Indigenous Crops of Asia and Southeast Asia: Exploring Health-promoting Properties

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Additional index words. indigenous vegetables, phytochemicals, carotenoids, human health

Abstract. Diets rich in vegetables and fruits are known to be protective against several diseases. Only a limited number of vegetables and fruits are consumed as part of the daily diet in Western countries. Historically, indigenous vegetables and fruits are known for their medicinal and nutritional value in countries where they were originated and/or domesticated. However, relatively few systemic studies and reviews were conducted to enumerate the potential of these vegetables to human health benefits. Although certain indigenous crops have received attention, the majority of these crops with strong potential biological activities were neglected and/or not reported. Considering the current health-related problems and obesity-related diseases, it is timely to enumerate the health-promoting properties of certain indigenous vegetables. In this report, we have reviewed some of the important crops indigenous to Southeast Asia and their potential health-promoting properties.

Approximately 250,000 flowering species of plants are known and ~50,000 of these species are edible. Although humankind has used ~3000 plant species for food (Vietmeyer, 1986), only 11 crops (wheat, rice, corn, barley, sorghum/millet, potato, sweetpotato/yam, sugarcane, and soybean) contribute ~75% of human food (Prohens et al., 2003). It is now well established that diets rich in fruits and vegetables (FAV) may have protective effects against cardiovascular disease and certain forms of cancer. These protective effects are attributed to bioactive compounds such as carotenoids, flavonoids, and other phenylpropanoids, which are present in FAV. Recently, health-maintaining properties of some of the bioactive compounds were reviewed (Patil et al., 2009). Indigenous vegetables have long been a vital component of the traditional diet in Asian and African countries. In contrast, food habits in the European and American countries are centered on meat, poultry, and dairy products. Although the Western diet is rich in protein, including certain amino acids and vitamins, which are present in lower concentrations in FAV, the Western diet seems to be deficient in certain bioactive compounds present only in certain indigenous vegetables and fruits. In comparison, a plant-based diet provides the essential nutrients as well as other bioactive compounds. Although these bioactive compounds and/or phytochemicals do not qualify as essential nutrients, they are increasingly being recognized for their potential health-maintaining properties. In general, consumption of FAV may account for the lower incidence of various chronic diseases. Several of the indigenous vegetables, including bitter melon, fenugreek, and *Moringa*

oleifera Lam., are currently being studied for their health-promoting properties. Interestingly, recent studies seem to provide contradicting results of role of FAV in cancer prevention (Pierce et al., 2007; van Gils et al., 2005), which adds more confusion for consumers. There is an apparent need to study such potential crops to determine their effectiveness. This review discusses the health beneficial properties and bioactives of selected crops indigenous to Asia and Southeast Asia.

BITTER GOURD (BITTER MELON)

Bitter gourd (*Momordica charantia* L.) is cultivated throughout the world as a vegetable crop and considered to have potential benefits in reducing risk of diabetes (Grover and Yadav, 2004). Bitter gourd is intensively studied for its antidiabetic properties and several studies have reported potential biological properties such as hypoglycemic (Sarkar et al., 1996) and antihyperglycemic (Ahmed et al., 2004) activity from different plant parts such as fruit pulp, seed, leaves, and whole plant. Oral intake of freeze-dried bitter gourd juice reportedly reduced weight gain and body fat without affecting energy intake in high-fat-fed rats (Chen et al., 2003). The observed effects may possibly be attributed to reduced fat absorption, lowered serum insulin, and improvement in glucose tolerance. Furthermore, clinical trials (Table 1) using pulp and juice extracts of bitter gourd were reported to reduce blood glucose levels and improve glucose tolerance (Ahmad et al., 1999; Baldwa et al., 1977). The postulated mechanisms of bitter gourd hypoglycemic activity involve 1) modulation of xenobiotic metabolism by improving the activity of glutathione and glutathione S-transferase (Raza et al., 2000); 2) stimulation of insulin secretion by β -cells in obese-hyperglycemic (Welihinda et al., 1982); and 3) activation of peroxidase proliferator-activated receptor (PPAR) (Che-Yi and Ching-jang, 2003). In addition, crude extracts from bitter gourd and purified fractions were documented to inhibit the growth of a number of human cancer cell lines (Grover and Yadav,

2004; Kobori, 2003). PPAR plays a role in lipid and glucose homeostasis, cellular differentiation, apoptosis, and cancer development as well as controlling the inflammatory response (Kersten et al., 2000; Picard and Auwerx, 2002). These observations suggest that bitter gourd may exert its anticancer and antidiabetic activities through similar mechanisms. This hypothesis further gains strength from the reported modulation of apoB secretion and triglyceride synthesis in HepG2 cells (Nerurkar et al., 2005) and amelioration of hyperlipidemia (Senanayake et al., 2004). Furthermore, the emerging evidence suggests that many of the diseases influenced by the bitter gourd such as diabetes, cancer, inflammation, and obesity may have common roots (Masur et al., 2008). Altogether, these observations suggest a central modulatory activity of bitter gourd. However, lack of conclusive evidence seems to keep consumers in the dark and leads to continuation of debate.

In addition to its effect on human diseases, the extracts from different plant parts of bitter gourd were also demonstrated to possess antimicrobial activities, in particular against intestinal pathogens (Omeregbe et al., 1996) as well as antiviral activity (Bourinbaier and Lee-Huang, 1996; Lee-Huang et al., 1995). Another important bioactivity demonstrated by several studies is the abortifacient properties by *Momordica* proteins. Momorcharins, basic glycoproteins from the bitter gourd, showed abortifacient activity (Chan et al., 1984, 1986; Ng et al., 1992). However, scientific evidence is not sufficient to recommend the use of bitter gourd glycoprotein in pregnancy. More research is required to establish its safe use.

Several bioactive compounds (Fig. 1) were reported from the bitter gourd (Chena et al., 2005; Parkash et al., 2008). Although charantin, vicine, and polypeptide-p are suggested as the main hypoglycemic components (Yeh et al., 2003), the majority of the studies have used crude extracts to demonstrate the hypo-/antihyperglycemic activity. Furthermore, carotenoids, alkaloids, saponins, and triterpenoids were reported from the bitter gourd (Chen et al., 2008). Carotenoids such as β -carotene,

Received for publication 14 Dec. 2011. Accepted for publication 12 Mar. 2012.

This paper was part of the workshop "Asia's Indigenous Horticultural Crops" held 26 July 2009 at the ASHS Conference, St. Louis, MO, and sponsored by the Working Group of Asian Horticulture (WGAH).

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Table 1. Clinical trials of bitter gourd.

Trial	Outcome	Reference
Controlled clinical trial with polypeptide-p	Decrease in serum glucose levels	Baldwa et al., 1977
Administration of fruit juice to maturity-onset diabetic patients	Decrease in glucose levels in glucose tolerance test and HbA1c	Welihinda et al., 1986
Aqueous extract of fruit	Reduction in mean blood and serum glucose and HbA1c levels	Srivastava et al., 1993
Aqueous extract of fruit	Reduction in fasting and postprandial serum glucose	Ahmad et al., 1999
Bitter gourd capsules	Non-significant reduction in HbA1C	Dans et al., 2007

Fig. 1. Bioactive compounds of bitter melon (A) momordicin, (B) kuguacin, (C) charantin, (D) vicine, (E) 5-hydroxytryptamine, (F) β -carotene, (G) cryptoxanthin, (H) zeaxanthin, (I) lutein.

lutein, and zeaxanthin and their potential health benefits were well documented (Pryor et al., 2000). Momordicin, a triterpenoid, is reported to possess insulin-like activity (Saxena and Vikram, 2004). It is noteworthy that triterpenoids such as limonoids from citrus were reported to demonstrate anticancer activity (Jayaprakasha et al., 2008; Patil et al., 2009; Poulouse et al., 2005; Vanamala et al., 2006). It is possible that momordicin may also possess anticancer activity. Identification of the principal bioactive components and mechanisms responsible for their effect on glycemic control and anticancer activity is a major challenge. Elucidation of such components may lead to a better understanding about their incorporation in the diet and chronic disease prevention. Moreover, identification of bioactive compounds will help in understanding

molecular mechanisms, which will eventually lead to better appreciation of the indigenous vegetables and fruits. Although several investigations have enumerated the health-promoting properties of bitter gourd, very few studies have demonstrated the underlying mechanism responsible by the specific bioactive compounds. Elucidation of the mode of action of principal components will lead to a better understanding of their role in disease prevention.

OTHER CUCURBITS

A large variety of cucurbits are consumed as fresh and cooked vegetables throughout the world. Certain cucurbits are cultivated throughout the globe; however, a few are prevalent in Asian and African subcontinent. These include snake gourd, ridge gourd, fuzzy gourd, sponge

gourd, and bottle gourd. Ridge gourd (*Luffa acutangula* L.) is commonly grown in hot, humid tropical areas in Asia. Plants are generally grown on a trellis. Immature fruits, which are dark green with tender ridges, are used in soups and curries or as a cooked vegetable. Ridge gourd seeds contain ribosome-inactivating peptide luffangulin (Wang and Ng, 2002). Another ribosome-inactivating peptide has been isolated from Snake gourd (Chow et al., 1999). In addition, antiviral and hepatoprotective activities were also documented for Snake gourd (*Trichosanthes anguina* (L.) Haines.) (Chow et al., 1999). However, a detailed investigation about the phytochemical profile and health benefits is still lacking. A particular isoflavone glycoside (Fig. 2), 5,6,6'-trimethoxy-3',4'-methylenedioxyisoflavone 7-O- β -(2''-O-p-coumaroyl)glucopyranoside and Kaempferol-3-O-sophoroside were reported from Snake gourd. The reported isoflavone glycoside (Fig. 2A) is structurally very interesting due to presence of several methoxyl groups because addition of methoxyl groups is speculated to increase the potency in various assays. For example, polymethoxy flavonoids (Raman et al., 2005) and addition of the methoxyl group in citrus limonoids were reported to enhance the potency in anticancer and biofilm assays (Perez et al., 2009; Vikram et al., 2012).

FENUGREEK

Fenugreek (*Trigonella foenum graecum*) is a native of Southeastern and West Asia and widely grown in India, Argentina, Egypt, and Mediterranean countries. It is commonly used as a condiment and leafy vegetable as well as widely used in the traditional system of medicine in India. Fenugreek leaves are a rich source of calcium, iron, β -carotene, and vitamin K. In addition, fenugreek leaves and seeds exhibit hypoglycemic (Abdel-Barry et al., 1997; Vijayakumar et al., 2005) and antihyperglycemic effects in rats (Devi et al., 2003). A few of the case studies related to consumption of fenugreek on diabetes and obesity are presented in Table 2. Consumption of fenugreek seeds was reported to reduce the oxidative stress (Annida and Prince, 2005). Antihyperglycemic activity by fenugreek seems to stem from its ability to modulate GLUT4 and IRS- β , which subsequently resulted in activation of insulin signaling pathways (Vijayakumar et al., 2005). In addition to the effect on blood glucose and corresponding markers, fenugreek was demonstrated to lower the levels of total serum cholesterol, triglycerides, low-density lipoprotein, and very low-density lipoprotein in human volunteers without affecting high-density lipoprotein levels (Prasanna, 2000; Sowmya and Rajyalakshmi, 1999).

Protodioscin, trigoneoside, and diosgenin (Fig. 3) are the major bioactive compounds isolated from fenugreek seeds (Murakami et al., 2000; Yoshikawa et al., 1997). Protodioscin and diosgenin possess anticancer activity (Hibasami et al., 2003; Raju et al., 2004). The literature indicates that diosgenin acts on the cell cycle and induces apoptosis

Fig. 2. Bioactive compounds of Snake gourd (A) 5,6,6'-trimethoxy-3',4'-methylenedioxyisoflavone 7-*O*-β-(2''-*O*-*p*-coumaroyl)glucopyranoside, (B) Kaempferol 3-*O*-sophoroside.

Table 2. Case studies of fenugreek research.

Study	Outcome	Reference
Case-control study with 18 subjects fed fenugreek fiber product	Increase in fullness, satiety simultaneous decrease in hunger	Mathern et al., 2009
Case-control study in insulin-dependent diabetic patients fed fenugreek seed powder	Significant reduction in fasting blood sugar	Sharma et al., 1990
Case-control study in non insulin-dependent diabetic patients fed fenugreek seed powder	Significant reduction in postprandial blood glucose	Madar et al., 1988

Fig. 3. Bioactive compounds of fenugreek, (A) Trigoneoside, (B) Diosgenin, (C) Protodiosgenin, (D) Tigenin, (E) Caffeic acid, (F) Vitexin, (G) Orientin.

(Leger et al., 2004; Liagre et al., 2005). Although few compounds affecting apoptosis in cancerous cell line were enumerated, the compounds imparting hypoglycemic and hypocholesterolemic properties to fenugreek are yet to be identified. Furthermore, isolation and identification of other bioactive compounds, which may have anticarcinogenic properties, is warranted.

DRUMSTICK

Drumstick (*Moringa oleifera* Lam.) is native to India, Arabia, and possibly Africa and the East Indies. It is widely cultivated and naturalized in tropical Africa, tropical America, Sri Lanka, India, Mexico, Malabar, Malaysia, and the Philippine Islands. Drumstick plant extract is used in Bangladesh folk medicine as anticancer agents (Costa-Lotufo et al., 2005) and in the treatment of female reproductive disorders (Bose, 2007).

Drumstick leaves are a rich source of β-carotene, protein, vitamin C, calcium, and potassium as well as of natural antioxidants

such as ascorbic acid, flavonoids, phenolics, and carotenoids (Dillard and German, 2000; Siddhuraju and Becker, 2003). A unique group of compounds, glucosinolates, and isothiocyanates (Figs. 4C and 4E–J) were reported from the drumstick plant (Bennett et al., 2003; Fahey et al., 2001). In addition, a rich diversity of other secondary metabolites such as moringine and moringinine, vanillin, β-sitosterol, β-sitostenone, 4-hydroxymellin and octacosanoic acid, flavonoids kaempferol, rhamnetin, isoquercitrin, and kaempferitrin (Faizi et al., 1994) were reported from drumstick.

Several bioactivities including anti-inflammatory, hypocholesterolemic, and hypoglycemic were documented for drumstick preparations (Dangi et al., 2002). The anti-hypertensive property of drumstick was attributed to nitrile, mustard oil glycosides, and thiocarbamate glycosides (Fig. 4F–J) (Faizi et al., 1998). Drumstick roots, leaves, flowers, gum, and the aqueous infusion of seeds were demonstrated to possess diuretic activity (Caceres et al., 1992) and such diuretic components are likely to play a complementary

role in the overall blood pressure-lowering effect. Furthermore, cholesterol-lowering properties of drumstick fruit and leaves were demonstrated (Ghasi et al., 2000; Mehta et al., 2003). In addition, antispasmodic activity of the roots and leaves of the drumstick plant was attributed to the presence of thiocarbamates (Dangi et al., 2002; Gilani et al., 1994). Furthermore, leaf and flower extracts were found to be antiulcerogenic and hepatoprotective (Nadro et al., 2006).

Several reports have documented the antimicrobial activities of root, leaf, flower, and bark extracts, which was attributed to the presence of 4-α-L-rhamnosyloxy benzyl isothiocyanate, aglycone of deoxy-niazimicin and a peptide (Nikkon et al., 2003; Suarez et al., 2005). Drumstick was also reported to exhibit other diverse activities (reviewed in Anwar et al., 2007). One of the most important bioactivity of drumstick, reported in the literature, was against different types of tumors and cancers. Drumstick leaves were found to be a potential source for antitumor activity. Several compounds isolated from drumstick such as *O*-ethyl-4-(α-L-rhamnosyloxy) benzyl carbamate, 4(α-L-rhamnosyloxy)-benzyl isothiocyanate, niazimicin, and 3-*O*-(6'-*O*-oleoyl-β-D-glucopyranosyl)-β-sitosterol showed significant inhibitory effects on Epstein-Barr virus early antigen (Murakami et al., 1998). On the other hand, niazimicin was proposed as a potent chemopreventive agent for chemical carcinogenesis (Guevara et al., 1999). Although numerous studies were conducted using different parts of drumstick, very little information is available related to isolation and identification of new compounds from different parts of the tree. Although preliminary studies are underway in different laboratories to determine the potential of drumstick seed as antispasmodic, antiinflammatory, antihypertensive, and diuretic activities, it will be prudent to include the scope of these studies to understand the in vivo effect of various bioactive compounds and their mode of action.

AMARANTH

Amaranth is one of the few cultivated plants used both as a vegetable and cereal. Amaranth is also cultivated for their ornamental and forage value. Several species, notably *Amaranthus tricolor* and *A. dubius*, are commonly grown as leafy vegetables in Eastern Asia, whereas *A. cruentus* is cultivated in West Africa. *Amaranthus cruentus*, *A. hypochondriacus*, and *A. caudatus* are pale-seeded cultivated varieties developed in pre-Columbian times for their edible grain; these continue to be grown on a small scale in Mexico, Central America, and parts of South America (Harley and Ehleringer, 1987). Amaranth is rich in antioxidants (Kelawala and Ananthanarayan, 2004), β-sitosterol, and other phytosterols (Marcone et al., 2003). Several studies have documented the cholesterol-lowering property of different species of amaranth (Berger et al., 2003; Czerwinski et al., 2004) in animal models. It needs to be emphasized that most

of the studies related to health-promoting properties were conducted on amaranth grains, which is normally used as cereal. Therefore, different processing products such as extruded amaranth were used in previous studies to understand the health-promoting properties. Research is required to establish the correlation between the bioactive compounds present in the leaves and the health-promoting properties.

Amaranth seems to provide gastroprotection against absolute ethanol (Zayachkivska et al., 2005). Trypsin–chymotrypsin inhibitor protein isolated from amaranth was found to inhibit the anchorage-independent growth of MCF-7 breast cancer cells (Tamir et al., 1996). Amaranthin, a lectin, isolated from the seeds of *Amaranthus caudatus* was used as a detection tool in colon cancer diagnosis (Tetsutaro and Jürgen, 1994). A few major secondary metabolites of *Amaranthus* spp. are presented in Fig. 5. However, further research is needed to establish the effect of these compounds on human health by conducting cohort and randomized controlled human clinical trials.

CLUSTER BEAN (*CYAMOPSIS TETRAGONOLOBA* L.)

Cluster bean (*Cyamopsis tetragonoloba* L.) is a native of the Indian subcontinent and widely distributed across Africa and Asia. The cluster bean is being cultivated in smaller area of certain states in the United States and Australia. The immature pods of cluster bean are used as a vegetable in India. The seeds are source of guar-gum, a galactomannan storage polysaccharide, which was reported to help in irritable bowel syndrome and reduction in serum cholesterol and diabetes as well as used for targeted delivery of drugs to the colon (Jenkins et al., 1979). In a study, conducted with 25 non-obese volunteers, guar-gum increased the effect of insulin, lowered the glucose and lipid concentrations as well as plasminogen activator inhibitor-1 activity and blood pressure without affecting body weight (Landin et al., 1992). Another study reported a significant reduction in fasting blood glucose and serum total cholesterol over a 3-month period by guar-gum consumption. However, the metabolic conditions of patients with diabetes did not improve in the same study (Uusitupa et al., 1989). Furthermore, a guar-gum-based diet was reported to reduce total and low-density lipoprotein cholesterol levels (Khan et al., 1981). Another line of evidence indicates that guar-gum may be beneficial for reducing body weight. It was suggested that guar-gum increases the viscosity of the bowel content and the feeling of postprandial fullness, which in turn may reduce appetite and food intake (Blackburn et al., 1984; Tuomilehto et al., 1989). In addition, guar-gum was suggested to exert an action on glucose absorption by impairing diffusion rate (Lembcke et al., 1984), which may lead to a prolonged period of glucose uptake in the intestine and consequently a prolonged influence on blood glucose and possibly on insulin levels. These results, along with the fact that

Fig. 4. Bioactive compounds of Drumstick (A) quercetin, (B) kaempferol, (C) moringine, (D) chlorogenic acid, (E) benzylisothiocyanate, (F) niazimicin, (G) 4(α-L-rhamnosyloxy) benzyl isothiocyanate, (H) 4(4'-Oacetyl-α-L-rhamnopyranosyloxy) benzyl isothiocyanate, (I) 4(α-L-rhamnosyloxy)benzyl isothiocyanate, (J) Pterygosperrmin.

Fig. 5. Bioactive compounds of *Amaranthus* spp. (A) Amaranthine, (B) Riboflavin, (C) Catechin, (D) Procyanidin.

other nutrients may be absorbed at a lower rate, may affect satiety. Although accumulating evidence suggests that guar-gum consumption may be beneficial, studies related to specific bioactive compounds and their

structure–function relationship needs to be carried out to fully understand their mechanism of action. It is very important that both positive and negative effects of these vegetables need to be understood. Further

Table 3. Proximate and nutrient compositions of selected crops indigenous to Asia and Southeast Asia.

		Amaranth leaves	Bitter melon	Fenugreek seeds	Drumstick leaves
Proximates (per 100 g fresh wt)					
Water	G	91.69	94.03	8.84	78.66
Energy	Kcal	23	17	323	64
Protein	G	2.46	1	23	9.4
Total lipid (fat)	G	0.33	0.17	6.41	1.4
Carbohydrate, by difference	G	4.02	3.7	58.35	8.28
Fiber, total dietary g			2.8	24.6	2
Minerals (per 100 g fresh wt)					
Calcium	mg	215	19	176	185
Iron	mg	2.32	0.43	33.53	4
Magnesium	mg	55	17	191	147
Phosphorus	mg	50	31	296	112
Potassium	mg	611	296	770	337
Sodium	mg	20	5	67	9
Zinc	mg	0.9	0.8	2.5	0.6

Source: USDA Nutrient Database (USDA-ARS, 2011).

research needs to determine toxicity of the guar-gum before reaching any conclusions about its potential benefits of risk reduction of certain diseases.

KANGKONG

Kangkong (*Ipomoea aquatica* Forsk), also known as Swamp Cabbage or Water Convolvulus, is widely cultivated throughout the world; however, it is regarded as an important leafy crop only in South and Southeast Asia. Kangkong is a very rich source of β -carotene, riboflavin, and ascorbic acid (Ismail and Fun, 2003). In addition, kangkong is reported to be a good source of total phenolics and consequently has a high total antioxidant activity (Ismail et al., 2004).

Kangkong is a good source of β -carotene with good bioavailability. In a feeding trial of rats, conversion of β -carotene to liver retinol for the first 2 weeks was efficient (Tee et al., 1996). However, poor conversion of β -carotene to retinol after 2 weeks was observed. This loss in conversion of β -carotene to retinol was attributed to the poor conversion and incomplete consumption of the all the vegetables as a result of poor acceptance by the animals. Lutein, another carotenoid found in kangkong, was present in high concentrations in the liver of the rats fed with a kangkong diet. In another study, kangkong was found to reduce the absorption of the cholesterol by increasing the fecal excretion (Chen et al., 1984).

Kangkong is an important constituent of the South and Southeast Asian diet. However, the nutritional composition of kangkong was not elucidated until now, suggesting an opportunity for investigation of different components of this important vegetable. Furthermore, exploration of human health properties by isolating and identifying the specific bioactive compounds is required. Although one study demonstrated lower absorption of cholesterol in rats, more detailed studies are critical to establish the “proof of the concept” of kangkong’s potential in reducing cholesterol. Moreover, the effect of kangkong on different biological activities, which eventually affect human health, needs to be investigated.

CONCLUSION

Indigenous vegetables are considered an important part of the diet in Asia and Southeast Asia. However, in recent times, FAVs are being replaced by more convenient foods. This trend also correlates with an increased incidence of chronic diseases such as cancer and cardiovascular diseases. Literature suggests that these indigenous vegetables may contain certain health beneficial properties. In addition, these vegetables are excellent sources of various nutrients (Table 3). However, their potential for human health benefits has not been explored to the full potential. Therefore, there is an apparent need to evaluate these indigenous crops for their bioactive components and effect on various chronic diseases. Such studies may provide the necessary information to incorporate these vegetables in a dietary regime for prevention or sustenance of health in disease conditions. The incorporation of these crops in the dietary regime may also reduce the healthcare cost. In this review, we have presented the information about only certain indigenous vegetables grown in Southeast Asia, but there are a number of indigenous crops grown and used in different parts of world. These crops should be explored for their potential health-promoting properties. It is clear that certain indigenous crops play an important role in reducing hunger and providing protection against several deadly diseases. This goal is possible only after conducting more research from “farm to consumer” including randomized clinical trials to provide a complete “proof of concept” of the potential of the indigenous crops.

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