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REVISED CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF POTATO (Solanum tuberosum): Key Food and Feed Nutrients, Toxicants, Allergens, Anti-nutrients and Other Plant Metabolites

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Revised Consensus Document on Compositional Considerations for New Varieties of POTATO (*Solanum tuberosum*):

Key Food and Feed Nutrients, Toxicants, Allergens, Anti-nutrients and Other Plant Metabolites

Environment Directorate

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Also published in the Series on the Safety of Novel Foods and Feeds:

[No. 1, Consensus Document on Key Nutrients and Key Toxicants in Low Erucic Acid Rapeseed (Canola) (2001) – ***REPLACED with revised consensus document No. 24 (2011)***]

[No. 2, Consensus Document on Compositional Considerations for New Varieties of Soybean: Key Food and Feed Nutrients and Anti-nutrients (2001) – ***REPLACED with revised consensus document No. 25 (2012)***]

No. 3, Consensus Document on Compositional Considerations for New Varieties of Sugar Beet: Key Food and Feed Nutrients and Anti-nutrients (2002)

[No. 4, Consensus Document on Compositional Considerations for New Varieties of Potatoes: Key Food and Feed Nutrients, Anti-nutrients and Toxicants (2002) – ***REPLACED with revised consensus document No. 33 (2020)***]

No. 5, Report of the OECD Workshop on the Nutritional Assessment of Novel Foods and Feeds, Ottawa, Canada, February 2001 (2002)

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No. 19, Consensus Document on Compositional Considerations for New Varieties of Grain Sorghum [*Sorghum bicolor* (L.) Moench]: Key Food and Feed Nutrients and Anti-nutrients (2010)

No. 20, Consensus Document on Compositional Considerations for New Varieties of Sweet Potato [*Ipomoea batatas* (L.) Lam.]: Key Food and Feed Nutrients, Anti-nutrients, Toxicants and Allergens (2010)

No. 21, Consensus Document on Compositional Considerations for New Varieties of Papaya (*Carica papaya* L.): Key Food and Feed Nutrients, Anti-nutrients, Toxicants and Allergens (2010)

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No. 24, Revised Consensus Document on Compositional Considerations for New Varieties of Low Erucic Acid Rapeseed (Canola): Key Food and Feed Nutrients, Anti-nutrients and Toxicants (2011)

No. 25, Revised Consensus Document on Compositional Considerations for New Varieties of Soybean [*Glycine max* (L.) Merr.]: Key Food and Feed Nutrients, Anti-nutrients, Toxicants and Allergens (2012)

No. 26, Consensus Document on Compositional Considerations for New Varieties of Oyster Mushroom (*Pleurotus ostreatus*)*:* Key Food and Feed Nutrients, Anti-nutrients and Toxicants (2013)

No. 27, Consensus Document on Compositional Considerations for New Varieties of Common Bean (*Phaseolus vulgaris* L.)*:* Key Food and Feed Nutrients, Anti-nutrients and Other Constituents (2015)

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No.32, Developments in Delegations on the Safety Assessment of Novel Foods and Feeds, April 2019 - March 2020 (2020)

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This publication is available electronically, at no charge.

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FOREWORD

The OECD's Task Force for the Safety of Novel Foods and Feeds [1] decided at its first session, in 1999, to focus its work on the development of science-based ***consensus documents***, which are mutually acceptable among member countries. These consensus documents contain information for use during the regulatory assessment of a particular food/feed product. In the area of food and feed safety, consensus documents are being published on the nutrients, anti-nutrients or toxicants, information of its use as a food/feed and other relevant information.

This document updates and revises the original *Consensus Document on Compositional Considerations for New Varieties of Potatoes: Key Food and Feed Nutrients, Anti-Nutrients and Toxicants* issued in 2002. The revised document addresses compositional considerations for new varieties of potato by identifying key food and feed nutrients, toxicants, allergens, anti-nutrients and other plant metabolites. A general description of these components is provided. In addition, there is background material on the production, and uses of potato, and considerations to be taken into account when assessing new varieties of this crop. Constituents to be analysed, related to food use and feed use, are suggested.

Sweden, the Netherlands and South Africa served as the lead countries in the preparation for the document along with the Ad hoc group comprising Canada, the Netherlands, Nigeria (nominated by NEPAD-ABNE), South Africa and EFSA. The draft has been revised on a number of occasions based on the input from other member countries and stakeholders.

The Working Group for the Safety of Novel Foods and Feeds endorsed this document, which is published under the responsibility of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology of the OECD.

[1] From 1 January 2017, the Task Force for the Safety of Novel Foods and Feeds has changed denomination, becoming the Working Group for the Safety of Novel Foods and Feeds.

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PREAMBLE

Food and feed products of modern biotechnology are being commercialised and marketed in OECD member countries and elsewhere. The need has been identified for detailed technical work aimed at establishing appropriate approaches to the safety assessment of these products.

At a Workshop held in Aussois, France (OECD, 1997a), it was recognised that a consistent approach to the establishment of substantial equivalence might be improved through consensus on the appropriate components (e.g. key nutrients, key toxicants and anti-nutritional compounds) on a crop-by-crop basis, which should be considered in the comparison. It is recognised that the components may differ from crop to crop. The Working Group for the Safety of Novel Foods and Feeds[2] therefore decided to develop Consensus Documents on phenotypic characteristics and compositional data. These data are used to identify similarities and differences following a comparative approach as part of a food and feed safety assessment. They should be useful to the development of guidelines, both national and international and to encourage information sharing among OECD member countries.

These documents are a compilation of currently available information that is important in food and feed safety assessment. They provide a technical tool for regulatory officials as a general guide and reference source, and also for industry and other interested parties and will complement those of the Working Group on Harmonisation of Regulatory Oversight in Biotechnology. They are mutually acceptable to, but not legally binding on, OECD member countries. They are not intended to be a comprehensive description of all issues considered to be necessary for a safety assessment, but a base set for an individual product that supports the comparative approach. In assessing an individual product, additional components may be required depending on the specific case in question.

In order to ensure that scientific and technical developments are taken into account, member countries have agreed that these Consensus Documents will be reviewed periodically and updated as necessary. Users of these documents are invited to provide the OECD with new scientific and technical information, and to make proposals for additional areas to be considered. Comments and suggestions can be sent to:

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[2] From 1 January 2017, the Task Force for the Safety of Novel Foods and Feeds has changed denomination, becoming the Working Group for the Safety of Novel Foods and Feeds.

THE ROLE OF COMPARATIVE APPROACH AS PART OF A SAFETY ASSESSMENT

In 1990, a joint consultation of the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) established that the comparison of a final product with one having an acceptable standard of safety provides an important element of safety assessment (WHO, 1991).

In 1993, the Organisation for Economic Co-operation and Development (OECD) further elaborated this concept and advocated the approach to safety assessment based on substantial equivalence as being the most practical approach to addressing the safety of foods and food components derived through modern biotechnology (as well as other methods of modifying a host genome including tissue culture methods and chemical or radiation induced mutation) (OECD, 1993). In 2000, the Task Force for the Safety of Novel Foods and Feeds[3] concluded in its report to the G8 that the concept of substantial equivalence will need to be kept under review (OECD, 2000).

The Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology in 2000 concluded that the safety assessment of genetically modified foods requires an integrated and stepwise, case-by-case approach, which can be aided by a structured series of questions (FAO/WHO, 2000). A comparative approach focusing on the determination of similarities and differences between the genetically modified food and its conventional counterpart aids in the identification of potential safety and nutritional issues and is considered the most appropriate strategy for the safety and nutritional assessment of genetically modified foods. The concept of substantial equivalence was developed as a practical approach to the safety assessment of genetically modified foods. It should be seen as a key step in the safety assessment process although it is not a safety assessment in itself; it does not characterise hazard, rather it is used to structure the safety assessment of a genetically modified food relative to a conventional counterpart. The Consultation concluded that the application of the concept of substantial equivalence contributes to a robust safety assessment framework.

A previous Joint FAO/WHO Expert Consultation on Biotechnology and Food Safety held in 1996 elaborated on compositional comparison as an important element in the determination of substantial equivalence. A comparison of critical components can be carried out at the level of the food source (i.e. species) or the specific food product. Critical components are determined by identifying key nutrients, key toxicants and anti-nutrients for the food source in question. The comparison of key nutrients should be between the modified variety and non-modified comparators with an appropriate history of safe use. Any difference identified would then be assessed against the natural ranges published in the literature for commercial varieties or those measured levels in parental or other edible varieties of the species (FAO/WHO, 1996). The comparator used to detect unintended effects should ideally be the near isogenic parental line grown under identical conditions.

While the comparative approach is useful as part of the safety assessment of foods derived from plants developed using recombinant DNA technology, the approach could, in general,

3 From 1st of January 2017, the Task Force for the Safety of Novel Foods and Feeds has changed denomination, becoming the Working Group for the Safety of Novel Foods and Feeds.

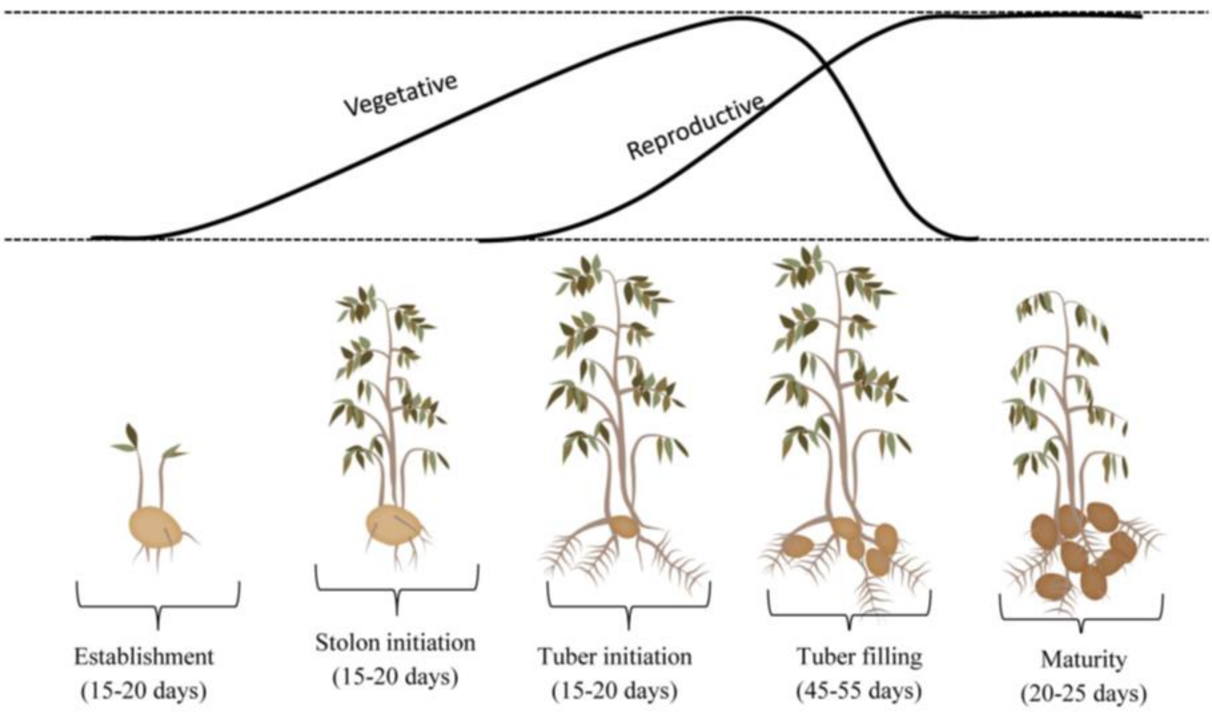
be applied to foods derived from new plant varieties that have been bred by other techniques.

1. BACKGROUND

1.1. General description of potato (*Solanum tuberosum* ssp. *tuberosum* L.)

1. Potato is a member of the *Solanaceae* or nightshade family which includes some of the world's most important crop plant species like peppers, tomatoes, eggplant and tobacco (OECD, 1997b; CIP, 2010; PGSC, 2011). It is an herbaceous perennial plant that grows up to 0.4-1.4 m in height (Spooner and Knapp, 2013), and the growth habit varies between and within species (Patil et al., 2016). The growth cycle of the potato plant, which is grown as an annual crop, is illustrated in Figure 1. The potato tubers can be harvested from 90 to 150 days after planting (Bradshaw and Bonierbale, 2010).

Figure 1. Commercial potato plant growth cycle



Source: Obidiegwu et al. (2015)

2. Potato tubers are swellings of the rhizome as an enlarged fleshy portion of an underground stolon (Struik, 2007). Anatomically, the tuber can be viewed as an enlarged stem. Its protective periderm, or "peel/skin", covers the exterior of the tuber, containing many small holes or "lenticels" facilitating gas exchange. Below the periderm is the cortex layer, which consists of a thin layer of parenchyma, i.e. soft tissue. Underneath the cortex is a ring of vascular tissue whilst the deeper parts consist of storage parenchyma divided by a central medulla structure ("pith") running from the base (stolon) to the top (apical bud) of the tuber. The tuber exterior bears "eyes", which are the buds from which next seasons' growth will emerge. Eye number and distribution are characteristic of the variety (Patil et al., 2016). Tuber shapes are of four types: compressed, round, oval and long, an important feature for processing (Figure 2). Flesh colour varies from white and

yellow to blue, and skin colour goes from white, yellow, tan, red, pink and purple to blue (Custers, 2015).

Figure 2. Tuber shape/colour diversity of potato varieties

Source: © Scott Bauer (USDA ARS, k9152-1)

3. The potato is mostly propagated vegetatively by means of tubers or pieces of tubers cut to include at least one or two eyes, and sometimes by true potato seeds (TPS) (Patil et al., 2016; Ghebreslassie, 2017; Schumann and D'Arcy, 2017). Traditionally, new potato varieties have been created by conventionally crossing parents with traits of interest. Given that *Solanum tuberosum* L. is a highly heterozygous, tetraploid crop, reproduction through seed from selected plants showing desirable attributes will result in loss of genetic integrity. Clonal propagation methods are therefore commonly used to maintain the combination of traits in new varieties and produce a homogenous population of tubers that can be used in further field tests (Karp et al., 1987). In some torrid tropical and subtropical regions of the globe, conditions, such as flexible timing of planting and freedom from viral diseases are favourable for the use of TPS besides propagated clones (Bradshaw, 2007).

4. In addition, somatic cell selection methods based on screening populations of cultured cells for desirable characteristics are increasingly replacing conventional crossing methods (Conner and Christey, 1994; Barrell et al., 2013). Characteristics commonly measured by breeders include agronomic traits (e.g. time to maturity, tuber yield, storage), quality (e.g. shape, sugar content), and pest and disease resistance (e.g. against blight, viruses, and tuber moth) (Bonierbale et al., 2020).

5. There are more than 100 closely related wild species of potato throughout Central and South America. Whilst the use of wild germplasm in breeding programmes is increasing, the full potential of this genetic diversity has not been exhausted yet (Bethke, Halterman and Jansky, 2017).

6. Further description on the potato taxonomy, centre of diversity of the species, morphology and identification methods, genome characteristics, reproductive biology, crosses and ecology can be found in the OECD Consensus Document on the Biology of *Solanum tuberosum* subsp. *tuberosum* L. (Potato) (OECD, 1997b).

1.2. Production

7. The world production of potato tubers (*Solanum tuberosum* L.) in 2018 was estimated to exceed 368 million tonnes (Table 1), grown in 160 countries (FAOSTAT, 2020). With a global cropping area of almost 20 million hectares, the potato is the fourth most important staple crop after rice, wheat and maize (Ezekiel et al., 2013; de Haan and Rodriguez, 2016; Zhang et al., 2017). In 2018 the largest producers of potatoes in the world were the regions Asia and Europe (Table 1).

Table 1. Global production of potato (*S. tuberosum* L.) in 2018

Region	**Production** (thousand tonnes)
Asia	188 645
Europe	105 181
Americas	46 596
Africa	26 042
Oceania	1 705
World	***368 169***

Note: Continents are listed in order of production.
Source: FAOSTAT (2020), FAO statistics database http://www.fao.org/faostat/en/, accessed May 2020. Aggregate may include official, semi-official, estimated or calculated data.

8. The total area of harvested potatoes through the period 2003-2018 has increased in Africa, the People's Republic of China and India, and decreased in Europe, the Americas and the Russian Federation (Table 2). Over the same 16-year period, the total area harvested in the world has decreased 6% from 18.7 to 17.6 million hectares.

Table 2. Total area of harvested potato (*S. tuberosum* L.) in 2003 and 2018

	Area harvested (thousand ha)	
Region/Country	**2003**	**2018**
China (People's Republic of)	4 524	4 814
Europe *(without Russia)*	4 959	3 441
India	1 337	2 151
Russia	2 516	1 313
Americas	1 940	1 578
Africa	1 410	1 904
World	***18 702***	***17 579***

Source: FAOSTAT (2020), FAO statistics database http://www.fao.org/faostat/en/, accessed May 2020. Aggregate may include official, semi-official, estimated or calculated data.

1.3. Uses

Potatoes for human consumption

9. Potato is a staple food, which is produced in substantive amounts and processed in different forms. It is consumed routinely across the globe (Camire, Kubow and Donnelly, 2009). Average world food supply amounted to 34 kg of potatoes per capita per year in 2013. This figure varied amongst continental regions, and, within each of these, also amongst sub-regions (Table 3).

10. In terms of nutritional value, potato primarily contains carbohydrates with little fat, and some protein. Potato protein has a good amino acid balance (Kumari, Kumar and Solankey, 2018). It is a source of vitamin C (ascorbic acid), vitamin B6 (pyridoxine) and potassium, and also contains other B vitamins (Hale et al., 2008; Camire, Kubow and Donnelly, 2009; Chandrasekara and Josheph Kumar, 2016; Beals, 2019). Potato skins and flesh also contain dietary fibre, contributing to >16% of daily dietary intake amongst consumers of most age groups (Camire, Kubow and Donnelly, 2009; Beals, 2019), but skins may also contain relatively high levels of glycoalkaloids (see section 3.1 below).

11. Potatoes for direct consumption should be cooked before eating because of the indigestibility of non-gelatinised starch and the presence of anti-nutritional proteins in raw, unheated potatoes (Camire, Kubow and Donnelly, 2009). Potatoes are baked, boiled or fried and used in a range of recipes: mashed potatoes, potato pancakes, potato dumplings, potato soup, potato salad, potato au gratin, jacket potatoes, potato wedges, fries/chips, and hashed browns/rösti (AHDB, 2019).

12. Different potato preparations can result in various amounts of nutrient losses (e.g. 13% loss of ascorbic acid when cooking unpeeled potatoes vs. 41% loss when peeled (Weber and Putz, 1998)).

Table 3. Potato supply in different global regions in 2013

Global	Region	Sub-Region	Value (kg/capita/year)
World			34.2
	Africa		19.1
		Eastern Africa	22.5
		Middle Africa	9.5
		Northern Africa	38.5
		Southern Africa	30.0
		Western Africa	3.7
	Americas		34.8
		Northern America	53.8
		Central America	13.7
		Caribbean	8.2
		South America	29.3
	Asia		29.0
		Central Asia	67.5
		Eastern Asia	38.6
		Southern Asia	27.0
		South-eastern Asia	4.6
		Western Asia	31.3
	Europe		82.6
		Eastern Europe	109.2
		Northern Europe	91.9
		Southern Europe	51.4
		Western Europe	62.3
	Oceania		51.8
		Australia and New Zealand	54.5
		Melanesia	22.2
		Micronesia	0.4
		Polynesia	23.7

Source: FAOSTAT (2020), FAO statistics database http://www.fao.org/faostat/en/, accessed May 2020. Aggregate may include official, semi-official, estimated or calculated data.

Commercial processing

13. Potato is processed for use in food and alcohol, starch and biofuel production (Scott and Suarez, 2012; Liang and McDonald, 2014). For food use, potatoes may be processed shortly after harvesting or after weeks to months of storage. Potato can be transformed into many different food products and food ingredients (Camire, Kubow and Donnelly, 2009), with the rest being diverted into industrial starch or ethanol production, or used on farms as planting material and animal feed (CIP, 2018). Global consumption of potato as food is shifting from fresh potatoes to added-value processed food products (CIP, 2018), such as chips, fries, dehydrated products as well as starch and alcohol production (Lisińska et al., 2009). In North America and some European countries, between 50 and 60% of the potato crop is processed into edible products or other industrial products (Talburt and Smith, 1987). The global trade of frozen processed potato products has

increased within 10 years from 3 million tonnes in 2007 to 7 million tonnes in 2017. Whereas major exporters of these products are the Netherlands, Belgium, US and Canada, most of the market growth has been taking place in Asia, the Middle East, and Latin America (van Merrienboer, 2019). Major processed products include potato chips (crisps) and fries (chips) and other frozen products, followed by dehydrated products, chilled-peeled potatoes and canned potatoes.

14. The potato food industry uses potatoes in a variety of ways:

- Frozen potatoes (pre-cooked products). Fries (also named 'chips' in the United Kingdom) are served in restaurants and fast food spots worldwide. More than 7 million tonnes of factory-made fries are consumed per year (CIP, 2018).
- Dehydrated products (potato flakes, potato flours, diced potatoes and granules). Potato flakes are used in retail mashed potato products, as ingredients in snacks and even as food aid (CIP, 2018). Potato flour is used by the food industry to bind meat mixtures and thicken gravies and soups (CIP, 2018).
- Purified proteins from potatoes are used commercially in food formulations as emulsifiers (e.g. Alting et al., 2011).
- Potato starch (a fine tasteless powder, with excellent mouth feel) provides higher viscosity than wheat and maize starches. It is used as a thickener for sauces and stews and as a binding agent in cake mixtures, dough, biscuits and ice-cream (CIP, 2018). Potato starch is also used for various non-food purposes, particularly as an adhesive. Non-food starch is used in various chemically modified forms, such as hydrolysed, esterified, cationised, and/or cross-linked (Kraak, 1992).
- Alcoholic beverages. In Eastern Europe and Scandinavia, crushed potatoes are heated to convert their starch to fermentable sugars that are used in the distillation of alcoholic beverages, such as vodka and akvavit (CIP, 2018).
- Other products (gnocchi/dumplings, salads, ready prepared meals and others).

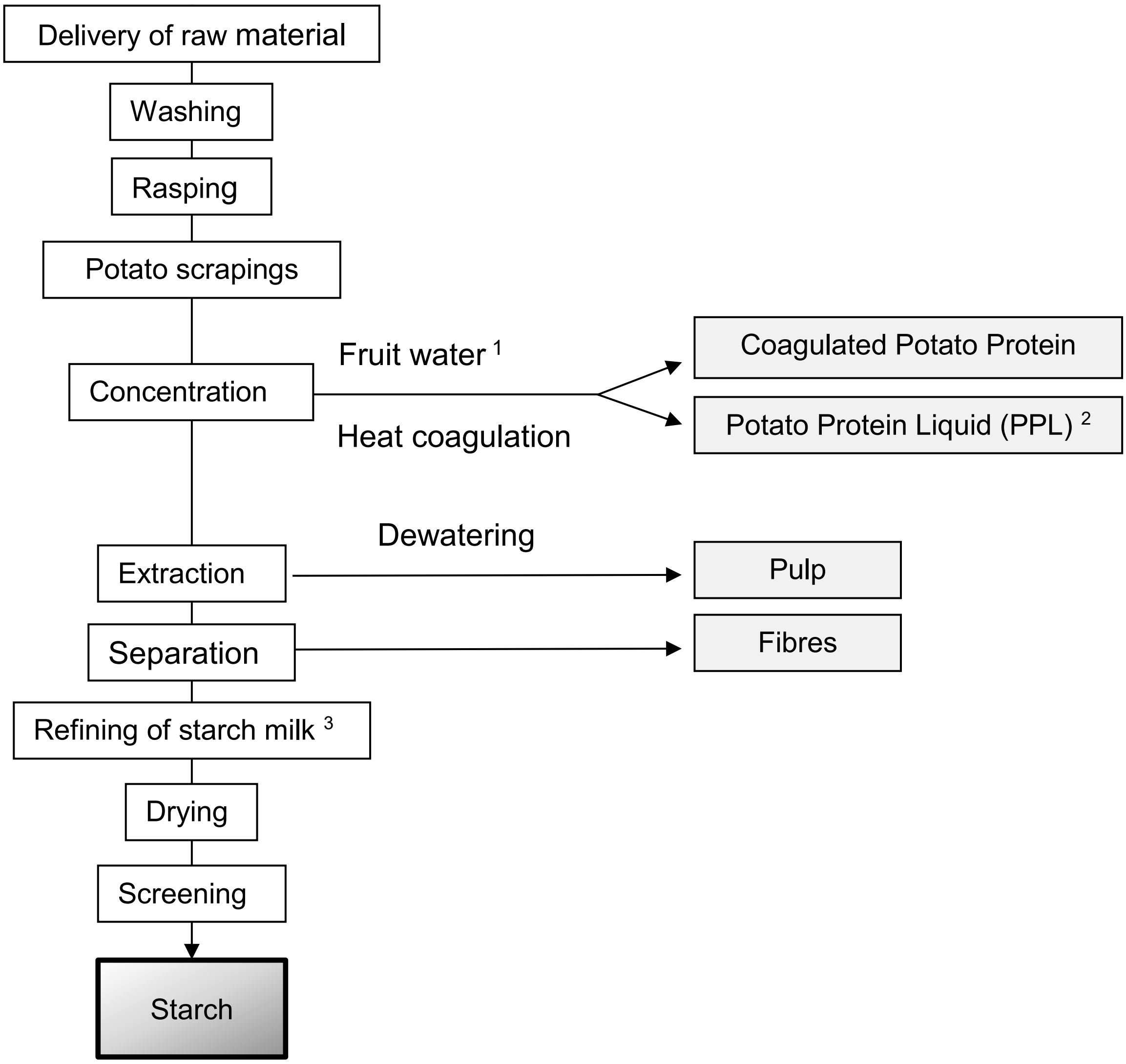
Starch

15. Especially in Europe, potatoes are used as raw material for starch manufacturing. Within the European Union the annual sold production of potato starch was about 1.2 million tonnes (De Cicco and Jeanty, 2019).

16. Potato starch is easily separated from tubers because of its large grain size and the structure of the tubers, and does not need elaborate equipment to process. In addition to large factories, very small and simple processing units exist. A typical potato starch processing line is described in Figure 3.

17. Potato starch, which is composed of amylose and amylopectin, shows specific properties different from starch of other sources. Potato starch is used in the food industry in pre-gelatinised or modified forms (Grommers and van der Krogt, 2009; Flottweg, 2019). Several industrial applications prefer potato starch instead of other starches for use in paper, adhesives and textiles. Starch from potatoes has absorbing and gelling properties, and its swelling ability after gelatinisation is generally greater than for starch from other common botanical sources (Yadav, Kumar and Yadav, 2016).

Figure 3. Schematic description of food-grade potato starch processing



[1] Fruit water: the aqueous phase removed by centrifugation during concentration of the starch granules that have been liberated from potato tissue by rasping.
[2] PPL: concentrated, de-proteinated fruit water fraction remaining after separation from coagulated protein.
[3] Starch milk: isolated, crude starch fraction still containing small fibre particles and remnants of fruit water.

18. By-products of potato processing (pulp, coagulated protein from fruit water[4]) are normally used in animal feeding, but trends also exist for food use, when these by-products come from food processing facilities with food grade quality. Coagulated protein prepared from potatoes with a high glycoalkaloid content (particularly from unpeeled potatoes) cannot be used in the food/feed industry.

[4] The aqueous phase removed by centrifugation during concentration of the starch granules that have been liberated from potato tissue by rasping.

Bio-ethanol

19. Potatoes are also used for industrial ethanol production. The basic method for alcohol production is to crush and cook the potatoes in water. The resulting gelatinised starch is hydrolysed to sugars (either by acids or by enzymes), and pumped into vats, where it is fermented by yeast addition. The residues of the distillation process are used as feed.

Potatoes as animal feed

20. Potatoes are not grown specifically for animal feed. Production statistics from the United States, for example, show that, in the years 2015-2017, 0.2-0.4% of the total production volume was sold for animal feed (National Potato Council, 2019). Whereas potato tubers are considered a good feed for farm animals (Maynard, 1929), potato foliage is toxic, due to glycoalkaloids, lectins, and protease inhibitors, and is not used for animal feed.

21. Surplus or culled[5] potato tubers, either raw or cooked, are suitable for most classes of livestock. As animal feed, potato tuber size is an important factor since small potatoes may result in choking (Snowdon, 2017). Usually used as energy concentrates, potatoes contain high levels of water, with dry matter level between 16-25% (Fiems et al., 2013).

22. Potato tubers can also be incorporated into silage. They can be ensiled with hay, maize stover, or straw as ensiling enhances shelf life and reduces choking hazards (Schroeder, 2012). When dry forages are used, up to 67% of potatoes can be included in the silage without any leaching issues (Halliday, 2015). Ensiling potato tubers may be a good way to preserve potato as feed for up to a year. When potatoes which contain 80% moisture are turned into silage for cattle, it is recommended either that dry hay, straw or chaff be run through the silage cutter with potato, or that maize silage be chopped with potato (Boyles, 2000).

- Ruminants – As feed, culled potatoes are mostly fed to ruminants in the form of fresh whole tubers or as chopped material. Potatoes are a good source of energy for ruminants. Potatoes and potato products are high in starch but have low levels of protein and fibre (Charmley, Nelson and Zvomuya, 2006) suggesting a need for supplementary protein-rich feeds and roughages in ruminant diets (Boyles, 2000; Heuzé et al., 2018). Vitamins and minerals also need to be supplemented, such as calcium, phosphorus, magnesium, vitamins A, D, and E, and trace minerals (IANR, 2019). Per day, up to 20 kg of potatoes can be given to beef cattle and 15 kg to dairy cattle (Fuller, 2004). For optimal performance of beef cattle, potato intakes are limited to 30% of diet dry matter (Snowdon, 2017). A good use of potato in lactating cows was as a partial replacement of cereal grains to reduce feed cost (Jans, 1989). Studies show it is best to limit the amount of potatoes fed to not more than 11 to 14.5 kg per cow per day, or 2.3 to 3.6 kg on a dry matter basis (Boyles, 2000). When feeding silage from cull potatoes to dairy cattle, it is best to wash the potatoes before ensiling to avoid interference with the silage fermentation process caused by clostridial bacteria, possibly present in the soil microflora on the potatoes' surface (Halliday, 2010).

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[5] Potatoes unusable for fresh market, processing, or dehydration because they do not meet minimum size, grade, or quality standards, or potatoes disposed of because of low market value due to overproduction, are considered waste, or "cull," potatoes (Olsen et al., 2001; Schroeder, 2012).

- Pigs – Raw potatoes should be avoided in swine diets because raw potatoes are unpalatable to pigs and are not well digested (Braude and Mitchell, 1951). Six kg per day is the recommended level of cooked potatoes for growing and finishing pigs (Pond and Maner, 1984). However, it is worth noting that some studies have reported that potato steam peel can be included at a level up to 30% dry matter in feed during the growing-finishing phase (van Lunen et al., 1989). Steam peel is a by-product of potato processing where the peel is removed through steaming. Pigs also may consume cooked potatoes from restaurant and catering waste.
- Poultry – Cooked potatoes can be mixed into rations for poultry, at up to 40% of the total ration (Heuzé et al., 2018). In laying hens, a dietary inclusion rate of 15% potato meal gave satisfactory egg production. Inclusion of 20% potato in grower diets yielded good results (Whittemore, 1977).
- Rabbits – Raw potato tubers are a good source of highly digestible energy for rabbits with low levels of fibre and a protein content similar to that of cereals (Lebas, 2013). Green potatoes are toxic to rabbits because of glycoalkaloid content.

23. Unwanted potato material is sometimes incorporated into ruminant livestock feed. This can include potato culls and potato process waste (wet and dry peel, raw chip, fries, and cooked potatoes). According to OECD (2013), beef cattle in North America may consume up to 30% of their diet (as fed) from potatoes, and sheep may consume up to 10% of their diet (as fed) from potatoes.

24. Various by-products of potato processing, such as from frozen-food production or from starch extraction, have found applications as animal feed. Food potato by-products include waste from various production stages, including 1) peels; 2) screening solids and other small pieces, as well as small potatoes; 3) processed (heated) products, such as fries, batter, etc.; and 4) recovery from process water, e.g. solids, microbial cells, and filter cake. Given the high water content of many of these products, they are relatively perishable and therefore usually fed to animals on farms at a short distance from the potato processing facilities (Nelson, 2010). This also holds true for the potato pulp obtained as a by-product of starch extraction from starch potatoes. Through dehydration of pulp, pellets can be produced with extended storage ability. Care should be taken to avoid hazards in these feed materials, such as rotten potatoes, physical hazards (e.g. stone, glass, metal particles), heavy metals and pesticide and contaminant residues above threshold levels, and high levels of glycoalkaloids (Starch Europe, 2014).

25. Peels can be rich in starch, depending on the peeling method used, and also contain high levels of phenolics (chlorogenic and gallic acids) and, in some cases, of glycoalkaloids (Mullen et al., 2015). Potato pulp is a source of energy (starch), dietary fibre (mainly pectin), and protein (Mullen et al., 2015). Stillage, a by-product produced from the waste water stream of distilleries utilising feedstock containing starchy crops, such as potatoes, is rich in carbohydrates, and contains fibre and protein as well (Krzywonos et al., 2009).

1.4. Appropriate comparators for testing new varieties

26. This document suggests parameters that potato breeders should measure when developing new modified varieties.

27. The data obtained in the analysis of a new potato variety should ideally be compared to those obtained from an appropriate near isogenic non-modified variety, grown

and harvested under the same conditions.[6,7] The comparison can also be made between values obtained from new varieties and data available in the literature, or chemical analytical data generated from other commercial potato varieties.

28. Components to be analysed include key nutrients, anti-nutrients, toxicants and allergens (*where relevant*). Key nutrients are those which have a substantial impact in the overall diet of humans (food) and animals (feed). These may be quantitatively major (fats, proteins, and structural and non-structural carbohydrates) or minor constituents (vitamins and minerals). Similarly, the levels of known anti-nutrients and allergens should be considered. Key toxicants are those toxicologically significant compounds known to be inherently present in the species, whose toxic potency and levels may impact human and animal health (e.g. glycoalkaloids). Standardised analytical methods and appropriate types of material should be used, adequately adapted to each product and by-product. The key components analysed are used as indicators of whether unintended effects of the genetic modification influencing plant metabolism have occurred or not.

1.5. Breeding characteristics screened by developers

29. Potato is a crop with multiple characteristics and uses. There are more than 50 traits required to be described and/or screened for commercial cultivars (Mackay, 2005). Today an array of tools, including molecular markers are used to complement the phenotypic selection process (Ramakrishnan et al. 2015; Bradshaw, 2017).

30. Although detailed screening practices may differ between breeding programmes because of different objectives, market requirements, and available resources, all breeding programmes usually target adaptation and production, as well as protection and utilisation traits for fresh consumption, processing or industrial uses (Mackay, 2005; Bonnel, 2008).

31. Production traits and morpho-physiological traits respond to environmental conditions and management practices during the various phases of growth in production fields. These are critical for determining the productivity and economic attributes of the field crop. Traits include plant emergence, plant vigour, duration of vegetative growth, tuber number, shape and size, cold hardiness and heat tolerance. Assessments also include stable and reliable yield and utilisation traits over multiple years in target production areas.

32. Protection traits are resistance characteristics to diseases, pests and physiological disorders. Details of these can be found in the OECD Consensus Document on the Biology of *Solanum tuberosum* subsp. *tuberosum* (Potato) (OECD, 1997b).

33. Quality traits are related to aspects of potato food processing, composition and nutrients. Traits contributing to quality components, table market value (boil, bake, mash) and processing (potato chips, fries) are dry matter, bruising, and reducing sugars at harvest and after storage. Resistance to mechanical damage (bruising, shattering and skinning) during harvest and handling, as well as resistance to greening are also considered (Mori

[6] For additional discussion of appropriate comparators, see the Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant DNA Plants CAC/GL 45/2003 of the Codex Alimentarius Commission (2003, paragraphs 44 and 45).

[7] It is considered almost impossible to produce near-isogenic lines from tetraploid potato plants through sexual reproduction. If potato lines are maintained through vegetative clonal propagation, plants from the parental line that served as host for the modification can be used as the near-isogenic comparator in comparative analyses (Barrell et al., 2013).

et al., 2015). Glycoalkaloid levels are assessed to ensure they are below the accepted threshold for human consumption.

34. Other traits are market specific. For example, potatoes for frozen processing, dehydration and flour products need to have a high dry matter content, low levels of reducing sugars and white flesh and good stable colour during and after processing. Potatoes for starch production have similar requirements – including high starch content and large starch grain size for high recovery.

35. Another trait of interest to potato developers is reduced potential for formation of acrylamide, a processing contaminant which is not present in fresh potatoes. Acrylamide is a chemical substance classified by the International Agency for Research on Cancer (IARC) as a likely human carcinogen (Class 2A), and with known neurotoxic effects at high exposure rates (IARC, 2015). It is spontaneously formed under certain cooking conditions, particularly in starch-rich foods when the moisture is low and the temperature exceeds 100ºC (Rosén and Hellenäs, 2002; Tareke et al., 2002). Acrylamide can be regarded as a Maillard product resulting from the reaction between certain amino acids, such as asparagine, and reducing sugars (glucose, fructose, etc.) during heating (Mottram, Wedzicha and Dodson, 2002). Since asparagine and glucose are abundant in many foods, measurable levels of acrylamide are found in many heated products. Fried potatoes, fries, and crisps are examples of fried potato-containing foods with relatively high levels of acrylamide while non-fried, i.e. fresh and boiled, potatoes have comparatively lower levels (EFSA CONTAM Panel, 2015). Indicators of acrylamide-forming potential include the levels of free asparagine and reducing sugars.

36. Various agronomic, practical and genotypic (i.e. variety-related) factors contribute to the acrylamide-forming potential of potatoes during processing. The use of nitrogen fertilizers during cultivation may increase the levels of asparagine, for example, Harvest of potato tubers should preferably be done when their dry matter is at its peak and reducing sugars at a low. During post-harvest storage, tuber levels of reducing sugars tend to increase over time, and more pronouncedly so at lower temperatures, a phenomenon known as "cold-induced sweetening" (CIS), as opposed to the irreversible senescence-induced sweetening over longer periods of time. Breeding efforts towards potato varieties with low acrylamide formation potential therefore currently focus on lack of CIS and low asparagine content (Mori et al., 2015; Rosen et al., 2018).

2. NUTRIENTS

37. The nutrient content of potatoes varies depending mainly on the variety (Toledo and Burlingame, 2006), although environmental, agricultural and post-harvest factors can also play a significant role. Together with starch, the main component, many other compounds, such as proteins, fat, vitamins, minerals, fibre and phytochemicals are also present in potato tubers contributing to their organoleptic characteristics and nutritional value.

38. The presence of skin increases the amount of fibre available (up to 2.5%) and changes the content of different minerals. Additionally, the skin seems to have a key role in protecting minerals and water-soluble vitamins from leaching out into the cooking water, in particular during boiling (Camire, Kubow and Donnelly, 2009; Ngobese et al., 2017).

2.1. Proximate nutrient composition

39. The proximate composition of potatoes is shown in Table 4 from worldwide composition databases as reference; composition data refer to peeled potatoes, except for the USDA and AFSI databases. The main component of potatoes is water (approximately 80%). Carbohydrates are the most abundant (mainly starch), representing the main source of energy (approximately 95%). Typical levels of proteins are around 2%; potatoes are naturally very low in fat, from not detected amounts to a maximum of 0.3 g/100 g depending on varieties.

Table 4. Proximate, starch, sugar, and dietary fibre composition of raw potato tubers

Nutrient	Peeled potatoes							Non-peeled potatoes	
	France 2017 [1]	Denmark 2019 [2]	Netherlands 2019 [3]	Finland 2019 [4]	UK 2015 [5]	ASEAN 2014 [6]	Australia 2019 [7]	USA 2019 [8]	AFSI 2019 [9]
	Mean value, g/100 g fresh weight								
Water	79.0	79.5	77.0	-	78.1	79.4	81.5	79.3	79.0
	Mean value, g/100 g dry matter [10]								
Protein	10.3	9.8	8.7	9.1	8.7	10.7	12.2	9.9	10.7
Fat	0.86	1.46	0.00	0.48	0.46	0.49	0.30	0.4	0.8
Carbohydrate									
total [11]	72.4	84.4	82.6	74.1	89.5	76.2		84.3	83.9
available [12]	63.8	77.6	74.3	69.3	80.4	68.4		74.2	
Starch	69.0	81.5	78.3	71.2	85.4	-		73.7	
Sugars	3.5	6.0	4.3	2.9	4.1	-		4.0	
Dietary fibre	8.6	6.8	8.3	4.8	9.1	7.8	8.4	10.1	
Ash	4.9	4.4	-	-	-	4.9	4.8	5.3	4.7

Notes: [1] French Food Composition Table CIQUAL (ANSES, 2017), "Potato, peeled, raw".
[2] Danish Food Composition Database FRIDA (DTU, 2019), "Potato raw".
[3] Dutch Foodstuff Database NEVO (RIVM, 2019), "Potatoes raw".
[4] Finnish Food Composition Database FINELI (THL, 2019), "Potato peeled".
[5] Public Health England (2015), "Potatoes, old, raw, flesh only".
[6] Concise ASEAN Food Composition Tables (Institute of Nutrition, Mahidol University, 2014), "Potato, fresh, raw".
[7] Australian Food Composition Database (FSANZ, 2019), "Potato, peeled, raw, pale skin, pontiac, red skin, sebago)
[8] USDA Food Composition Databases (USDA, 2019), "Potatoes, flesh and skin, raw" (Nutrient Database Number (NDB No.) 11352).
[9] AFSI Crop Composition Database v7.0 (AFSI, 2019), average values provided.
[10] Mean values based on dry matter were calculated from a fresh weight basis (wet weight) using the mean moisture level reported from each source. For data from the Finnish food composition database, for which moisture was lacking, the average moisture content for peeled potato tubers from the six other databases was taken (79.1%).
[11] Carbohydrate total calculated by difference = 100 – protein – fat – ash – moisture.
[12] Carbohydrates available = Carbohydrates total - dietary fibre.

Dry matter

40. On average, potato tubers contain around 20% dry matter (DM), with a range from 16% to 30% (Jiménez, Rossi and Sammán, 2009; Lombardo, Pandino and Mauromicale, 2012; Rodríguez Galdón et al., 2012; van Niekerk et al., 2016; Ngobese et al., 2017). The specific gravity of potato is commonly measured by potato processors since it is correlated with DM and the potential yield of processed products from these potatoes. The measurement of specific gravity is done by comparing the weight of the sample in the air and under water, and usually has values greater than unity, which means that they are denser than water. The amount of DM determines the suitability of the different varieties for processing. Cultivars high in DM (high specific gravity) are specially indicated for baking and in particular frying, while potatoes with low DM content are ideal for boiling. Besides the influence of genotype on DM content, seasonal variations have also been reported, e.g. between potato tubers grown in spring and those grown in autumn (de Freitas et al., 2012).

Fibre

41. Fibre composition in potatoes varies between the pulp and the peel; the three main components of the dietary fibre in the pulp are hemicellulose, cellulose and pectins, while

in the peel lignin is also present in relevant amounts (~20%) (Mayer, 1998; Liang and McDonald, 2014). Peeling generally decreases the amount of fibre but the variety also plays a very important role (Camire, Kubow and Donnely, 2009). As an average the content of fibre in raw, peeled potato tubers is around 2% fresh weigh (FW), although amounts between 1.4% and 3.6% have been reported for different varieties (Öhrvik et al., 2010; comparable to 5-10% DM values in Table 4).

42. As for "dietary fibre", comparing analytical results with other, historical data should be done cautiously given the various deviations by different institutions from the internationally harmonised definition of the Codex Alimentarius[8], as well as from the recommended analytical methods (Codex Alimentarius Commission, 2009; Jones, 2014).

2.2. Carbohydrates

Starch

43. Starch is the main constituent among potato carbohydrates. Potato starch has a semi-crystalline structure and consists of two polymers of D-glucose: amylose, an essentially linear polysaccharide and amylopectin, a highly branched polysaccharide. Amylopectin is the major component in potato starch with amylose typically representing a quarter to less than a third of the total starch, although amylose content from 18-19% up to 30% has been reported in some consumed cultivars (Rodríguez Galdón et al., 2012; Ngobese et al., 2017).

44. Starch can represent between 60-85% of the DM content of potato tubers. Broad ranges of starch content are reported in the literature; starch levels in unpeeled potatoes have been reported to vary between 11.6 and 19.7 g/100 g FW (Öhrvik et al., 2010; Rodríguez Galdón et al., 2012; van Niekerk et al., 2016; Ngobese et al., 2017).

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[8] Codex Alimentarius definition:

> "Dietary fibre means carbohydrate polymers [1] with ten or more monomeric units [2], which are not hydrolysed by the endogenous enzymes in the small intestine of humans and belong to the following categories:
>
> - Edible carbohydrate polymers naturally occurring in the food as consumed,
> - carbohydrate polymers, which have been obtained from food raw material by physical, enzymatic or chemical means and which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities,
> - synthetic carbohydrate polymers which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities.
>
> [1] When derived from a plant origin, dietary fibre may include fractions of lignin and/or other compounds associated with polysaccharides in the plant cell walls. These compounds also may be measured by certain analytical method(s) for dietary fibre. However, such compounds are not included in the definition of dietary fibre if extracted and re-introduced into a food.
>
> [2] Decision on whether to include carbohydrates from 3 to 9 monomeric units should be left to national authorities."

Sugars

45. The sugar content of potato tubers varies depending on the variety, maturity and physiological stage (from tuberisation to maturity), handling, storage and other post-harvest conditions to which the potatoes are exposed. The main soluble sugars in potatoes are sucrose (0.08-1.39 g/100 g FW), glucose (0.015-0.34 g/100 g FW), and fructose (0.0- 0.18 g/100 g FW), although levels up to 1.5, 1.8 and 1.0 g/100 g FW have also been reported for these three sugars, respectively (Table 5; Burlingame, Mouillé and Charrondière, 2009; Öhrvik et al., 2010).

Table 5. Sugar composition of potato tubers (raw, g/100 g dry matter) [1]

Nutrient	Peeled potatoes					Non-peeled potatoes	
	France 2017 [2]	Denmark 2019 [3]	Netherlands 2019 [4]	Finland 2019 [5]	Australia 2019 [6]	USA 2019 [7]	AFSI 2019 [8]
Sugars	3.5	6.0	4.3	2.9	5.5	4.0	
Sucrose	-	3.2	-	-	0.8	0.8	1.1
Fructose	-	1.2	-	1.4	1.8	1.3	0.2
Glucose	-	1.7	-	1.4	2.8	1.5	0.4

Notes: [1] Mean values based on dry matter were calculated from a fresh weight basis (wet weight) using the mean moisture level reported from each source. For data from the Finnish food composition database, for which moisture was lacking, the average moisture content for peeled potato tubers from the six other databases was taken (79.1%).
[2] French Food Composition Table CIQUAL (ANSES, 2017), "Potato, peeled, raw".
[3] Danish Food Composition Database FRIDA (DTU, 2019), "Potato raw".
[4] Dutch Foodstuff Database NEVO (RIVM, 2019), "Potatoes raw".
[5] Finnish Food Composition Database FINELI (THL, 2019), "Potato peeled".
[6] Australian Food Composition Database (FSANZ, 2019), "Potato, peeled, raw" (coliban, desiree, new, pale skin, pontiac, red skin, sebago).
[7] USDA Food Composition Databases (USDA, 2019), "Potatoes, flesh and skin, raw" (NDB No. 11352).
[8] AFSI Crop Composition Database v7.0 (AFSI, 2019), average values provided.

46. The level of sugars present is an important determinant of tuber quality; in particular those of the reducing sugars (glucose and fructose) as they have a negative effect during processing. Cold storage increases reducing sugars levels (cold-induced sweetening) due to the enzymatic conversion of starch and sucrose. High levels of reducing sugars in potato are associated with higher levels of acrylamide during certain types of processing (particularly frying).

2.3. Proteins / amino acids

47. Reported protein levels for potato tubers are based on variety, growth conditions, and on the detection method used. However, a substantial portion of the nitrogen in potatoes is not protein-bound, such as free amino acids and inorganic nitrogen, but also contributes to measured protein levels using the Kjeldahl method. The non-protein nitrogen fraction has been reported to account for 28-47% of total nitrogen in tubers (Kapoor, Desborough and Li, 1975; Imafidon and Sosulski, 1990). The estimation of protein content often entails multiplication of the figure for total nitrogen content with a conversion factor. This has also been done for the protein contents from the food composition databases summarised in Table 4. Alternatively, protein levels *excluding* non-protein nitrogen may

have been established by nitrogen analysis of the residue from samples extracted with 80% ethanol (which removes non-protein nitrogen compounds; Owusu-Apenten, 2002) or by assays not affected by non-protein nitrogen compounds, such as the colourimetric Bradford assay (Snyder and Desborough, 1978). Using the latter assay, tubers were found to contain protein at levels ranging between 4% and 7% of tuber dry matter in 10 food and 10 processing varieties of potatoes, for example (Bárta et al., 2012).

48. A major part of this protein fraction (approximately 40% of soluble tuber proteins) is made up by patatin, previously also referred to as tuberin (Waglay and Karboune, 2016). Patatin is a complex of different glycoproteins with molecular masses ranging from 40- 42 kDa and different forms of covalently attached N-glycans (Pots et al., 1999). Multiple isoforms of patatin have been identified, with different electrophoretic properties based on amino acid sequence differences. The number of isoforms varies across potato cultivars, e.g. four in Bintje, nine in Désirée, and 17 in Kuras (Kärenlampi and White, 2009). One of the patatin constituents, also known as Sola t 1, is an allergen (see Section 3.2).

49. The amino acid profile of whole potatoes is dominated by the amide amino acids asparagine and glutamine, or their corresponding acid-hydrolysis products aspartic and glutamic acids in the total-amino-acids profile (Table 6). Their levels may vary, being further increased upon N-fertilisation of the potato crop, for example (Eppendorfer and Bille, 1996). Approximately 50% of the total amino acids in potato tubers are in free form and not protein-bound, while their level may further increase during prolonged storage, when dormancy is broken and depending also on other storage conditions (Brierley, Bonner and Cobb, 1996; Uri et al., 2014). Whereas potato protein has a favourable content of lysine, it is relatively poor in sulphur-containing amino acids, including cysteine and methionine (Friedman, 1996; Massey, 2003).

Table 6. Amino acid profiles of raw potato tubers (mg/100 g dry matter) [1]

Amino acid	Peeled	Non-peeled		
	Total amino acids	Total amino acids		Free amino acids
	Australia, 2019 [2]	USA, 2019 [3]	AFSI, 2019 [4]	AFSI, 2019 [4]
Alanine	328	304	302	61
Arginine	726	487	505	264
Asparagine [5]	-	-	-	1,086
Aspartic Acid	3,259	2,313	2,304	255
Cystine/Cysteine	112	116	108	49
Glutamic Acid	2,404	1,692	1,758	291
Glutamine [5]	-	-	-	816
Glycine	307	275	380	49
Histidine	219	169	158	61
Isoleucine	451	318	346	77
Leucine	626	472	560	51
Lysine	637	516	538	90
Methionine	196	154	169	69
Phenylalanine	492	390	404	91
Proline	285	304	354	85
Serine	417	357	326	78
Threonine	428	323	340	66
Tryptophan	155	101	99	49
Tyrosine	351	231	343	61
Valine	679	496	478	264

Notes: [1] Mean values for USA data based on dry matter were calculated from a fresh weight basis (wet weight) using the mean moisture level reported (79.25%).
[2] Australian Food Composition Database (FSANZ, 2019), "Potato, peeled, raw" (new, pontiac, sebago).
[3] USDA Food Composition Databases (USDA, 2019), "Potatoes, flesh and skin, raw" (NDB No. 11352).
[4] AFSI Crop Composition Database v7.0 (AFSI, 2019), "Potato, tuber".
[5] For total amino acids, asparagine and glutamine are not available as they are converted to aspartic and glutamic acids, respectively, by acid hydrolysis prior to amino acid analysis.

2.4. Lipids / fatty acids

50. Lipids in potatoes represent approximately 0.1-0.5% FW of the potato tuber; they are mainly located between the skin and the vascular ring (Ramadan and Oraby, 2016). The three main constituents are phospholipids (47%), glycolipids (22%), and acylglycerols (21%) (Table 7).

Table 7. Fatty acid composition of potato tubers (raw, g/100 g dry matter) [1]

Nutrient	Peeled potatoes				Non-peeled potatoes
	France 2017 [2]	Denmark 2019 [3]	Finland 2019 [4]	UK 2015 [5]	USA 2019 [6]
Fatty acids, total saturated	0.18	0.27	< 0.4	-	0.15
Palmitic acid (C16:0)	0.13	0.22	-	0.05	-
Fatty acids, total monounsaturated	0.035	0.073	< 0.4	-	0.01
Oleic acid (C18:1)	0.035	0.049	-	0.05	-
Fatty acids, total polyunsaturated	0.45	0.80	< 0.4	-	0.25
Linoleic acid (C18:2)	0.20	0.34	0.17	0.05	-
Linolenic acid (C18:3)	0.26	0.45	0.061	trace	-

Notes: [1] Mean values based on dry matter were calculated from a fresh weight basis (wet weight) using the mean moisture level reported from each source. For data from the Finnish food composition database, for which moisture was lacking, the average moisture content for peeled potato tubers from the six other databases was taken (79.1%).
[2] French Food Composition Table CIQUAL (ANSES, 2017), "Potato, peeled, raw".
[3] Danish Food Composition Database FRIDA (DTU, 2019), "Potato raw".
[4] Finnish Food Composition Database FINELI (THL, 2019), "Potato peeled".
[5] Public Health England (2015), "Potatoes, old, raw, flesh only".
[6] USDA Food Composition Databases (USDA, 2019), "Potatoes, flesh and skin, raw" (NDB No. 11352).

2.5. Vitamins

51. Vitamin C (ascorbic acid) is the most predominant vitamin in potatoes (Table 8). In general, vitamin C content decreases by 30-45% during the first three months of storage (Tudela, Espín and Gil, 2002). Further losses during cooking due to leaching and thermal sensitivity. Losses should be considered when estimating the real contribution of potatoes to the total intake of vitamin C (Decker and Ferruzzi, 2013). In the literature, contents of vitamin C in unpeeled potatoes range between 10.4 and 25.9 mg/100 g FW (Rodríguez Galdón et al., 2012) or between 8.4 and 26.1 mg/100 g FW in peeled potatoes (Öhrvik et al., 2010). Lower contents of vitamin C have been reported for the variety "Liseta" (2.8 mg/100 g FW) (Tudela, Espín and Gil, 2002), and up to 46 mg/100 g FW in a Korean cultivar (Han et al., 2004).

52. Potatoes are considered dietary sources of vitamins B6 (pyridoxine) (Camire, Kubow and Donnelly, 2009) and B9 (folate) (Ezekiel et al., 2013). Contents reported in the literature for pyridoxine range from 0.13 to 0.26 mg/100 g FW, and between 13 and 36.5 µg/100 g FW for folate (Öhrvik et al., 2010). Potatoes are generally low in provitamin A carotenoids, namely β-carotene, α-carotene and β-cryptoxanthin. Levels of β-carotene of up to 111 µg/100 g FW have been reported (Burlingame, Mouillé and Charrondière, 2009; Öhrvik et al., 2010).

Table 8. Vitamin composition of potato tubers (raw, per 100 g dry matter) [1]

Nutrient	Unit	Peeled potatoes							Non-peeled potatoes	
		France 2017 [2]	Denmark 2019 [3]	Netherlands 2019 [4]	Finland 2019 [5]	UK 2015 [6]	ASEAN 2014 [7]	Australia 2019 [8]	USA 2018 [9]	AFSI 2019 [10]
Vitamin C (ascorbic acid)	mg	90	129	61	62	64	146	83	95	115
Vitamin B1 (thiamin)	mg	0.32	0.27	0.52	1.00	0.91	0.58	0.44	0.39	
Vitamin B2 (riboflavin)	mg	0.23	0.31	0.17	0.14	0.05	0.34	0.16	0.15	
Vitamin B3 (niacin)	mg	6.3	7.8	-	4.3	1.4	6.3	6.5	5.1	9.1
Vitamin B5 (pantothenic acid)	mg	1.6	1.9	-	-	2.0	-	1.4 [11]	1.4	
Vitamin B6 (pyridoxine)	mg	1.2	1.0	1.3	2.5	0.6	-	0.6	1.4	0.6
Vitamin B7 (biotin)	µg	-	-	-	-	1	-	-	-	
Vitamin B9 (folate)	µg	124	176	100	48	59	-	76	72	
Vitamin E	mg	0.26	0.49	-	< 0.5	0.05	-	-	0.05	
Vitamin K1	µg	43	78	-	5.0	4.3	-	-	10	
β-carotene (provitamin A)	µg	5	49	22	-	trace	0	-	5	
Vitamin A, RAE[12]	mg	-	4.1		1.4	trace	0	-	0	

Notes: [1] Mean values based on dry matter were calculated from a fresh weight basis (wet weight) using the mean moisture level reported from each source, except for the AFSI Crop Composition Database, which already provides data on a dry-weight basis. For data from the Finnish food composition database, for which moisture was lacking, the average moisture content for peeled potato tubers from the six other databases was taken (79.1%).

[2] French Food Composition Table CIQUAL (ANSES, 2017), "Potato, peeled, raw".

[3] Danish Food Composition Database FRIDA (DTU, 2019), "Potato raw".

[4] Dutch Foodstuff Database NEVO (RIVM, 2019), "Potatoes raw".

[5] Finnish Food Composition Database FINELI (THL, 2019), "Potato peeled".

[6] Public Health England (2015), "Potatoes, old, raw, flesh only".

[7] Concise ASEAN Food Composition Tables (Institute of Nutrition, Mahidol University, 2014), "Potato, fresh, raw".

[8] Australian Food Composition Database (FSANZ, 2019), "Potato, peeled, raw" (coliban, desiree, new, pale skin, pontiac, red skin, sebago).

[9] USDA Food Composition Databases (USDA, 2019). "Potatoes, flesh and skin, raw" (NDB No. 11352).

[10] AFSI Crop Composition Database v7.0 (AFSI, 2019). "Potato, tuber".

[11] Four potato samples (coliban, desiree, pale skin, red skin).

[12] Retinol activity equivalents, µg/100g.

2.6. Minerals

53. Potassium, magnesium and phosphorus are the minerals typically present at high levels in potato tubers (Table 9). Potassium is the most abundant mineral in potatoes, reported to represent between 35-45% of the total mineral content (Rodríguez Galdón et al., 2012). One-hundred grammes of potatoes provides up to 15% of the daily nutrient reference values for potassium. The level of minerals does not differ much between tubers with and without skin, except for a significant decrease in calcium and iron, and increase in manganese (van Niekerk et al., 2016). However, the skin plays a key role in preventing minerals from leaching out into the cooking water, during boiling (Camire, Kubow and Donnelly, 2009; Ngobese et al., 2017).

54. Potassium levels up to 799 mg/100 g FW have been reported in the cultivar Bonita (Rivero et al., 2003). Öhrvik et al. (2010) reported potassium levels ranging between 328 and 451 mg/100 g FW in peeled potatoes; this includes levels reported for unpeeled potatoes from different European varieties cultivated in South Africa (Ngobese et al., 2017). Levels of potassium across 11 different varieties (unpeeled potatoes) ranged between 366 and 618 mg/100 g FW in cultivars grown in South Africa. A smaller range was reported in unpeeled potatoes from 10 different cultivars from the Canary Islands, 274.1-393.6 mg/100 g FW (Rodríguez Galdón et al., 2012).

55. Magnesium levels range between 7.7 and 31.5 mg/100 g FW in unpeeled potatoes (Rodríguez Galdón et al., 2012; van Niekerk et al., 2016).

56. Levels of phosphorus in different studies range from 32 mg/100 g FW in peeled potatoes (Öhrvik et al., 2010) to 72.9 mg/100 g FW in unpeeled potatoes of the cultivar Darius (van Niekerk et al., 2016). Levels of sodium are relatively low in potatoes at 1.75- 12.2 mg/100 g FW. Trace elements, such as zinc and iron are also present in potatoes, although contradictory reports exist about their bioavailability (Phillippy, Lin and Rasco, 2004; Burgos et al., 2007; Camire, Kubow and Donnelly, 2009). Levels reported in the literature for the presence of iron in potato tubers range from 0.28 mg/100 g FW in peeled potatoes (Öhrvik et al., 2010) to 2.91 mg/100 g FW in unpeeled potatoes (Ngobese et al., 2017). Zinc levels in potatoes are usually lower than those reported for iron; levels vary between 0.177 mg/100 g FW and 0.49 mg/100 g FW with both being reported in unpeeled potatoes (Rodríguez Galdón et al., 2012; Ngobese et al., 2017). Whilst levels of nitrate are considered to be very low in potatoes as compared to other vegetables, the relatively high quantities consumed make it a major nitrate source yet staying well below the acceptable daily intake (Rytel, 2012; Santamaria, 2006).

Table 9. Mineral composition of potato tubers (raw, per 100 g dry matter) [1]

Nutrient	Unit	Peeled potatoes							Non-peeled potatoes	
		France 2017 [2]	Denmark 2019 [3]	Netherlands 2019 [4]	Finland 2019 [5]	UK 2015 [6]	ASEAN 2014 [7]	Australia 2019 [8]	USA 2018 [9]	AFSI 2019 [10]
Calcium, Ca	mg	68	33	26	22	32	117	22	58	
Chloride, Cl	mg	238	-	-	-	379	-	201	-	
Copper, Cu	mg	0.38	0.25	0.39	-	0.27	-	0.16	0.53	0.46
Chromium, Cr	µg	-	2.9	-	-	-	-	-		
Iron, Fe	mg	4.3	5.1	2.2	2.9	1.5	6.8	2.3	3.9	
Iodine, I	µg	5.7	5.9	10.9	4.8	4.6	-	-	-	
Magnesium, Mg	mg	105	100	96	96	96	-	105	111	104
Manganese, Mn	mg	0.52	1.12	-	-	0.64	-	1.02 [11]	0.74	
Phosphorus, P	mg	268	270	261	258	155	282	294	275	
Potassium, K	mg	1990	2020	1957	2249	2023	854	2230	2048	2127
Selenium, Se	µg	109	1	4	3	trace	-	-	2	
Sodium, Na	mg	< 2	34	9	5	9	146	21	29	
Zinc, Zn	mg	1.7	1.5	1.6	1.4	1.4	-	1.6	1.4	

Notes: [1] Mean values based on dry matter were calculated from a fresh weight basis (wet weight) using the mean moisture level reported from each source, except for the AFSI Crop Composition Database, which already provides data on a dry-weight basis. For data from the Finnish food composition database, for which moisture was lacking, the average moisture content for peeled potato tubers from the six other databases was taken (79.1%).

[2] French Food Composition Table CIQUAL (ANSES, 2017), "Potato, peeled, raw".

[3] Danish Food Composition Database FRIDA (DTU, 2019), "Potato raw".

[4] Dutch Foodstuff Database NEVO (RIVM, 2019), "Potatoes raw".

[5] Finnish Food Composition Database FINELI (THL, 2019). "Potato peeled".

[6] Public Health England (2015), "Potatoes, old, raw, flesh only".

[7] Concise ASEAN Food Composition Tables (Institute of Nutrition, Mahidol University, 2014), "Potato, fresh, raw".

[8] Australian Food Composition Database (FSANZ, 2019), "Potato, peeled, raw" (coliban, desiree, new, pale skin, pontiac, red skin, sebago).

[9] USDA Food Composition Databases (USDA, 2019), "Potatoes, flesh and skin, raw" (NDB No. 11352).

[10] AFSI Crop Composition Database v7.0 (AFSI, 2019), "Potato, tuber".

[11] Four potato samples (coliban, desiree, pale skin, red skin).

2.7. Organic acids

57. Organic acids in potato tubers account for around 0.4-1.0 % of their FW. They are represented mainly by citric, malic, tartaric, oxalic, fumaric and succinic acids. The level of organic acids usually decreases during storage, except for citric acid which increases.

3. TOXICANTS, ALLERGENS, ANTI-NUTRIENTS AND OTHER PLANT METABOLITES

3.1. Toxicants

Glycoalkaloids

58. Potatoes contain different types of glycoalkaloids, which are toxins commonly found in Solanaceous plants. The most important group of alkaloids in commercial conventional potato varieties are the steroidal glycoalkaloids. One or more sugar molecules (usually three) are linked to the steroidal alkaloid, solanidine. They may contribute to the typical potato flavour at low levels. Higher amounts affect the organoleptic properties of potato (WHO, 1993; Pariera Dinkins et al., 2008).

59. Ninety five percent of total glycoalkaloids (TGA) in potato tubers consists of α- chaconine (solanidine-glucose-rhamnose-rhamnose) and α-solanine (solanidine-galactose-glucose-rhamnose). Contents of glycoalkaloids are generally expressed as TGA in milligrammes per kilogramme, calculated as the sum of α-chaconine and α-solanine, often called chaconine and solanine, respectively.

60. TGA content of potato tubers varies widely (WHO, 1993). Values ranging from 10 to 350 mg/kg FW are found in commercial varieties (Friedman, 2006; Elvingsson and Norlin, 2015), but in most cases the TGA concentration in commercial tubers is below 200 mg/kg FW (~1000 mg/kg DM) (Machado, Toledo and Garcia, 2007; Knuthsen et al., 2009).

61. Other combinations between the solanidine alkaloid and sugar molecules that may be present in small amounts are (Friedman, 2006):

- β-chaconine (solanidine-glucose-rhamnose)
- γ -chaconine (solanidine-glucose)
- β1-solanine (solanidine-galactose-glucose)
- β2-solanine (solanidine-galactose-rhamnose)
- γ-solanine (solanidine-galactose)

62. Glycoalkaloids are produced in various amounts in all parts of the potato plant including flowers, stems, leaves, roots, tubers, berries and sprouts. The lowest levels are found in tubers and stems, typically 10-33 mg/kg FW. In the berries and leaves the levels are about 10 times higher (180-1,450 mg/kg FW) and in sprouts and flowers the levels are about 10 to 20 times higher (2,000-9,970 mg/kg FW) (Hellenäs, 1994; Omayio, Abong and Okoth, 2016).

63. In the tuber, glycoalkaloids are particularly concentrated in the outer region, i.e. the periderm (skin) and cortex (peel) and in germinating potatoes high levels can be found in sprouts and around the eyes (Table 10). The tuber size is thus important for the glycoalkaloid level as a small tuber has relatively more peel and skin than a larger tuber.

Table 10. Levels of total glycoalkaloids (TGA) in various potato tuber tissues

Tissue	TGA mg/kg fresh weight	Reference
Whole tuber	7-187	Friedman and Levin, 2016
Flesh (storage parenchyma and vascular tissue) 60-75% of tuber	1-148	Friedman and Levin, 2016
Skin (periderm) 2-3% of tuber	300-600	WHO, 1993
Peel (cortex) 10-15% of tuber	12-543	Friedman and Levin, 2016
Bitter-tasting tuber (stressed)	250-800	WHO, 1993
Peel from bitter-tasting tuber	1500-2000	WHO, 1993
Sprouts	2000-9970	Omayio, Abong and Okoth, 2016
Leaves	230-1000	Milner et al., 2011
Flowers	2150-5000	Milner et al., 2011
Berries	180-1350	Omayio, Abong and Okoth, 2016

64. Whilst the AFSI Crop Composition Database reports average values of 51 and 30 mg/100 kg for α-chaconine and α-solanine, respectively (n=435), corresponding to a ratio of α-chaconine to α-solanine larger than unity (>1), this ratio shows substantive variability at the singular variety level. For example, the ratio of α-chaconine to α-solanine in the skin ranged from 0.7 to 4.5 and from 0.5 to 1.3 in the flesh in 60 commercial varieties (Valcarcel et al., 2014) and from 1.4 to 2.2 in whole potatoes in eight commercial varieties (Friedman and Levin, 2016).

65. Large and often unpredictable variations in glycoalkaloid levels can arise from differences in variety, locality, season, cultural practices and stress factors during growth and storage (Friedman and Levin, 2016). Stress factors include exposure to light, mechanical damage, and improper storage conditions (WHO, 1993). Particularly, light and mechanical damage stimulate the production of glycoalkaloids in the tuber (Machado, Toledo and Garcia, 2007) but the responses differ between varieties (Friedman and Levin, 2016).

66. Processing methods influence the level of glycoalkaloids in the potato for consumption. Removal of the peel, green parts and sprouts are effective ways to significantly reduce glycoalkaloid content (BfR, 2018). Peeling of the tuber reduces the glycoalkaloid levels by about 58% and is reduced by a further 22% during cooking (Mäder, Rawel and Kroh, 2009). Rytel (2012) reported that blanching[9] (Lindhauer, Haase and Putz, 2003) reduces levels of glycoalkaloids by up to 28%. Frying also appears to

[9] Blanching is a short-term heat treatment (70-100°C) of peeled raw potatoes or potato pieces.

significantly lower the level of glycoalkaloids, with reported differences between raw, peeled and fried potatoes of 77-94% (Omayio, Abong and Okoth, 2016; Tajner-Czopek et al., 2014). The method[10] for producing chuño negrocan reduces the level of glycoalkaloids from 300 mg/kg to 50 mg/kg FW (Burton, 1989).

67. Glycoalkaloid poisoning causes several symptoms ranging from gastrointestinal disorders, to confusion, hallucination and partial paralysis to convulsions, coma and death (Smith, Roddick and Jones, 1996). Available information suggests that the susceptibility of humans to glycoalkaloid poisoning is high and variable: oral doses in the range of 1- 5 mg/kg body weight (bw) are marginally to severely toxic to humans (Hellenäs et al., 1992) whereas 3-6 mg/kg bw can be lethal (WHO, 1993). α-chaconine is reported to be more toxic than α-solanine and there are also observations of synergistic effects (Friedman and Levin, 2016). A recently-published EFSA scientific opinion on the risks related to the presence of glycoalkaloids in food and feed concluded that the estimated dietary exposure of potato consumers to TGA in Europe was still safe, but only with a limited margin (factor <10) below levels considered safe for intake. For livestock, though, the few studies provided did not allow to set a reference point (EFSA CONTAM Panel et al., 2020).

68. Currently the accepted limit for glycoalkaloid levels in tubers in many countries is 200 mg/kg FW (Slanina, 1990; Smith, Roddick and Jones, 1996). In Germany, it has been suggested that the glycoalkaloids content in table potatoes should be lower than 100 mg/kg FW (BfR, 2018), whilst maximum levels for glycoalkaloids in potatoes at the EU community level are still to be set following the recent EFSA scientific opinion (EFSA CONTAM Panel et al., 2020).

Calystegines

69. Calystegines constitute a group of nortropane alkaloids with glycosidase inhibitory activity in solanaceous food plants. They were identified in potatoes for the first time in the 1990s (Friedman and Levin, 2016). Like glycoalkaloids they differ in levels with varieties and are induced by various pre- and post-harvest stresses, but not by wounding or by light (Petersson et al., 2013). In a study with 308 potato samples collected from retail stores in nine European countries, the mean level of calystegines in potatoes (based on the analysis of six calystegines, A3, A5, B1, B2, B3, and B4) was 164 mg/kg FW and the maximum level was 507.3 mg/kg FW (Mulder et al., 2016).

70. Notwithstanding their similarities with swainsonine (present in *Ipomea* species), calystegines appeared to be much less toxic, if at all, in experimental laboratory animals (e.g. Stegelmeier et al., 2008). There are no definitive studies that calystegines are a safety hazard to humans or livestock (EFSA et al., 2019).

3.2. Allergens

71. Potato is not considered a commonly allergenic food. Despite being a food highly consumed worldwide and a staple crop in Western/Asian countries, allergic reactions to potatoes are not frequent (Chiriac et al., 2017; De Swert, Cadot and Ceuppens, 2007; Dogru et al., 2015; Jeannet-Peter, Piletta-Zanin and Hauser, 1999; Seppälä et al., 1999, 2001).

[10] A traditional method where potatoes are dehydrated in the open air by in short tending, treading, freezing and drying potatoes, benefitting the night frosts in the high Andes.

72. A variety of adverse immune reactions to raw and cooked (heat-treated) potato have been identified in atopic individuals. Exposure to raw potato, via skin contact when peeling tubers and/or eating, has been shown to trigger skin and oral mucosa reactions as well as respiratory symptoms. These reactions are more frequently seen in adults, but can also occur in children (Quirce et al., 1989; Jeannet-Peter, Piletta-Zanin and Hauser, 1999; Martínez de Lagrán et al., 2009; Schubert, Steinhart and Paschke, 2003). Furthermore, anaphylactic reactions to raw potato have also been reported (Beausoleil, Spergel and Pawlowski, 2001; Eke Gungor et al., 2016; Steiß, Simon and Langner, 2015).

73. Dietary exposure to cooked potato has been shown to provoke adverse immune reactions in sensitised infants and young children, mainly represented as eczema, gastrointestinal complaints and immediate hypersensitivity reactions (Carolino et al., 2016; Castells et al., 1986; De Swert, Cadot and Ceuppens, 2002, 2007; Martín-Muñoz et al., 2017; Monti et al., 2011; Nowak-Wegrzyn et al., 2003). In children, severe allergic reactions have also been reported (De Swert, Cadot and Ceuppens, 2002) and even anaphylactic reactions can occur (Castells et al., 1986; De Swert, Cadot and Ceuppens, 2002, 2007; Eke Gungor et al., 2016; Martín-Muñoz et al., 2017; Monti et al., 2011). However, it has been described that most children develop tolerance to potato allergies at around four years of age (De Swert, Cadot and Ceuppens, 2007).

74. The proteins currently included in the WHO/IUIS database (www.allergen.org) as allergens in potato are Sola t 1, Sola t 2, Sola t 3 and Sola t 4. Sola t 1 has been identified as a major allergen in potatoes (Majamaa et al., 2001; Seppälä et al., 1999); known as patatin, it is the main storage protein (43 kDa) in potato (Seo, L'Hocine and Karboune, 2014). The other Sola t proteins described in WHO/IUIS belong to the family of soybean trypsin inhibitors (Kunitz type) (Seppälä et al., 2001). Sola t 2 protein, referred by WHO/IUIS as a cathepsin D protease inhibitor, is a 21-kDa glycoprotein. Sola t 3 protein (21 kDa) is referred to as a cystein protease inhibitor (Seppälä et al., 2001), and Sola t 4 (16 kDa) is referred to as a serine protease inhibitor 7 which has been identified as being responsible for anaphylactic reactions (Martín-Munñz et al., 2017).

75. Expression levels of specific proteins in potato, including those described here, are known to vary depending on various factors, such as genotype, environment or tuber life cycle (Lehesranta et al., 2006; Nakamura et al 2010; Peña-Cortés et al., 1992).

3.3. Anti-nutrients and other plant metabolites

Phytate

76. Potatoes have a relatively low content of phytate (myo-inositol hexakisphosphate) as compared to other vegetables (0.035-0.073% FW) (Phillippy, Bland and Evens, 2003).

Lectins

77. Lectins or agglutinins are carbohydrate-binding proteins known to cause deleterious effects on human health following their consumption, including intestinal problems and red blood cell agglutination. The lectin from potato tubers is classified as a chitin-binding lectin and is a glycoprotein containing 50% sugar, and is rich in hydroxyproline and arabinose moieties (Pramod, Vigneshwaran and Venkatesh, 2015). Levels of lectins in potato tubers are relatively low as compared to other vegetables, representing 0-4% of total protein (Pramod, Venkatesh and Mahesh, 2007). Potato lectins are inactivated by heat processing whilst potato tubers are preferably consumed cooked (e.g. for starch digestibility) by humans and monogastric animals.

Protease inhibitors

78. Potato tuber protease inhibitors are a diverse group of proteins, such as serine proteases, cysteine proteases, aspartate proteases and metallo-proteases, known to inhibit a broad spectrum of enzymes. They are considered to have roles in both plant defence and internal protein turnover during development and homeostasis (Waglay and Karboune, 2016). The most abundant are inhibitors of serine proteases from the Kunitz-type family. The protease inhibitors represent a major fraction, besides patatin, of the total amount of soluble protein present in the tuber and derived products (e.g. protein concentrate from fruit water) (Pouvreau et al., 2001; Ralla et al., 2012). Protease inhibitors in potatoes are largely inactivated by boiling and other thermal processes, which are commonly applied to potatoes for human consumption and feeds for non-ruminants (e.g. monogastrics, poultry).

Other compounds

79. Various stresses, such as wounding, nutrient deficiencies, or microbial infections induce phenolic compounds in the tubers (Friedman 1997; Kanatt et al., 2005). Blackening of raw potatoes occurs due to the oxidation of phenolic compounds by polyphenol oxidases present in the tuber. Among the phenolic compounds, chlorogenic acid is the most abundant in potato tubers; levels of between 0.4 and 90 mg/100 g FW, and between 0.2 and 2193 mg/100 g DM have been described (Lewis et al., 1998; Akyol et al., 2016; Stewart and Taylor, 2017). Tubers with purple or red coloured flesh have three to four times higher concentrations of phenolic acids than white-fleshed tubers (Lewis et al., 1998).

80. In addition, red and purple potatoes also contain elevated levels of flavonoids, antioxidants belonging to another class of phenolics, particularly due to the presence of anthocyanin glycosides, as compared to tubers with white flesh and skin, which contain flavonols, predominantly glycosides of quercetin and kaempferol (Lewis et al., 1998; Burgos et al., 2020).

81. Carotenoids without provitamin A activity present in potatoes are lutein, zeaxanthin, violaxanthin, neoaxanthin and antheraxanthin (Nesterenko and Sink, 2003; Lachman et al., 2016). Yellowish-orange-fleshed potato cultivars possess higher levels of carotenoids than white-fleshed cultivars; total carotenoids content between 50- 350 µg/100 g and 800-2000 µg/100 g (FW) have been reported in white- and yellow-fleshed potato cultivars, respectively (Brown, 2008).

4. SUGGESTED CONSTITUENTS TO BE ANALYSED IN NEW VARIETIES RELATED TO FOOD USE

4.1. Key products consumed by humans

82. Potato is a staple food typically consumed after cooking. Food products can be boiled, baked, fried or made into flakes or flour.

4.2. Suggested analysis for food use of new varieties

83. Table 11 lists suggested parameters for analysis of new varieties of potato destined for food use. When the breeding is aimed at introducing distinct compositional traits, it may be considered to extend the analysis with parameters not listed in this table (for example, asparagine as discussed in section 1.5).

Table 11. Suggested nutritional and compositional parameters to be analysed in potato for food use

Constituent	Tuber
Moisture	X
Protein [1]	X
Fat [2]	X
Carbohydrates [3]	X
Ash	X
Dietary fibre	X
Starch	X
Vitamin C (ascorbic acid)	X
Vitamin B6 (pyridoxine)	X
Potassium	X
Magnesium	X
Total glycoalkaloids [4]	X

Note: [1] Derived from proximate analysis (e.g. crude protein).
[2] Derived from proximate analysis (e.g. crude fat).
[3] Carbohydrate by calculation or by suitable analytical method.
[4] Specific glycoalkaloids are not listed in the table as some analytical methods yield a total, overall figure for the glycoalkaloid content, which is also commonly measured in some breeding programs and dietary surveys.

5. SUGGESTED CONSTITUENTS TO BE ANALYSED IN NEW VARIETIES RELATED TO FEED USE

5.1. Key products consumed by animals

84. Potato is considered a good feed for farm animals. Typically, potato is fed as culled potatoes, silage, or by-products from potato processing. Levels of incorporation are used to supply energy, with dry matter being an important consideration.

5.2. Suggested analysis for feed use of new varieties

85. Table 12 lists suggested parameters for analysis of new varieties of potato destined for feed use.

Table 12. Suggested nutritional and compositional parameters to be analysed in potato for feed use

Constituent	Tuber
Moisture	X
Protein [1]	X
Fat [2]	X
Carbohydrates [3]	X
Ash	X
Fibre (ADF, NDF)	X
Total glycoalkaloids [4]	X

Note: [1] Derived from proximate analysis (e.g., crude protein).
[2] Derived from proximate analysis (e.g. crude fat).
[3] Carbohydrate by calculation from proximate analysis or by suitable analytical method.
[4] Specific glycoalkaloids are not listed in the table as some analytical methods yield a total, overall figure for the glycoalkaloid content, which is also commonly measured in some breeding programs and dietary surveys.

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