Gac: a Fruit from Heaven

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Abstract

Solutions to micronutrient deficiencies that capitalize upon indigenous resources and foodstuffs offer a long-term mechanism for elevating the health status of disadvantaged people. In populations where intakes of animal foods are inadequate and food sources of retinol are not economically possible, efficient use of carotene-rich plants may prevent vitamin A deficiency. In Vietnam, the Gac fruit (Momordica Cochinchinnensis Spreng) is an excellent source of beta-carotene (17-35 mg/100g of edible part). This fruit is familiar to indigenous people and is easy to grow. However it has been under-utilized because it is available only 3 months out of a year; there has been no effort to educate the at-risk population about its nutritional benefit and research efforts in production or preservation techniques have been lacking. This paper describes the fruit, compares its nutritional value with familiar carotenoid-rich fruits, details its traditional usage in preparing rice, and discusses the acceptance of this rice preparation (xoi gac) to Vietnamese preschoolers in their daily diet. Financial support for research directed at improving the production and preservation of indigenous b-carotene-rich crops is needed to alleviate the problem of vitamin A deficiency of children in northern Vietnam.

Introduction

In the battle against malnutrition, chronic vitamin A deficiency stands out as one of the most resistant nutritional problems in developing countries, in spite of the fact that the symptoms are not difficult to identify, the aetiology is well understood, treatments are available, and in most cases a food source of retinol and provitamin A carotenoids is plentiful.

Vitamin A deficiency in Vietnam

The problem of vitamin A deficiency among children was first recorded in 1958, with 1,502 hospitalized cases of keratomalacia in the northern region between 1951 and 1953 (1). However, it was not until 1985, when the prevalence of vitamin A deficiency disorders (VADD) in school age children exceeded WHO's cut-off point criterion for a public health problem, that VADD in Vietnam received international attention. This triggered measures to control the problem and a program was begun to distribute high dose vitamin A capsules to children under age 2 years in all provinces in 1990 (2-4). Nevertheless, chronic vitamin A deficiency persists as one of the prevailing nutritional problems among children in the rural areas of Vietnam (5). Physiologically, sub-clinical deficiencies manifest as susceptibility to infection and growth retardation (6,7). As a public health issue, such widespread infirmities have an equal or higher human and economic cost in developing countries than the more advanced stages of deficiency.

Vitamin A distribution programs do not provide a long-term solution in the rural areas of Vietnam for a number of reasons. Distribution in remote areas is difficult and fragmentary, and can further be confounded by the unstable sociopolitical factors common to emerging countries. Such programs are frequently not available to all age groups of children, or to women of reproductive age. For people of lower economic groups and inhabitants of rural areas, animal products, which can be the best source of vitamin A, are not available in sufficient abundance to prevent vitamin A deficiency. Our dietary assessment of 193 pre-schoolers in two communities of northern Vietnam in 1997 found that daily consumption of meat was less than 15g per child (8). A national survey among 13,000 children in northern Vietnam in 1991 reported that consumption of vegetables and fruits among the children with xerophthalmia was 13% of total energy, significantly lower than that among children without xerophthalmia (24%) (9).

Plant food as source of pro-vitamin A

In the diet, vitamin A comes in two forms: preformed vitamin A and provitamin A. Preformed vitamin A is usually in the form of retinyl ester, derived from animal tissue such as egg, fish oils, and flesh, and organ meats. Milk, cream, butter, cheese and fortified foods such as margarine also contain vitamin A. Vitamin A can also be obtained from provitamin A carotenoids which can be converted enzymatically in the intestine and liver to retinol. Carotenoids in plants are the primary dietary source of vitamin A worldwide (10,11). The most efficient pro-vitamin A carotenoid is carotene which is abundant in yellow and orange fruits, such as mangoes, papayas, and yams and in green leafy vegetables such as spinach, kale, sweet potato leaves, and sweet gourd leaves. Consumption of foods rich in b-carotene theoretically can replete individuals to a healthy vitamin A status (12-17).

In the winter of 1997 and summer of 1998, dietary assessment, household-gardens and market surveys were conducted in two communes in the low lands of northern Vietnam. The fruits and vegetables that are available are listed in Table 1. Among the indigenous plants of northern Vietnam, the Gac fruit (Momordica Cochinchinnensis Spreng) has the highest B-carotene content (Table 2). Pro-vitamin A from orange fruits has been shown to be more bioavailable than that from dark-green leafy vegetables (20). The seed membrane and pulp of the gac fruit also contains a significant amount of oil, which is essential for the absorption and transport of b-carotene (21-23). This is especially critical in this population where dietary fat intake is very low (24). Traditionally, Gac seed and pulp are mixed with cooked rice to impart a red color and distinct flavour (25-27). The local name of the dish is Xoi Gac. Because this dish is already well accepted, promoting its consumption could produce a substantial increase in b-carotene intake.

Momordica Cochinchinnensis Spreng (Gac) is botanically classified as Family Cucurbitaceae, Genus Momordica,Species Cochinchinnensis. This rampagenous perennial vine was given the name Muricia cochinchinensis by Loureiro, a Portuguese missionary-priest who published Flora Cochinchinensis in 1790. Later, Sprengel concluded that the plant belonged in the Linnean genus Momordica and changed the name in 1826 (28). The Vietnamese name of Momordica cochinchinensis Spreng is Day Gac (25-27,29-30). M. cochinchinensis is also indigenous to China, Moluccas (Burma), Japan, India, Thailand, Laos, Cambodia, Philippines, Malaysia, and Bangladesh (30-32). Other common names of the plant are listed in Table 3. The plant can be cultivated either from seeds or root tubers. Leaves are alternate and deeply three-to-five-lobed with toothed margins. The leaf stalk is glandular. The gac plant is dioecious, that is, the male and female plants are separate. The flowers are pale-yellow and solitary in the axils of the leaves. The production of parthenocarpic fruits, which is of economic importance, can be accomplished using growth regulators in the female plant in the absence of male plants. However induced parthenocarpic fruits have no seed, whereas hand pollinated fruits contain 18 seeds per fruit on average (33).

The plant starts flowering about 2 months after root tubers have been planted. Flowering usually occurs in April and continues to July/ August and sometimes until September. On average, it takes about 18-20 days for a fruit to mature from emergence of the bud of the female flower. A plant produces 30 to 60 fruits on average in one season. The ripe fruit is picked from August to February (34).

Fruits of M. cochinchinensis are large, densely aculaeate, and green, turning to dark orange or red when ripe. Unlike that of the bitter gourd (Momordica charantia), the exocarp (rind) of the gac fruit is hard and is covered with conical points one-eighth-inch high. The gac fruit available in Vietnam comes in oblong and almost round shapes. There are no differences in the ways the fruits are used or consumed. There are also variations among different fruits with respect to their spine and fruit tips. In some fruits, the spines are smooth and dense, whereas in some, they are hard and widely spaced. The oblong types are 6-10cm in length and round types are 4-6 cm in length. In Vietnam , the oblong fruit weighs between 500g and 1600g and can be 10 to 13 cm long. Shadeque and Baruah reported that in Assam, the fruit weighs from 1 to 3 kg (35). Unlike bitter gourd, which is mostly harvested in the developmental stages, gac fruits in Vietnam are only picked at maturity when the fruit is bright red and seeds are hardened.

The mesocarp of the M. cochinchinensis fruit is one-half-inch thick, spongy and orange. The core is divided into cartilaginous chambers containing bright red fleshy seed pods. Each fruit has on average between 15 to 20 round, compressed and sculptured seeds. The seed membrane and kernels contain oil and are used in traditional medicine (25-27,32). There is no record of any use of the mesocarp. The average weight of the pulp is about 19% of the total fruit weight. An average gac fruit weighing 1kg yields approximately 190g of fruit pulp and 130g of seeds. The seed pulp of a ripe fruit is bright red in color and has a palatable bland to nutty taste.

Nutritional composition of M. cochinchinensis seed pulp

Carotenoid was first identified in gac fruit by Guichard and Bui in 1941 (29). A Vietnamese publication reported that 100g of gac pulp contain 45,780 mg of b-carotene (27). Our chemical analyses of carotene contents gac pulp have been described elsewhere (8). In ripe gac fruit, b-carotene is the dominant carotenoid with concentration as high as 35,500 mg/100g. The mean concentration of b-carotene in Gac fruit from 4 separate HPLC (high-performance liquid chromatography) assays was 26.06 ? 9.38 mg per 100g. In addition to b-carotene, lycopene was the only carotenoid present in quantifiable amounts. West and Poovlet reported a concentration of 18,810 mg of b-carotene and 89,150 mg of total carotenoids per 100g (18).

In addition to carotene, gac pulp also contains a significant amount of oil. Fatty acid analyses indicate that gac contains 10,198 mg per 100g of edible portion. Of the total fatty acids of gac pulp, 70% are unsaturated, 50% of these are polyunsaturated. The approximate nutrient composition of gac fruit and pulp is shown in Table 4, and the fatty acid composition of gac pulp is given in Table 5.

Traditional use of the gac fruit in Vietnam

In Vietnam, the gac vine is often seen growing on lattices at the entrances of rural homes. The Vietnamese use the seed membranes and the pulp of the fruit in the preparation of xoi gac (red rice) (25-27,32). Traditionally, xoi gac is served at weddings, the New Year (Tet), and for other important celebrations (27). During these occasions, it is essential to mask the white colour of rice, since white is considered the colour of death. To make xoi gac, the pulp of gac fruit is mixed with rice. The seeds are often left in the rice, as proof of authenticity.

The color and fatty acids from the fruit pulp and seed membrane are stirred into the rice, giving it a lustrous appearance and oil-rich taste. The name xoi gac means red rice; and when the gac fruit is not in season, rice with red food colourant is also called xoi gac, which local people occasionally eat for breakfast. In addition to their use in xoi gac, the seed membranes are also used to make a tonic (gac oil) for lactating or pregnant women and children, to treat "dry eyes" (xerophthalmia), and night blindness. Vo reported that when applied to wounds, skin infections, and burns, gac oil stimulated the new growth of skin, and closure of wounds (25). A document on Vietnamese traditional medicine lists the use of the gac seed membrane, which contains carotene and lycopene, to treat infantile rachitis, xerophthalmia and night-blindness. The report notes that the oil extract from the seed membrane can be given to small children to improve growth (26).

Supplementation Trial

A supplementation trial was conducted from December 1997 to Februrary 1998 in Hai-Hung province, northern Vietnam. The objective of the trial was to assess the efficacy of the traditional carotene-rich rice preparation known as xoi gac for improving vitamin A status of children in rural Vietnam. The length of the supplementation period was 30 days. The participants were 193 village children from 31 to 70 months of age in two communes Doan-Ket and Tan-Trao of Hai-Hung province. The children were selected from 711 village children in the above age groups. Selection criteria included a low haemoglobin concentration (100-120 g/L), which has been associated with vitamin A deficiency (36-38). The selected children were assigned to one of the three groups: a fruit group that received rice cooked with gac containing 3.5 mg carotene, a powder group that received rice mixed with synthetic b-carotene powder containing 5 mg carotene, and a control group that received rice without fortification. The usual vitamin A and carotenoid intakes were assessed by a food frequency questionnaire administered to the child's mother before and after the supplementation.

Results

Plasma micro-nutrient concentrations

After the child's initial weight and carotene values had been controlled for, the mean increases in plasma carotene concentrations among children in the fruit group (106?g/dL;95% confidence interval 93 - 119 ?g/dL) and powder group (83 ?g/dL; 95% confident interval, 66 - 101 ?g/dL) were significantly higher than those of the control group (5 ?g/dL; 95% confident interval 2 - 7 ?g/dL). The increase in plasma lycopene concentration was significantly higher in the fruit group (940%) than in either the control group (99%) or the powder group (386%). Plasma retinol concentrations increased significantly in all three groups compared to initial values; the increase was significantly higher in the fruit group than the other two groups. After supplementation, 52% of the children in the fruit group and 47% of those in the powder group reached an adequate haemoglobin concentration (120 g/L). Changes in the hemoglobin concentration of children with a baseline value less than 110 g/L were significantly greater in the fruit group than in the control group (mean difference 16.62 g/L, $p <0.05$).

Acceptance of xoi gac by the children

All children completed the 30-day feeding program. The attendance of children and mothers at the feeding centre was 100%. One hundred and forty-six children (76%) completed the entire portion (about 120g) every day of the study. The number of the children who consumed the whole amount increased as the program progressed and on the last day of supplementation most children expressed disappointment about the termination of the programme. Eighty-four percent of the children in the fruit group, 72% of those in the powder group, and 76% of those in the control group completely consumed the food. More children in the fruit group than in the other two groups consumed the entire amount every day; however, the difference was not statistically different.

Mothers' health perception and usual consumption of xoi gac

Ninety-five percent of the mothers interviewed recognized that xoi gac is nutritious, and 66% said that their children had consumed xoi gac since the beginning of the season. Eighty-four percent of the women prepared the xoi gac themself, 4% purchased xoi gac at the market and 2% received it as gift. Few houses in the villages grew gac. Among the mothers who prepared xoi gac at home, only 23% used gac from their home garden, 98% purchased the gac fruit from the market, and only 1% received gac as gifts. Among the 46% of the mothers who did not give xoi gac to their children, 74% said that they did not have gac fruit, 3% did not have money to buy gac, 4% did not have time to cook xoi gac, and only 3% reported that the children did not like xoi gac.

The results of the trial suggest that xoi-gac is well accepted by the children. The pro-vitamin A from Xoi Gac, a rich source of b-carotene and lycopene, is highly bioavailable, and that severely anemic children might benefit from b-carotene supplementation.

Discussion

Under-utilization of gac fruit in Vietnam

Production and consumption of M. cochinchinensis (gac) fruit in northern Vietnam in recent years has decreased for the following reasons. The local people have a poor perception of the health and commercial benefits of the plant. There have been no efforts to promote the production of gac fruit, and educate the target population about its nutritional benefits. Consequently, land is allocated to cultivation of staples or crops that bring greater commercial benefits, such as onion, black pepper, or potatoes. This situation has been observed in other regions of the world (39). Traditional micronutrient-rich plant foods have become less abundant and more expensive to obtain because their production has fallen and/or not kept abreast with demand because of increased population pressure. In fact, in many nations in Asia, consumption of vegetables has not met the recommended per capita vegetable supply of 73 kg/year per person, the minimum amount to prevent micronutrient malnutrition. Mean while, there has been a greater research focus on increasing the production of calorie-rich staple crops such as rice, wheat, corn, casava (40).

The gac fruit is only available three months out of the year. In Vietnam, gac vines are grown mainly in the Red River Delta areas. Harvesting of the fruits begins on September and lasts until December. Gac fruits are picked when they are at optimal size, weight, and colour. Poor post-harvest handling and transportation reduce the shelf-life of the fruit. After harvesting, fruits perish quickly and lose marketability after one week without proper storage. In the markets of urban areas, gac fruits are available for only about 3 months, from November to January. A survey of mothers of participants in the supplementation trial revealed that the main reason that mothers didnot feed xoi gac to their children was the unavailability of gac. The use of gac fruit in making xoi gac has declined, because synthetic food colourant is more available and economical. The consumption of gac fruit will be increased if gac fruit is more available. Gac pulp can be simply preserved in sugar, oil, or alcohol however there has been no effort to promote or improve preservation of the fruit.

Improve availability of indigenous nutrient-rich plants to prevent micro-nutrient malnutrition

The problems encountered in most food-based approaches to improving micronutrient status are multifaceted. They include concerns about nutrient concentrations and interactions in the selected food; bioavailability and bioconversion of the nutrient of interest; and issues related to cultural sensitivity (41-43). Despite those problems, solutions to micro-nutrient malnutrition that make used of local food sources offer many benefits. The most apparent advantage is the self-sustainability of the program. Another benefit is that the foods provide not only the deficient nutrients but also calories and other nutrients. Another attributes to long-term success of a food-based strategies are the ready acceptability to target groups due to familiarity. Improved production of the foods will motivate the advancement of methods of processing, storing and preserving the foods, which in turn not only will improve availability of the foods but also will increase household income, which quite often is positively correlated with low nutritional status.

In the attempt to prevent micronutrient deficiency in developing countries by food-based strategies, most efforts have been spent on fortifying foods with synthetic ingredients, or supplying foods that provide the needed nutrients to populations, rather than finding local sources of foods that contain the needed nutrients and promoting local production of those foods. Fortification requires centralized, well-monitored food processing, and effective distribution channels; this type of infrastructure is often rudimentary in third world countries. Fortification of certain nutrients also changes the appearance and taste of the food and renders it less desirable to the target population. The fortification of sugar, monosodium glutamate and fish sauce has been tested in several countries in Latin America and South-East Asia. None of the above fortification methods provides a sustainatable solution to prevent vitamin A deficiency in developing countries. Daily supplementation of needed micronutrients to prevent deficiency, requires commitment of suppliers, often foreign sources, and is usually not appropriate to the local food habits, hence this should only be a short-term measure.

Although the consumption of caloric by people in developing nations has increased since the 1960s, the focus on staple crops such as rice and wheat, has resulted in the decreased availability of micronutrient-rich food crops to millions of disadvantaged people and contributes to the increase in micronutrient malnutrition namely 'hidden hunger' globally (40,44). To rectify the problem of vitamin A deficiency in developing countries, research efforts need to be directed towards identifying local plant foods rich in provitamin A carotene (in addition to staple crops), traditional use of the plants, and methods to improve production and/or preservation Compilations of plants available in South-East Asia and their carotenoid contents have been made available by the work of numerous researchers (34,45,46). For many of these plants, the local use should be identified, because cooking and storing methods can change bioavailability of carotenoids to humans (48). Advanced food processing techniques can be applied to facilitate beneficial local usage, such as the use of provitamin A carotenoid-rich plants in rice coloring or in seasoning of foods. Environment appropriateness and the plant matrix are also important factors in the bioavailability of beta-carotene and should be considered in the selection of plant sources of beta-carotene (21,49). Genetic manipulation of plant genomes by traditional plant breeding or by genetic engineering has been applied to characterize the genes that control the biosynthesis of carotenes in tomatoes, maize kernels in carrot root (50,51). Currently these methods are under investigation to increase the amount of provitamin A carotenoids in staple foods (rice, casava) (39). These technologies and knowledge can be applied to improve the shelf-life of local crops rich in provitamin A carotenoids, to provide continuously and currently available provitamin A in fruits and vegetables, to overcome environmental stress and to enhance marketability of indigenous fruits. Commercial and nutritional benefits will encourage the cultivation of these carotene-rich crops, and their sustainability will be acheived by maintaining sensible local traditions.

Table 1. Summer and winter fruits and vegetables in northern Vietnam

Vietnamese names	English names	Latin names
Rau lang	sweet potato leaves	Ipomoea batatas
Rau mong toi	Ceylon spinach	Basella rubra
rau muong	water spinach	Ipomoea aquatica
rau day	jute potherb	Corhorus olitorius
rau ngot	sauropus leaves	Sauropus androgynus
rau bi	pumpkin leaves	Cucurbita pepo
rau cai cuc	chrysanthemum	Chrysanthemum coronatium
rau cai soong	watercrest	Nasturtium offcinale
rau cai xanh	mustard green	Brassica Juncea
rau cai bap	cabbage	Brassica oleracea
rau can	celery water	Oenanthe stolonifera
rau cai thia	Chinese cabage	Brassica spp.
rau rut		Neptunia oleracea
gia	mungbean sprouts	Vigna radiata
khoai lang	sweet potato	Ipomoea batatas
ngo	corn	Maize
hanh	onion	Allium cepa
ca chua	tomato	Solanum lycopersicum
ca rot	carrot	Daucus carota
xu hao	kohlrabi	Brassica oleracea
ca bat	aubergine	Solanum melongena
ca phao	eggplant	Solanum melongena
bi do	pumpkin	Cucurbita pepo
bi xanh	ashgourd, waxgourd	Benincasa cerifera
khoai tay	potato	Solanum tubersorum
muop dang	bitter melon	Momordica charantia
bac ha		Colocasia indica
gac	spiny gourd	Momordica Cochinchinensis
muop	sponge gourd	Luffa cylindrical

mang	bamboo shoot	Bambusa spp.
du du	papaya	Canca papaya
chuoi	banana	Musa sapientum
quit	madarin orange	Citrus reticulata
buoi	grapefruit	Citrus maxima
vai	lychee	Litchi sinensis
dua	pineapple	Ananas sativus
chanh	lemon	Citrus limon
ot	chilli pepper	Capsicum frutescens
cam	orange	Citrus sinensis
khe	star fruit	Averrhoa carambola
dua hau	watermelon	Citrusllus vulgaris
dua chuot	cucumber	cucumis sativus
dua gang	large cucumber	cucumis melo

Table 2.Beta-carotene contents of gac and other commonly consumed fruits and vegetables in northern Vietnam. Source: refs. 18 and 19

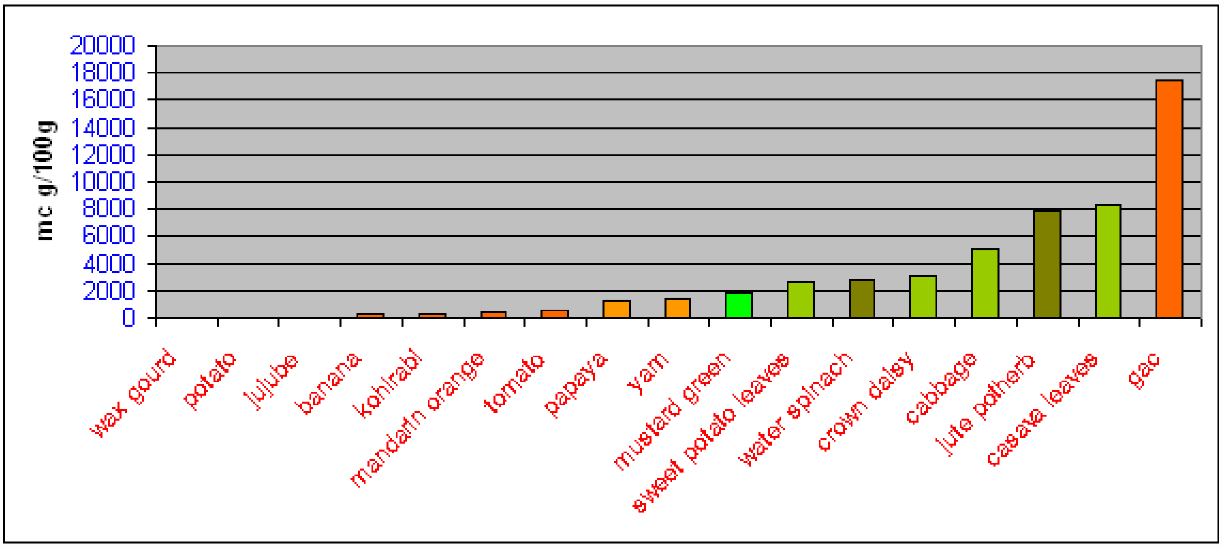

Table 3. Names of Momordica cochinchinnensis in different languages

Language	Name
Latin	Momordica Cochinchinnensis Spreng
	Muricia cochinchinnensis Lour.
	Muricia mixta Roxb.

Indian	Bhat kerala
Chinese	Moc Niet Tu
English	Spiny bitter gourd
	Sweet gourd
	Cochinchin gourd
Japanese	Kushika
	Mokubetsushi
Hindu	Hakur
	Kakrol
	Kakur
Laos	Mak kao
Malais	Teruah
Thai	Fak kao
Vietnamese	Gac

Table 4. Approximate nutrient composition of Momordica cochinchinensis spreng (per 100g of edible portion)

	Water %	Calories Kcal	CHO g	Protein g	Fat g	Fiber g	Ash mg	β –χαρ μ γ	Ca mg	P mg
Fruit	90.2	29	6.4	0.6	0.1	1.6			27	38
Seed pulp	77	125	10.5	2.1	7.9	1.8	0.7	45780	56	6.4

Table 5. Fatty acid composition of gac pulp

shorthand	name	mg/100g edible portion	% total fatty acids	type
14:0	myristic	89	0.87	saturated
16:0	palmitic	2248	22.04	saturated
16:1	palmitoleic	27	0.26	unsaturated
18:0	stearic	720	7.06	saturated
18:1n9	oleic	3476	34.08	monounsaturated
18:1n7	vaccenic	115	1.13	monounsaturated
18:2	linoleic	3206	31.43	polyunsaturated

18:3n3	alpha linolenic	218	2.14	polyunsaturated
20:0	eicosanoic	40	0.39	saturated
20:1	gadoleic	15	0.15	monounsaturated
20:4	arachidonic	10	0.10	polyunsaturated
22:0	docosanoic	19	0.19	saturated
24:0	tetracosanoic	14	0.14	saturated
	TOTAL	10,198	mg / 100g edible portion	

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