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The Quality of Potato for Processing and Consumption

Grażyna Lisińska* • Anna Pęksa • Agnieszka Kita • Elżbieta Rytel • Agnieszka Tajner-Czopek

Department of Food Storage and Technology, Wrocław University of Environmental and Life Science, Norwida 25 Str., 50-375 Wrocław, Poland

Corresponding author: * Grazyna.Lisinska@wnoz.up.wroc.pl

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

CONTENTS

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; Prośba-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 (Prośba-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 tones 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.

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Invited Mini-Review

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; Cieślik 1995; Frydecka-Mazurczyk and Zgórska 1996; Hasse 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; Głuska 1999; Mazurczyk and Lis 1999; Mochnacki and Kołpak 1999; Prośba-Białczyk 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; Bèlanger *et al.* 2002; Hasse *et al.* 2007b).

High N rates are likely to reduce starch content (Mozolewski 1997; Głuska 1999; Mozolewski 2003; Jarych 2007; Trawczyński 2008), and increase reducing sugars (Talburt and Smith 1987; Głuska 1999; Kumar *et al.* 2004; Putz 2004; Jarych 2007) and nitrates (Grassert *et al.* 1984; Claassen *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; Ezekiel 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 prevails 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 Zgórska 2008).

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.

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 into account the elapse of time from potato harvesting to processing, potato tubers destined for starch production should meet the following requirements regarding their external features: sizes >2.5 cm, no traces of mechanical damage or diseased tubers, damages no deeper than 5 mm, free of deep eyes, no frozen or even slightly frozen tubers or wet breakdown following freezing injury. The internal features of potatoes that should be taken into consideration in starch production include: starch content, sizes of starch granules from 20 to 60 µm, low content of insoluble non-starch (INS) substances, including cellulose, hemicelluloses, lignin, some pectin and proteins and also foam-forming constituents (saponines, free amino acids, soluble proteins, glycoalkaloids, etc.). It is also important that potato flesh is not susceptible to discoloration (browning) (Lisińska and Leszczyński 1989; Leszczyński 2004).

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

Potatoes for the food industry

The requirements of food manufacturers have always been the strictest of all the industries processing potatoes (Zgórska 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

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

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

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

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

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

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

small number of shallow hollows (eyes), undamaged, unfrozen, over-chilled or greenish potato flesh (Talburt and Smith 1987; Lisińska and Leszczyński 1989; Zgórska 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) (Lisińska and Leszczyński 1989; Zgórska and Frydecka-Mazurczyk 2002; Zgórska 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 manufacturing and, therefore, need individual approach and discussion.

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 processing 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 production 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 (Zgórska and Frydecka-Mazurczyk 2002; Zgórska 2003; Lisińska 2006). Susceptibility of potato flesh to enzymatic discoloration is also important, but to a lesser degree, since the entire technological process, from potato peeling to packaging of the finished product does not take longer than half an hour. Susceptibility of potato flesh to chemical discoloration can be neglected, since the fried product dried to the moisture content <2% and containing 33–39% of fat can by no means turn gray.

Table 2 shows the effects of raw material characteristics 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 standardized with regard to the potato cultivar. Due to these restrictions, only a few potato cultivars out of many registered in different countries of Central and East Europe can be used for French fries manufacturing (Zgórska 2003; Lisińska 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 (Zgórska 2003; Lisińska 2006; Hasse *et al.* 2007a). 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 susceptibility 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 atmospheric oxygen (Lisińska and Leszczyński 1989). Susceptibility 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 discoloration prior to blanching (enzyme inactivation).

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

Potatoes for granulate and flakes production

The requirements for the raw material destined for the production 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 manufacturing of dehydrated potato products from uncooked potatoes (dice, slices or grit), especially regarding dry matter

Table 4 Effect of raw material properties on the yield and quality of potato granules and flakes.

Properties of raw material	**Stage of processing**	**Yield / quality of dry product**
size of tubers, shape regularity, eyes deepness, thickness of skin	tubers washing, cleaning and cutting	yield decreasing
internal damages of tubers, outgrow of tuber pith	mixers, remixer, sieves	too close, coarse, grainy texture
too low content of dry matter and starch	tubers cooking, mixing with add-beck, watering of puree	too close, coarse, grainy texture
too high content of dry matter and starch	tubers cooking, mixing with add-beck, watering of puree	falling of pieces of tubers during cooking, free starch content increasing, greasy texture of puree
increased tubers susceptibility on flesh darkening	ready product, storing	grey colour of dry product, puree of soil colour
too high content of reducing sugars, their not regular distribution in tubers	drying of product, storing	not suitable colour of dried product (brown points, discolouring)

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 (Lisińska an Leszczyński 1989; Zgórska 2005; Lisińska 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, greening), 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, 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 likings. 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 high 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, B_1, B_2, PP, B_6) and mineral nutrients (K, Mg, Fe, Cu, J, P).

Table 5 Chemical composition of edible potatoes (Lisińska and Leszczyński 1989; Leszczyński 2000b; Kunachowicz *et al.* 2005).

Component	**Content**	
	Range	**Mean**
Dry matter (%)	16-22	19
Starch (%)	10-16	14
Total sugar (%)	0.3-0.6	0.5
Reducing sugar (%)	0.1-0.4	0.3
Total nitrogen (Nx6.25) (%)	1.7-2.3	2
Protein nitrogen (Nx6.25) (%)	0.7-1.3	1
Lipids (%)	0.1-0.12	0.1
Dietary fiber (%)	1.2-2.3	1.5
Mineral compounds (%)	1.0-1.2	1
Potassium (mg/100 g)		443
Phosphorus (mg/100 g)		56
Magnesium (mg/100 g)		23
Calcium (mg/100 g)		4
Iron (mg/100 g)		0.5
Organic acids (%)	0.2-1.0	0.4
Vitamins		
C (Ascorbic acid) (mg/100 g)	10-30	15
PP (Niacin) (mg/100 g)		1.46
B_1 (Thiamine) (μg/100 g)		87
B_2 (Riboflawin) (μg/100 g)		46
B_6 (Pyridoxine) (μg/100 g)		30
Phenolic compounds (mg/100 g)	15-30	
Glycoalkaloids (mg/100 g)	1-6	
Nitrates (mgNaN0_3/100 g)	10-75	15-30
Energy value (kcal/100 g)		70

Vitamin C present in potatoes (10-30 mg/100 g) (Leszczyński 2000b; Rytel and Lisińska 2007; Pęksa 2008) 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; Gołubowska 2005; Lisińska and Gołubowska 2005), improves bowel movements and increases the volume of digesta in the small intestine by increasing water binding capacity (WBC) and forming appetite satient 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 B_1, 20% of vitamin PP, 26-30% of vitamin B_6, 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 bred (275 kcal/100 g), cornflakes (354 kcal/100 g), white rice (123 kcal/100 g) or walnuts (666 kcal/100 g) (Lisińska and Leszczyński 1989; Kunachowicz *et al.* 2005; Pęksa 2008).

Potatoes contain scarce amounts of sugars (about 0.2% of sucrose and 0.3% of glucose and fructose). Higher concentrations of sugars (>1%) result in undesired sweet flavour of cooked potatoes. Besides, when reducing sugars exceed 0.2%, they have an adverse impact on the colour of fried potato products.

The total content of crude protein (Nx6.25) in potato tubers accounts for approximately 2% (8-9% of dry matter), half of this is protein. Protein content of potato dry matter is similar to that found in cereal grain and it is considered high as compared to protein concentration in other vegetables. The biological value of protein present in potato tubers is higher as compared to that of wheat, rice or such pulse crops as pea or bean 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 glycoalcaloids, 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 1995).

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. Pungent flavour is an effect of glycoalkaloid content > 11 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 2000b). Glycoalkaloids are mainly accumulated in potato skin and immediately beneath it. Particularly high concentrations of glycoalkaloids are found around eyes. Due to peeling, about 50-95 % of glycoalkaloids is removed, resulting in the amounts of 1-6 mg/100 g in the pith (Leszczyński 2000b; Tajner-Czopek *et al.* 2008).

Toxic nitrates (III) are usually present in potatoes in trace amounts (0.0-0.5 mg $NaNO_2$/100 g) and the concentrations of nitrates (V) found in potatoes grown in Central European countries range from 10 to 75 mg/100 g (on average 15-30 mg/100 g) (Leszczyński 2000b). Nitrates (V) are not toxic, but it may happen that the intestinal microflora can reduce them to nitrates (III), which may contribute to the formation of carcinogenic nitrosamines. Nitrates are concentrated in potato skin and immediately beneath it. Due to peeling and cooking about 20-70% is removed (Cieślik 1992; Gołaszewska and Zalewski 2001; Zgórska 2003, Zgórska 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 1.6 µg/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 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

Agblor A, Scanlon M G (2002) Effect of storage period, cultivar and two locations on the processing quality of French fried potatoes. *American Journal of Potato Research* **79**, 167-172

Bèlanger G, Walsh J R, Richards J E, Milburn P H, Ziadi N (2002) Nitrogen fertilization and irrigation affects tubers characteristics of two potato cultivars. *American Journal of Potato Research* **79**, 269-279

Bibak A, Stürup S, Haahr V, Gundersen P, Gundersen V (1999) Concentrations of 50 major and trace elements in danish agricultural crops measured by inductively coupled plasma mass spectrometry. 3 Potato (*Solanum tuberosum* Folva). *Journal of Agriculture and Food Chemistry* **47**, 2678-2681

Bronkowska M, Figurska-Ciura D, Orzeł D, Styczyńska M, Wyka J, Łoźna K, Żechałko-Czajkowska A, Biernat J (2008) Evaluation of plant products from the Legnicko-Głogowski region for their contamination with arsen. *Food Chemistry* **109**, 4-7

Cieślik E (1992) Zmiany azotanów i azotynów podczas obróbki kulinarnej ziemniaków. *Przemysł Spożywczy* **46 (10)**, 226-228

Cieślik E (1995) The effect of weather conditions on the level of nitrates in tubers of some potato varieties. *Polish Journal of Food and Nutrition Science* **45 (4)**, 11-19

Claassen PAM, Budde MAW, Van Calker MH (1993) Increase in phosphorylase activity during cold – induced sugar accumulation in potato tubers. *Potato Research* **36**, 205-217

Czerko Z, Zgórska K (2008) Storage technology of potato using for processing. *Zeszyty Problemowe Postępów Nauk Rolniczych* **530**, 69-79 (in Polish)

Ezekiel R, Singh B (2007) Effect of cooking and processing on CIPC Residue concentrations in potatoes and processed potato products. *Potato Research* **50**, 175-184

Friedman M (1996) Nutritional value of proteins from different food sources. A review. *Journal of Agriculture and Food Chemistry* **44**, 6-19

Friedman M, McDonald G (1997) Potato glycoalkaloids: chemistry, analysis, safety and plant physiology. *Critical Reviews in Plant Science* **16 (1)**, 55-132

Frydecka-Mazurczyk A, Zgórska K (1996) Wpływ warunków klimatycznych podczas wegetacji oraz przechowywania na jakość ziemniaków przeznaczonych na produkty spożywcze. *Materiały Konferencji: „Ziemniak jako surowiec do przetwórstwa spożywczego"* Jadwisin, pp 44-48

Gawęcki J (2004) Podstawowe składniki pożywienia. In: Gawęcki J, Mossor-Pietraszewska T (Eds) *Kompendium wiedzy o żywności i żywieniu*. Wydawnictwo Naukowe PWN, Warszawa, pp 206-249

Głuska A (1999) Wpływ agrotechniki na kształtowanie jakości plonu. *Materiały Konferencji: „Ziemniak jadalny i dla przetwórstwa spożywczego – czynniki agrotechniczne i przechowalnicze warunkujące jakość"* Jadwisin, pp 20-24

Gołaszewska B, Zalewski S (2001) Optimization of potato quality in culinary process. *Polish Journal of Food and Nutrition Science* **51 (1)**, 59-63

Gołubowska G (2005) Changes of polysaccharide content and texture of potato during French fries production. *Food Chemistry* **90**, 847-851

Gould WA (1999) *Potato production, processing and technology,* CTI Publications, INC. Maryland, pp 259

Grassert V, Vogel J, Bartel W (1984) Effect of cultivar and some environmental factors on the tendency of potato tubers to form sugars during several months storage at 4°C. *Potato Research* **27**, 365-372

Grudzińska M (2007) Stabilność cech technologicznych i konsumpcyjnych bulw ziemniaka w czasie przechowywania. PhD thesis, University of Technology, Koszlin, 109 pp

Hasse NU (2007) The canon of potato science: The nutritional value of potatoes. *Potato Research* **50**, 415-417

Hasse NU, Plate J (1996) Properties of potato starch in relation to varieties and environmental factors. *Starch* **48**, 167-171

Hasse T, Schüler C, Hasse NU, Hess J (2007a) Suitability of organic potatoes for industrial processing: Effect of agronomical measures on selected quality parameters at harvest and after storage. *Potato Research* **50**, 115-141

Hasse T, Schüler C, Piepho HPP, Thöni H, Hess J (2007b) The effect of preceding crop and pre-sprouting on crop growth, N use and tuber yield of main crop potatoes for processing under conditions of N stress. *Journal of Agronomy and Crop Science* **93**, 270-291

Jarych M (2007) Zależność zawartości związków pro- i anty- żywieniowych i jakości konsumpcyjnej ziemniaka od warunków uprawy i oraz zabiegów technologicznych. PhD thesis, Agricultural University, Wrocław, 112 pp

Kita A (2002) The influence of potato chemical composition on crisp texture. *Food Chemistry* **76**, 173-179

Kolbe H, Müller K, Olteanu G, Gorea T (1995) Effects of nitrogen, phosphorus and potassium fertilizer treatments on weight loss and changes in chemical composition of potato tubers stored at 4°C. *Potato Research* **38**, 97-107

Kucharzewski A, Nowak L, Dmowski Z, Markowska J (2002) Heavy metal and sulphur contents in potatoes from Lower Silesia. *Zeszyty Problemowe Postępów Nauk Rolniczych* **489**, 489-497

Kumar D, Singh BP, Kumar P (2004) An overview of the factors affecting sugar concentration of potatoes. *Annals of Applied Biology* **145**, 247-256

Kunachowicz H, Nadolna I, Przygoda B, Iwanow K (2005) *Food Composition Tables*, Wydawnictwo Lekarskie PZWL, Warszawa, 672 pp

Leszczyński W (1994) Ziemniak jako produkt spożywczy. *Postępy Nauk Rolniczych* **247 (1)**, 15-29

Leszczyński W (2000a) Kryteria oceny jakościowej ziemniaka spożywczego i skrobi. *Materiały Konferencji: „Ziemniak spożywczy i przemysłowy oraz jego przetwarzanie"* Wrocław, pp 41-50

Leszczyński W (2000b) The quality of table potato. *Żywność, Nauka, Technologia, Jakość* **25 (4)**, 5-27

Leszczyński W (2002a) The influence of fertilizer and pesticide use on potato quality. *Zeszyty Problemowe Postępów Nauk Rolniczych* **489**, 65-72

Leszczyński W (2002b) Wpływ chemizacji rolnictwa na jakość ziemniaka i właściwości skrobi. *Materiały Konferencji: „Ziemniak spożywczy i przemysłowy oraz jego przetwarzanie"* Wrocław 41-46

Leszczyński W (2004) Starch – raw material for industry, the structure and properties. *Zeszyty Problemowe Postępów Nauk Rolniczych* **500**, 69-98

Leszczyński W (2008) Wartość technologiczna ziemniaka (technological potato of value). In: Lewicki P (Ed) *Leksykon nauki o żywności i żywieniu człowieka*, Wydawnictwo SGGW, Warszawa, 521 pp

Leszczyński W, Lisińska G (1988) Influence of nitrogen fertilization on chemical composition of potato tubers. *Food Chemistry* **28**, 45-52

Lewandowicz G, Balcerek G, Walkowski A (2008) Produkcja i zastosowanie skrobi modyfikowanych. *Materiały Konferencji: „Ziemniak spożywczy i przemysłowy oraz jego przetwarzanie"* Wrocław, pp 97-103

Lisińska G (2004) Potato processed food products: scale of production, nutritive value. *Zeszyty Problemowe Postępów Nauk Rolniczych* **500**, 57-68

Lisińska G (2006) Technological and nutritive value of the polish potato cultivars. *Zeszyty Problemowe Postępów Nauk Rolniczych* **511**, 81-94

Lisińska G, Gołubowska G (2005) Structural changes of potato tissue during French fries production. *Food Chemistry* **93**, 681-687

Lisińska G, Leszczyński W (1989) *Potato Science and Technology*, Elsevier Applied Science, London, 391 pp

Lutomirska B (1999) Zmienność wybranych cech jakości bulw odmian jadalnych i przydatnych dla przemysłu spożywczego. Materiały Konferencji: *„Ziemniak jadalny i dla przetwórstwa spożywczego – czynniki agrotechniczne i przechowalnicze warunkujące jakość"* Jadwisin 15-17

Mazurczyk W, Lis B (1999) Zmienność składu chemicznego dojrzałych bulw ziemniaka odmian jadalnych. Materiały Konferencji: *„Ziemniak jadalny i dla przetwórstwa spożywczego – czynniki agrotechniczne i przechowalnicze warunkujące jakość"* Jadwisin, pp 17-20

McLaughlin MJ, Maier NA, Correl RL, Smart MK, Sparrow LA, McKay A (1999) Production of cadmium concentrations in potato tubers (*Solanum tuberosum* L.) by pre-plant soil and irrigation water analyses. *Australian Journal of Soil Research* **37**, 191-194

Mochnacki M, Kołpak R (1999) Czynniki agrotechniczne a wartość spożywcza ziemniaków. *Materiały Konferencji: „Ziemniak jadalny i dla przetwórstwa spożywczego – czynniki agrotechniczne i przechowalnicze warunkujące jakość"* Jadwisin, pp 15-17

Mozolewski W (1997) Czynniki kształtujące przydatność bulw do produkcji czipsów i frytek. *Materiały Konferencji: „Lepsza żywność"* Olsztyn 101-106

Mozolewski W (2003) A study into the relationship between the quality of potato varietes and the quality of chips and French fries. Dissertations and Monographs UWM, Olsztyn, 64 pp

Pęksa A (2003) Potato protein – characteristics and properties. *Postępy Nauk Rolniczych* **305 (5)**, 79-94

Pęksa A (2008) Nutritive value of potato and potato products as compared with other foods. *Wieś Jutra* **115 (2)**, 3-5

Pęksa A, Gołubowska G, Aniołowski K, Lisińska G, Rytel E (2006) Changes of glycoalkaloids and nitrate contents in potatoes during chips processing. *Food Chemistry* **97**, 151-156

Pęksa A, Gołubowska G, Rytel E, Lisińska G, Aniołowski K (2002) Influence of harvest date on glycoalkaloid contents of three potato varieties. *Food Chemistry* **78**, 313-317

Prośba-Białczyk U (2008) Produkcja ziemniaka skrobiowego. *Materiały Konferencji: „Ziemniak spożywczy i przemysłowy oraz jego przetwarzanie"*, pp 48-54

Prośba-Białczyk U, Mydlarski M (1999) Zmiany zawartości pierwiastków śladowych w bulwach ziemniaka pod wpływem nawożenia organicznego i mineralnego. *Materiały Konferencji Naukowej IHAR*, Jadwisin, 35 pp

Putz B (2004) Reduzierende Zucker in Kartoffeln. *Kartoffelbau* **55**, 188-192

Rembeza J (2007) Rynek ziemniaków w Europie. *Rynek Ziemniaka* **31**, 7-9

Rocznik statystyczny Rzeczypospolitej Polskiej (Statistical Yearbook of the Republic of Poland) GUS (2007) Warszawa

Rytel E, Gołubowska G, Lisińska G, Pęksa A, Aniołowski K (2005) Changes in glycoalkaloid and nitrate contents in potatoes during French fries processing. *Journal of the Science of Food and Agriculture* **85**, 879-882

Rytel E, Lisińska G (2007) Changes in the content of vitamin C in potato tubers during the cooking and processing to fried and dried products. *Żywność, Nauka, Technologia, Jakość* **55 (4)**, 186-197

Sowokinos JR, Schock CC, Stieber TD, Eldredge EP (2000) Compositional and enzymatic changes assciated witch sugar-end defect in Russet Burbank potato. *American Journal of Potato Research* **77**, 47-56

Tajner-Czopek A, Jarych-Szyszka M, Lisińska G (2008) Changes in glycoalkaloids content in potatoes destined for consumption. *Food Chemistry* **106**, 706-711

Talburt WF, Smith O (1987) *Potato Processing* (4^{th} Edn), AVI Book, published by Van Nostrand Reinhold Company, New York, 796 pp

Thybo AK, Mølgaard JP, Kidmose U (2001) Effect of different organic growing conditions on quality of cooked potatoes. *Journal of the Science of Food and Agriculture* **82**, 12-18

Trawczyński C (2008) The reaction of new potato cultivars on nitrogen fertilization. *Zeszyty Problemowe Postępów Nauk Rolniczych* **530**, 187-196 (in Polish)

Wang-Pruski G, Nowak J (2004) Potato after-cooking darkening. *American Journal of Potato Research* **81**, 7-16

Zgórska K (2003) Wymagania jakościowe wobec odmian ziemniaka do przetwórstwa spożywczego. *Ziemniak Polski* **14 (4)**, 26-28

Zgórska K (2005) Odmiany ziemniaka wykorzystywane do przetwórstwa spożywczego w Polsce i UE. *Wieś Jutra* **79 (2)**, 34-35

Zgórska K, Frydecka-Mazurczyk A (2002) Normy i wymagania jakościowe ziemniaków jadalnych oraz do przetwórstwa spożywczego. In: Chotkowski J (Ed) *Produkcja i rynek ziemniaków jadalnych*. Wydawnictwo Wieś Jutra, Warszawa, pp 183-192

Zgórska K, Grudzińska M (2004) Content of nitrates in potato tubers after preliminary and thermal processing. *Zeszyty Problemowe Postępów Nauk Rolniczych.* **500**, 475-481

Zhao J, Camire ME (1995) destruction of potato peel trypsin inhibitor by peeling and extrusion cooking. *Journal of Food Quality* **18**, 61-64