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Series on the Safety of Novel Foods and Feeds, No.17

CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF TOMATO: KEY FOOD AND FEED NUTRIENTS, TOXICANTS AND ALLERGENS

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Series on the Safety of Novel Foods and Feeds

No. 17

Consensus Document on Compositional Considerations for New Varieties of TOMATO: Key Food and Feed Nutrients, Anti-nutrients, Toxicants and Allergens

Environment Directorate

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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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 tomato by identifying the key food and feed nutrients, toxicants and allergens. A general description of these components is provided. As well, there is background material on the production, processing and uses of tomato and considerations to be taken when assessing new tomato varieties. Constituents to be analysed, related to food use and to feed use, are suggested.

Greece served as the lead country in the preparation for this document but the draft has been revised on a number of occasions based on the input from other member countries.

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 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 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.

A short, pre-addressed questionnaire is included at the end of this document. The information requested should be sent to the OECD at one of the addresses shown.

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 (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. 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, 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. 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 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. Production

1. Tomatoes are cultivated in more than 150 countries around the world on approximately 4 million hectares (ha). The total average annual production over the period 1999-2003 was approximately 108 million tonnes, as shown in Table 1. The main producer is China with approximately 23 million tonnes or 21.8% of the total production. USA follows, with approximately 12 million tonnes or 10.6% of the total production. Tomato is considered as one of the most important vegetables produced in commercial agriculture because of income generated from export.

Table 1. Average Annual World Tomato Production (1999-2003)

Rank	**Country**	**Production Area (ha) (mean value)**	**Production (1,000 ton) (mean value)**
1	China	958,585	23,610.36
2	USA	173,030	11,876.86
3	Turkey	226,000	8,944.20
4	India	494,000	7,564.00
5	Italy	129,728	6,792.40
6	Egypt	185,515	6,417.62
7	Spain	62,539	3.858.83
8	Brazil	60,624	3,318.42
9	Iran, Isl. Rep. of	119,670	3,360.99
10	Mexico	73,219	2,163.64
11	Russian Fed.	150,758	1,896.32
12	Greece	41,157	1,849.91
13	Chile	19,413	1,255.53
14	Ukraine	107,832	1,108.50
15	Uzbekistan	28,740	1,028.64
	World	**3,985,737**	**108,365.46**

Source: FAO, 2004

Note: The production values are the sum of tomatoes grown for industrial use and fresh consumption. The countries are listed in order of production quantities.

2. The commercial tomato belongs to the genus *Lycopersicon.* It is a relatively small genus within the large and diverse botanic family *Solanaceae.* The genus is currently thought to consist of the cultivated tomato, *Lycopersicon esculentum*, and seven closely related wild *Lycopersicon* species. It is worth mentioning that some of the wild species contain valuable genes for disease and pest resistance that can be useful for plant breeders in developing new types of cultivated tomatoes when crossed with *L. esculentum*. All cultivated tomato varieties belong to the species *L. esculentum.*

3. The most likely region where the tomato was first domesticated is the Puebla–Veracruz area of Mexico, where the greatest varietal diversity of the cultivated form can be found today (Jenkins, 1948). It is thought to have reached this area as a weedy cherry tomato, var. *cerasiforme*, and upon domestication, to have become the large-fruited *L. esculentum* by selection.

B. Appropriate comparators for testing new varieties

4. This document suggests parameters that tomato breeders should measure. Measurement data from the new variety should ideally be compared to those obtained from the near isogenic non-modified counterpart. Moreover, comparison can be made between values obtained from new varieties and data available in the literature, or chemical analytical data generated from other commercial tomato varieties. Components to be analysed include key nutrients, toxicants and allergens. Key nutrients are those components in a particular product, which may have a substantial impact in the overall diet. These may be major constituents (fats, proteins, and structural and non-structural carbohydrates) or minor compounds (vitamins and minerals). Similarly, the levels of known allergens should be considered. Key toxicants are those toxicologically significant compounds known to be inherently present in the species, *i.e.*, compounds whose toxic potency and levels may impact human and animal health. The key components analysed are used as indicators of whether unintended effects of the genetic modification influencing plant metabolism has occurred or not.

C. Processing

5. Tomato is processed as shown in Figure 1. The most important processing methods are drying (to produce dried tomatoes or a powder) and concentration (to a paste or purée). For each of the processes the tomato should be ripe, red, firm to soft, free of mould growth (by cutting out infected parts) and free of stems, leaves and dirt (by washing) (Gould, 1992). Also common in some places of the world is the use of green tomatoes (normally home-grown) for different recipes e.g. fried green tomatoes, green tomatoes ketchup or chutney or pickles.

6. Traditional methods in hot, dry regions include **sun drying**. The tomato halves are placed on clean flat surfaces (e.g. roofs) with the cut side facing up or thread on to strings that are hanged in the sun from a branch or beam. In both cases, drying is relatively rapid (depending on the temperature and humidity of the air) but it is a risk that the product may be contaminated by insects, dirt and dust. This risk can be reduced by covering the tomatoes with fine muslin cloth or mosquito netting. The end-product is dark, red, leathery pieces with a strong tomato flavour. Re-hydration is relatively slow, but this may be of little importance in cooking applications. Layers of pulp can also be dried to a rubbery consistency and stored in plastic film bags. Alternatively, the post dried pulp can be formed into balls or cubes and then dried in the sun or over a fire. Provided that the humidity is low, the dried product will keep without special packaging for several months. If the humidity rises the product will go mouldy and should be protected either by suitable packaging (e.g. in sealed plastic bags, preferably polypropylene or thick polythene, or in sealed pottery jars covered in oil) or dried slowly over a fire to a low moisture content. The tomatoes should be far enough away from the fire to prevent cooking and contamination with PAH. They will be fully dried when they are hard and brittle. Alternatively, artificial drying may be considered.

7. Tomatoes dried to a low moisture content to become hard (e.g. 5% water) can be pounded or milled to a **powder**. The most convenient way to store tomato powder is in sealed glass or pottery jars or in sealed thin polypropylene film bags.

8. Tomatoes can be **boiled** to evaporate the water. Depending on how much water is removed and what other ingredients are mixed to the pulp, it is possible to obtain a large number of products, the most common of which are shown in Table 2.

9. The basic preservation principle behind all of these products is to remove water by boiling. It results in destruction of enzymes and micro-organisms by heat and concentration of the product so that contaminating microorganisms cannot re-grow.

Table 2. Products from tomato pulp

PRODUCT	Other ingredients
Paste	salt, spice, flavoring, baking soda
Purée	salt
Jam	(pectin) sugar, (acid) vinegar, salt, spices
Chutney	
Ketchup	sugar, vinegar, salt, onions, starches and spices
Soup	flour, salt, sugar

Note: The solids content is usually measured by refractometer as °Brix

10. There are tomato products for which quality and specification standards are under development by the Codex Committee on Processed Fruits and Vegetables (CCPFV), while for other products no such specifications have been implemented. The main quality parameters of tomato purée and paste are colour, consistency and flavour. However, there are no standardized methods and instruments for defining quality. While colour can be measured objectively, there are currently no standard colour requirements for tomato concentrates. The volatiles responsible for flavour and odour have been identified to the point where the natural odour of tomato paste can be imitated (Hayes *et al.*, 1998).

11. Processed fruits and vegetables have been long considered to have lower nutritional value than their fresh commodities due to the loss of vitamin C during processing. Studies that have been conducted in order to investigate the effect of thermal processing of ripe raw tomatoes on the quality of the final products in relation to nutrient content and antioxidant activities showed that thermal processing of tomato juice, baked tomatoes, tomato sauce and tomato soup reduced the vitamin C content but increased the amount of total phenolics and the water soluble antioxidant capacity of the tomato products (Gahler *et al*., 2003; Abushita *et al.,*, 2000). Ascorbic acid, alpha-tocopherol quinone and beta-carotene were the most susceptible components to thermal degradation.

12. Studies on the influence of processing on content of various other antioxidants (phenolics, flavonoids and carotenoids) and total antioxidant activity (TAA) of tomato sauce show that processing mainly reduce naringenin (a flavonoid) content, and increase the content of chlorogenic acid and all-*trans*-lycopene (Dewanto *et al*., 2002; Re *et al.*, 2002). The effects of processing on the overall antioxidant activity support the theory of a general increase in bioavailability of individual antioxidants. Thus the TAA, of both hydrophilic and lipophilic extracts of processed tomatoes were increased.

13. Processing seems to increase nutrient bioavailability, which could be due to the fact that the nutrients are detached or extracted from their structures. This is particularly true for lycopene (Rao *et al.*, 1998; Shi *et al.*, 2000). Moreover, lycopene in raw tomatoes is present mainly as all-*trans*-lycopene. Heat processing of tomato juice enhances its isomerisation to the *cis* isomer, contributing to an increased bioavailability (Stahl and Sies, 1992; Shi *et al*., 2000).

D. Uses

14. Tomato is consumed fresh, in salads, as well as processed. It should be noted that high quality “salad” tomatoes have the highest value when sold fresh and in good condition. These would not normally be used for processing, unless for home use to save excess at the height of the season. Although tomatoes are commonly consumed fresh, over 80% of the tomato consumption comes from processed products such as tomato juice, paste, puree, ketchup and sauce (Gould, 1992).

15. **Tomato juice** is the unconcentrated liquid extracted from mature tomatoes of red or reddish varieties, with or without scalding followed by straining. In tomato juice extraction, heat may be applied without adding water. Tomato juice is strained free from skins, seeds and other coarse or hard substances, but carries finely divided insoluble solids from the flesh of the tomato. The juice may be homogenized, and may be seasoned with salt. When sealed in a container it is processed by heat, before or after sealing to prevent spoilage (Gould, 1974; Gould, 1992).

16. **Tomato purée, tomato pulp** is the product prepared by combining at least two of the following optional ingredients:

- The liquid obtained from mature tomatoes of red or reddish varieties;
- The liquid obtained from the residue from preparing such tomatoes for canning; consisting of peelings and cores with or without such tomatoes or pieces thereof;
- The liquid obtained from the residue from partial extraction of juice from such tomatoes;
- Salt.

17. **Tomato paste** is the product prepared by combining at least two of the following optional ingredients:

- The liquid obtained from mature tomatoes of red or reddish varieties;
- The liquid obtained from the residue from preparing such tomatoes for canning, consisting of peelings and cores with or without such tomatoes or pieces thereof;
- The liquid obtained from the residue from partial extraction of juice from such tomatoes;
- Salt (sodium chloride formed during acid neutralizations should be considered added salt);
- Spices;
- Flavouring;
- Baking soda.

18. **Tomato Ketchup** is the product prepared by combining at least two of the following optional ingredients:

- The liquid obtained from mature tomatoes of red or reddish varieties;
- The liquid obtained from the residue from preparing such tomatoes for canning, consisting of peelings and cores with or without such tomatoes or pieces thereof;
- The liquid obtained from the residue from partial extraction of juice from such tomatoes.

The constituents used in the manufacture of ketchup, in addition to tomatoes, are sugar, vinegar, salt, onions, starches and spices.

19. **Chili sauce** is of the same general character as ketchup but is made from peeled and cored tomatoes without removing the seeds. It contains more sugar and onions and sometimes is made hotter in flavour than ketchup by the use of more cayenne pepper.

20. **Tomato soup** is produced mostly from fresh tomatoes but may also be produced from tomato paste.

21. **Tomato squash** is tomato pulp with added sugar syrup to give a concentration of 30-50% total solids (Brix) measured by refractometer. It is not a widespread product as people tend to prefer squashes from other fruits. It is processed in a similar way to juice and may, in addition, contain up to 100 ppm of sodium (or potassium) benzoate preservative in most countries (Gould, 1992).

Figure 1. Processing of tomatoes (Gould, 1992)

Receiving
Dry sort
Soak
Wash
Trim

WHOLE TOMATOES	CHILI SAUCE	JUICE	PULP	PASTE	KETCHUP	SOUP
Peel	Peel	Chop	Chop	Chop	Chop	Chop
Steam or Chemical	Steam or Chemical					
Trim & Core	Trim & Core	Hot break	Hot break	Hot break	Hot Break	Hot Break
Sort for Grade	Chop	Extract	Pulp	Pulp	Pulp	Pulp
Fill	Preheat	Sterilize	Concentrate	Concentrate	Concentrate	Concentrate
Juice	Evaporate	Fill	Finish	Fill	Add ingredients (sugar, salt, acid, spices and flavor)	Finish
Add flavour ingredients (salt, sugar, and acid)	Add ingredients (sugar, salt, acid, onions and spice)	Salt	Fill	Close and Code	Cook	Other ingredients
Exhaust or Steam flow	Reheat	Close and Seal	Close and Code	Cool - Water	Finish	Cook
Close and Code	Fill	Hold	Process		Deaerate	Finish
Process	Close and Seal	Water Cool	Cool (Water or Air)		Fill	Fill
Cool (Water or Air)	Hold				Seal and Code	Close
	Water Cool				Hold	Process
					Water Cool	Cool

E. Screening characteristics screened by developers

22. Domesticated varieties (cultivars) have been developed by selection during the last 10,000 years and inevitably represent a subset of the variation found in their wild ancestors. Unusual or extreme phenotypes, such as large fruit or seed size, intense colour, sweet flavour, or pleasing aroma are often selected by humans and maintained in varieties for aesthetic reasons, while synchronous ripening or inhibition of seed shattering (a dispersal mechanism) are selected to facilitate harvest. In the evaluation of tomato varieties, morphological (i.e. stand count, seedling vigour, pesticide resistance and disease resistance), agronomic (i.e. yield, fruit size, fruit uniformity, fruit colour and firmness), and chemical (composition) as well as biochemical parameters (i.e. aroma, flavour) are widely used (FAO- IPGRI, 2005).

23. At present, great efforts of genetic improvement of tomatoes have focused on the resistance against diseases caused by fungi, bacteria and viruses as well as on the tolerance to stress and pesticide exposure. In some cases, tomato plants are bred for development of varieties having nutritional or health benefits. Research focuses on altering the level of vitamins in order to create a food with enhanced health benefits. Transformation of tomatoes, using molecular techniques, has resulted in transgenic plants with elevated levels of provitamin A, and vitamin C and E, respectively (Herbers, 2003).

SECTION II – NUTRIENTS

24. The average composition of fresh red tomato is shown in Tables 3-8, while the average compositions of yellow and orange-coloured ripe tomato fruit varieties and green tomato fruits of non-ripe red-coloured tomato fruit varieties are shown in Tables 10-13.

A. Ripe red tomato fruits

1. Proximate composition

25. The amount of total solids varies with genetic constitution (tomato variety) and environmental factors such as site of cultivation, soil condition, climate, not least precipitation during the period of fruit development and harvesting. Tomato usually consists of 5.5-6.2% total solids (Table 3). However, it have also been reported to be as high as 7.0-8.5% (Gould, 1992).

Table 3. Proximate composition of red ripe tomato

NUTRIENT	Danish database, 2005	USDA database, 2007	Favier J.Cl. *et coll.*, 1995	Souci *et al.*, 1994	National Public Health Institute (Finland), 2004	Range of mean values
	Mean value, g per 100g fresh weight[1]					
Water	94.00	94.50	93.80	94.20	94.00[2]	93.80 – 94.50
	Mean value, g per 100 g dry weight					
Protein	11.67	16.00	12.90	16.38	10.00	11.67 - 16.38
Fat		3.64		3.62	5.00	3.62 - 3.64
Ash	8.33	9.09				8.33 - 9.09
Carbohydrate, by difference	76.67	71.27		44.83	75.00	44.83 - 76.67
Fiber, total dietary	31.67	21.82	19.35	16.38	23.33	16.38 - 31.67
Sugars, total	38.67	47.82	56.45	47.84	55.00	38.67 - 56.45
Sucrose				1.45	1.67	1.45 – 1.67
Glucose (dextrose)	15.00	22.73		18.64		15.00 - 22.73
Fructose	23.67	24.91		23.28	33.33	23.28 - 24.91
Starch	1.50			1.38		1.38 - 1.50
Pentosan				1.21		1.21
Hexozan				1.90		1.90

[1] Values calculated based on the % water of fresh weight
[2] Varo P., *et al.*,1980

26. Most of the dry matter in tomatoes is carbohydrates (Table 3). On a fresh weight basis, the carbohydrate content of tomatoes varies between 2.2 and 3.6%. A substantial fraction is dietary fibre. The major sugars in mature tomato fruit are the hexoses, fructose and glucose, the latter two being derived mainly from the hydrolysis of translocated sucrose (Davies and Hobson, 1981). Of simple sugars, the sucrose level is negligible as it rarely exceeds 0.1% of the fresh weight. The polysaccharide fraction consists of pectins and arabinogalactanes (50%), xylanes and arabinoxylanes (28%), and cellulose (approximately 25%). Reducing carbohydrates comprise approximately 50-65% of the total solids of tomato and consist mainly of glucose and fructose, with fructose usually occurring at higher levels than glucose (Table 3, Gould, 1992).

27. Pectins are polymers of D-galacturonic acid linked together via 1,4–bonds. They are natural constituents of the mature tomato and are responsible for the development of the fleshy red tissue strongly binding the cells together. During the early development of the fruit, an insoluble substance called protopectin is formed and this compound binds firmly to the fruit cells. During maturation of the fruit protopectin is converted to pectin, which also contributes to stabilizing the interaction between cells, but to a lesser extent than protopectin. During the last stages of fruit maturation, when the fruit goes from pink to being red, protopectine is converted to pectin. Further maturation allows pectin to be degraded to smaller soluble fragments which show limited binding capacity, leading to soft mature fruits. The modification of pectin occurring during maturation is due to the action of enzymes formed in fruit cells during growth and development. Although these enzymes are formed exclusively during fruit development, their action is continued after harvest. Therefore, these enzymes have an important role in regulating the texture of both fresh and processed tomato products. The total content of pectin in fresh fruit of commercial tomato varieties lies between 0.17% and 0.23% (Goose and Raymond, 1964; Gould, 1974; Gould, 1992).

28. Citric acid is the predominant organic acid in tomato (Table 8). Malic acid is the second most important organic acid in the juice of fresh tomato. Processing of tomato juice leads to an increase in the levels of organic acids. Acetic acid level increases by 32% during processing (Gould, 1992), apparently due to the oxidation of aldehydes and alcohols as well as deamination of amino acids. Citric and malic acid levels also increase after processing.

2. Minerals

29. The total ash content of red mature tomatoes is a little less than 10% of the dry matter. Tomatoes and tomato products are important sources of potassium, and they also contribute substantially to the magnesium and iron intake (Table 4). It is worth mentioning that the relatively high ascorbic acid level in tomatoes maintains iron in its reduced form, increasing its potential for being taken up by the body (Gould, 1992).

3. Fatty acids and phytosterols

30. Tomatoes have very low fat content (Table 3). The most important saturated, mono-unsaturated and polyunsaturated fatty acids are reported in Table 5. However, the level of phytosterols is high (approximately 7 mg/100 g of product).

4. Proteins and amino acids

31. Proteins constitute around 11-17% of the dry matter in tomato fruits (Table 3). Glutamic acid is the most common amino acid, comprising 48.5% of the total weight of amino acids (Table 6). Aspartic acid is the second most abundant amino acid. Proline occurs at the lowest quantity. High temperature processing of tomatoes (e.g. 104.4^{o}C for 20 min) increases the level of free amino acids, due to degradation and partial hydrolysis of certain proteins. The greatest increase occurs in the levels of glutamic acid, aspartic acid, alanine and threonine (Goose and Raymond, 1964; Gould, 1992).

Table 4. Mineral composition of red ripe tomato

MINERALS	**Danish database, 2005**	**USDA database, 2007**	**Favier *et al.*, 1995**	**Souci *et al.*, 1994**	**National Public Health Institute, (Finland), 2004**	**Range of mean values**
	Mean value, per 100g of dry matter [1]					
Calcium, Ca (mg)	166.67	181.82	145.16	162.07	150.00	145.16 - 181.82
Iron, Fe (mg)	8.33	4.91	6.45	5.69	5.00	4.91 - 8.33
Magnesium, Mg (mg)	116.67	200.00	177.42	206.90	183.33	116.67 - 206.90
Nitrate (mg)				86.21		86.21
Boron (mcg)				1982.76		1982.76
Nickel (mcg)	16.67			100.00		16.67 - 100.00
Phosphorus, P (mg)	500.00	436.36	387.10	379.31	500.00	379.31 - 500.00
Potassium, K (mg)	3600.00	4309.09	3645.16	4172.41	4833.33	3600.00 – 4833.33
Sodium, Na (mg)	116.67	90.91	80.65	56.90	41.67	56.90 - 116.67
Zinc, Zn (mg)	1.50	3.09		2.59	3.33	1.50 - 3.09
Cobalt (mcg)				29.31		29.31
Copper, Cu (mg)	0.67	1.07		1.00		0.67 - 1.07
Manganese, Mn (mg)	1.83	2.07		1.88		1.83 - 2.07
Chromium (mcg)	6.67			327.59		6.67 - 327.59
Iodin (mcg)	3.33			18.97	16.67	3.33 - 18.97
Fluoride (mcg)				413.79		413.79
Chloride (mg)				517.24		517.24
Aluminium (mcg)				1241.38		1241.38
Silicon (mg)				46.55		46.55
Selenium, Se (mcg)	5.00			16.90	3.33	3.33 - 16.90

[1] Values calculated based on the % water given in Table 3

Table 5. Fatty acid composition of red ripe tomato

FATTY ACIDS	Danish database, 2005	USDA database, 2007	Favier *et al.*, 1995	Souci *et al.*, 1994	National Public Health Institute, (Finland), 2004	Range of mean values
	Mean value, per 100g dry matter [1]					
Fatty acids, total saturated (g)	0.97	0.51			1.67	0.51 - 0.97
Palmitic - 16:0 (g)	0.75	0.36		0.55		0.36 - 0.75
Stearic - 18:0 (g)	0.13	0.15		0.09		0.13 - 0.15
Fatty acids, total monounsaturated (g)	0.58	0.56			1.67	0.56 - 0.58
Palmitoleic - 16:1 undifferentiated (g)	0.05	0.02		.03		0.02 - 0.05
Oleic - 18:1 undifferentiated (g)	0.53	0.55		0.40		0.40 - 0.55
Fatty acids, total polyunsaturated (g)	2.50	1.51	2.26		1.67	1.51 - 2.50
Linoleic - 18:2 undifferentiated (g)	2.17	1.45		1.57	1.38	1.45 - 2.17
Linolenic - 18:3 undifferentiated (g)	0.22	0.05		0.16	0.12	0.05 - 0.22

[1] Values calculated based on the % water of fresh weight given in Table 3

Table 6. Amino acid composition of red ripe tomato

AMINO ACIDS	Danish database, 2005	USDA database, 2007	Souci *et al.*, 1994	Range of mean values
	Mean value, per 100g dry matter[1]			
Tryptophan (g)	0.12	0.11	0.10	0.10 - 0.12
Threonine (g)	0.32	0.38	0.40	0.32 - 0.40
Isoleucine (g)	0.53	0.36	0.40	0.36 - 0.53
Leucine (g)	0.47	0.56	0.52	0.47 - 0.56
Lysine (g)	0.53	0.56	0.50	0.50 - 0.56
Methionine (g)	0.13	0.13	0.12	0.12 - 0.13
Cystine (g)	0.10	0.20	0.02	0.02 - 0.20
Phenylalanine (g)	0.32	0.40	0.41	0.32 - 0.41
Tyrosine (g)	0.43	0.27	0.21	0.21 - 0.43
Valine (g)	0.33	0.40	0.40	0.33 - 0.40
Arginine (g)	0.43	0.38	0.31	0.31 - 0.43
Histidine (g)	0.18	0.24	0.22	0.18 - 0.24
Alanine (g)	0.30	0.44	0.45	0.30 - 0.45
Aspartic acid (g)	1.33	2.15	2.09	1.33 - 2.15
Glutamic acid (g)	3.17	5.69	5.69	3.17 - 5.69
Glycine (g)	0.33	0.38	0.31	0.31 - 0.38
Proline (g)	0.37	0.29	0.28	0.28 - 0.37
Serine (g)	0.42	0.42	0.48	0.42 - 0.48

[1] Values calculated based on the % water of fresh weight given in Table 3

Table 7. Vitamin and anti-oxidant composition of red ripe tomato

VITAMINS	Danish database, 2005	USDA database, 2007	Favier *et al.*, 1995	Souci *et al.*, 1994	National Public Health Institute, (Finland), 2004	Range of mean values
	Mean value, per 100g dry matter [1]					
Vitamin C, total ascorbic acid (mg)	250.00	230.91	290.32	327.59	235.00	230.91 - 327.59
Thiamin (Vitamin B1) (mg)	0.72	0.67	0.97	0.98	1.00	0.67 - 0.98
Riboflavin (mg)	0.33	0.35	0.81	0.60	0.67	0.33 - 0.81
Niacin (mg)	11.67	10.80	9.68		13.33	9.68 - 11.67
Pantothenic acid (mg)	5.50	1.62	4.52	5.34		1.62 - 5.50
Vitamin B-6 (mg)	1.48	1.45	1.29	1.72		1.29 - 1.72
Folate, total (mcg)		272.73				
Folic acid (mcg)		0.00		379.31		379.31
Folate, food (mcg)	516.67	272.73	322.58		193.33	193.33 - 516.67
Folate, DFE (mcg DFE)		272.73				272.73
Vitamin A, IU		15145.45				15145.45
Vitamin A, RAE (mcg RAE)	1383.33	763.64			1113.33	763.64 - 1383.33
Retinol (mcg)				1672.41		1672.41
Carotene, beta (mcg)	16533.33	8163.64	9677.42	10206.90		8163.64 - 16533.33
Carotene, alpha (mcg)		1836.36				1836.36
Lycopene (mcg)		46781.82				46781.82
Vitamin E (alpha-tocopherol) (mg)	18.33	9.82	16.13	14.02	11.67	9.82 - 18.33
Tocopherol, alfa (mg)				13.79		13.79
Tocopherol, beta (mg)		0.18				0.18
Tocopherol, gamma (mg)		2.18		2.24		2.18 - 2.24
Vitamin K (phylloquinone) (mcg)	283.33	143.64		98.28	83.33	83.33 - 283.33
Biotin(mcg)	25.00			68.97		25.00 - 68.97
Nicotinamide (mg)				9.14		9.14

[1] Values calculated based on the % water given in Table 3

Table 8. Other Metabolite composition of red ripe tomato

OTHER METABOLITES	Danish database, 2005	USDA database, 2007	Favier *et al.*, 1995	Souci *et al.*, 1994	Range of mean values
	Mean value, per 100 g dry matter[1]				
Malic Acid (g)				0.88	0.88
Citric Acid (g)				5.66	5.66
Lactic Acid (g)				0.10	0.10
Acetic Acid (g)				0.14	0.14
Chlorogenic Acid (g)				0.17	0.17
Quinic Acid (g)				0.14	0.14
Ferulic Acid (mg)				12.07	12.07
Fumaric Acid (g)				0.03	0.03
Pyruvic Acid (mg)				3.28	3.28
Oxaloacetic Acid (g)				0.41	0.41
Salicylic Acid (mg)				2.24	2.24
Histamine (mg)				34.48	34.48
Carotene, beta (mcg)	16533.33	8163.64	9677.42	10206.90	8163.64 - 16533.33
Carotene, alpha (mcg)		1836.36			1836.36
Lycopene (mcg)		46781.82			46781.82
Lutein + zeaxanthin (mcg)		2236.36			2236.36
Cellulose (g)				6.21	6.21
Polyuronic Acid (g)				3.97	3.97
Myoinositol (mg)				189.66	189.66

[1] Values calculated based on the % water of fresh weight given in Table 3

5. Vitamins and other anti-oxidants

32. Fresh tomato, tomato juice and other tomato products make a significant contribution to human nutrition due to the concentration and availability of several nutrients in these products and to their wide spread consumption. Differences in the amount of nutrients contained in different varieties have been confirmed. In the research of Sahlin *et al.* (2004) it was shown that between Aranca and Excell (two varieties of tomato), Aranca was found to contain higher levels of ascorbic acid, total phenolics and lycopene, as well as showed higher antioxidant activity overall.

33. Levels of vitamins and other antioxidants vary between tomato varieties (Sahlin et al., 2004) and are for the red ripe tomato summarised in Table 7. Vitamin C, ascorbic acid, is a vitamin necessary for normal metabolism, wound healing and collagen synthesis. Ascorbic acid levels lie between 12.7 and 19.0 mg per 100g of fresh weight in red ripe tomatoes (Table 7). Tomatoes also contain vitamin E, and low amounts of the water-soluble type B vitamins thiamin, niacin and riboflavin (Beecher, 1998).

34. Lycopene is the most prominent carotenoid in ripe red tomatoes (Table 7), where it commonly constitutes around 90-99% of the total carotenoids (Dumas et al., 2003). Other carotenoids in ripe red tomatoes are beta–carotene, gamma–carotene and phytoene as well as several other carotenoids occurring at low levels.

35. Lycopene is a product extracted from tomato, commonly by the use of solvents. A more environmentally-friendly process is the use of supercritical fluid extraction which minimizes the risk of lycopene degradation via isomerisation and oxidation (Gomez-Prieto *et al.*, 2003). The lycopene content in various tomato products is shown in Table 9. Also polyphenols contribute to the antioxidant activity of the tomato fruits (Takeoka *et al.*, 2001). The levels of several polyphenols are reported in Table 8.

Table 9. Lycopene contents of commonly consumed commercial tomato products

Group	Product	Lycopene (mg/kg)
I. Products for food preparation	Tomato paste	365.0
	Tomato puree	195.6
	Crushed tomatoes	223.8
II. Sauces	Tomato sauce	130.6
	Spaghetti sauce	191.2
	Pizza sauce	121.7
	Seafood sauce	185.6
	Chili sauce	168.3
III. Condiments	Tomato ketchup	123.9
	Light ketchup	141.0
	Barbecue sauce	42.9
IV. Readily consumed	Tomato juice	101.6
	Condensed soup	72.7
	Ready to serve soup	44.1
	Clam cocktail	43.3
	Bloody Mary mix	42.3

Source: Rao *et al.*, 1998

B. Yellow and orange-coloured ripe tomato fruit varieties and green tomato fruits of non-ripe red-coloured tomato fruit varieties

36. The proximate content of yellow, and orange-coloured ripe tomato fruit varieties and the proximate content of green tomato fruits of non-ripe red-coloured tomato fruit varieties are shown in Table 10.

C. Tomato products

37. The proximate content of sun-dried red tomatoes is shown in Table 10.

38. The fatty acid, amino acid, mineral, vitamin and other antioxidants composition of sun-dried red tomatoes is shown in Tables 11-13. The composition of other tomato products - tomato juice, tomato puree, ketchup, chilli sauce and tomato paste - is shown in table 14.

39. Tomato pomace is the residue that remains after pressing tomato in the production of ketchup, juice, paste, puree, soup or sauce (NRC, 1983). It is made up of skin, pulp crushed seed that remain after pressing and some adhering pulp (Ensminger *et al.*, 1990; NRC, 1983). It contains a high amount of water and is usually dried prior to being used in feed. The proximate composition of tomato pomace is shown in table 15, and its amino acid and mineral contents in Tables 16 and 17, respectively.

Table 10. Proximate composition of yellow, green, orange and sun-dried tomatoes

NUTRIENT	Tomatoes, yellow, raw	Tomatoes, orange, raw	Tomatoes, green, raw	Tomatoes, sun-dried
	Mean value, g per 100g fresh weight			
Water	95.28	94.78	93.00	14.56
	Mean value, per 100g dry matter[1]			
Energy (kcal)	317.80	306.51	328.57	301.97
Energy (kj)	1334.75	1283.52	1357.14	1265.22
Protein (g)	20.76	22.22	17.14	16.51
Total lipid (fat) (g)	5.51	3.64	2.86	3.48
Ash (g)	10.59	13.22	7.14	14.75
Carbohydrate, by difference (g)	63.14	60.92	72.86	65.26
Fiber, total dietary (g)	14.83	17.24	15.71	14.40
Sugars, total (g)			57.14	44.00

Source: USDA, 2007
[1] Values calculated based on the % water of fresh weight

Table 11. Fatty acid and phytosterol composition of yellow, orange, green, and sun-dried tomatoes

	Tomatoes, yellow, raw	Tomatoes, orange, raw	Tomatoes, green, raw	Tomatoes, sun-dried
FATTY ACIDS	**Mean value, per 100g dry matter[1]**			
Fatty acids, total saturated (g)	0.76	0.48	0.40	0.50
16:0 (g)	0.57	0.36	0.29	0.38
18:0 (g)	0.21	0.13	0.10	0.11
Fatty acids, total monounsaturated (g)		0.54	0.43	0.57
16:1 undifferentiated (g)		0.02	0.01	0.01
18:1 undifferentiated (g)	0.85	0.54	0.41	0.56
20:1 (g)	0.04			
22:1 undifferentiated (g)	0.83			
Fatty acids, total polyunsaturated (g)	2.29	1.46	1.16	1.31
18:2 undifferentiated (g)	2.20	1.40	1.11	1.29
18:3 undifferentiated (g)	0.08	0.06	0.04	0.01
Phytosterols (mg)	127.12	76.63		

Source: USDA, 2007
[1] Values calculated based on the % water of fresh weight given in Table 10

Table 12. Amino acid composition of yellow, orange, green, and sun-dried tomatoes

	Tomatoes, yellow, raw	Tomatoes, orange, raw	Tomatoes, green, raw	Tomatoes, sun-dried
AMINO ACIDS	**Mean value, per 100g dry matter[1]**			
Tryptophan (g)	0.15	0.15	0.13	0.12
Threonine (g)	0.51	0.56	0.43	0.42
Isoleucine (g)	0.49	0.52	0.41	0.40
Leucine (g)	0.76	0.80	0.63	0.61
Lysine (g)	0.76	0.80	0.63	0.61
Methionine (g)	0.17	0.19	0.14	0.14
Cystine (g)	0.28	0.29	0.23	0.21
Phenylalanine (g)	0.53	0.57	0.44	0.43
Tyrosine (g)	0.36	0.38	0.30	0.28
Valine (g)	0.53	0.57	0.44	0.42
Arginine (g)	0.51	0.56	0.41	0.40
Histidine (g)	0.32	0.34	0.26	0.25
Alanine (g)	0.59	0.63	0.49	0.47
Aspartic acid (g)	2.86	3.08	2.37	2.29
Glutamic acid (g)	7.61	8.18	6.31	6.09
Glycine (g)	0.51	0.56	0.43	0.41
Proline (g)	0.38	0.42	0.33	0.31
Serine (g)	0.55	0.59	0.46	0.44

Source: USDA, 2007

[1] Values calculated based on the % water of fresh weight given in Table 10

Table 13. Mineral, vitamin and carotenoid composition of yellow, orange, green, and sun-dried tomatoes

	Tomatoes, yellow, raw	Tomatoes, orange, raw	Tomatoes, green, raw	Tomatoes, sun-dried
MINERALS	**Mean value, per 100g dry matter[1]**			
Calcium, Ca (mg)	233.05	95.79	185.71	128.75
Iron, Fe (mg)	10.38	9.00	7.29	10.64
Magnesium, Mg (mg)	254.24	153.26	142.86	227.06
Phosphorus, P (mg)	762.71	555.56	400.00	416.67
Potassium, K (mg)	5466.10	4061.30	2914.29	4011.00
Sodium, Na (mg)	487.29	804.60	185.71	2452.01
Zinc, Zn (mg)	5.93	2.68	1.00	2.33
Copper, Cu (mg)	2.14	1.19	1.29	1.67
Manganese, Mn (mg)	2.54	1.69	1.43	2.16
Selenium, Se (mcg)	8.47	7.66	5.71	6.44
VITAMINS	**Mean value, per 100g dry matter[1]**			
Vitamin C, total ascorbic acid (mg)	190.68	306.51	334.29	45.88
Thiamin (mg)	0.87	0.88	0.86	0.62
Riboflavin (mg)	1.00	0.65	0.57	0.57
Niacin (mg)	24.98	11.36	7.14	10.59
Pantothenic acid (mg)	2.33	3.56	7.14	2.44
Vitamin B-6 (mg)	1.19	1.15	1.16	0.39
Folate, total (mcg)	635.59	555.56	128.57	79.59
Folate, food (mcg)	635.59	555.56	128.57	79.59
Folate, DFE (mcg DFE)	635.59	555.56	128.57	79.59
Vitamin A, IU		28659.00	9171.43	1022.94
Vitamin A, RAE (mcg RAE)		1436.78	457.14	51.50
Carotene, beta (mcg)			4942.86	613.30
Carotene, alpha (mcg)			1114.29	
Lycopene (mcg)				47720.04
Lutein + zeaxanthin (mcg)				1413.86
Vitamin E (alpha-tocopherol) (mg)			5.43	0.01
Vitamin K (phylloquinone) (mcg)			144.29	50.33

Source: USDA, 2007

[1] Values calculated based on the % water of fresh weight given in Table 10

Table 14. Composition of tomato products, per 100 g

	Canned Tomato	Tomato juice: Regular	Tomato juice: Concentrated	Tomato juice: Dehydrated	Tomato juice: Cocktail	Tomato puree (pulp)	Ketchup	Chili sauce	Tomato paste
Water %	93.7	93.6	75.0	1.0	93.0	87.0	68.6	68.0	75.0
Food energy (calories)	21.0	19.0	76.0	303.0	21.0	39.0	106.0	104.0	82.0
Protein, g	1.0	0.9	3.4	11.6	0.7	1.7	2.0	2.5	3.4
Fat, g	0.2	0.1	0.4	2.2	0.1	0.2	0.4	0.3	0.4
Carbohydrates									
Total, g	4.3	4.3	17.1	68.2	5.0	8.9	25.4	24.8	18.6
Fiber, g	0.4	0.2	0.9	3.1	0.2	0.4	0.5	0.7	0.9
Ash, g	0.8	1.1	4.1	17.0	1.2	2.2	3.6	4.4	2.6
Calcium, mg	6.0	7.0	27.0	85.0	10.0	13.0	22.0	20.0	27.0
Phosphorus, mg	19.0	18.0	70.0	279.0	18.0	34.0	50.0	52.0	70.0
Iron, mg	0.5	0.9	3.5	7.8	0.9	1.7	0.8	0.8	3.5
Sodium, mg	130.0	200.0	790.0	3934.0	200.0	399.0	1042.0	1338.0	38.0
Potassium, mg	217.0	227.0	888.0	3518.0	221.0	426.0	363.0	370.0	888.0
Vitamin A (IU)	900.0	800.0	3300.0	13100.0	800.0	1600.0	1400.0	1400.0	3300.0
Thiamin, mg	0.05	0.05	0.20	0.52	0.05	0.09	0.09	0.09	0.20
Riboflavin, mg	0.03	0.03	0.12	0.40	0.02	0.05	0.07	0.07	0.12
Niacin, mg	0.7	0.8	3.1	13.5	0.06	1.4	1.6	1.6	3.1
Ascorbic acid, mg	17.0	16.0	49.0	239.0	16.0	33.0	15.0	16.0	49.0

Source: Gould, 1992

Table 15. Proximate composition of tomato pomace

PROXIMATES	NRC, 1982	Ensminger, 1990	NRC, 2001	Preston, 2007	Range
	Grams per 100g fresh weight[1]				
Dry Matter (g)	92.0[é]	25.0[1]– 92.0[2]	24.7[1]	92.0[2]	24.7[1] – 92.0[2]
	Grams per 100g dry matter				
Protein (g)	23.5	21.5 – 22.9	19.3	23.0	19.3 – 23.5
Ether Extract (fat) (g)	10.3		13.3	10.6	10.3 - 13.3
Ash (g)	7.5		5.5	6.5	5.5 - 7.5
NDF			60.0	54.4	54.4 - 60.0
ADF			47.6	59.8	47.6 - 59.8
Crude Fiber	26.4	27.2 – 33.7		26.0	26.0 – 33.7

[1] Tomato pomace, dehydrated
[2] Tomato pomace, wet

Table 16. Amino acid composition of tomato pomace

AMINO ACIDS	NRC, 2001
	per 100g dry matter[1]
Argenine	1.07
Histidine	0.35
Isoleucine	0.62
Leucine	1.52
Lysine	1.43
Methionine	0.09
Cystine	0.09
Phenylalanine	0.80
Threonine	0.62
Valine	0.18
Tryptophan	0.90

[1] Values calculated based on the % crude protein of 19.3

Table 17. Mineral composition of tomato pomace

MINERALS	NRC, 1982	Ensminger, 1990	NRC, 2001	Preston, 2007[1]	Range
	Value per 100g dry matter				
Calcium (g)	0.43	0.43	0.22	0.43	0.22 - 0.43
Magnesium (g)	0.20		0.28		0.20 - 0.28
Phosphorus (g)	0.60	0.49	0.47	0.59	0.47 – 0.60
Potassium (g)	3.63		0.98		0.98 - 3.63
Sodium (g)			0.12		0.12
Iron (mg)	460.00		54.10		54.10 – 460.00
Zinc (mg)			5.40		5.40
Copper (mg)	3.30		1.10		1.10 – 3.30
Manganese (mg)	5.10		1.10		1.10
Molybdenium (mg)			0.18		0.18

[1] Values calculated based on % dry matter shown for Preston, 2007 in Table 15

SECTION III – OTHER CONSTITUENTS: TOXICANTS AND ALLERGENS

A. Toxicants

40. The most important natural toxins in tomatoes are the steroidal glycoalkaloids α-tomatine and dehydrotomatine, possibly produced by the plant as a defense against pathogens and predators including bacteria, fungi, viruses, and insects (Andersson, 1999; Friedman, 2002; Kozukue, 2004). Together with phenolic compounds (caffeic acid and naringin) tomatine also contributes to the bitter taste of non-ripe green tomatoes. Tomato glycoalkaloids are synthesized in tomato fruits during early development and then degraded during fruit maturation (Eltyeb and Roddick, 1984a and 1985; Kozukue *et al.,* 1994; Friedman *et al.,* 1995). Three factors seem to play a pivotal role in determining changes in glycoalkaloid content in tomatoes: (i) cultivar (genotype); (ii) ripening stage; and (iii) growing conditions (Leonardi, 2000). Non-ripe green fruits contain substantial amounts of α-tomatine. The reported levels vary between negligible and 1165 mg/kg fresh weight and typically range from 20 to 200 mg/kg fresh weight (Andersson, 1999; Friedman, 2004). In contrast, red ripe tomato fruits contain negligible concentrations of tomatine, between nondetectable levels and 23 mg/kg fresh weight, typically around 1 mg/kg fresh weight. The tomato fruit becomes almost tomatine-free if the red fruit is left on the plant for two or three days before being harvested (Kajderowicz-Jarosinska, 1965). A pronounced reduction in the α-tomatine content is obtained also after induction of ripening with artificial techniques (ethylene treatment) (Eltayeb and Roddick, 1984b) but not to the same extent as in vine-ripened fruit. Retardation of fruit ripening by treatment with reduced pressure delays the reduction in alkaloid content. Consumer exposure to tomatine may be of toxicological concern mainly in cases where substantial quantities of green non-ripe fruits or red ripe fruits of varieties with naturally high levels of tomatine are consumed. However, tomatoes cultivated in Peru with tomatine content in the range of 500–5000 mg/kg of dry weight (approximately 30-300 mg/kg of fresh weight) are consumed without apparent acute toxic effects (Rick *et al*., 1994).

41. Tomatoes also contain calystegine alkaloids (polyhydroxylated nortropane alkaloids) (Asano *et al.* 1997, 2001; Andersson, 2002). At higher concentrations, these compounds may inhibit mammalian glycosidases and produce conditions in grazing animals that are phenocopies of inherited deficiencies in various glycosidases leading to lysosomal storage diseases. It is not known whether such diseases can also occur in humans, although hereditary diseases of glycosidase deficiency have been described. The calystegine alkaloids occur as a set of similar compounds, only differing in the number of hydroxyl groups. Tomato fruits contain calystegines A_3 and B_2 at the respective levels of 1.1 and 4.5 mg/kg fresh weight (Asano *et al.*, 1997).

42. Tomatoes, like several other members of the alkaloid-rich nightshade family (*Solanaceae)*, contain nicotine, but levels are low and are unlikely to be harmful to consumers (Andersson et al., 2003). The levels reported for red ripe tomatoes range from 2.7 to 9.1 µg nicotine per kg fresh weight with only small differences observed between tomato varieties (Domino *et al*., 1993; Siegmund *et al.*, 1999). The nicotine content is inversely related to the degree of fruit ripening. The highest levels are found in unripe, green fruits and the lowest levels in ripe fruits (Castro and Monji, 1986; Siegmund *et al.*, 1999). Processed tomato products, such as tomato sauce and tomato ketchup, contain slightly higher levels of nicotine than fresh tomatoes (although still very low), probably due to the reduced water content of the processed products (Castro and Monji, 1986; Siegmund *et al*., 1999).

B. Allergens

43. Today, there is limited information available regarding the nature of tomato allergens and rather few attempts have been made to identify and characterize them. Usually, allergy to tomatoes is linked to other types of allergies such as grass pollen and latex. The proportion of food-allergic patients being allergic to tomatoes varies world-wide from 1.5% to 16%, indicating that tomato is a significant allergenic food (Westphal *et al.*, 2003). In Central Europe tomatoes account for approximately 1.5% of all food allergies, whereas in countries with high tomato consumption it is responsible for approximately 20% of the oral allergy syndromes (ALLERGOPHARMA, Allergen Database, *www.allergopharma.com*). Immunoglobulin E (IgE) cross – reactive profilins have been suggested to account for allergic symptoms in patients suffering from tomato allergy. The most common tomato allergens known to elicit symptoms in food allergic patients are Lyc e 1, Lyc e 2, Lyc e 2.0101, Lyc e 2.0102, Lyc e 3, Lyc e LAT52, and Lyc e NP24 (Structural Database of Allergenic Proteins, The University of Texas Medical Branch, http://Fermi.utmb.edu/cgi-bin.SDAP/). Based on the *in vitro* histamine release assays with human basophils, Westphal *et al.,* (2003, 2004) concluded that tomato profilin, Lyc e 1, is a minor human allergen whereas profilin Lyc e 2, beta-fructofuranosidase, is an important human allergen. Additionally, lipid transfer protein (Lyc e 3), which belongs to a family of structurally highly conserved proteins, is a potentially severe food allergen due mainly to its extreme resistance to pepsin digestion and is, therefore, considered a pan-allergen (Asero *et al.,* 2000).

SECTION IV – SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FOOD USE

44. Tomato and tomato products are widely consumed by humans all over the world. The popularity of tomato is understandable since the tomato is tasty and is an important source of minerals and vitamins. Tomatoes and tomato products are used as ingredients in many traditional dishes, because of the compatibility with other food ingredients and high nutritional value.

45. Besides the use of tomatoes and tomato products for direct human consumption, tomatoes and its by-products serve as raw materials for several secondary products. A very valuable constituent of tomato is the red pigment carotenoid lycopene, an exceptionally efficient quencher of singlet oxygen and therefore an important anti-oxidant. Lycopene, as well as other valuable substances such as beta-carotene, alpha-carotene, alpha-tocopherol, gamma-tocopherol and delta-tocopherol can be effectively extracted from tomato skins, seeds, and other by-products using supercritical fluid extraction technology (Baysal *et al*., 2000, Rozzi *et al.,* 2002).

46. Tomato seeds contain high quality plant proteins that can be supplemented into various food products (Sogi *et al.,* 2005). Studies have revealed that it is economic to utilize protein isolated from tomato seeds, due to their higher contents of most essential amino acids compared to the peels, as a substitute for wheat flour used in bakery products, whereas cake made from 10% protein isolate as a substitute for wheat flour had the highest palatability (Attia *et al.,* 2000). Table 18 shows suggested nutritional and compositional parameters to be analysed in tomato matrices for food use.

Table 18. Suggested Nutritional and Compositional Parameters to be Analysed in Tomato Matrices for Food Use

Parameter	Tomato (raw)
Proximate analysis[1]	X
Minerals[2]	X
Vitamins[3]	X
Beta Carotene	X
Lycopene	X
Tomatine[4]	X

[1] Proximate includes protein, fat, total dietary fibre, ash and carbohydrates
[2] Magnesium, Potassium
[3] Vitamins include: Vitamins C, K, Folate
[4] Tomatine includes alpha-tomatine and dehydrotomatine

SECTION V – SUGGESTED CONSTITUENTS TO BE ANALYSED RELATED TO FEED USE

47. Tomato processing waste has been used successfully as animal feed. According to a report on underutilized feedstuffs (NRC, 1983), tomato processing wastes can be divided into 3 categories according to the type of product that can be recovered. The first is cull tomatoes not accepted for processing. The second is peel residue from whole tomato canning, and about 12 % of the original tomato is removed as peel and adhering pulp. The third is tomato pomace, the residue from the manufacture of juice, paste, puree, sauce and ketchup. NRC (1983) reported that 15 % of processed tomatoes are processed as whole tomatoes, and 85 % are processed as pulp products. USDA (1994) reports that tomato paste is the primary processed product produced worldwide. Thus, the primary residue product available for animal feed is tomato pomace.

48. NRC (1983) reported that the work of Ammerman *et al*. (1963, 1965) showed that cull tomatoes have been successfully used as feed for cattle feeder steers, lambs and poultry. Cull tomatoes are reported to contain higher levels of energy and lower levels of fibre than tomato pomace. However, if the tomatoes are green, they could contain glycoalkaloids (see Section III, first paragraph) which have a bitter taste which could restrict animal intake. Also, Ammerman *et al*. reported reduced carotenoid pigment in skins and shanks of poultry when cull tomatoes were included at 3 % of the diet, replacing alfalfa meal.

49. NRC (1983) reported that the peel residue is limited as animal feed because of the addition of caustic to tomatoes to enhance the mechanical peeling process. The process may increase the pH to 13–14. Also, the moisture remains high at 97–98 percent.

50. Tomato pomace has been successfully used as animal feed for many years (NRC, 1983). Because moisture content of the fresh tomato pomace is relatively high (75%; Table 15), storage is a problem. Also, its availability is seasonal, mostly in the summer, and requires further processing to make it a useful feed product. Weiss et al. (1997) successfully mixed fresh tomato pomace with corn forage in a 12:88 ratio, respectively and ensiled the mixture as a feed for dairy cattle. A dairy cow feeding study revealed no significant differences between the tomato pomace mixed silage and corn silage on milk yield, milk composition or dry matter intake. A test silo study found that no fermentation occurred when only tomato pomace was included in a silo, but that ensiling it in an air tight plastic bag would provide two months of storage without spoilage. The same researchers found a high lignin level in the tomato pomace which could be of nutritional concern.

51. Most tomato pomace used for animal feed is dried to about 8 percent moisture (Table 15). NRC (1983) reports that it has been successfully fed to cattle, swine and poultry at a 10–15 percent dietary level.

52. The results of feeding tomato pomace on the performance of dairy crossbred steers, showed that (a) the average daily gain of the cattle fed dried tomato pomace was higher than the cattle fed with hey and fresh grass, (b) total voluntary intake of the cattle fed with tomato pomace was higher than the cattle fed with hay and fresh grass and (c) the economical return of the cattle in the group fed with tomato pomace was the best (Satchaphun *et al.*). Another study, conducted on ducks showed that there were no statistical differences in average daily gain, average feed intake and feed conversion ratio, but there was a significant

reduction of feed cost per gain (Wanasitchaiwat *et al.*). Finally, Al-Betawi reported in 2005, that tomato pomace has relatively high lysine content, and has been used in feed for poultry at a rate up to 10% of the ration. Ayhan and Aktan (2004) have also shown that tomato pomace can be used in broiler diets at a 5% level.

53. Table 19 shows suggested nutritional and compositional parameters to be analysed in tomato pomace for feed use. As reported, most of the use of tomato processing waste for animal feed is tomato pomace, and most of the tomato pomace is fed to cattle. The nutrients of major concern for cattle are the proximates (crude protein, crude fat (ether extractable), ash, crude fibber and carbohydrates), neutral detergent fibre (NDF), acid detergent fibre (ADF), calcium and phosphorus. Some tomato pomace may be used for poultry where in addition to the aforementioned nutrients, lysine is also important. There are no reports to indicate that any natural toxicants in ripe tomato-based pomace, such as tomatine, are a concern to animals.

54. For comparative purposes, it is suggested that analysing either the tomato fruit or tomato pomace would suffice. The nutrient content of the pomace would not be expected to change if the nutrient content of the tomato fruit does not change.

Table 19. Suggested Nutritional and Compositional Parameters to be Analysed in Non Processed Tomatoes or Tomato Pomace for Feed Use

Parameter	Non Processed Tomatoes	Tomato Pomace
Proximate analysis[1]	X	X
Minerals[2]	X	X
Lysine	X	X

[1] NDF (Neutral Detergent Fibre) and ADF (Acid Detergent Fibre) should be substituted for crude fibre.
[2] Calcium, Magnesium, Potassium, Phosphorous and Sodium

SECTION VI – REFERENCES

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