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Series on the Safety of Novel Foods and Feeds No. 21

CONSENSUS DOCUMENT ON COMPOSITIONAL CONSIDERATIONS FOR NEW VARIETIES OF PAPAYA (Carica papaya L.): KEY FOOD AND FEED NUTRIENTS, ANTI NUTRIENTS, TOXICANTS AND ALLERGENS

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Series on the Safety of Novel Foods and Feeds

No. 21

Consensus Document on Compositional Considerations for New Varieties of PAPAYA (*Carica papaya* L.): Key Food and Feed Nutrients and 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 papaya (*Carica papaya* L.) by identifying the key food and feed nutrients, anti-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 papaya and considerations to be taken into account when assessing new varieties of papaya. Constituents to be analysed, related to food use and to feed use, are suggested.

Thailand served as the lead country in the preparation for the document, in collaboration with the United States (co-lead), and the draft has been revised on a number of occasions based on the input from other member countries and stakeholders.

The Task Force endorsed this document, which is published under the responsibility of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology of the OECD.

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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 <u>at the end of this document</u>. 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

1. Papaya (*Carica papaya* L.) belongs to the family *Caricaceae* and is the only species in the genus *Carica*. It is an herbaceous perennial plant with a green or purple hollow stem which is usually single, erect and bears a crown of palmately lobed leaves. The leaves are clustered, 40-60 cm in width, normally with 7-9 lobes. The petioles are long, hollow, and pale green or purple tinged in colour (Campostrini and Yamanishi, 2001).

2. Papaya is a polygamous species. It has male, female and hermaphrodite plants that produce staminate, pistillate and perfect flowers under different seasonal or environmental conditions. The fruit of papaya is a fleshy berry, variable in weight from 200 g up to 9 kg (Yon, 1994). The fruit shape is a sex-linked character. The fruits from female flowers are spherical to ovoid in shape while the fruit from hermaphrodite flowers are long, cylindrical or pyriform. The skin of unripe fruit is smooth and green. When ripe, the skin turns yellow or orange. The flesh of ripe fruit is yellow, orange or red in colour. Papaya seeds are in the ovarian cavity, which is larger in female fruit than hermaphrodite. The seeds are small and dark brown or black with translucent sarcotesta mucilaginous (Yon, 1994; Paull *et al*., 2008).

A. Production of papaya

World production

3. The world production of papaya (*Carica papaya* L.) in 2008 was estimated to be approximately 9.1 million tonnes (FAOSTAT, 2008).

4. The countries with the largest papaya production in 2008 were India and Brazil (about 2.7 and 1.9 million tonnes respectively) followed by Nigeria, Indonesia, and Mexico (Table1). Within the "top-15" papaya producing countries of that year, Indonesia showed the highest yield raising at 72,7 t/ha on average, and Nigeria the greatest area harvested with 92,500 ha. Brazil, Colombia, Guatemala and the Philippines showed significant increases in papaya production and yield between 2004 and 2008.

5. Mexico had the greatest papaya export value in 2007 (approximately 55 million dollars) followed by Brazil, United States, the Netherlands and Belize (Table 2). Although Belize and Malaysia did not belong to the "top-15" producing countries, they were in 2007 the fifth and sixth leading exporters of papaya in terms of value. The Netherlands was the fourth exporter and second importer in terms of value (Tables 2 and 3). This can be explained by the fact that the country, with its location and port facilities, imports agricultural commodities including papaya and re-exports them to other countries in the European Union (Carter, 1997).

6. The United States was a major papaya importing country in 2007 with an import value of approximately 73 million dollars followed by the Netherlands, the United Kingdom, Canada and Germany (Table 3). Papaya imported into the US market in 2006 came from Mexico (69%), Belize (25%), Brazil (2.8%), Jamaica (1%) and elsewhere (2.2%) (Pollack and Perez, 2008). Between 2004 and 2007, several

countries, primarily Canada, Portugal, Spain, France and United Arab Emirates, increased the quantity of papaya imported.

Table 1. World production of papaya

Country	Production (Tonnes)		Area Harvested (Ha)		Yield (Tonnes/ha)	
	2004	2008	2004	2008	2004	2008
India	2, 535,100	2,685,900[2]	73,800	80,300[2]	34.4[3]	33.4[3]
Brazil	1,612,348	1,900,000[2]	34,445	36,750[2]	46.8[3]	51.7[3]
Nigeria	755,000[2]	765,000[2]	91,000[2]	92,500[2]	8.3[3]	8.3[3]
Indonesia	732,611	653,276	9,134	8,982	80.2[3]	72.7[3]
Mexico	787,663	638,237	20,610	16,084	38.2[3]	39.7[3]
Ethiopia	260,000[2]	260,000[2]	12,500[2]	12,500[2]	20.8[3]	20.8[3]
Congo, DR	214,070	223,770[2]	12,712	13,500[2]	16.8[3]	16.7[3]
Colombia	103,870	207,698	4,464	5,498	23.3[3]	37.8[3]
Guatemala	84,000[2]	184,530[2]	2, 100[2]	3,500[2]	40.0[3]	52.7[3]
Philippines	133,876	182,907	8,969	9,175	14.9[3]	19.9[3]
Peru	193,923	157,771[2]	13,449	11,043[2]	14.4[3]	14.3[3]
Venezuela	131,753	132,013[2]	7,103	7,107[2]	18.5[3]	18.6[3]
China	157,620[1]	120,359[2]	5,743[1]	5,826[2]	27.4[3]	20.7[3]
Thailand	125,000[2]	131,000[2]	10,500[2]	11,000[2]	11.9[3]	11.9[3]
Cuba	119,000	89,400	6,088	4,006	19.5[3]	15.0[3]

[1] Unofficial figure
[2] FAO Estimate
[3] Calculated data
Source: FAOSTAT

Table 2. World papaya export

Country	Export Value (1000 $)		Export Quantity (Tonnes)	
	2004	2007	2004	2007
Mexico	72,722	55,327	96,525	101,306
Brazil	26,563	34,404	35,930	32,267
United States	15,917	17,715	9,789	9,604
Netherlands	17,242	16,907	9,554	8,625
Belize	17,429[1]	13,101	28,751[1]	33,341
Malaysia	21,893	8,407	58,149	26,938
Philippines	4,182	6,374[1]	3,324	4,880[1]
France	2,802	3,766	1,307	1,830
Cote d'Ivoire	671	3,203	1,048	5,296
Spain	1,269	2,749	1,464	1,637
Jamaica	2,124	2,748	1,229	1,340
India	1,119	2,721	3,475	10,880
Costa Rica	482	2,525	579	2,972
Ecuador	2,057	2,383	7,196	5,486
China	817	2,277	4,455	10,067
Dominican Republic	741[1]	2,108[1]	1,515[1]	5,200[1]
Guatemala	372	1,372	1,069	6,680
Fiji	644	1,254	303	470
Germany	1,881	1,029	1,084	442
Belgium	3,004	800	980	527

[1] Estimated data using trading partners database
Source: FAOSTAT

Table 3. World papaya import

Country	Import Value (1000 $)		Import Quantity (Tonnes)	
	2004	2007	2004	2007
United States	95,844	73,125	126,024	138,115
Netherlands	19,305	19,208	15,432	12,569
United Kingdom	18,422	18,231	11,108	8,588
Canada	11,965	17,987	10,324	14,487
Germany	16,433	16,873	10,581	8,155
Portugal	8,909	12,932	5,682	5,992
Spain	5,849	11,695	3,541	6,686
Japan	12,547	9,497	4,763	3,996
France	4,906	8,533	2,048	3,414
China, Hong Kong SAR	11,953	5,075	25,972	9,800
Italy	3,343	4,097	1,630	2,008
Singapore	4,224	4,040	24,606	19,086
Switzerland	3,118	3,628	1,345	1,339
United Arab Emirates	1,371[1]	1,847[1]	3,152[1]	6,315[1]
New Zealand	734	1,620	393	874
Sweden	1,350	1,460	603	580
Belgium	2,247	1,392	1,302	847
Austria	833	1,190	466	406
China	3,582	1,126	4,734	1,411
Norway	292	1,016	95	293

[1] Estimated data using trading partners database
Source: FAOSTAT

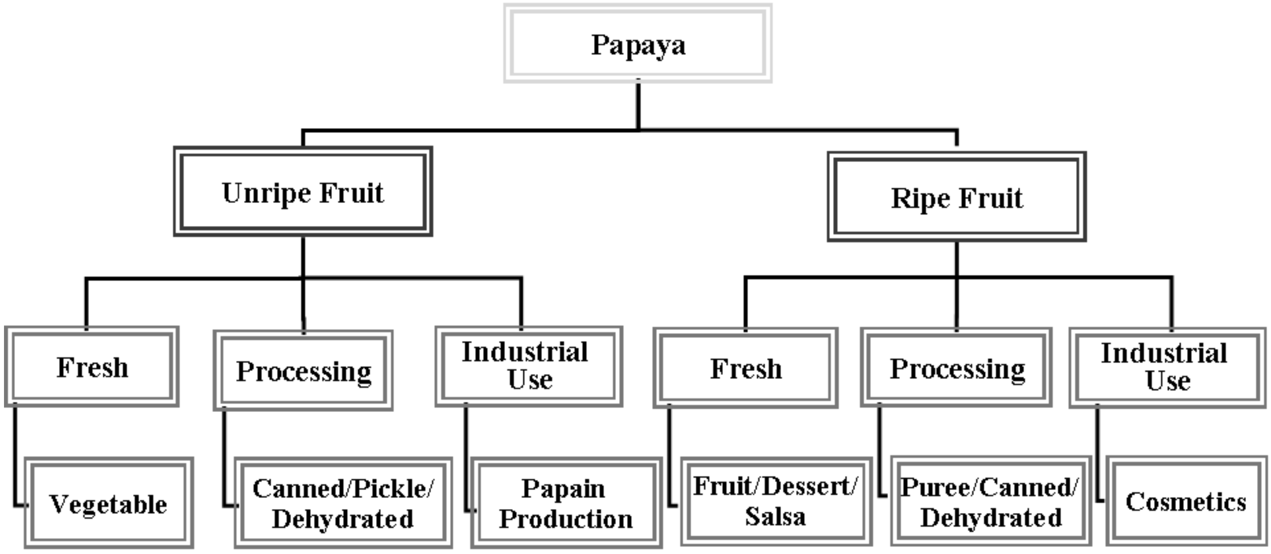
Domestic and foreign markets

7. Small papaya farmers and commercial farmers in many countries grow papaya for both local and foreign markets. The local markets prefer medium- and large-fruited varieties that have yellow and red flesh. Exported papaya fruit are usually small or of medium size (Codex, 2005; Stice *et al*., 2010), with yellow or red flesh (Picha, 2006; Pesante, 2003). Both hermaphrodite fruits (pear-shaped) and female fruits (round) are accepted by consumers in some countries, but the fruits have to be fresh, free from bruises and blemishes, and uniform in size and ripeness. The latest Codex Alimentarius standard for papaya, amended in 2005, included standards regarding quality, size, uniformity, packaging, labelling, contaminants and hygiene (Codex, 2005).

B. Papaya for human and animal consumption

8. Papaya fruit is consumed at both the unripe and ripe stages. Unripe fruits are cooked and utilized as vegetables, processed products and as a source of papain. Ripe papaya is consumed as a fresh fruit and is also used for processing (Figure 1).

Figure 1. Papaya processing



Unripe fruit or green fruit

9. At the unripe stage, the fruit is consumed as a cooked vegetable in some Asian countries where papaya is widely grown (Mendoza, 2007; Mano *et al*., 2009). In Thailand, unripe fruits are used as ingredients in papaya salad and cooked dishes (Sone *et al*., 1998). In Puerto Rico, unripe fruits are canned in sugar syrup and sold either in local markets or exported (Morton, 1987). The preserved unripe papaya fruit, which contains high sugar content, is used as an additive in ice cream. Green or unripe papaya must be cooked (often boiled) prior to consumption to denature the papain in the latex (Odu *et al.,* 2006; Morton, 1987).

Ripe fruit

10. Ripe papaya fruit is consumed in many different ways. The most common one is to eat it like a melon. It can be peeled, the seeds removed, cut into pieces and served as a fresh fruit. It can also be cut into wedges and then served with lime or lemon. Ripe papaya is also used in jam, jelly, marmalade and other products containing added sugar**.** Other processed products include puree, nectar (a non-fermented beverage produced from fruit juice, sugar and water; Matsuura *et al*., 2004), juice, frozen slices or chunks, mixed beverages, papaya powder, baby food, concentrated and candied items (Mugula *et al*., 1994; OECD, 2005; OGTR, 2008).

Puree

11. Papaya puree is prepared from fully ripe peeled fruit with the seeds removed. Papaya flesh is pulped, passed through a sieve and thermally treated (Figure 2). Papaya puree is an important intermediate product in the manufacture of several products such as beverages, ice cream, jam and jelly (Brekke *et al*., 1972; Ahmed *et al*., 2002).

Nectar and beverages

12. Papaya nectar is prepared from papaya puree and consumed either alone or with other fruit juices such as passion fruit juice and pineapple juice (Brekke *et al*., 1972). Canned papaya beverages should be stored at 24°C or below to maintain acceptable quality (Brekke *et al*., 1976).

Dehydrated products

13. Drying and freeze drying are used to reduce the moisture content of papaya chunks and slices. Powdered or dried papaya can be used as a flavouring agent, meat tenderizer or as an ingredient in soup mixes (Singfield, 1998).

Seeds and leaves

14. Papaya seeds are sometimes used to adulterate whole black pepper (Morton, 1987). Papaya leaves contain papain, a strong proteolytic enzyme. Crushed leaves may be used to tenderize meat, however, stomach trouble, purgative effects and abortion may result from consumption of the dried papaya leaves (Morton, 1987).

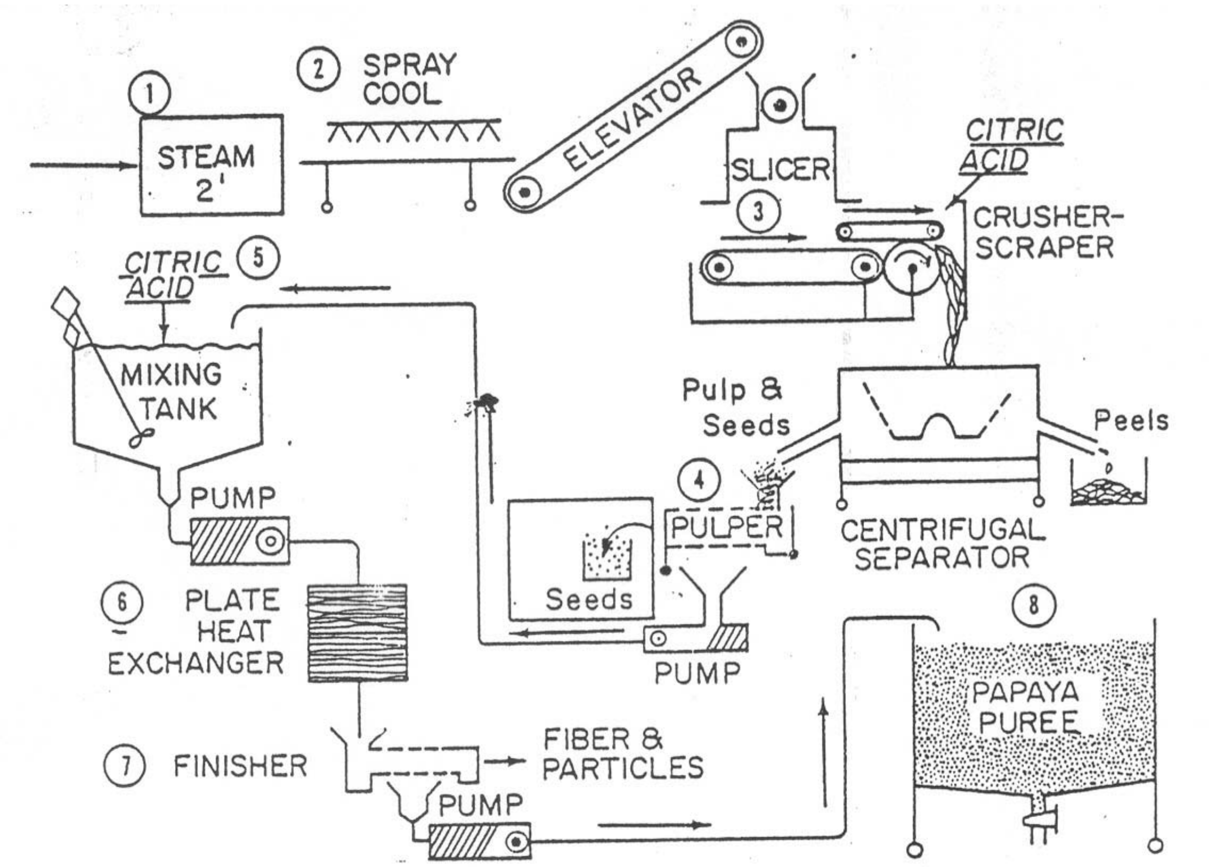
Papain

15. Papaya latex is obtained by cutting the green fruit surface with glass, sharp bone or bamboo and collecting the exuding latex in porcelain or earthenware containers over a couple of days. The latex is then sun dried or oven dried, and ground into powder. A proteolytic enzyme, papain, is purified from papaya latex and used in the food and feed industries, as well as the pharmaceutical and cosmetic industries (OGTR, 2008). Papain is used in food processing to tenderize meat, clarify beer and juice, produce chewing gum, coagulate milk, prepare cereals, and produce pet food (Morton, 1987).

Papaya pomace, skins and leaves

16. Papaya pomace, skins, leaves, and other by-products of papaya processing may find use in animal feed applications (Babu *et al.*, 2003; Fouzder *et al*., 1999; Munguti *et al*., 2006; Reyes and Fermin, 2003; Alobo, 2003; Ulloa *et al*., 2004).

Figure 2. Papaya puree processing



Note:
1. Steaming whole ripe fruits for 2 minutes
2. Spraying the fruits with cold water, slicing and rotating
3. Separating pulp and seeds without breakage from the peel after acidification with citric acid
4. Separating seeds the pulp
5. Adjusted pH of the pulp in mixing tank to 3.4 to 3.5 by citric acid
6. Heating the acidified pulp at 96°C for 2 minutes
7. Removing fibre and seed specks from the puree
8. Transferring papaya puree to containers for freezing.

Source: Brekke *et al.* (1972)

C. Appropriate comparators for testing new varieties

17. This document suggests parameters that papaya breeders should measure when developing new modified varieties. The data obtained in the analysis of a new papaya variety should ideally be compared to those obtained from an appropriate near isogenic non-modified variety, grown and harvested under the same conditions.[1] The comparison can also be made between values obtained from new varieties and data available in the literature, or chemical analytical data generated from other commercial papaya varieties.

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

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

D. Breeding characteristics screened by developers

19. Papaya varieties (cultivars) have been developed by selection of desired fruit phenotypes (fruit shape, taste, size, flesh-colour, firmness and uniformity as well as agronomic characteristics (disease resistance, fruit column compaction, yield) (Martin *et al*., 2006; Chan, 2007). Due to consumer preference and economic reasons, fruits from hermaphrodite plants are selected for consumption. Recently, production of papain from papaya has been developed on an industrial scale. Therefore, high papain levels in papaya fruits could be a desired characteristic to be taken into consideration in future papaya breeding programs (Magdalita *et al*., 2007).

20. Molecular techniques have been developed with the potential to aid papaya-breeding programs. Generally, farmers grow excess papaya plants until flowering time when papaya sex can be determined. The hermaphrodite plants with desired fruit shape are preferable over male and female plants which are consequently removed from the field. Sex specific molecular markers have been developed that could potentially reduce the cost of growing and removing the unwanted plants (Parasnis *et al*., 1999; Deputy *et al*., 2002). Establishing genetic relationships among papaya varieties is important for the introduction of desired characteristics into papaya breeding programs. Amplified Fragment Length Polymorphism (AFLP) studies indicate limited genetic diversity among papaya cultivars (Kim *et al*., 2002). Recently, microsatellite markers that are capable of distinguishing DNA polymorphisms between close cultivars have been developed (Eustice *et al*., 2008) and the first draft of the papaya genome was published (Ming *et al*., 2008). Genes associated with fruit development and ripening may aid in the development of new varieties with desirable qualities.

SECTION II – NUTRIENTS

A. Constituents of papaya fruit

21. At an unripe stage, papaya is consumed as a cooked vegetable while at a ripened stage it is consumed as a fruit. Similar to other vegetables or fruits, the main constituent of papaya is water. The dry matter content increases during fruit development from unripe to ripe stages. Proximate nutrient content, fibre composition, and total sugar composition of papaya fruit per 100 g of dry weight of edible portion are shown in Table 4. Other components including minerals, vitamins, fatty acids and amino acids are presented in Tables 5 to 8.

22. Cultivation conditions vary depending on the climate, growing seasons, site of cultivation and papaya varieties. All these factors can influence the nutrient content of papaya (Hardisson *et al*., 2001; Chavasit *et al*., 2002; Wall, 2006; Marelli de Souza *et al*., 2008; Charoensiri *et al*., 2009). Differences in the nutrient content among cultivation sites and papaya varieties are shown in Table 9.

23. Stages of maturity affect the nutrient content of papaya fruits. For example, the vitamin C content of papaya increases with ripening (Table 6) (Bari *et al*., 2006; Hernandez *et al*., 2006). Consequently, when comparing the nutrient content of papaya fruits, it is important to compare fruits harvested and stored under similar conditions.

Proximate nutrient content, fibre and total sugars

24. The major components of papaya dry matter are carbohydrates. The total dietary fibre content of ripe papaya fruit varies from 11.9 to 21.5 g/100 g dry matter (Puwastien *et al*., 2000; Wills *et al*, 1986; USDA, 2009; Saxholt *et al*, 2008). The crude protein content ranges from 3.74 to 8.26 g/100 g dry matter and the total lipid content varies between 0.92 and 2.2 g/ 100 g dry matter (Table 4).

Carbohydrates

25. There are two main types of carbohydrates in papaya fruits, the cell wall polysaccharides and soluble sugars. During an early stage of fruit development, glucose is the main sugar. The sucrose content increases during the ripening process and can reach levels up to 80% of total sugars (Paull, 1993). Among the major soluble sugars in ripe fruits (glucose, fructose and sucrose), sucrose is most prevalent. During fruit ripening, the sucrose content was shown to increase from 13.9 ± 5.0 mg/g fresh weight in green fruit to 29.8 ± 4.0 mg/g fresh weight in ripe fruits (Gomez *et al*., 2002).

Minerals

26. The edible portion of the ripe papaya fruit contains both macrominerals and microminerals. The macrominerals include sodium, potassium, calcium, magnesium and phosphorus. The microminerals include iron, copper, zinc, manganese and selenium (Table 5).

Vitamins and precursors

27. Papaya is a source of carotenoids, vitamin C, and folate (Table 6). A serving of 100 g of ripe papaya fruit contributes about 19% of the nutrient reference value (NRV) for folate (Codex CAC/GL 2-1985, Rev. 1-1993, Amd. 2003). Papaya fruit also contains thiamin, riboflavin, niacin, pantothenic acid, vitamin B-6 and vitamin K (Bari *et al*., 2006; Adetuyi *et al*., 2008; Saxholt *et al*, 2008; USDA, 2009).

Carotenoids

28. Carotenoids are responsible for the flesh colour of papaya fruit mesocarp. Red-fleshed papaya fruits contain five carotenoids: beta-carotene, beta-cryptoxanthin, beta-carotene-5-6-epoxide, lycopene and zeta-carotene. Yellow-fleshed papaya contains only three carotenoids: beta-carotene, beta-cryptoxanthin and zeta-carotene (Table 9 and 10) (Chandrika *et al*., 2003). As shown in Table 6, the content of beta-carotene varies from 866 µg/100g dry matter to 7,807 µg /100g dry matter in ripe fruits (Puwastien *et al*., 2000; Saxholt *et al*, 2008). Differences in the methods of analysis have been shown to contribute to the variations in reported beta-carotene content (Rodriguez-Amaya *et al.*, 2008).

Vitamin C

29. Papaya is a source of vitamin C with amounts varying between the maturation stages (Table 6) (Bari *et al*., 2006; Hernandez *et al*., 2006). Variation in vitamin C content was also reported among papaya varieties (Table 9) (Franke *et al*., 2004; Wall, 2006).

Fatty acids

30. Papaya contains a low level of fatty acids. Palmitic acid and linolenic acid are two major fatty acids in papaya (Table 7). Chan and Taniguchi (1985) studied fatty acid composition changes in papaya pulp during fruit ripening and reported no significant difference in lipid composition with maturity of papaya fruits.

Proteins and amino acids

31. Proteins constitute approximately 3.74 g - 8.26 g/100 g of dry matter (Table 4). Aspartic acid is the most abundant amino acid in ripe fruits followed by glutamic acid (Table 8).

Organic acids

32. The major organic acids found in ripe papaya are citric acid (335 ± 32 mg/100 g FW) followed by L-malic acid (209 ± 12 mg/100 g FW), qiunic acid (52 ± 5 mg/100 g FW), succinic acid (52 ± 3 mg/100 g FW), tartaric acid (13 ± 2 mg/100 g FW), oxalic acid (10 ± 1 mg/100 g FW), and fumaric acid (1.1 ± 0.1 mg/100 g FW) (Hernandez *et al*., 2009).

B. Chemical composition of by-products from papaya processing

33. Most papaya processing by-products are fed to buffalo, fish, and poultry. The nutrients of major concern for buffalo are crude protein, crude fat (ether extractable), crude ash, carbohydrates, neutral detergent fibre (NDF), acid detergent fibre (ADF), calcium and phosphorus. The major nutrient considerations for fish feedstuff are apparent protein digestibility (APD) and amino acid levels in papaya leaf meal, however APD is not expected to be routinely measured in feed stuff (OECD, 2008; Eusebio and Coloso, 2000). Composition of papaya processing by-products is shown in Table 11.

Table 4. Proximate, fibre, and total sugar composition of papaya fruit (per 100 g of edible portion)

Nutrient	Unit	Ripe				Unripe		*Range of mean values (ripe fruits)*
		USDA, 2009[1]	Saxholt *et al.*,2008[3]	Puwastien *et al.*, 2000[4]	Wills *et al.*, 1986[5]	USDA, 2008[2]	Puwastien *et al.*, 2000[4]	
Mean value, g per 100g fresh weight								
Water	g	88.83	86.5	89.1	89.3	92.16	92.6	*86.5–89.3*
Mean value, g per 100g dry weight								
Protein	g	5.46	4.4–5.2	8.26	3.74	5.48	10.8	*3.74–8.26*
Total lipid (fat)	g	1.25	1.5–2.2	0.92	0.93	1.3	1.35	*0.92–2.2*
Ash	g	5.46	3.7	4.59	2.80	NR	6.76	*2.8–5.46*
Carbohydrate by difference	g	87.8	73.3	86.2	64.5	87.5	81.1	*64.5–87.8*
Total DF (Dietary fibre)	g	16.1	14.1–17.0	11.9	21.5	16.6	27.0	*11.9–21.5*
Total sugars	g	52.8	53.3	NR	64.5	52.7	NR	*52.8–64.5*

NR = Not reported

Mean values reported on a dry weight basis were calculated from a fresh weight basis using the mean moisture level reported for each source

[1] Based on orange-fleshed papaya (possibly including genetically engineered varieties)
[2] Based on papaya, green, cooked (possibly including genetically engineered varieties)
[1, 2, 3] Refuse: 33% (seed and skin)
[4] Percentage of refuse is not determined
[5] Based on orange-fleshed Australia type and refuse: 30% (seed and skin)

Table 5. Mineral content of papaya fruit (per 100 g dry weight of edible portion)

Nutrient	Unit	Ripe					Unripe		*Range of mean values (ripe fruits)*
		USDA, 2009[1]	Saxholt *et al.*, 2008	Puwastien *et al.*, 2000	Sanchez Castillo *et al.*, 1998	Wills, 1986[3]	USDA, 2008[2]	Puwastien *et al.*, 2000	
Minerals									
Macrominerals									
Sodium (Na)	mg	26.86	15.55–54.07	128.4	35.71	65.42	38	283.8	*15.55–128.4*
Potassium (K)	mg	2,300	1,370–1,622	1,238	2,309	1,308	2,066	2,743	*1,238–2,309*
Calcium (Ca)	mg	214.9	57.93–285.9	229.4	190.5	261.7	216	635.1	*57.93–285.93*
Magnesium (Mg)	mg	89.53	111.1–229.6	NR	95.24	130.8	89	NR	*89.53–229.63*
Phosphorus (P)	mg	44.76	63.41–92.59	146.8	95.24	NR	38	432.4	*44.76–146.8*
Microminerals									
Iron (Fe)	mg	0.90	1.93–14.81	12.84	3.57	4.67	0.90	8.11	*0.9–14.81*
Copper (Cu)	mg	0.14	0.12	0.18	0.83	NR	0.17	0.14	*0.12–0.83*
Zinc (Zn)	mg	0.63	0.39–0.62	0.92	0.60	2.80	0.64	0	*0.39–2.80*
Manganese (Mn)	mg	0.10	0.081	NR	0.24	NR	NR	NR	*0.081–0.24*
Selenium (Se)	µg	5.4	NR	NR	NR	NR	5.1	NR	-

NR = Not reported

Means values reported on a dry weight basis were calculated from a fresh weight basis using the mean moisture level reported for each source, as shown in Table 4.

[1] Based on orange-fleshed papaya (possibly including genetically engineered varieties)
[2] Based on papaya, green, cooked (possibly including genetically engineered varieties)
[3] Based on orange-fleshed Australia type and refuse: 30% (seed and skin)

Table 6. Vitamin content of papaya fruit (per 100 g dry weight of edible portion)

Nutrient	Unit	Ripe				Unripe		*Range of mean values (ripe fruits)*
		USDA, 2009[1]	Saxholt *et al.*, 2008	Puwastien *et al.*, 2000	Wills, 1986[3]	USDA, 2008[2]	Puwastien *et al.*, 2000	
Vitamins								
Vitamin C, total ascorbic acid	mg	553.3	457.8	568.8	560.75	386.5	391.9	*457.8–568.8*
Thiamin	mg	0.242	0.200	0.275	0.28	0.191	0.54	*0.200–0.28*
Riboflavin	mg	0.286	0.237	0.459	0.28	0.26	0.41	*0.237–0.459*
Niacin	mg	3.03	2.504	2.75	2.80	2.717	4.05	*2.504–3.03*
Pantothenic acid	mg	1.95	1.615	NR	NR	NR	NR	*1.615–1.95*
Vitamin B-6	mg	0.17	0.141	NR	NR	0.153	NR	*0.141–0.17*
Total folate	µg	340.2	385.2–466.7	NR	NR	165	NR	*340.2–466.7*
Folate, DFE	µg DFE	340.2	NR	NR	NR	165	NR	-
Vitamin B-12	µg	0.00	0.00	NR	NR	0	NR	-
Vitamin A, IU	IU	9,794	NR	NR	NR	NR	NR	-
Vitamin A, RAE	µg RAE	492.4	145.9	NR	NR	369	NR	*145.9–492.4*
Vitamin E (alpha-tocopherol)	mg	6.54	NR	NR	NR	6.51	NR	-
Vitamin K (phylloquinone)	µg	23.28	NR	NR	NR	23.0	NR	-
Carotene, beta	µg	2,471	866–3,103	7,807	2,243	1,849	0	*866–7,807*
Cryptoxanthin, beta	µg	6,813	NR	NR	NR	5,089	NR	-
Lutein + zeaxanthin	µg	671.4	NR	NR	NR	497	NR	-

NR = Not reported, DFE = dietary folate equivalent, RAE = retinol activity equivalent
Mean values reported on a dry weight basis were calculated from a fresh weight basis using the mean moisture level reported for each source, as shown in Table 4

[1] Based on orange-fleshed papaya (possibly including genetically engineered varieties)
[2] Based on papaya, green, cooked (possibly including genetically engineered varieties)
[3] Based on orange-fleshed Australia type and refuse: 30% (seed and skin)

Table 7. Fatty acid content of ripe papaya (percent total fatty acids)

Nutrient	USDA, 2009[1]	Saxholt *et al.*, 2008	*Range of values*
Total saturated fatty acids	38.4	38.9	*38.4–38.9*
12:0 lauric acid	0.9	0.89	*0.89–0.9*
14:0 myristic acid	6.3	6.2	*6.2–6.3*
16:0 palmitic acid	28.5	28.3	*28.3–28.5*
18:0 stearic acid	1.8	1.77	*1.77–1.8*
Total monounsaturated fatty acids	33.9	33.6	*33.6–33.9*
16:1 undifferentiated palmitoleic acid	17.8	17.7	*17.7–17.8*
18:1 undifferentiated oleic acid	16.1	15.9	*15.9–16.1*
Total polyunsaturated fatty acids	27.7	27.4	*27.4–27.7*
18:2 undifferentiated linoleic acid	5.4	5.31	*5.31–5.4*
18:3 undifferentiated linolenic acid	22.3	22.1	*22.1–22.3*

[1] Based on orange-fleshed papaya (possibly including genetically engineered varieties)

Table 8. Amino acid content of ripe papaya (percent total amino acids)

Nutrient	USDA, 2009[1]	Saxholt *et al.*, 2008	Blakesley, 1979	*Range of mean values*
Alanine	5.6	5.7	5.7	*5.6–5.7*
Arginine	4.1	3.9	4.2	*3.9–4.2*
Aspartic acid	19.8	20.0	21.0	*19.8–21.0*
Glutamic acid	13.3	13.5	14.1	*13.3–14.1*
Glycine	7.2	7.1	7.7	*7.1–7.7*
Histidine	2.0	2.1	2.3	*2.0–2.3*
Isoleucine	3.2	3.2	3.4	*3.2–3.4*
Leucine	6.4	6.4	6.9	*6.4–6.9*
Lysine	10.1	10.3	8.4	*8.4–10.3*
Methionine	0.8	0.7	0.8	*0.7–0.8*
Phenylalanine	3.6	3.6	3.8	*3.6–3.8*
Proline	4.1	3.9	4.2	*3.9–4.2*
Serine	6.0	6.1	6.5	*6.0–6.5*
Threonine	4.4	4.3	4.6	*4.3–4.6*
Tryptophan	3.2	3.2	NR	*3.2*
Tyrosine	2.0	2.1	2.3	*2.0–2.3*
Valine	4.1	3.9	4.2	*3.9–4.2*

NR = not reported

[1] Based on orange-fleshed papaya (possibly including genetically engineered varieties)

Table 9. Nutritive value of different varieties[1] of ripe papaya grown at different locations (per 100 g of dry weight of edible portion)

Nutrient	Unit	Varieties		
		Sunrise[2]	Sunrise[3]	Kapoho[2]
Mean value, per 100 g fresh weight of edible portion				
Water	g	87.5	84.9	86.0
Mean value, per 100 g dry weight of edible portion				
Ascorbic acid	mg	374.4	427.2	324.3
β-carotene	μg	644	2,717	1,042
α-carotene	μg	ND	ND	ND
β-cryptoxanthin	μg	2,307	6,092	3,045
Lutein	μg	878.4	857.6	1,701
Lycopene	μg	10,801	24,334	ND
Vitamin A	μgRAE	149.6	480.1	213.6
Phosphorus (P)	mg	40	52.98	57.14
Potassium (K)	mg	1,384	1,466	640.7
Calcium (Ca)	mg	99.2	131.8	70
Magnesium (Mg)	mg	199.2	216.6	137.1
Sodium (Na)	mg	51.2	92.7	40
Iron (Fe)	mg	3.36	3.05	2.07
Manganese (Mn)	mg	0.24	0.13	0.21
Zinc (Zn)	mg	0.56	0.60	0.64
Copper (Cu)	mg	0.56	0.53	0.79
Boron (B)	mg	1.12	1.32	0.93

ND = Not detected, RAE = Retinol activity equivalent
Mean values reported on a dry weight basis were calculated from a fresh weight basis using the mean moisture level as shown
Source: Wall (2006); Wall also reports data on other papaya varieties grown at various locations in Hawaii

[1] The Sunrise papaya variety is a red-fleshed variety while Kapoho is a yellow-fleshed variety
[2] Cultivated in Kapoho area on the island of Hawaii, Hawaii
[3] Cultivated in Moloaa area on the island of Kauai, Hawaii

Table 10. Major provitamin A and non-provitamin A carotenoids in fruit pulp of yellow- and red-fleshed papaya (μg /100 g dry matter)

Carotenoid	Yellow flesh* (n = 10)	Red flesh* (n = 10)
Provitamin A carotenoids		
Beta-carotene	140 ± 0.4	700 ± 0.7
Beta cryptoxanthin	1540 ± 3.3	1690 ± 2.9
Beta-carotene-5-6-epoxide	ND	290 ± 0.6
Calculated retinol equivalent (μg/kg DW)	1516 ± 342	2815 ± 305
Non-provitamin A carotenoids		
Lycopene	ND	1150 ± 1.8
Zeta-carotene	1510 ± 3.4	990 ± 1.1

ND = Not detected, DW = Dry Weight
* The varieties of papaya fruits were not specified by the authors
Source: Chandrika *et al*. (2003)

Table 11. Chemical composition of papaya processing by-products (% DM basis)

	Pomace (Babu *et al.*, 2003)	**Dried skins** (Fouzder *et al.*, 1999)	**Dried skins** (Munguti *et al.*, 2006)	**Leaves** (Reyes and Fermin, 2003)	**Leaves** (Munguti *et al.*, 2006)	**Defatted papaya kernel flour** (Alobo, 2003)	**Fresh papaya processing (pulp, peels and seeds)** (Ulloa *et al.*, 2004)
Dry matter[1]	92.2	87.41	83.9 ± 0.13	94.6	90.3 ± 0.29	92.5 ± 0.52	> 80
Crude protein	18.44	22.9	17.9 ± 0.24	23.0	28.2 ± 0.5	32.4 ± 0.48	23.2
Total fat (ether extract)	4.73	3.68	1.8 ± 0.31	11.1	10.5 ± 0.25	0.7 ± 0.21	NR
Crude fibre	29.58	12.2	19.4 ± 0.22	11.4	13.0 ± 0.13	4.2 ± 0.06	18.2
Nitrogen free extract	28.59	49.78	45.6 ± 0.40	38.5	32.9 ± 0.33	NR	29.5
Crude ash	18.66	11.44	15.4 ± 0.34	15.9	15.4 ± 0.12	5.3	8.6
Acid insoluble ash	4.04	NR	NR	NR	NR	NR	NR
Calcium	1.81	NR	NR	NR	NR	NR	NR
Phosphorus	0.61	NR	NR	NR	NR	NR	NR

[1] Dry matter is reported as percentage of fresh weight
NR = not reported

SECTION III - OTHER CONSTITUENTS

A. Anti-nutrients

34. Ripe papaya fruits (including peel and pulp) contain low amounts of anti-nutrients (tannin, phytate and oxalate). The mean levels of tannin, phytate and oxalate are 10.16, 3.29 and 1.89 mg/100 g of dry matter, respectively (Onibon *et al*., 2007). A significant reduction in the levels of anti-nutrients was reported in papaya fruits stored at 27 ± 1 ˚C and 10 ± 1 ˚C. After 8 days of storage at 27±1 ºC, the phytate content was reduced from 1.22% to 0.34% and the oxalate content from 0.45% to 0.13%. The content of tannin was reduced from 0.062% to 0.006% and 0.021% to an undetectable level, for condensed and hydrolysable tannin, respectively (Adetuyi *et al*., 2008).

B. Toxicants

35. The major natural toxicants found in papaya are benzylglucosinolate (BG), benzyl isothiocyanate (BITC) and alkaloids. These substances are important for plant natural defence mechanisms (El Moussaoui *et al*., 2001). BITC is derived from BG by the action of the myrosinase enzyme. Although both BG and BITC are found in papaya peel, pulp and seed, the highest levels of BG and BITC are found in seeds, 1269.3 ± 90.0 and 461.4 ± 14.2 µmol/100 g fresh weights respectively. The levels of BG and BITC in papaya pulp were < 3.0 and < 0.3 µmol/100 g fresh weight respectively (Nakamura *et al*., 2007). The concentration of BITC decreases in pulp and increases in seeds during fruit ripening (Tang, 1971). Wills and Widjanarko (1995) reported that BITC content decreased from 109 µg BITC/g when papaya is green to 10 µg BITC/ g when papaya is fully ripe. Sheu and Shyu (1996) reported BITC content ranging from 5.4 to 33.6 µg/ g fresh weight in pulp from four different papaya varieties. BITC content in papaya pulp is shown in Table 12.

Table 12. BITC content of papaya pulp (µg/g fresh wt)

Developmental stage	BITC content in papaya pulp (µg BITC/ g -fresh wt)				
	Tang, 1971[1]	MacLeod and Pieris, 1983[1]	Wills and Wid-janarko, 1995[1,2]	Sheu and Shyu, 1996[3,4]	Nagamura *et al.*, 2007[5]
Green	74[6]	NR	109	NR	NR
Ripe	4	0.0014	10	5.4–33.6	<0.447

NR= not reported

[1] BITC content was determined by gas chromatography
[2] Concentrations of BITC in green and ripe Australian papaya at 20°C
[3] Sheu and Shyu (1996) reported concentrations for Tainoung No. 2, Tainoung No. 5, Solo, and Sunrise varieties
[4] BITC content was determined by solid phrase extraction and gas chromatography
[5] BITC content was determined by high performance liquid chromatography
[6] Green immature papaya fruit weighing 187 g

36. Carpaine, is a major alkaloid found in various parts of papaya, but is primarily found in leaves (Krishna *et al.*, 2008). Papaya leaves contain the bitter alkaloids carpaine and pseudocarpaine and must be boiled with several changes of water before consumption (Morton, 1987). Carpaine has been found in papaya leaves at concentrations between 1,000-1,500 mg/kg (Duke, 1992).

C. Allergens

37. Papaya contains four cysteine endopeptidases including papain, chymopapain, glycyl endopeptidase and caricain. Papain is commonly found in papaya latex (Azarkan *et al.*, 2003). The recorded level of papain in papaya latex is 51,000-135,000 mg/kg (OGTR, 2008).

38. Papain can induce IgE-mediated allergic reactions through oral, respiratory or contact routes of exposure. Occupational allergy to papain in exposed workers has been documented in a number of studies. The typical symptoms include bronchial asthma, rhinitis or both (Baur and Fruhmann, 1979; Baur *et al.*, 1982; Niinimaki *et al*., 1993; Soto-Mera *et al.*, 2000; Van Kampen *et al*., 2005). One case of a life-threatening anaphylaxis due to occupational exposure to papain was also reported (Freye, 1988).

39. Allergy to papaya-derived products unrelated to occupational exposure has also been described. Garcia-Ortega *et al.* (1991) showed that administration of chymopapain for chemonucleolysis (a medical procedure that involves the dissolving of the gelatinous cushioning material in an intervertebral disk by the injection of an enzyme such as chymopapain) resulted in sensitization in some patients. In some sensitized chemonucleolysis patients IgE specific to all four cysteine proteinases was detected (Dando *et al*., 1995). Mansfield and Bowers (1983) reported severe systemic allergic reactions mediated by papain-specific IgE in some individuals that ingested papain-containing meat tenderizer. In addition, two cases of allergy to papain in individuals using soft contact lens solution have been reported (Bernstein *et al.*, 1984; Santucci *et al*., 1985).

40. Pollen from papaya flowers has been shown to induce respiratory allergy (Blanco *et al*., 1998; Singh and Kumar, 2002). Using RAST inhibition assay, Blanco *et al*. (1998) demonstrated that papaya pollen, papaya fruit, and papain extracted from papaya contain common allergens. Papaya pollen in papaya planting areas can contribute to aeropollen and aeroallergen loads (Chakraborty *et al*., 2005).

41. Sensitization to papaya does not typically occur from eating papaya fruit. However, once sensitized, individuals may suffer allergic reactions following any type of exposure to papaya or papaya-derived products (Morton, 1987).

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

42. Ripe papaya fruits and papaya products are consumed by humans for their flavour and nutritional value. Unripe papaya fruits are consumed both as a cooked vegetable and processed products.

43. The colour of the papaya fruit flesh is related to the carotenoids present in papaya. For example, three provitamin A caroteniods (beta-carotene, beta-carotene-5-6-epoxide, and beta-cryptoxanthin and two nonprovitamin A carotenoids (zeta-carotene and lycopene) are found in red ripe papaya fruits. Yellow ripe papaya fruits, however, only contain beta-carotene, beta-cryptoxanthin and zeta-carotene.

44. The constituents that should be analyzed in ripe and unripe papaya fruits are shown in Table 13.

Table 13. Suggested constituents to be analysed in the unripe and ripe papaya fruits

Parameter	Unripe / Ripe papaya
Moisture[1]	X
Crude Protein[1]	X
Total fat (ether extract)[1]	X
Ash[1]	X
Carbohydrate by difference[2]	X
Total dietary fibre	X
Total sugars	X
Total Ascorbic acid	X
Beta-carotene	X
Beta-cryptoxanthin	X
Benzylisothiocyanate (BITC)	X

[1] These components should be measured using a method suitable for the measurement of proximates
[2] Carbohydrates are calculated as follows: 100 - (water + crude protein + total fat + ash) g/100g fresh weight

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

45. Papaya leaf, peel, and pomace may be used as feedstuffs. Papaya peels from ripe and unripe fruits are by-products from processing papaya in kitchens, hotels or restaurants, while papaya pomace is discarded from fruit juice factories. The use of papaya by-products in animal feed is mainly limited to experimental studies and small scale farms. Hasan *et al*. (2007) reported the use of papaya leaves as a feed ingredient for Gouramy fish cultured in extensive aquaculture systems in Indonesia. Diets of green papaya leaves, an artificial diet containing 25% crude protein, or a 1:1 ratio mixture of green papaya leaves and artificial diet were compared as potential diets for African giant land snail (*Archachatina marginata*). It was found that a 1:1 ratio mixture of green papaya leaves and artificial diet resulted in significantly higher body weight gain as well as other morphological parameters including shell length, shell width and shell aperture of the animal (Ejidike, 2007). Papaya leaf meal in a diet formulated to contain 27% crude protein was evaluated for its potential as a feed ingredient for farmed abalone (*Haliotis asinine* Linnaeus 1758) diets in the Philippines (Reyes and Fermin, 2003). As a fish feedstuff, papaya leaf meal is comparable in amino acid and nutrient content to white cowpea and mungbean seed meals (Eusebio and Coloso, 2000). There was no difference in apparent protein digestibility value (APD) between papaya leaf meal and white cowpea and mungbean seed meals (Eusebio and Coloso, 2000).

46. Fouzder *et al*. (1999) reported that use of dried papaya skin (DPS) in pullet diets at levels up to 90 g/kg diet showed no significant difference in growth including weight gain, feed intake, feed conversion ratio and protein efficiency ratio between test and control animals. Papaya pomace was shown to provide rumen degradable dry matter (DM) and crude protein (CP) in buffaloes (Babu *et al*., 2003).

47. Papaya leaves and green fruits contain toxicants such as benzyl isothiocyanate (BITC) that can cause irritation of the mucus epithelial membrane. Munguti *et al*. (2006) reported that soaking in water and heat treatment destroys such toxic compounds in papaya and other plants. In the process of making papaya leaf meal, papaya leaves are soaked for 24h, drained, rinsed and air-dried prior to heat treatment and grinding (Eusebio and Coloso, 2000; Reyes and Fermin, 2003). Ulloa *et al.* (2004) reported that papaya meal (pulp, peel and seeds) has high gross energy content and high potential digestible energy levels and may be suitable for use as a fish feed.

48. The constituents suggested for analysis related to feed use are shown in Table 14.

Table 14. Suggested constituents to be analysed in papaya for feed use

Parameter	Fruit	Leaves	Skins
Moisture[1]	X	X	X
Crude protein[1]	X	X	X
Crude fat[1]	X	X	X
Ash[1]	X	X	X
Carbohydrates[2]	X	X	X
Total dietary fibre[3]	X	X	X
Neutral detergent fibre (NDF)[4]	X	X	X
Acid detergent fibre (ADF)[4]	X	X	X
Amino acids	X	X	
Calcium	X	X	X
Phosphorus	X	X	X
Carpaine		X	
Benzylisothiocynate (BITC)	X	X	X

[1] These components should be measured using a method suitable for the measurement of proximates
[2] Carbohydrates are calculated as follows: 100 - (water + crude protein + total fat + ash) g/100g fresh weight
[3] Total dietary fibre analysis is more relevant for dietary considerations of non-ruminant animals
[4] NDF and ADF analyses are more relevant for dietary considerations of ruminant animals

SECTION VI – REFERENCES

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