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Freshwater fish as a dietary source of vitamin A in Cambodia

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Abstract

Vitamin A deficiency is a public health problem among children and women. Common Cambodian fish species were sampled and screened for vitamin A content. Contents of vitamin A-active compounds (all-*trans* retinol, all-*trans* dehydroretinol, 13-*cis* retinol, 13-*cis* dehydroretinol and β-carotene) were determined by high-performance liquid chromatography in samples of raw, whole fish from 29 fish species and in raw, edible parts from 24 species. Replicate samples were analysed in seven selected species. Two species, *Parachela siamensis* and *Rasbora tornieri* had very high vitamin A contents >1500 RAE/100 g raw, whole fish, and six species (*Barbodes altus*, *Barbodes gonionatus*, *Dermogenys pusilla*, *Puntioplites proctozysron* and *Thynnichthys thynnoides*) had high contents of 500–1500 RAE/100 g raw, whole fish. Two species, *Puntioplites proctozysron* and *Thynnichthys thynnoides* had high vitamin A contents in raw, edible parts, after employing traditional cleaning practices. (RAE: The amount of vitamin A active compounds in food is expressed as retinol activity equivalents (RAE), defined as the bioefficacy relative to all-*trans*-retinol [West, C. E., & Eilander, A. (2002). Consequences of revised estimates of carotenoid bioefficacy for the control of vitamin A deficiency in developing countries. *Journal of Nutrition*, *132*, 2920S–2926S]. Dehydroretinoids (vitamin A_2) are not converted to all-*trans*-retinol but have similar metabolic functions. In this paper, RAE refers to the functional bioefficacy as defined by Brouwer et al. [Brouwer, I. A., Dusseldorp, M. V., West, C. E., & Steegers-Theunissen, R. P. M. (2001). Bioavailability and bioefficacy of folate and folic acid in man. *Nutrition Research Review*, *14*, 267–293]).

Keywords: Fish; Vitamin A; Dehydroretinol; Developing countries

1. Introduction

1.1. The role of fish in food and nutrition security in Cambodia

Fish is fundamental for the livelihood and food security of large population groups in the productive and densely populated river basins in Asia. Cambodia, situated in the large Mekong basin, is among the poorest countries in the world and the population is burdened by poor health and malnutrition (SCN, 2004; Victora, Fenn, Bryce, & Kirkwood, 2005). Low intakes of micronutrients, such as vitamin A, iron and zinc, are widespread, causing retarded growth and mental development in children, as well as high morbidity rates and increased risk of early death in other vulnerable population groups, such as women at the reproductive age (SCN, 2004).

The ecosystem of the Mekong river basin sustains extremely diverse and productive freshwater fish fauna. More than 500 fish species of the 1200 species indigenous to the Mekong basin are found in Cambodia (Rainboth, 1996; Van Zalinge, Thouk, Tana, & Loeung, 2000) and indigenous freshwater fish from floodplains and rivers contribute to the everyday diets of millions of people. Fish can be considered “the poor man’s animal food” (Kent, 1997) and, for large population groups, fish is an irreplaceable animal

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source food. Most fish species are consumed, with small fish species generally being less preferred than larger species and therefore having low market value. This means that small fish species are more accessible to the poor, particularly in the season of high production. National consumption data in Cambodia are not available but it is commonly perceived that fish is an extremely important food in the everyday diet in Cambodia. Regional surveys give some indications of the role of fish in the Cambodian diet. In 1998, fish consumption in fishing communities around the Tonle Sap lake was estimated to be 67 kg raw, whole fish/person/y (Ahmed, Navy, Vuthy, & Tiongco, 1998), corresponding to a mean daily intake of 128 g raw, edible parts/person/d, assuming a cleaning loss of 30% by weight, confirming that fish is an important food in the everyday Cambodian diet. Despite the importance of fish in the Cambodian diet and widespread micronutrient malnutrition in Cambodia (Connoly, Panagides, & Bloem, 2001), fish is not considered to be included in programmes to alleviate micronutrient malnutrition (HKI, 2004).

1.2. The nutritional role of fish in Cambodia

Small amounts of animal food in diets are significantly improving the nutritional quality of diets otherwise dominated by staple foods, and stimulating physical growth (Grillenberger et al., 2006), as well as cognitive development in children (Whaley et al., 2003). Fish, as a whole, is therefore to be recognised as a nutritionally important food in the Cambodian diet. In addition, in poor populations in developing countries, with fish as the main or only accessible animal food, the nutritional contribution from fish must be seen in light of the specific nutritional disorders recognised as public health problems. The prevalence of vitamin A deficiency in Cambodia is high and a recognised public health problem (Connoly et al., 2001). In some regions, up to 8% of women experience night blindness caused by vitamin A deficiency during pregnancy. Night blindness is the "tip of the iceberg", indicating that a much larger proportion of the population suffers from sub-clinical vitamin A deficiency (Underwood, 2004).

The primary cause of the high prevalence of micronutrient malnutrition, including vitamin A deficiency, is poor nutritional quality of the diet, due to lack of diversity and low intake of animal source foods. In Cambodia, as in most developing countries, vitamin A supplementation is routinely given to pre-school children but complementary strategies are urgently needed to improve the effectiveness and the long-term sustainability of combating vitamin A deficiency (HKI, 2001). Long-term solutions must address the underlying problem of the poor nutritional quality of the diets. Food-based strategies aim to increase the micronutrient intake by improving the availability and accessibility of nutrient-dense foods (Ruel & Levin, 2002). However, data on the nutritional composition of commonly consumed indigenous foods in most developing countries are lacking or incomplete and thus an important tool for the development of food-base strategies based on indigenous foods is unavailable.

The vitamin A content of fish is highly variable, depending on the species and the cleaning practice, which determines which parts of the fish are edible (Roos, Leth, Jakobsen, & Thilsted, 2002). The main vitamin A-active compounds in freshwater fish are the retinoids (vitamin A_1), all-*trans* retinol and 13-*cis* retinol and the dehydroretinoids (vitamin A_2), all-*trans* dehydroretinol and 13-*cis* dehydroretinol (Sivell et al., 1984; Stancher & Zonta, 1984). Small amounts of β-carotene may be present.

Fish is also a dietary source of other important nutrients. Small fish, which are eaten with bones, are a valuable source of highly bioavailable calcium (Larsen, Thilsted, Kongsbak, & Hansen, 2000). Our previous studies in Bangladesh have shown that small indigenous fish is an important source of vitamin A, as well as calcium, in poor rural, households (Roos, Islam, & Thilsted, 2003). Iron deficiency is also a highly prevalent nutritional disorder in developing countries (SCN, 2004). Iron content in small fish species from Bangladesh and Cambodia ranged from 2 to 7 mg/100 g raw, edible parts while, in two species of the genus *Esomus* (*Esomus danricus* from Bangladesh and *Esomus longimanus* from Cambodia), the iron content was much higher, >12 mg/100 g raw, edible parts (Roos et al., 2003, 2006a).

The species specific nutritional value of common fish species in regions where the populations are highly dependent on fish in their diets indicates that the conservation of biodiversity in these environments is important and can contribute toward improved nutrition.

The aim of this study was to screen commonly consumed Cambodian fish species for contents of vitamin A-active compounds. This is the first step to evaluate the role of fish as a dietary source of vitamin A in Cambodia.

2. Materials and methods

2.1. Selection of fish species for nutrient analyses

From the more than 500 fish species recorded in the Cambodian Mekong river basin, species were selected for vitamin A analysis from the following categories: (1) indigenous species, common in commercial catches (Loeung & Van Zalinge, 2001) and hence assumed to be commonly consumed; (2) small fish species with low market value (Loeung & Van Zalinge, 2001) and therefore assumed to be commonly consumed in poor households, without entering the market; (3) other small non-commercial species common in rice fields (Rainboth, 1996) and therefore assumed to be consumed in poor, rural households; (4) species belonging to the same genus as the Bangladeshi fish species previously found to be rich in vitamin A (Roos et al., 2002) and (5) common species of potential interest in aquaculture. Twenty-nine fish species were selected for screening, based on the above criteria (Table 1).

Table 1
Common Cambodian fish species selected for nutrient analysis

Group	Scientific name[a]	Common name
1. Common species in commercial catches	*Anguilla bicolor*	Chlok
	Channa marulius	Raws
	Channa micropeltes	Diep/Chhaur
	Cyclocheilichthys apogon	Srawka kdam/
	Cyclocheilichthys armatus	Pka kor
	Dangila lineata	Khnawng veng
	Dangila spilopleura	Ach kok
	Henicorhynchus siamensis	Riel tob
	Notopterus notopterus	Slat
	Osteochilus hasselti	Kros
	Parambassis wolffi	Kantrang preng
	Puntioplites proctozysron	Chrakaing
	Thynnichthys thynnoides	Linh
2. Small species with low market value	*Dermogenys pusilla*	Phtoung
	Helostoma temmincki	Kantrawb
	Parachela siamensis	Chanteas phluk
	Trichogaster microlepis	Kawmphleanh pluk
	Trichogaster trichopterus	Kawmphleanh samrei
3. Other small, non-commercial species likely to be consumed in poor, rural households	*Euryglossa panoides*	Andat chhke veng
	Clupeoides borneensis	Bawndol ampeou
	Corica laciniata	Bawndol ampeou
	Luciosoma setigerum	Changwa ronaung
	Rasbora tornieri	Changwa mool
	Trichopsis pumila	Kroem tun sai
4. Species related to vitamin A rich species in Bangladesh	*Esomus longimanus*	Changwa phlieng
	Pseudambassis notatus	Kanchanhchras touch
5. Common species of potential interest in aquaculture	*Barbodes altus*	Kahe kro horm
	Barbodes gonionotus	Chhpin brak
	Osteochilus melanopleurus	Krum

[a] In each category, species are listed alphabetically.

2.2. Sampling of fish species

Fish samples were collected fresh, either at landing sites or local markets, close to the landing sites in Kampong Chhnang, Kandal and Phnom Penh in October and November, 2001. Species common in rice fields were collected from fishermen and farmers. Three separate samples of each species were collected. Each sample contained variable numbers of fish of uniform size (either juvenile or full-grown, depending on availability at sampling sites). The mean weight of fish in each sample was calculated as the total weight of the whole sample/number of fish in the sample. Each sample was divided into a sub-sample of raw, whole fish and another sub-sample of raw, edible parts. Raw, edible parts were obtained by employing rural Cambodian women to clean the fish according to their traditional practices. It was noted whether the head was discarded or included in the raw, edible parts. The samples were cooled immediately, using ice, kept dark and placed in a freezer at −12 °C within 8 h of sampling. Within two weeks, the frozen samples were transported to Denmark and stored at −20 °C prior to analysis. Before analysis, the samples were homogenized and divided into sub-samples for analyses of other nutrients and dry matter.

2.3. Determination of vitamin A-active compounds in fish species

Major vitamin A compounds (all-*trans* retinol, all-*trans* dehydroretinol, 13-*cis* retinol, 13-*cis* dehydroretinol and β-carotene) were analysed by high-performance liquid chromatography (HPLC), as described by Leth and Jacobsen (1993). Retinoids, dehydroretinoids and β-carotene were isolated by alkaline hydrolysis and extracted into diethylether. Vitamin A acetate was added as the internal standard for the HPLC procedure. After fractionation on a silica column, with a gradient running from 0.5% to 8.5% isopropanol in *n*-heptane, retinoids were measured by UV at 325 nm and β-carotene at 450 nm. The response factor for all-*trans* retinol was assessed, while the correction factors established by Stancher and Zonta (1984) for the other vitamin A-active compounds were used: 1.60 for all-*trans* dehydroretinol, 1.10 for 13-*cis* retinol and 1.76 for 13-*cis* dehydroretinol. For the conversion to retinol activity equivalents (RAE), the following factors for the functional biological activities in relation to all-*trans* retinol were used: 75% for 13-*cis* retinol, 40% for isomers of dehydroretinol (Shantz & Brinkman, 1950) and 16% for β-carotene. The analytical procedure was identical to the procedure for a previous screening of Bangladeshi fish species (Roos et al., 2002).

The screening was carried out in a stepwise manner: (1) one sample of raw, whole fish of each of the 29 species was analysed; (2) one sample of raw, edible parts of the 16 species with the highest vitamin A contents in the raw, whole samples was analysed and (3) in seven species, replicate samples were analysed.

In addition, values for the vitamin A content in raw, edible parts of eight additional common Cambodian species are reported. These were obtained from a preliminary screening conducted in 2000, using the same sampling and analytical procedures as in this study.

3. Results

3.1. Vitamin A content in whole and cleaned fish

The first step in the screening – analysis of one sample of raw, whole fish/species – was used to categorize species into the following categories for vitamin A content: low (<100 RAE/100 g raw, whole fish); medium (100–500 RAE/100 g raw, whole fish); high (500–1500 RAE/100 g raw, whole fish) and very high (>1500 RAE/100 g raw, whole fish) (Table 2).

For the species *Clupeoides borneensis*, *Henicorhynchus siamensis*, *Parachela siamensis*, *Rasbora tornieri* and

Table 2
Screened Cambodian fish species categorised according to vitamin A contents in raw, whole fish and raw, edible parts

Category[a]	Vitamin A content RAE/100 g [b]	Raw, whole fish	Raw, edible parts[c]
Very high	>1500	*Parachela siamensis* *Rasbora tornieri*[1]	
High	500–1500	*Barbodes altus* *Barbodes gonionatus* *Dermogenys pusilla* *Parachela siamensis (juvenile)* *Puntioplites proctozysron* *Thynnichthys thynnoides*	*Puntioplites proctozysron* *Thynnichthys thynnoides*
Medium	100–500	*Anguilla bicolor* *Channa marulius* *Channa micropeltes* *Clupeoides borneensis* *Corica laciniata* *Cyclocheilichthys apogon* *Cyclocheilichthys armatus* *Luciosoma Setigerum* *Dangila lineata* *Esomus longimanus* *Euryglossa panoides* *Helostoma temmincki* *Henicorhynchus siamensis* *Notopterus notopterus* *Osteochilus hasselti* *Osteochilus melonopleurus* *Parambassis wolffi* *Pseudambassis notatus* *Trichogaster microlepis* *Trichogaster tricopterus* *Trichopsis pumila*	*Barbodes gonionatus* *Clupeoides borneensis* *Danio regina*[d] *Esomus longimanus* *Parachela siamensis* *Parambassis wolffi* *Rasbora tornieri*
Low	<100		*Anabas testudines*[d] *Anguilla bicolor* *Barbodes altus* *Channa micropeltes* *Channa striata*[d] *Clarias batrachus*[d] *Cyclocheilichthys apogon* *Dangila* sp. *Danio regina (juvenile)*[d] *Dermogenys pusilla* *Mastacembulus siamensis*[d] *Mystus vittatus*[d] *Notopterus notopterus* *Osteochilus hasselti* *Parachela siamensis (juvenile)* *Trichopsis vittata*[d] *Kryptopterus limpok*[d]

[a] In each category, the species are listed alphabetically.
[b] RAE = retinol activity equivalents, defined as the functional bioefficacy of vitamin A-active compounds relative to all-*trans*-retinol.
[c] Edible parts obtained by employing Cambodian women to clean the fish according to traditional practices.
[d] From a preliminary screening, using the same sampling and analytical procedures as in this study.

Thynnichthys thynnoides, replicate samples were analysed of raw, whole fish. For the species *Anguilla bicolor*, *Dermogenys pusilla*, *Parachela siamensis*, and *Rasbora tornieri*, replicate samples of raw, edible parts were analysed. For the species *Parachela siamensis* and *Thynnichthys thynnoides*, the replicate samples represented full grown and juvenile fish, respectively. The results for vitamin A content in the fish samples are shown in Tables 3a and 3b.

For 17 samples (covering 14 species), sub-samples of raw, whole fish and raw, edible parts were analysed. The cleaning loss ranged from 38% to 98% of the total vitamin A content in the raw, whole fish.

3.2. Vitamin A compounds

The relative distribution between vitamin A_1 and vitamin A_2 was highly variable between species (Tables 3a

Table 3a
Vitamin A content in Cambodian fish species (raw, whole fish)

Species	Growth stage	Number of samples	Size of fish in sample g/fish[a]	Major vitamin A-active compounds μg/g		Total vitamin A RAE/100 g[d]
				Vitamin A_1[b]	Vitamin A_2[c]	
			Mean (range)	Mean (range)	Mean (range)	Mean (range)
Rasbora tornieri	Full grown	3	20.5 (16.0–25.0)	1269 (1061–1426)	697 (544–891)	1548 (1360–1698)
Clupeoides borneensis	Full grown	2	2.2 (2.0–2.4)	20 (12–32)	556 (491–626)	250 (231–270)
Henicorhynchus siamensis	Full grown	2	12.0 (11.6–12.3)	148 (83–226)	228 (116–376)	247 (166–327)
Parachela siamensis	Full grown	1	19.0	1232	1404	1812
	Juvenile	1	3.0	644	690	920
	Full grown and juvenile	2	11.0 (3.0–19.0)	938 (644–1232)	1047 (690–1404)	1366 (920–1366)
Thynnichthys thynnoides	Full grown	1	25.5	594	1968	1381
	Juvenile	1	7.7	379	1090	823
	Full grown and juvenile	2	166 (7.7–25.5)	486 (379–594)	1529 (1090–1968)	1102 (823–1102)

Table 3b
Vitamin A content in Cambodian fish species (raw, edible parts), after traditional cleaning [e]

Species	Head included (+) or excluded (−)	Number of samples	Size of fish in sample g/fish [a]	Major vitamin A-active compounds μg/g		Total vitamin A RAE/100 g [d]
				Vitamin A_1[b]	Vitamin A_2[c]	
			Mean (range)	Mean (range)	Mean (range)	Mean (range)
Rasbora tornieri	+	3	16.5 (13.5–20.3)	284 (211–383)	206 (148–274)	374 (282–498)
Anguila bicolour	−	2	53.2 (26.0–81.0)	2 (1–3)	3 (0–6)	21 (16–25)
Dermogenys pusilla	−	3	17.0 (8.5–23.7)	14 (7–22)	18 (7–32)	23 (11–33)
Parachela siamensis	+	2	15.0 (13.5–26.5)	291 (197–383)	270 (176–357)	416 (282–550)
	−	1	2.0	51	42	51

[a] The mean size of fish in a sample is the total weight of sample/number of fish in sample.
[b] Vitamin A_1: vitamin A-active retinoids (all-*trans* retinol and 13-*cis* isomers).
[c] Vitamin A_2: dehydroretinoids (all-*trans*-dehydroretinol and 13-*cis* isomers).
[d] RAE = retinol activity equivalent. Vitamin A_2 is calculated as having 40% activity of all-*trans*-retinol. β-Carotene (values not shown) is included in the total RAE. In all analysed samples, β-carotene contributed <10 RAE.
[e] Edible parts were obtained by employing Cambodian women to clean the fish according to their traditional practices. The cleaning practices varied with fish species, size of fish and person cleaning the fish.

and 3b). For example, in the species, *Rasbora tornieri*, more than 80% of the total vitamin A (expressed as RAE) is present as vitamin A_1 while, in *Clupeoides borneensis*, 90% of the total vitamin A is present as vitamin A_2. The contribution from vitamin A_2 to the total vitamin A content ranged from 5% to 90% in the screened fish samples.

4. Discussion

4.1. Vitamin A content in Cambodian fish species

The screening of commonly consumed fish species is a first step toward identifying species of potential nutritional importance as a vitamin A source in population groups vulnerable to vitamin A deficiency in Cambodia. In this study, from the screening of 29 common fish species, selected from an environment with more than 1200 species, two species, *Parachela siamensis* and *Rasbora tornieri*, were found to have very high vitamin A contents (>1500 RAE/100 g raw, whole fish) and six species had high contents >500 RAE/100 g raw, whole fish.

There are no obvious biological explanations for the variations in vitamin A content between fish species. There seems to be a species-specific distribution between vitamin A_1 and vitamin A_2 (Table 3a), confirming the findings in a previous screening of fish from Bangladesh (Roos et al., 2002).

Is the variation in vitamin A content and compound distribution associated with the feeding biology of the fish species? An early study showed that dehydroretinol was formed in the intestines of the freshwater fish *Saccobranchus fossilis* after admission of lutein (3,3′-dihydroxy-αcarotene) to vitamin A deficient fish (Barua & Goswami, 1977). Lutein is a marker pigment for green algae, a widely distributed microalgae class with more than 2500 species (Jeffrey & Vesk, 1997). This indicates that species rich in vitamin A_2 are microphagous and, at least partly, feeding on green algae. Of the fish species analysed for vitamin A content, the species with the highest contents of vitamin A_2 were *Thynnichthys thynnoides* and *Parachela siamensis* (Table 3a). Previously, the species *Amblypharyngodon mola* was found to have high vitamin A_2 (Roos et al., 2002). These are all pelagic and microphagus species. However, other microphagus species collected from the same environment as *Amblypharyngodon mola*, such as *Hypophthalmichthys molitrix* and *Cirrhinus mrigala*, have low vitamin A_2 – as well as vitamin A_1 – contents (Roos et al., 2002). It is therefore suggested that the capacity to synthesise vitamin A_2 from lutein – and possibly other carotenoids – is a random genetic characteristic in freshwater fish, but the accumulation of vitamin A_2 may specifically be found in microphagus pelagic species.

The results from this study indicated that the vitamin A content increased with the age of the fish, though this was inconclusive. For two species, *Parachela siamensis* and *Thynnichthys thynnoides*, samples of juvenile fish had a lower vitamin A content than had samples of full grown fish. The accumulation of vitamin A with the age of the fish was also indicated in a study in Bangladesh (Roos et al., 2002) and similar tendencies have been found in mammals – pig and ox – with the vitamin A stores in the liver increasing with age (Leth & Jacobsen, 1993).

To quantify the nutritional contribution from fish species, determination of the content of vitamin A in edible parts is necessary. The cleaning practice, to obtain the edible parts, varies with the fish species, the size of the fish as well as the person cleaning the fish. Vitamin A is unevenly distributed in fish, with an accumulation in the eyes and viscera (Roos et al., 2002). The vitamin A retained in the edible parts is therefore greatly influenced by the cleaning practice. Information on the traditional cleaning practices, as well as processing and cooking procedures, of fish species, identified to be rich in vitamin A, is therefore needed.

In calculating the total vitamin A content (RAE), a conversion factor of 40% was used for the functional bioefficacy of vitamin A_2. This factor stems from an old study (Shantz & Brinkman, 1950) in which the biological efficacy of vitamin A_2 was assessed as rehabilitation of growth in vitamin A-deficient rats. In another early study, a replacement of retinol with dehydroretinol in the retina of rats was shown (Shantz, Embree, Hodge, & Wills, 1946). A more recent study has shown that vitamin A_2 is absorbed in humans (Tanumihardjo, Muhilal, Permaesih, Sulaiman, & Karyadi, 1990). However, the specific vitamin A function of vitamin A_2 has not yet been confirmed in human studies.

4.2. The role of fish as source of vitamin A in Cambodia

The total annual fish production in Cambodia is estimated to be in the range of 289,000–431,000 t/y (Van Zalinge et al., 2000), corresponding to 50–74 g raw, edible parts available/person/d, for a population of 12 million. Assuming that the vitamin A content of a pool of common fish species is 50–100 RAE/100 g raw, edible parts, a rough estimate of the vitamin A contribution from fish can be calculated (Table 4). On a national level, this amounts to fish contributing 5–15% of the total vitamin A needed to meet the daily recommended intake of the whole population (FAO/WHO, 2004). The accessibility of nutrient-dense fish species to population groups vulnerable to vitamin A deficiency, and other nutritional disorders associated with poor dietary quality, needs to be assessed in order to quantify the potential contribution of fish to improved micronutrient nutrition. In this study, we have identified common Cambodian fish species with high vitamin A contents. These results contribute to the inclusion of fish in food-based strategies for improved nutrition.

The documentation of the nutritional value of indigenous fish species also provides a tool for developing policies for fisheries management in order to optimise the nutritional benefits of fish to the Cambodian population. In our previous research in Bangladesh, we identified the popular fish species, mola, *Amblypharyngodon mola*, as having a very high vitamin A content (Roos et al., 2002). This species, together with other small indigenous fish

Table 4
Estimates of vitamin A available from fish in Cambodia on a national level

Estimated fish production t/y[a]	Fish availability (g raw, whole fish/capita/d[b])	Vitamin A content (RAE[c]/100 g raw, edible parts)	Vitamin A available from fish (RAE[c]/capita/d)	% of Recommended safe intake[d]
289,000	50	50	25	5
289,000	50	100	49	10
431,000	74	50	37	7
431,000	74	100	79	15

[a] t/y = tonnes/year. From Van Zalinge et al. (2000).
[b] Based on a population estimate of 12 million.
[c] RAE = retinol activity equivalent.
[d] Recommended safe intake = 500 RAE/capita/d on population level, derived from age and sex-specific recommendations, for children, ranging from 375 to 500 RAE/d and, for adults, ranging from 400 to 850 RAE/d (FAO/WHO, 2004).

species, was documented as being an important dietary source of vitamin A, as well as calcium, in poor, rural households (Roos et al., 2003). This information was central for developing an aquaculture production system in which mola was introduced in the successful pond polyculture of carp species, thereby combining cash-earning with increased household consumption of a nutrient-dense fish (Roos et al., 1999; Wahab, Alim, & Milstein, 2003). This production system is presently being disseminated by non-governmental organizations and government extension officers to poor, rural households in certain parts of Bangladesh.

5. Conclusion

The vitamin A content was confirmed to be highly variable between fish species. By screening 29 common fish species from the Cambodian Mekong basin, two species, belonging to the category, "very high in vitamin A", were identified. The relative distribution between vitamin A_1 and vitamin A_2 is species-specific and vitamin A_2 contribution to the total vitamin A content ranges from 5% to 90% in the screened fish species.

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