

Novel Food and Feed Safety

# **Safety Assessment of Foods and Feeds Derived from Transgenic Crops, Volume 2**

## *Table of contents*

<b>Executive summary</b> .....	13
<b>Introduction</b> .....	15
<b>Part I Towards harmonised assessments of food and feed safety</b> .....	21
<b>Chapter 1 Molecular characterisation of plants derived from modern biotechnology</b> .....	23
Introduction .....	24
Background .....	24
Transformation methods .....	27
Inserted DNA, the insertion site and expressed material .....	29
Inheritance and genetic stability.....	32
Summary .....	34
Notes .....	34
References .....	35
<b>Part II Compositional considerations for transgenic crops</b> .....	37
<b>Chapter 2 Cotton (<i>Gossypium hirsutum</i> and <i>G. barbadense</i>)</b> .....	39
Introduction .....	40
Background .....	40
Nutrients in whole cottonseed and cottonseed products.....	43
Anti-nutrients in cotton .....	49
Food use .....	50
Feed use.....	51
References .....	53
<b>Chapter 3 Cassava (<i>Manihot esculenta</i>)</b> .....	57
Background .....	58
Nutrients.....	66
Other constituents.....	77
Suggested constituents to be analysed related to food use.....	81
Suggested constituents to be analysed related to feed use .....	83
Note.....	85
References .....	86
<b>Chapter 4 Grain sorghum (<i>Sorghum bicolor</i>)</b> .....	93
Background .....	94
Nutrients.....	100
Anti-nutrients .....	105
Suggested constituents to be analysed related to food use.....	107

Suggested constituents to be analysed related to feed use .....	109
Note .....	111
References .....	111
<b>Chapter 5 Sweet potato (<i>Ipomoea batatas</i>)</b> .....	115
Background .....	116
Nutrients .....	121
Other constituents .....	126
Suggested constituents to be analysed related to food use .....	128
Suggested constituents to be analysed related to feed use .....	130
Notes .....	131
References .....	131
<b>Chapter 6 Papaya (<i>Carica papaya</i>)</b> .....	135
Background .....	136
Nutrients .....	142
Other constituents .....	149
Suggested constituents to be analysed related to food use .....	151
Suggested constituents to be analysed related to feed use .....	152
Note .....	153
References .....	153
<b>Chapter 7 Sugarcane (<i>Saccharum</i> ssp. hybrids)</b> .....	159
Background .....	160
Nutrients .....	168
Other constituents .....	174
Suggested constituents to be analysed related to food use .....	175
Suggested constituents to be analysed related to feed use .....	176
Notes .....	178
References .....	178
<b>Chapter 8 Low erucic acid rapeseed (canola)</b> .....	183
Background .....	184
Nutrients .....	192
Other constituents .....	198
Suggested constituents to be analysed related to food use .....	200
Suggested constituents to be analysed related to feed use .....	202
Notes .....	203
References .....	204
<b>Chapter 9 Soybean (<i>Glycine max</i>)</b> .....	209
Background .....	210
Nutrients .....	213
Other constituents .....	222
Suggested constituents to be analysed related to food use .....	228
Suggested constituents to be analysed related to feed use .....	230
Notes .....	232
References .....	233

<b>Chapter 10 Oyster mushroom (<i>Pleurotus ostreatus</i>)</b> .....	239
Background .....	240
Nutrients .....	244
Other constituents.....	253
Suggested constituents to be analysed related to food use .....	255
Suggested constituents to be analysed related to feed use .....	256
Notes .....	257
References .....	257
<b>List of OECD consensus documents on the safety of novel foods and feeds, 2002-14</b> .....	267

## Tables

Table 2.1.	World cotton production, 2001/02 .....	41
Table 2.2.	Proximate analysis of cottonseed .....	44
Table 2.3.	Levels of minerals and vitamins in cottonseed .....	45
Table 2.4.	Amino acid composition of cottonseed in percentage of dry weight .....	46
Table 2.5.	Fatty acid composition of cottonseed in percentage of dry weight.....	46
Table 2.6.	Relative fatty acid composition of refined cottonseed oil.....	47
Table 2.7.	Proximate analysis of meal and hulls in percentage of dry weight .....	48
Table 2.8.	Levels of minerals in hulls and meal.....	48
Table 2.9.	Amino acid composition of cottonseed meal in percentage of meal dry weight.....	49
Table 2.10.	Levels of gossypol and cyclopropenoid fatty acids in whole cottonseed, cottonseed meal and cottonseed oil.....	50
Table 2.11.	Suggested nutritional and compositional parameters to be analysed in cottonseed matrices for human food .....	51
Table 2.12.	Suggested nutritional and compositional parameters to be analysed in cotton matrices for animal feed.....	53
Table 3.1.	Estimated global cassava production .....	59
Table 3.2.	Estimated global cassava harvest area.....	59
Table 3.3.	Terms commonly found in literature to describe parts, types and uses of cassava.....	60
Table 3.4.	Formula for silage from different sources .....	62
Table 3.5.	Proximate composition of fresh cassava roots .....	67
Table 3.6.	Proximate composition of fresh cassava leaves .....	67
Table 3.7.	Amino acid composition in the protein of cassava roots.....	70
Table 3.8.	Amino acid composition in the protein of cassava leaves and meal .....	71
Table 3.9.	Lipid composition of cassava roots.....	72
Table 3.10.	Fatty acid composition of raw cassava roots.....	72
Table 3.11.	Fatty acid composition and content of unfermented and fermented cassava tuber meal.....	72
Table 3.12.	Mineral composition of cassava roots .....	74
Table 3.13.	Mineral composition of dried cassava leaves and processed leaf meal.....	74
Table 3.14.	$\beta$ -carotene and vitamin content of cassava roots and flour .....	75
Table 3.15.	Nutrient composition of processed cassava roots.....	76
Table 3.16.	Proximate composition of processed cassava leaves and foliage.....	76
Table 3.17.	Moisture, protein and energy content of cassava products/by-products used in animal feed.....	77
Table 3.18.	Tannin content (Vanillin-HCl assay) of cassava leaf meal as influenced by processing methods .....	77

Table 3.19.	Average polyphenol and trypsin inhibitor content, and saponin in activity in cassava leaf meal at three ages of the plant.....	79
Table 3.20.	Hydrocyanic acid potential of fresh cassava leaves (at different maturity stages) and roots.....	80
Table 3.21.	Hydrocyanic acid potential and crude protein contents of cassava leaf meal as influenced by storage time.....	80
Table 3.22.	Suggested constituents to be analysed in fresh roots and leaves of cassava.....	83
Table 3.23.	Suggested constituents to be analysed in cassava matrices for animal feed.....	85
Table 4.1.	World sorghum production 2007-08.....	95
Table 4.2.	Proximate analysis of <i>S. bicolor</i> grain (dry matter basis).....	101
Table 4.3.	Mineral concentrations in <i>S. bicolor</i> grain (dry matter basis).....	101
Table 4.4.	Vitamin concentrations in <i>S. bicolor</i> grain.....	102
Table 4.5.	Amino acid composition of <i>S. bicolor</i> grain.....	102
Table 4.6.	Fatty acid composition of <i>S. bicolor</i> and <i>S. vulgare</i> grain.....	103
Table 4.7.	Nutrient concentrations of silages produced by <i>S. bicolor</i> , BMR mutant <i>S. bicolor</i> , Sudangrass ( <i>S. sudanense</i> ) and the hybrid <i>S. bicolor</i> BMR x <i>S. sudanense</i> .....	103
Table 4.8.	Mineral composition of sorghum silages from <i>S. bicolor</i> , Sudangrass ( <i>S. sudanense</i> ) and the hybrid <i>S. bicolor</i> BMR x <i>S. sudanense</i> .....	104
Table 4.9.	Nutrient composition of sorghum distillers' grains.....	104
Table 4.10.	Nutrient and essential amino acid composition of by-products of sorghum ( <i>S. bicolor</i> ) starch extraction.....	105
Table 4.11.	Concentrations of anti-nutrients in sorghum sprouts and grain.....	107
Table 4.12.	Suggested constituents to be analysed in grain sorghum ( <i>S. bicolor</i> ) for food use.....	109
Table 4.13.	Suggested constituents to be analysed in grain sorghum for feed use.....	110
Table 5.1.	Sweet potato production in selected countries, 2008.....	117
Table 5.2.	Sweet potato import and export figures for selected countries, 2007.....	118
Table 5.3.	Proximate composition of raw sweet potato.....	122
Table 5.4.	Proximate composition of processed sweet potato.....	123
Table 5.5.	Mineral composition of raw sweet potato (per 100 g dry weight).....	123
Table 5.6.	Mineral content of processed sweet potato (per 100 g dry weight).....	124
Table 5.7.	Vitamin composition of raw sweet potato (per 100 g dry weight).....	124
Table 5.8.	Vitamin composition of processed sweet potato (per 100 g dry weight).....	125
Table 5.9.	Fatty acid composition of sweet potato (per 100 g dry weight).....	125
Table 5.10.	Amino acid composition of sweet potato (per 100 g dry weight).....	126
Table 5.11.	Suggested nutritional and compositional parameters to be analysed in sweet potato matrices for food use.....	129
Table 5.12.	Suggested nutritional and compositional parameters to be analysed in sweet potato matrices for feed use.....	131
Table 6.1.	World production of papaya.....	136
Table 6.2.	World papaya export.....	137
Table 6.3.	World papaya import.....	138
Table 6.4.	Proximate, fibre and total sugar composition of papaya fruit.....	143
Table 6.5.	Mineral content of papaya fruit.....	144
Table 6.6.	Vitamin content of papaya fruit.....	145
Table 6.7.	Fatty acid content of ripe papaya.....	146
Table 6.8.	Amino acid content of ripe papaya.....	147
Table 6.9.	Nutritive value of different varieties of ripe papaya grown at different locations.....	147

Table 6.10.	Major provitamin A and non-provitamin A carotenoids in fruit pulp of yellow- and red-fleshed papaya.....	148
Table 6.11.	Chemical composition of papaya processing by-products.....	149
Table 6.12.	BITC content of papaya pulp ( $\mu\text{g/g}$ fresh weight).....	150
Table 6.13.	Suggested constituents to be analysed in the unripe and ripe papaya fruits.....	151
Table 6.14.	Suggested constituents to be analysed in papaya for feed use.....	153
Table 7.1.	Main sugarcane producing countries.....	161
Table 7.2.	Composition of sugarcane juice.....	169
Table 7.3.	Amino acid composition of sugarcane juice.....	169
Table 7.4.	Composition of final molasses.....	170
Table 7.5.	Mineral composition of final molasses.....	170
Table 7.6.	Composition of bagasse.....	171
Table 7.7.	Mineral composition of bagasse.....	171
Table 7.8.	Composition of sugarcane tops.....	172
Table 7.9.	Composition of mature whole sugarcane.....	173
Table 7.10.	Suggested constituents to be analysed for food use.....	176
Table 7.11.	Suggested constituents to be analysed for animal feed.....	178
Table 8.1.	Commodity view of major oilseed and plant-based oil production, 2009-10.....	185
Table 8.2.	World production, imports and exports, 2008.....	186
Table 8.3.	Recommended maximum rates of inclusion of low erucic acid rapeseed in feeds.....	191
Table 8.4.	Canadian and Australian average composition of low erucic rapeseed seed, oil and meal, 2006-09.....	192
Table 8.5.	Codex Standard for fatty acid composition of rapeseed oil and low erucic acid rapeseed oil.....	193
Table 8.6.	Vitamin K1 levels in low erucic acid rapeseed oil.....	194
Table 8.7.	Codex Standard for levels of tocopherols in low erucic acid rapeseed oil.....	195
Table 8.8.	Codex Standard of major sterols in low erucic acid rapeseed oil.....	195
Table 8.9.	Range in proximate and fibre composition of low erucic acid rapeseed seed and meal.....	196
Table 8.10.	Vitamin composition of low erucic acid rapeseed meal.....	197
Table 8.11.	Range in mineral composition of low erucic acid rapeseed meal.....	197
Table 8.12.	Mean and/or range of amino acid composition of low erucic acid rapeseed seed and meal.....	198
Table 8.13.	Mean levels of glucosinolates of low erucic acid rapeseed seed and meal.....	199
Table 8.14.	Anti-nutrients of low erucic acid rapeseed meal.....	200
Table 8.15.	Suggested constituents to be analysed in low erucic acid rapeseed for human food.....	201
Table 8.16.	Suggested constituents to be analysed in low erucic acid rapeseed for feed use.....	203
Table 9.1.	Production and export of soybeans in 2011.....	210
Table 9.2.	Proximates and fibre analysis of soybean seed.....	214
Table 9.3.	Amino acid composition of soybean seed.....	214
Table 9.4.	Fatty acid composition of soybean seed.....	215
Table 9.5.	Mineral composition of soybean seed.....	215
Table 9.6.	Vitamin composition of soybean seed.....	216
Table 9.7.	Fatty acid composition of soybean oil.....	216
Table 9.8.	Vitamin K1 levels in commercially available soybean oil as measured by various types of HPLC-based analytical methodologies.....	217

Table 9.9.	Vitamin E ( $\alpha$ -tocopherol) levels in soybean oil as measured by different analytical methodologies.....	218
Table 9.10.	Proximate and fibre content of soybean meal.....	219
Table 9.11.	Amino acid composition of soybean meal.....	220
Table 9.12.	Proximate and fibre content of soybean hulls.....	221
Table 9.13.	Proximate and fibre content of soybean forage.....	221
Table 9.14.	Proximate and fibre content of soybean hay.....	222
Table 9.15.	Oligosaccharide content of soybean seed (g/100 g dry matter).....	222
Table 9.16.	Anti-nutrient content of soybean seed.....	223
Table 9.17.	Isoflavone content of soybean seed (mg/kg dry matter, unless noted).....	225
Table 9.18.	Phospholipids content of soybean seed.....	226
Table 9.19.	Sterol levels in soybean oil.....	226
Table 9.20.	Potential soybean allergens.....	228
Table 9.21.	Suggested nutritional and compositional parameters to be analysed in soybean matrices for food use.....	229
Table 9.22.	Estimated possible inclusion of soybean fractions to animal feeds.....	230
Table 9.23.	Suggested nutritional and compositional parameters to be analysed in soybean matrices for feed use.....	232
Table 10.1.	Proximate composition of <i>P. ostreatus</i> .....	245
Table 10.2.	Amino acid composition of <i>P. ostreatus</i> .....	246
Table 10.3.	Fatty acid composition of <i>P. ostreatus</i> .....	249
Table 10.4.	Mineral content of the cultivated <i>P. ostreatus</i> .....	250
Table 10.5.	Content of toxic heavy metals in cultivated <i>P. ostreatus</i> .....	251
Table 10.6.	Mineral and toxic heavy metal content in wild <i>P. ostreatus</i> .....	251
Table 10.7.	Vitamin content of the <i>P. ostreatus</i> .....	253
Table 10.8.	Suggested constituents to be analysed in fresh fruit bodies of cultivated oyster mushroom, <i>P. ostreatus</i> , for food use.....	256

## Figures

Figure 2.1.	Processing of cotton.....	42
Figure 3.1.	Schematic representation of cassava processing into different food and feed products.....	63
Figure 3.2.	Schematic presentation of the ethanol production process from cassava.....	65
Figure 4.1.	Processing sorghum for animal feed.....	96
Figure 4.2.	Dry milling sorghum grain.....	97
Figure 4.3.	Processing sweet sorghum.....	98
Figure 4.4.	Wet milling of sorghum grain.....	99
Figure 4.5.	Traditional African sorghum beer production.....	99
Figure 5.1.	Sweet potato starch production, generalised process scheme.....	119
Figure 6.1.	Papaya processing.....	139
Figure 6.2.	Papaya puree processing.....	141
Figure 7.1.	Sugarcane industrial processing.....	164
Figure 7.2.	Sugarcane artisanal processing.....	165
Figure 8.1.	Prepress solvent extraction process.....	187
Figure 9.1.	Whole soybean processing.....	211
Figure 9.2.	Defatted soybean flakes processing.....	212
Figure 10.1.	Macroscopic feature of <i>P. ostreatus</i> .....	240