Monk fruit (*Siraitia grosvenorii*) - health aspects and food applications

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ABSTRACT: Monk fruit (*Siraitia grosvenorii*) commonly called as Luo Han Guo is a perennial herb and generally cultivated in Guangxi province of China. Traditionally the fruit was used in folk medicine for the treatment of several common diseases like cough, cold, sore throat, constipation and dire thirst. Studies over past decades advanced the knowledge of bio-chemical and pharmacological properties of monk fruit. Till now, several compounds have been identified and isolated from monk fruit, mainly triterpenoids, flavonoids, essential oils, amino acids, vitamins, minerals and polysaccharides. A triterpene glycoside consists of a group of mogrosides which are mainly considered to be responsible for higher biological effects of monk fruit. The mogroside extract of monk fruit gives >300 more sweetness as compared to 5% sucrose solution without giving extra calories during consumption. Biochemical properties as well as health benefits of monk fruit including scope for its utilization in food and beverage industries for the development of low calories products for diabetics and health conscious consumers are discussed in this article.

Key words: Luo Han Guo, monk fruit, mogroside, natural sweetener, non-nutritive sweetener

Monk fruit is indigenous to China and Indonesia and is one among seven species belonging to genus *Siraitia*. Among seven, *Siraitia grosvenorii* species is principally cultivated for more than 200 years in Guangxi province of China which accounts more than 90% of the global production (Liu *et al*., 2016a). The fruit of *Siraitia grosvenorii* is commonly known worldwide as monk fruit and regionally as Luo Han Guo. It is a perennial herb and belongs to family Cucurbitaceae. It contains diverse bioactive compounds which are considered to be good for health. Traditionally, the fruit is used as a natural sweetener of foods and also as a household remedy for nourishing the lungs, treating sunstroke, dire thirst, constipation, sore throat, cough and cold (Shen *et al*., 2014; Yan *et al*., 2010). Monk fruit contains essential oil, saccharides, proteins, vitamins and flavons. It is also rich in several triterpene glycosides, commonly known as mogroside (Fig. 1) having high biological effects and sweet taste (Li *et al*., 2014). A group of mogroside principally contains mogroside IV, V and VI, siamenoside I and 11-oxo-mogroside V, considered to be mainly responsible for strong sweetening property of monk fruit. The mogroside extract from ripe monk fruit could be an ideal replacement of sugar for diabetic and obese patients due to its high level of sweetness (>300 times) and low calorific value than sucrose (Fang *et al*., 2017). The relative sweetness of individual triterpene glycosides, i.e. mogroside IV, V, siamenodie I and 11-oxo-mogroside V were found 392, 425, 563 and 84 times higher than sucrose (Suzuki *et al*., 2007). In 1987, China's Ministry of Health enlisted monk fruit as an edible species and medicine. The countries like Australia, Japan, United States and New Zealand also approved the products of monk fruit as a dietary supplement. Japan approved mogroside V as a natural sweetening agent. Whereas, in 2010, the extract of monk fruit was approved in USA as generally recognized as safe (GRAS) for non-nutritive sweetening and flavor enhancing purpose (Tu *et al*., 2017). The quality parameters of monk fruit extract containing different level of mogroside percentage are described as GRAS (Table 1). In recent years, pharmacological studies have shown several health protective properties of monk fruit such as liver protection, anti-oxidative, anti-hyperglycemic, anti-asthmatic, anti-cancer and anti-inflammatory action (Li *et al*., 2014). Now-a-days, several health protective food products are also developed by the researchers from monk fruit such as jam (Shi *et al*., 2009), chocolate (Heine, 2017), sweet juice (Suzuki *et al*., 2007; Murray, 2018) etc. Monk fruit is also introduced as a non-nutritive table top sweetener by a leading manufacturer. Moreover, the manufacturers like Coke and Kashi introduced several products containing monk fruit extract as such (Tu *et al*., 2017).

The increasing demand of non-nutritive sweeteners from natural sources increased the popularity of monk fruit in international market including nutraceutical, food and beverage industries (Pawar *et al*., 2013). But, the cultivation of monk fruit is restricted to only limited area of China and Indonesia, therefore, availability of monk fruit is insufficient and only small amount in the form of dried fruits and extract are supplied to other countries. Low production rate and high market demand leads to higher trade price for monk fruits and its products (Konoshima and Takasaki, 2002). Several studies reported that monk fruit is one of the best natural sweetener substitutes for sucrose, but owing to unaffordable price, it is restricted to only pharmacological

uses. However, there is a great scope for utilization of monk fruit extract as a sugar alternative in low calories health protective food for diabetics and obese patient worldwide. In this article biochemical properties of monk fruit, its role in preventing several diseases and application in development of sugar free low calories foods including studies on development of non-nutritive natural sweeteners are summarized.

Biochemical Properties of Monk Fruit

Several compounds of different classes, such as polysaccharides, amino acids, essential oils, flavonoids, triterpenoids and nucleosides etc. have been identified and extracted from various parts of monk fruit. The composition of monk fruit is presented in Table 2; whereas, the composition of amino acid hydrolysate and mineral content of monk fruit extract are presented in Table 3. Glycosides, a group of triterpenoids, are mainly considered as one of the major biologically active compound of monk fruit. Development of cucurbitane glycosides in monk fruit starts at a specific period of time after pollination. Generally, monk fruit is harvested after ripening and the development of various mogrosides in monk fruit starts at different period of time after pollination and during maturation (Table 4). Till now, up to thirty cucurbitane glycosides have been identified in monk fruit (Li *et al*., 2014). However, only few compounds, like mogroside III, IV, V and siamenode I, were studied for their functional properties (Jin and Lee, 2012). The molecular formula and sweetness properties of widely studied major and minor cucurbitane glycosides are presented in Table 5.

Role of Monk Fruit on Prevention of Diseases

Anti-hyperglycemic and anti-diabetic property

Monk fruit extract and mogrosides not only work as a natural sweetener but also exhibit anti-diabetic activity by enhancing the rate of blood glucose uptake and have potential benefits for diabetic patients. Several *in-vitro* and *in-vivo* studies were conducted over last decade to determine the effectiveness of monk fruit extract and mogrosides on blood glucose level and diabetes. Mogroside V and some other minor elements of monk fruit extract can significantly suppress increase in maltose induced blood glucose level by the inhibition of intestinal maltase (Suzuki *et al*., 2005). Oxidative stress is also found as one of the major causes responsible for pathogenesis of diabetes. The extract of monk fruit has high antioxidative properties which can potentially suppress the oxidative stress mediated diabeties (Song *et al*., 2007). Qi *et al*. (2008) observed that supplementation of mogrosides extract of monk fruit significantly reduced the level of oxidative stress, hyperglycemia and hyperlipidemia in diabetic mice. They also found strong free radical scavenging activities of mogroside V which is the major component of mogroside in *in-vitro* study. The result showed that administration of monk fruit extract could be helpful in preventing hyperglycemia and diabetic complications in human. Zhou *et al*. (2009) also found monk fruit extract and mogroside V as a potential natural sweetener with a low glycemic index. They observed a significant activity of monk fruit extract and purified mogroside V for stimulation of insulin secretion in pancreatic beta cells. Afterwards, Chen *et al*. (F) suggested that the product of acid hydrolysis of monk fruit mogrosides, i.e. triterpenoids, might be potential AMPK activators in humans. Monk fruit extract can also be used for sweetening of tea as a natural sugar substitute and is comparable with sugar sweetened tea. Monk fruit extract sweetened tea has positive effects on reducing blood glucose level and metabolism of streptozotocin-induced diabetic mice (Lee *et al*., 2016). The level of glucose tolerance and rate of blood glucose increase can be decreased by the administration of monk fruit extract sweetened tea. Monk fruit extract sweetened tea was also found effective in overcoming problems like weight loss, liver function and lipid metabolism caused by streptozotocin-induced diabetes in mice. Li *et al*. (2017) purified eighteen mogrosides from the monk fruit extract and evaluated for their anti-diabetic activity in human HepG2 cells *in-vitro*. Their study showed that all mogrosides isolates of monk fruit extract significantly increased the glucose uptake in HepG2 cells, but the mechanism underlying still remains unclear.

Anti-obese property

Obesity is one of the widespread diseases but it causes are still unclear. According to the report of International Obesity Task Force (IOTF), obesity is a major life style related disease observed worldwide. Consumption of high caloric foods in excess stimulates abnormal excessive growth of adipose tissue and leads to obesity. Till date, several therapeutic medicines are developed to suppress the appetite, inhibit pancreatic lipase or inhibit α-glucosaccharides etc. to control obesity. However, long term consumption of these medicines causes adverse effect on health such as gastrointestinal disorder. Several studies reported wide pharmacological effects of Mogrosides. San *et al*. (2012) studied anti-obesity property of total mogrosides extracted from monk fruit as well as, mogrosides IV and V by analyzing there effect on pancreatic lipase *in-vitro*. They found significant inhibitory effect of total mogrosides, mogrosides IV and V on pancreatic lipase activity. The increase in body weight as well as triglyceride and total cholesterol level in mice was suppressed during *in-vivo* study by the oral administration of mogrosides. They also observed that triglyceride content of mice plasma was reduced within 1

to 3 hr after oral administration of total mogrosides with lipid emulsion pre-mix.

Anti-fatigue property

Fatigue could be best defined as difficulty in initiating or sustaining voluntary activities. It is a common symptom in both sickness and health and can be subcategorized into physical and mental fatigue. Physical fatigue mainly arises due to excessive or intense exercise which leads to not only accumulation of lactic acid in muscles but also changes energy metabolism. Sensation of muscle fatigue partially contributes to mental fatigue where lassitude, sleepiness and reduced motivation are the common symptoms that can be often observed after intense exercise. Moreover, patients suffering from cancer disease also experience fatigue and weakness along with high levels of pain. Liu *et al*. (2013) studied monk fruit extract for its anti-fatigue effect *in-vivo* model. Their study includes oral administration of mice with variable doses of monk fruit extract. They reported that administration of monk fruit extract increased the glycogen level of liver and muscle without increasing the level of serum urea nitrogen and blood lactic acid during forced swimming test of experimental mice. They also observed that monk fruit extract significantly improved physical fatigue of experimental mice but the effect was dose-dependent.

Anti-cancer property

Natural products have an important role in cancer prevention. Now-a-days, several chemicals used clinically for cancer therapy are derived from plant sources. Konoshima and Takasaki isolated non-nutritive natural sweeteners from plant source such as stevioside from *Stevia rebaudiana* leaves and mogroside V from monk fruit and studied for their chemo-preventive properties *in-vitro* and *in-vivo* model (Konoshima and Takasaki, 2002). They used 2 different combinations of chemicals, i.e. peroxynitrite and TPA (12-O-tetradecanoylphorbol-13-acetate), DMBA (7, 12-dimethylbenz anthracene) and TPA to induce two-stage skin carcinogenesis *in-vivo*. Their study showed that oral administration of mogroside V significantly worked against chemically induced carcinogenesis and had more potent activity against tumor than glycyrrhizin, a well known antitumor-promoter in chemical carcinogenesis. They also observed delay in formation of mice bore papilloma on TPA promoted two stage mouse skin carcinogenesis by the treatment of mogroside V. Liu *et al*. (2016a) studied anti-pancreatic cancer properties of a natural food sweetener, mogroside V, extracted from monk fruit. They found that mogroside V shows a potent anti-tumor activity against pancreatic cancer by targeting multiple biological targets such as promoting apoptosis and cell cycle arrest of pancreatic cancer cells in both *in-vivo* and *in-vitro* models. They demonstrated that administration of mogroside V might be useful as a potential drug that can suppress the growth and survival of pancreatic tumor cells through reducing vascular density and inhibiting angiogenesis. In another study, Liu *et al*. (2016b) also reported that proliferation of colorectal cancer HT29 and throat cancer Hep-2 cells in culture and

Table 1: US FDA GRAS specification for monk fruit extracts containing different mogroside V concentration

Parameter	GRAS Specification		Test Method
Assay: Mogroside V	≥25% to ≥30%	≥50% to ≥95%	CP2010
Color	Brown Yellow	White	GB/T 5495-2008
Odor	Mild fruity characteristic	Mild fruity characteristic	GB/T 5495-2008
Taste	Sweet	Sweet	GB/T 5495-2008
Sieve Analysis	NLT 95% pass 80 mesh	NLT 95% pass 80 mesh	CP2010
Method of Extraction	Water	Water	-
Moisture content	≤5.0%	≤5.0%	USP31-921
Ash	≤5.0%	≤5.0%	USP31-281
Mercury (Hg)	≤0.1 ppm	≤0.1 ppm	USP39<2232>
Arsenic (As)	≤0.5 ppm	≤0.5 ppm	USP39<2232>
Cadmium (Cd)	≤0.05 ppm	≤0.05 ppm	USP39<2232>
Lead (Pb)	≤0.5 ppm	≤0.5 ppm	USP39<2232>
Residual Ethanol	≤500 ppm	≤500 ppm	USP 37
Total Plate Count	≤1000 cfu/g	≤1000 cfu/g	AOAC 990.12
Salmonella	Negative	Negative	AOAC 2004.03
Yeast & Mold	≤100 cfug	≤100 cfug	ISO21527-1:2008
E. coli	Negative	Negative	AOAC 991.14

GB/T = Recommended Chinese National Standard; cfu = Colony Forming Units; CP = Chinese Pharmacopia; AOAC = Association of Official Analytical Chemists; USP = United States Pharmacopeia (*Source:* GRAS, 2017).

Table 2: Composition of fresh monk fruit

Composition	Content	Reference
Fat	0.8%	
Protein	7.1-7.8%	
Polysaccharides	2.88-5.65%	
Total sugar	25.17% - 38.31%	
Reducing sugar	16.11-32.4%	
Glucose	0.8%	(Xia, 2006; Li and Xiao, 2008)
Fructose	1.5%	
Thiamine (Vitamin B1)	338 mg/100 g	
Riboflavin (Vitamin B2)	123 mg/100 g	
Ascrobic acid (Vitamin C)	339-461 mg/100 g	
Total flavones	5-10 mg/100 g	
Total glycosides	1.19 mg/100 g	

Table 3: The amino acid hydrolysate and mineral composition of fresh monk fruit extract

Amino acid hydrolysate		Minerals				Reference
Amino Acids	Content g/100g (*db*)	Element	Content (ppm)	Element	Content (ppm)	
Aspartic acid	0.90	Mn	22.70	V	00.20	
Threonine	0.25	Fe	29.20	Co	00.10	
Serine	0.35	Ni	01.80	Se	00.20	
Glutamic acid	0.55	Zn	12.80	Sn	00.20	
Glycine	0.36	Mg	550.00	As	00.10	
Alamine	0.53	Ca	667.50	I	01.00	(Moore, 1999;
Cystine	0.24	Pb	00.07	Si	645.00	Xia 2006)
Valine	0.47	Cu	00.50	F	00.90	
Methionine	0.20	K	12290.80	Mo	00.40	
Isolucine	0.40	Na	16.50	-	-	
Leucine	0.50	Cd	00.02	-	-	
Tyrosine	0.28	Sr	01.70	-	-	
Phenylalanine	0.32	Ba	03.30	-	-	
Lysine	0.31	Cr	00.50	-	-	
Histine	0.18	Al	07.70	-	-	
Arginine	1.28	Be	0.01	-	-	
Proline	0.27	Ti	00.30	-	-	

in xenografted mice can be inhibited by mogroside IVe in a dose dependent manner. They observed that biologically-active phytochemical of monk fruit, i.e. mogroside IVe, worked as a potential supplement for the treatment of patients suffering from colorectal and throat cancers.

Monk Fruit in Food Processing

Sweet foods are highly relished by the consumers and popular worldwide. Sugar is the natural sweetener widely used for sweetening of food products. In food and beverage industries manufacturers generally use sugar in the form of sucrose, fructose and glucose to increase the sweetness of their products. Several studies revealed harmful effects of sugar consumption in humans. Aside from causing hyperglycemia and diabetes, excess intake of nutritive sweeteners may also results low immune response, metabolic disorders, dental problems, cancer, etc. (Woodyer *et al*., 2018). Now-a-days, consumers are aware of the harmful effect of refined sugar, which decreases their tendency to consume high sugar containing foods and beverages. Therefore, innovative and customized uses of non-nutritive natural sweeteners are encouraged for focused use and optimal benefits. The use of natural sweetener in functional foods has several benefits like providing required sweetness without giving extra calories, prevent radical increase in blood glucose level and does not have side-effects during long term consumption. There are several known non-nutritive sweeteners used in food processing to reduce adverse effect of traditionally refined sugar. However, monk fruit extract is found to be one of the most suitable low calorie natural sugar substitutes. It is particularly effective during treatment of diseases which require low or moderate sugar intake such as diabetes, obesity, hypertension and heart

Table 4: Emergence of glycosides, sweetening properties and harvesting period of Monk fruit

S. No.	Sweetening components	Period after pollination	Reference
1	Mogroside II E	5 days	
2	Mogroside III	30 days, highest content after 55 days	
3	Flavonol glycosides	40-50 days	
4	Mogroside V	50 days	(Li *et al*., 2014)
5	Mogroside IV A and Mogroside IV E	55 days and reach to highest after 70 days	
6	Development of main sweet component	85 days	
7	Harvesting Period	90 days	

Table 5: Some known cucubitane glycoside compounds isolated from monk fruit

		Major cucurbitane glycosides	
S. No.	Sweet glycosides	Chemical formula	Sweetness property in comparison to 5 % sucrose solution
1	Mogroside IV	C54H92O24*H2O	392 time more sweetness
2	Mogroside V	C60H102O29*2H2O	425 time more sweetness
3	Mogroside VI	C66H112O34	Less Sweeter than Mogroside V
		Minor cucurbitane glycosides	
4	Siamenoside I	C54H92O24*7/2H2O	563 time more sweetness
5	11 – OXO – mogroside V	C60H100O29*7/2H2O	Organoleptically sweet
6	Mogroside II E	C42H82O19	Taste less
7	Mogroside III	C48H82O19	Taste less
8	Mogroside III E	C48H82O19	Taste less
9	Mogroside A	C42H92O14*3H2O	-
10	Neomogroside	C66H112O34*5H2O	-
11	Mogroester	C44H92O4	-
12	Grosmomoside I	C54H92O24	-

(*Source:* Xia, 2006)

disease (Li *et al*., 2014). Over last decades, several studies confirmed pharmacological properties of monk fruit extract and its effectiveness against chronic diseases. Currently, researchers are also willing to establish monk fruit as a natural substitute of sugar in developing functional foods which have multiple health benefits against life style related problems (Konoshima and Takasaki, 2002;Chen *et al*., 2011; Heine, 2017).

The effect of processing on functional properties of monk fruit extract is also one of the major concerns while developing functional foods. Vacuum drying of monk fruit extract retains higher amount of major glycosides when compared with traditional drying methods (Zhou and Zhu, 2014). However, till date, only few products such as a non-nutritive sugar, syrup, jam, chocolate food product and skim chocolate milk etc. have been developed using monk fruit as a non-nutritive natural sweetener. Shi *et al*. (2009) patented a process for developing syrup and jam from monk fruit, where peel and pulp of fruit was extracted in continuous boiling water. They developed syrup and jam comprising natural flavor of whole monk fruit extracts with sugar-free, low calorie and low glycemic index properties. They found that developed syrup could be a better replacement of refined sugar in all sorts of situations like baking and cooking formulations, sweetening of tea or coffee or can be used as breakfast syrup. They also claimed that syrup and jam have a therapeutic function against diabetics as well as beneficial to people who worry about their health due to high calorie and sugar intake.

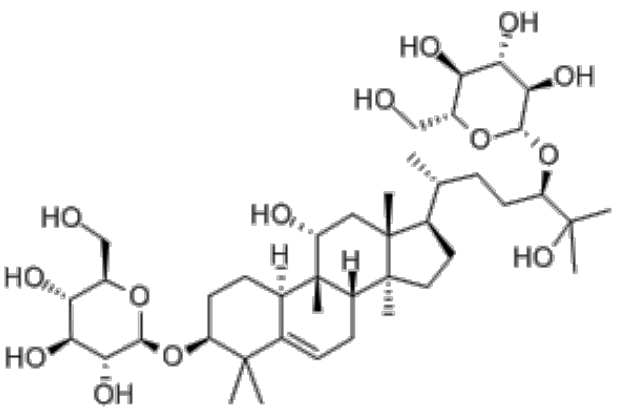

Fig. 1: Mogroside structure

Dark chocolate contains high percentage of cocoa but the consumption of chocolates by diabetics still remains problematic. Many individuals especially those who are suffering from diabetics avoid consuming cocoa based chocolates due to its high sugar, fat and starch content. Despite added benefits of cocoa most of the chocolates available in the market are still rich in sugar and fat including dark chocolate. A few chocolates developed recently with sugar substitute contain complex carbohydrates such as starch, maltitol,

isomaltooligosaccharides, crytritol etc. to provide texture, sweetness, mouth-feel and stability to the developed product. These added complex carbohydrates are undesirable due to their impact in digestion and insulin secretion during the time. Heine developed a chocolate food product free from added sugar using monk fruit blend preferably monk fruit fiber and fruit extract that have smooth flavor profile of chocolate (Heine, 2017). The developed chocolate food was low in fat and complex carbohydrates which could be beneficial to those who are insulin resistant or suffering from diabetes or have sensitivity towards sugar, gluten and indigestion.

Several studies were conducted in recent years to optimize the extraction efficiency of sweetening compounds and development of various sweetening compositions containing monk fruit. Zhang and Li (2017) developed a commercial process for extraction and purification of mogroside V from monk fruit. The extraction efficiency of the process can be increased up to 90% for commercial operation but higher extraction could increase the overall cost of production. They found that the taste profile of extracted mogroside V extract is similar to refined sugar and can be blended with variety of foods and beverages to reduce negative properties and customize sweetening goals.

Turner studied the effect of various sweetener compositions including natural sweeteners (Turner, 2017). They compared natural sugar composition containing stevia or monk fruit and their combination with various compositions of conventional as well as non-conventional sugars such as saccharine, dextrose, ribaudioside, sucralose etc. Natural sweetener composition has shown similar properties as in conventional sugar during various quality tests like sugar similarity test, yellow cake bake test, caramelization test, chocolate bar test and tea test, whereas, non-conventional sweetener failed the test. However, natural sweeteners were also found to have positive effect on glycemic test and repression test beyond the property of conventional sugar.

Recent studies show that development of non-caloric natural sugar containing mogrosides extract of monk fruit exhibit an off-taste and less desirable sensory profile. Studies show that presence of some mogrosides is responsible for development of off-flavor and/or undesirable sensory profile of natural sweeteners. Although, Quinlan and Zhou (2017) developed a non-caloric sweetener composition with improved taste and reduced aftertaste using naturally obtained glycosides. The developed sweetener composition contains mogroside extract of monk fruit and sweet steviol glycosides of *Stevia rebaudiana* i.e. rebaudiosides A and B. They claimed that the developed sweetener compositions are useful for non-caloric replacement of sugar in almost all foods and beverages. They also reported that the addition of rebaudioside B to a threshold level helps to reduce the perceived bitterness and taste profile and, therefore, improved the acceptability of developed sweetener composition. Woodyer *et al*. (2018) developed a natural sweetener composition using allulose and a single mogroside extract of monk fruit with improved taste and sensory profile. Allulose, a monosaccharide, is a known rare sugar available naturally in very small amount. It provides only around 70% of the sweetness and around 5% calories compared to sucrose. They found that the small amount of developed composition is required to achieve similar properties as sucrose with a significant reduction in calories. The developed composition can be used for satisfying the wide aspects of food and beverage industries including pharma products, sports products, cosmetics and also can be used as a table top sweetener.

Future Prospects of Monk Fruit

Literature reports suggest a wide scope for utilization of monk fruit in food and beverage industries including nutralceutical and pharmaceutical industries but very few studies are available on functional foods containing monk fruit extract or powder for targeted benefits (Heine, 2017; Liu *et al*., 2016; Shi *et al*., 2009). Effect of thermal processing of monk fruit still remains unclear, however, a few studies reported that the monk fruit extract can be used to develop low caloric sweetened bakery products where processing temperature generally remains above 150°C (Zhou and Zhu, 2014). Therefore, studies on effect of high temperature processing on known benefits of non-nutritive natural sweeteners including monk fruit need to be carried out. Till date, most of the sweetened products available in the market contain high caloric natural sweetening agents and could be replaced partially or completely using non-nutritive natural sweeteners. Use of monk fruit extract as a natural sweetening agent in foods and beverages can reduce the threat associated with today's life style and could also be beneficial to those who are suffering from diabetics and other diseases where low or controlled caloric intake is required. Studies on effect of non-nutritive natural sweeteners including mogrosides and monk fruit extract on humans during long term consumption could be a novel area of research in upcoming years.

CONCLUSION

Monk fruit is an excellent source of triterpinoids, a group of mogrosides responsible for higher sweetness and pharmacological properties of fruit. Mogroside extract of monk fruit gives higher (>300 times) sweetness as compared to sucrose with low or no caloric value. Several foods sweetened with mogrosides or monk fruit extract have shown significant reduction in glycemic index and

diabeties. The non-nutritive natural sweetener compositions developed using monk fruit have also shown similar taste and other sensory attributes as sucrose. As such, monk fruit as sweetener shows a wide scope for its use as a table top sweetener as well as in different food, confectionary, beverage and pharmaceutical industries.

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