tr>
<th>Property of raw material</th>
<th>Stage of processing</th>
<th>Yield / quality of dry product</th>
</tr>
</thead>
<tbody>
<tr>
<td>size of tubers, shape regularity, eyes deepness, thickness of skin</td>
<td>mixers, remixer, sieves</td>
<td>too close, coarse, grainy texture</td>
</tr>
<tr>
<td>internal damages of tubers, outgrow of tuber pith</td>
<td>tubers cooking, mixing with add-beck, watering of puree</td>
<td>to high content of dry matter and starch</td>
</tr>
<tr>
<td>too low content of dry matter and starch</td>
<td>tubers cooking, mixing with add-beck, watering of puree</td>
<td>falling of pieces of tubers during cooking, free starch content increasing, greasy texture of puree</td>
</tr>
<tr>
<td>too high content of dry matter and starch</td>
<td>ready product, storing</td>
<td>not suitable colour of dried product (brown points, discoloring)</td>
</tr>
<tr>
<td>increased tubers susceptibility on flesh darkening</td>
<td>drying of product, storing</td>
<td></td>
</tr>
<tr>
<td>too high content of reducing sugars, their not regular distribution in tubers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>16-22</td>
<td>19</td>
</tr>
<tr>
<td>Starch (%)</td>
<td>10-16</td>
<td>14</td>
</tr>
<tr>
<td>Total sugar (%)</td>
<td>0.3-0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Reducing sugar (%)</td>
<td>0.1-0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Total nitrogen (N×6.25) (%)</td>
<td>1.7-2.3</td>
<td>2</td>
</tr>
<tr>
<td>Protein nitrogen (N×6.25) (%)</td>
<td>0.7-1.3</td>
<td>1</td>
</tr>
<tr>
<td>Lids (%)</td>
<td>0.1-0.12</td>
<td>0.1</td>
</tr>
<tr>
<td>Dietary fiber (%)</td>
<td>1.2-2.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Mineral compounds (%)</td>
<td>1.0-1.2</td>
<td>1</td>
</tr>
<tr>
<td>Potassium (mg/100 g)</td>
<td>443</td>
<td></td>
</tr>
<tr>
<td>Phosphorus (mg/100 g)</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Magnesium (mg/100 g)</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Calcium (mg/100 g)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Iron (mg/100 g)</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Organic acids (%)</td>
<td>0.2-1.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Vitamins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C (Ascorbic acid) (mg/100 g)</td>
<td>10-30</td>
<td>15</td>
</tr>
<tr>
<td>PP (Niacin) (mg/100 g)</td>
<td>1.46</td>
<td></td>
</tr>
<tr>
<td>B₁ (Thiamine) (µg/100 g)</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>B₂ (Riboflavin) (µg/100 g)</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>B₆ (Pyridoxine) (µg/100 g)</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Phenolic compounds (mg/100 g)</td>
<td>15-30</td>
<td></td>
</tr>
<tr>
<td>Glycoalkaloids (mg/100 g)</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Nitrates (mgNaNO₃/100 g)</td>
<td>10-75</td>
<td>15-30</td>
</tr>
<tr>
<td>Energy value (kcal/100 g)</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>
26-30% of vitamin B6, 30-40% of potassium, 13-17% of magnesium, 20-28% of copper, 25-30% of iodine, 9-21% of iron and about 17% of fiber (Lisińska and Leszczyński 1989; Leszczyński 2000b; Pęksa 2008).

In general, cooked potatoes do not contain more than 15% of starch and only 0.1% of fat, so they are considered a low-caloric product. Their energy value (70 kcal/100 g) is lower than that of white bread (275 kcal/100 g), cornflakes (354 kcal/100 g) or beans and comparable to that present in animal proteins. Potato protein contains all exogenous amino acids in adequate quantities and it is especially high in lysine (Friedman 1996; Pęksa 2003, 2008).

**Anti-nutrients substances in potatoes**

Undesired anti-nutrients present in potatoes affecting the nutritional value of potato products include: inhibitors of proteolytic enzymes, toxic substances, including glycoalkaloids, nitrates and nitrites as well as compounds present in polluted environments, such as: heavy metals and pesticides. In contrast to other vegetables, potatoes accumulate lower amounts of pesticides, herbicides and heavy metals, and it is noteworthy that these compounds are primarily accumulated in potato skin, which is removed in peeling (Leszczyński 2002b).

Inhibitors of proteolytic enzymes account for 15% of proteins insoluble in water, which inhibit enzymatic decomposition of proteins, thus limiting their consumption by the digestive system. Some inhibitors are resistant to high temperatures and for this reason, special thermal treatment of potatoes is needed for their inactivation (Zhao and Camire 2005). Glycoalkaloids (chaconine and solanine, generally referred to as solanine) are natural, toxic constituents of potatoes. Generally, potato tubers are twice as high in chaconine as compared to solanine (Pęksa et al. 2002; Rytel et al. 2005; Pęksa et al. 2006). These compounds are very toxic (Friedman, McDonald 1997; Lisińska, Leszczyński 1989), a lethal dose for a human being amounts to 3-6 mg/kg of body weight, and doses ranging from 1 to 5 mg/kg of body weight may result in harmful effects. Fungent flavour is an effect of glycoalkaloid content >75 mg/100 g of potatoes. It is suggested that a permissive glycoalkaloid concentration of 20 mg/100 g of potatoes is decreased to the concentration of 6-7 mg/100 g (Lisińska and Leszczyński 1989; Leszczyński 2002b). Glycoalkaloids are mainly accumulated in potato skin and immediately beneath it. Particularly high concentrations of glycoalkaloids are found around eyes. To peel and cook about 20-70% is removed (Cieślik 1992; Gołaszewska and Zahlewski 2001; Zgórski 2003, Zgórski and Grudzińska 2004).

It is quite likely that potatoes accumulate heavy metals from the environment, harmful both to humans and animals. Normally, they occur in trace amounts, not exceeding one hundredth mg/100 g of potatoes. Lead concentration amounts from 0.2 to 1 mg/100 g, but its concentration can reach 100 µg/100 g in a polluted environment (Bibak et al. 1999; Leszczyński 1994). Cadmium concentration is found within a range of 0.2-23 µg/100 g and its concentration hardly ever exceeds a level 1 µg/100 g (McLaughlin et al. 1999). The amounts of Hg and As in potatoes are so scarce that they can hardly be detected (Leszczyński 2000b; Kucharzewski et al. 2002; Bronkowska et al. 2008).

Potatoes are low in fat, therefore, they are not able to accumulate pesticides, which are hardly soluble in water, but soluble in fats. Pesticide residues in potatoes are much lower than in other vegetables (Leszczyński 2002a).

**CONCLUSIONS**

The potato is a product of high nutritional and low-energy value, containing high quality protein. It is also a valuable source of vit. C and group B vitamins as well as minerals, especially potassium. Potato tubers do not accumulate toxic substances from the environment, e.g. pesticides or heavy metals and they are low in nitrates. Potatoes are an important raw material for food and starch industries and alcohol distilleries. Suitability of the potato destined for processing (chips, French-fries, granulate, flakes, starch, ethanol, etc.) is referred to as the “technological value of potato”. Potato cultivars have a great impact both on the technological value of the potato destined for industrial use and quality of potatoes destined for human consumption. However, a number of factors determining the technological and nutritional value of potato tubers can be influenced by human actions (fertilization, use of pesticides, planting and harvest dates, irrigation, storage conditions, etc.) and the environment (location of the field, weather and soil conditions).

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**REFERENCES**


