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Series on the Safety of Novel Foods and Feeds, No. 3

CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF SUGAR BEET: KEY FOOD AND FEED NUTRIENTS AND ANTINUTRIENTS

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Series on the Safety of Novel Foods and Feeds

No. 3

Consensus Document on Compositional Considerations for New Varieties of Sugar beet: Key Food and Feed Nutrients and Anti-Nutrients

Environment Directorate

Organisation for Economic Co-operation and Development

Paris 2002

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FOREWORD

The OECD's Task Force for the Safety of Novel Foods and Feeds 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 consensus document addresses compositional considerations for new varieties of sugar beet by identifying the key food and feed nutrients and anti-nutrients. A general description of these components is provided. As well, there is background material on the growing, processing and uses of sugar beet and considerations to be taken when assessing new sugar beet varieties.

Germany served as the lead country in the preparation of this document.

The Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology has recommended that this document be made available to the public. It is published on the authority of the Secretary-General of the OECD.

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Preamble

Food and feed products of modern biotechnology are being commercialised and marketed in OECD Member countries. 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, 1997), 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 Task Force therefore decided to develop consensus documents on 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 current 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, 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.

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). In 2000 the Task Force concluded in its report to the G8 that the concept of substantial equivalence will need to be kept under review.

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. 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 (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 and key toxicants and anti-nutrients for the food source in question. The comparison of critical components should be between the modified variety and non-modified comparators with an appropriate history of safe use. The data for the non-modified comparator can be the natural ranges published in the literature for commercial varieties or those measured levels in parental or other edible varieties of the species (FAO, 1996). The comparator used to detect unintended effects for all critical components 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, be applied to foods derived from new plant varieties that have been bred by other techniques.

Section I - Background

A. Growing of Sugar Beet[1]

1. Sugar beet (*Beta vulgaris* L.ssp. *vulgaris* var. *Altissima Doell*) is cultivated world-wide, but primarily in warm and temperate climates with sufficient precipitation. Today's sugar beets have a sucrose content of approx. 15 - 20 % depending on climate, soil type, variety and cultivation methods.

2. The world-wide growing area for sugar beet is about 8.2 million hectares (OECD, 1993) and the annual production of sugar beets is about 250 million t (FAO statistics, 2000). The leading producing countries in 1999 were France, Germany, USA, Turkey, Poland, Ukraine, Italy and United Kingdom (Langendorf et al., 1999/2000; FAO Statistics, 1999; CEDUS 1999). By 1998/1999, 28.4 % of all sugar produced was from sugar beets (Langendorf et al., 1999/2000; CEDUS, 1999).

B. Processing of Sugar Beet

3. In order to guarantee a continuous beet supply for processing, beets are usually stored in field clamps and/or at the factory yard. Maximum storage and thus the possible processing period depends on climate conditions, from a few weeks (Mediterranean) to up to several months (Scandinavia). Generally, the harvested beet metabolises some of the stored sugar, so that sugar losses are unavoidable and these losses increase with temperature (to up to 300 grams sucrose/tonne of beets/day). Frost damage also results in an increase in components undesirable for sugar processing. In northern regions the clamps are covered to avoid the irreversible effects of frost damage.

4. A typical processing line from beet to sugar including the fate of the by-products is described in Figure 1. For processing, beets are first washed with water to remove dirt and other large debris, then they are sliced into cossettes. The cossettes are extracted with water at temperatures around 70°C for about 100 min. The raw juice obtained is purified by a treatment with milk of lime and carbon dioxide. The material precipitated thereby, the carbonation sludge, is removed by filtration and pressed as carbonation lime. The resulting juice is called "thin juice". The "thin juice" is concentrated by evaporation to thick juice. The evaporation is carried out in multi-stage evaporators working at a temperature range of 98-130°C at different pressures. The resulting "thick juice" is further concentrated to crystal magma from which crystalline sugar is recovered by centrifugation. During the centrifugation process, the crystals are separated from the syrup. The crystals are dried, cooled and stored for further use. The remaining syrup, the so-called molasses is mainly used as animal feed or as fermentation substrate. The recovery of residual sucrose from molasses is applied in some regions, but to a minor extent. The material remaining from the treated cossettes is referred to as wet pulp. This pulp is pressed and dried to remove water and is commonly pelleted with added molasses. Carbonation lime is used as fertiliser (for further information see also Van der Poel et al., 1998; Schiweck et al., 1994).

1 For information on the environmental considerations for safety assessment of sugar beets, see OECD Draft Consensus Document on the Biology of *Beta vulgaris* L. (Sugar Beet).

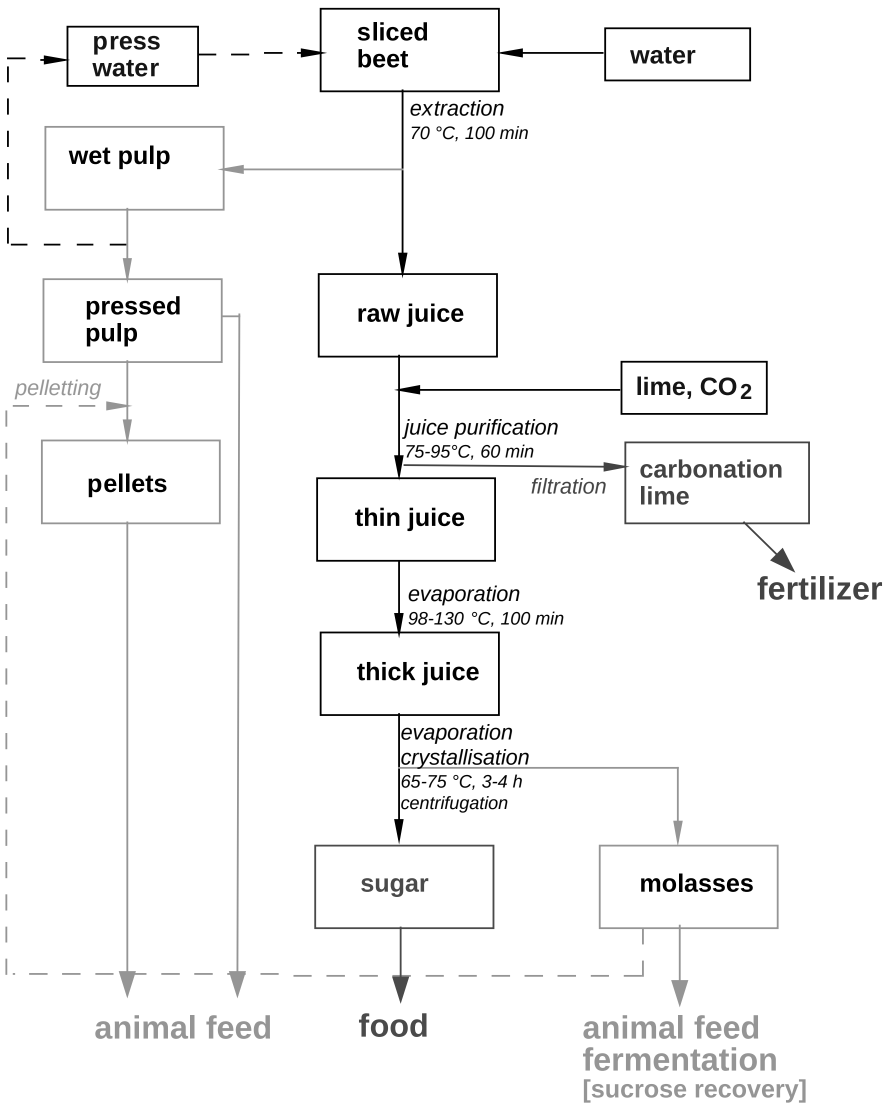

Figure 1: Principle Steps of Sugar Beet Processing and Common Product Uses

C. Uses of Sugar Beet and Derived Products

5. The main purpose[3] of sugar beet processing is sugar (sucrose) recovery (see section B). The world wide production of sugar from sugar beet is close to 40 million t/year, the world sugar consumption is about 120 million t/year and the supply per capita varies between 10 and 50 kg /year (FAO statistics, 1999; Langendorf et al., 1998/99). Sugar is mainly used as food ingredient.

6. The sugar beet crop provides a number of by-products after harvest and processing which are valuable feed stuffs (see Figure 1). Feed products from sugar beet are high in fibre and energy. Therefore, they are primarily used in feeding ruminants (dairy cows, beef cattle, sheep), but also non-ruminants. To

[3] A regional speciality in Central Europe is the use of beet syrup for human consumption. Beets are pressed (not extracted) and the juice obtained is directly thickened to syrup.

meet the animals requirement, feed rations containing sugar beets or their by-products are usually combined with other feed products.

7. Sugar beet tops are usually ploughed under. In rare cases tops are ensiled or directly used in ruminant feeding.

8. Wet pulp is typically pressed (22-30 % dry matter) and dried (85-90 % dry matter). To increase the ease of handling and storage dried pulp is usually (95%) pelleted with added molasses. Pressed or dried pulp is also directly used for feeding purposes. In some regions mixtures of pulp and molasses pulps as such are used for animal feed.

9. Molasses is mainly used in animal feeding (about 60 % of total molasses) as feed ingredient, pelleting aid or ensiling agent. Another major use (15 %) is as raw material in fermentation (yeast, citric acid, alcohol, etc.) (Langendorf et al., 1999/2000). Special applications of molasses, e.g. as source for single substances (e.g., betaine) are of minor economic importance. The recovery of remaining sucrose from molasses through ion exchange or other technologies is at present rarely applied with exception in regions of the USA where the Steffen process is applied (i.e. removal of sucrose from molasses as calcium saccharate precipitate). To a minor extent molasses is used for various industrial purposes such as fuels, rubber, printing, chemical and construction industries.

10. Vinasses results from fermentation of molasses and is used as soil conditioner or animal feed.

11. Another by-product of sugar production is carbonation lime (produced during beet juice purification). Lime is used in agriculture after mechanical conditioning as a fertiliser providing calcium and increasing the pH of the soil and thus improving its structure. It contains a certain amount of plant nutrients such as N and P and can therefore also be used as a fertiliser for agricultural application, as well as an ingredient in potting soils used in mushroom production, and as a binder for briquetting and/or pelleting dry materials.

Section II – Nutrients and Anti-Nutrients in Sugar Beets

A. Sugar Beet Roots

12. The composition of sugar beet roots is mainly rated in view of their technical quality relevance during the sugar recovery process and their agronomic properties.

13. The term "technical quality" is a convention based on compositional parameters by which sugar technologists and breeders assess the relative suitability of sugar beets for processing. It is mainly determined by the sucrose and non-sucrose components such as potassium, sodium and α-amino-N. In different countries the definition of the technical quality may vary as it is based on empirical factors. The respective technical quality is used by breeders as one selection criterion for developing new varieties. Therefore, during the past decades the composition of cultivated beet has largely improved with regard to the technical quality (Märländer & Ladewig, 1997). The technical quality is assessed in field trials prior to market approval.

14. As sugar beet roots are seldom used for food or feed as such, a distinction between nutrients and anti-nutrients in a toxicological sense is not made. Data arise either from animal feeding experiments applying analytical methods established in animal nutrition (Table 1) or from the technical quality determined basically by sucrose, cations and amino nitrogen content (Table 2). The beet composition depends considerably on the growing conditions of the plants such as location, climate and agronomical factors, mainly fertilising, variety and population density (Rother, 1998).

Table 1. Chemical composition of sugar beet roots (23.0 – 24.6 % dry matter)

	Ranges* **(% of dry matter)**
Crude ash	5.0 - 8.1
Crude protein	4.7 - 6.8
Ether extract	0.3 - 0.6
Crude fibre	4.9 - 6.3
Sucrose	64.7 - 70.0

Source: NOVUS, 1996

* reported as means of different feeding tables

Table 2. Major minerals and α-amino-nitrogen in sugar beet roots (23.0 - 24.6 % dry matter)

	Ranges (% of dry matter)
Sodium (Na)	0,4 – 0,8
Potassium (K)	5,6 – 7,2
Phosphorus (P)	1,4 – 2,2
α-amino-N	0,7 – 1,1

Source: Überregionaler Sortenvergleich 1997,1998,1999
Institute for Sugar Beet Research

15. Sucrose is the main constituent of the sugar beet root dry matter.

16. The non-sucrose substances in sugar beet roots include other soluble saccharides, cell wall components, saponins, proteins, free amino acids, betaine, as well as organic and inorganic ions and other nitrogen-free acids. Inorganic anions include phosphates, chlorides, sulfates and nitrates of ubiquitous cations mainly potassium, sodium, calcium, magnesium and ammonium. Anti-nutritional or other adverse effects to human or animal health due to beet components have not been found during their long history of safe use.

B. Sugar

17. White sugar is defined as "purified and crystallised sucrose with a polarisation of not less than 99.5 °Z" (degree sugar) (FAO, 1999). The remainder consists of water, ash, invert sugar (i.e., glucose and fructose) and some colouring organic compounds.

C. Pulp

18. Protein and lipid contents of beet pulp products are usually low. In addition, beet protein consists mainly of non-essential amino acids (Table 3 - 5).

Table 3. Chemical composition of dried sugar beet pulp (84.0 – 91.0 % dry matter)

	Ranges* (% of dry matter)
Crude ash	3.8 - 6.7
Crude protein	6.6 - 9.7
Ether extract	0.5 - 1.6
Crude fibre	15.0 - 21.3
Sucrose	4.7 - 10.0

Source: NOVUS, 1996

* reported as means of different feeding tables

Table 4. Major minerals in dried sugar beet pulp (84.0 – 91.0 % dry matter)

	Ranges* **(% of dry matter)**
Calcium (Ca)	0.6 - 1.1
Phosphate (P)	0.1 - 0.2
Magnesium (Mg)	0.1 - 0.3
Sodium (Na)	0.1 - 0.5
Potassium (K)	0.2 - 1.6

Source: NOVUS, 1996
* reported as means of different feeding tables

Table 5. Amino acids in dried sugar beet pulp (84.0 – 91.0 % dry matter)

	Ranges* **(% of dry matter)**
Lysine	0.33 - 0.6
Methionine	0.01 - 0.15
Methionine + Cystine	0.02 - 0.26
Threonine	0.25 - 0.47
Tryptophan	0.05 - 0.10
Isoleucine	0.23 - 0.36
Leucine	0.36 - 0.60
Valine	0.36 - 0.57
Histidine	0.19 - 0.29
Arginine	0.24 - 0.41
Phenylalanine	0.22 - 0.34

Source: NOVUS, 1996
* reported as means of different feeding tables

D. Molasses

19. The total sugar content in molasses is approximately 50 % (Table 6). Minor carbohydrates are glucose, fructose, raffinose and some other oligo- or polysaccharides. Their concentration is below 1 % and depends to a significant extent on the manufacturing process.

20. Major cations are potassium followed by sodium, calcium and magnesium. Their content depends mainly on soil type and water availability. Additionally, the calcium and sodium content is influenced by processing practices (Table 7).

21. About 20 % of the total mass consists of non-sucrose organic matter, in particular of non-protein nitrogen (NPN) containing substances, such as betaine (Table 9). In addition molasses contains free and bound amino acids (Table 8) and pryrrolidone carboxylic acid (a conversion product of glutamine) (Table 9). In the manufacturing process most of the amino acids undergo changes so that less than the amounts expected from beet roots are found in molasses (Reinefeld et al., 1982a and 1982b; Schiweck et al., 1993).

22. Molasses contains up to 4 % of organic acids predominantly lactic acid from the degradation of invert sugar (up to 1.7 %) followed by malic, citric, fumaric, and oxalic acid.

23. Molasses contains only low levels of trace elements except for iron. The main inorganic anions are chloride, sulfate, nitrate and traces of phosphate and nitrite (Table 10).

Table 6. Chemical composition of sugar beet molasses (73 – 79 % dry matter)

	Ranges* **(% of dry matter)**
Crude ash	6.6 - 10.0
Crude protein	6.6 - 11.1
Ether extract	0.0 - 0.3
Crude fibre	0.0 - 0.3
Sucrose	43.0 - 50.5

Source: NOVUS, 1996

* reported as means of different feeding tables

Table 7. Major minerals in sugar beet molasses (73 – 79 % dry matter)

	Ranges* **(% of dry matter)**
Calcium (Ca)	0.1 - 0.5
Phosphate (P)	0.02 - 0.06
Magnesium (Mg)	0.01 - 0.3
Sodium (Na)	0.6 - 1.9
Potassium (K)	3.2 - 4.7

Source: NOVUS, 1996

* reported as means of different feeding tables

Table 8. Amino acids in sugar beet molasses (73 – 79 % dry matter)

	Ranges* **(% of dry matter)**
Lysine	0.04
Methionine	0.04 - 0.01
Methionine + Cystine	0.1 - 0.11
Threonine	0.1 - 0.11
Tryptophan	0.1 - 0.24
Isoleucine	0.1 - 0.27
Leucine	0.12 - 0.26
Valine	0.17 - 0.20
Histidine	0 - 0.02
Arginine	0.02
Phenylalanine	0.04 - 0.06
Glutamic acid	3 - 4

Source: NOVUS, 1996

* reported as means of different feeding tables

Table 9. Contents of nitrogen-containing organic compounds in beet molasses (73 – 79 % dry matter)

Nitrogen-containing organic Compounds	**Ranges (% of dry matter)**
Total N-containing compounds	11 - 16
Betaine	4 - 5
Amino acids, pyrrolidone carboxylic acid, peptides, nucleic acid components	3 - 4
Amino acid sugar complexes	1 - 2

Source: van der Poel et al., 1998

Table 10. Contents of major anions in beet molasses (73 – 79 % dry matter)

Major anions	**Ranges (% of dry matter)**
Chloride	1.0 – 3.0
Sulfate	0.6 – 2.0
Phosphate	0.1 – 0.5
Nitrate	0.3 – 0.8
Nitrite	3.0 – 170 mg/kg

Source: van der Poel et al., 1998

Section III - Identification of key sugar beet products consumed by animals

24. Several whole and processed fractions of the sugar beet plant may contribute to the animal diet. Sugar beets can contain oxalate up to 55g/kg dry matter, which is present primarily in the leaves (Thacker and Kirkwood, 1990). The sparing soluble calcium oxalate is known to have a reduced availability to animals. This is to be taken into account when rations are formulated.

25. Sugar beet roots as such are seldom used in livestock feeding. However, the tops are fed fresh or as silage, primarily to cattle. Fresh roots are fed to dairy cattle on a limited basis, because sugar feeding involves the risk of acidosis. On the other hand feeding restricted amounts of sugar beets may have a favourable effect on feed consumption and rumen fermentation and on crude fibre digestibility (Kluge, H., 1996; Flachowsky et al., 1988/89).

26. For pigs sugar beet roots are suitable feedstuffs. Due to their high digestibility and energy concentration they have the potential for high growth performance rates when they are incorporated in the diet at a level up to 35 % (Jeroch et al., 1993). Because of the low protein content of sugar beets, sugar beet-based diets for monogastrics would need adequate protein or amino acid supplementation.

27. By-products from sugar beet processing i.e., beet pulp and molasses, are the main sugar beet products fed to animals.

28. Sugar beet pulp is more effectively used in ruminant than in pig feeding due to its high fibre content (up to 25 % in the dry matter). It has the potential to replace high portions of cereals in concentrate mixtures for dairy cattle. Incorporation rates of 30 % in the dry matter of diets for dairy cows and 50 % for growing cattle are possible.

29. Molasses can be used in feeding ruminants, but only to a limited extent. It has to be homogeneously distributed over the total diet. Maximal incorporation rates are reported not to exceed 15 % of dry matter intake. In pig feeding the maximum possible inclusion rate increases with age. For growing pigs the maximum level is reported to be 20 % of the dry matter.

30. The limiting factors of the by-products from sugar processing are the low protein content and the high content of fibre, which are known to have a low efficiency of energy utilisation in monogastrics. Additionally, the high concentration of highly fermentable substances (sugars) might negatively affect rumen fermentation. Effects of specific ingredients (undesired substances and anti-nutrients) on animal health or on meat and milk quality are not known.

31. In assessing the nutrient quality of all sugar beet products which could be fed to animals crude nutrients in roots, pulp, molasses and tops appear to be suitable indicators. The relevant nutrients in sugar beet matrices for animal feed use are shown in Table 11.

Table 11. Relevant nutrients of sugar beet for animal feed use

	Roots	Pulp	Molasses	Tops
Crude nutrients (crude ash, crude protein, ether extract, crude fibre)	X	X	X	X
Sucrose	X	X	X	
Pectins	X	X		

Section IV - Consideration for the assessment of new sugar beet varieties

32. Agronomic characteristics are important to consider since unspecific or unpredicted phenotypic traits or changes in phenotypic traits may be indicative of unintended effects of potential safety concern that would require further investigation. Parameters that are analysed for variety registration include yield, content of sucrose, potassium, sodium and α-amino-N. In addition, field emergence, bolting resistance, and certain disease tolerances of varieties are tested in variety trials.

33. The comparison of the chemical composition of a modified variety and a non-modified comparator should include the key nutrients crude ash, crude protein, crude fibre, sucrose and phosphorus as listed in Tables 1 and 2 for sugar beet roots. If the analyses of these parameters indicate that a novel variety is within the ranges given in the literature, apart from the intentional modifications resulting in recombinant DNA and new proteins, it can be considered equivalent with respect to its overall composition. Knowledge of the sugar recovery process permits the conclusion that sugar, as well as the intermediate products and molasses contain neither DNA nor protein. The safety assessment would focus on the recombinant DNA and newly expressed proteins in pulp in view of animal feed use, i.e. its specific behaviour, if any, in the gastrointestinal tract of the animals.

34. If, apart from the intentionally modified DNA and resulting new proteins, the genetic modification results in a qualitative change rather than a quantitative shift of the beet constituents outside the naturally occurring ranges, the safety assessment would focus on those differences; possibly requiring nutritional and/or toxicological studies.

35. For livestock feed, the comparison of the chemical composition of a modified variety and a non-modified comparator should include the nutrients listed in Table 11 for roots. A more thorough nutritional and toxicological evaluation has to be decided on a case-by-case basis. The required data would be a function of the nature and degree of the difference of the feed ingredient from an accepted source, target animal species, and also the potential dietary exposure.

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