MOGROSIDES FROM MONK FRUIT: NATURAL SWEETENING COMPOUNDS WITH THERAPEUTIC POTENTIAL

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ABSTRACT:

Mogrosides are a group of naturally occurring cucurbitane-type triterpene glycosides isolated from *Siraitia grosvenorii* (monk fruit), widely recognized for their intense sweetness and negligible caloric value. Beyond their application as natural sweeteners, mogrosides have attracted growing scientific interest due to their diverse therapeutic properties. Experimental studies have demonstrated antioxidant, anti-inflammatory, antidiabetic, anti-obesity, hepatoprotective, and anticancer activities, suggesting their potential role in the prevention and management of metabolic and chronic diseases. Mogrosides, particularly mogroside V, exhibit favourable safety profiles and do not induce glycemic spikes, making them suitable alternatives for individuals with diabetes and metabolic syndrome. Additionally, emerging evidence indicates their modulatory effects on oxidative stress pathways, inflammatory mediators, and glucose and lipid metabolism. This review summarizes the phytochemistry, pharmacological activities, mechanisms of action, and therapeutic prospects of mogrosides, highlighting their potential as functional food ingredients and promising candidates for future nutraceutical and pharmaceutical applications.

Key words: Mogrosides; Monk fruit; Natural sweeteners; Antidiabetic activity; Antioxidant potential; Nutraceuticals.

INTRODUCTION:

The monk fruit contains monopolized by Cucurbitane-type triterpene glycosides, called as mogrosides[1], Monk fruit extract is a natural sweetener obtain from the of the monk fruit tree(*Siraitia grosvenorii*), also called "Luo Han GUO" or "Lo Han Kuo"[2,3]. The monk fruit is cultivated in huge scale of southern part China, mainly in mountain area of Guilin of the Guangxi province. The High concentration of Mogrosides came from sweetness of monk fruit extract. A group of Glycosides of Cucurbitane derivates found from the fruit. Monk fruit has much compounds are sweeter than sugar but don't contain any calories. Mogrosides are in general recognized as a safe (GRAS) according to the Food and Drug Administration (FDA)[4]. Monk fruit extract is good alternative of sucrose (table sugar) for people who wise to reduce their calorie intake. Monk fruit extract may be healthy sweetener for the patients with diabetics. The human body doesn't recognize mogrosides as carbohydrates or sucrose, they doesn't trigger an insulin response. Monk fruit extract has several health benefits. Apart from sweetening property, based on *in vitro* and *in vivo* studies have shown that the mogroside may have antioxidant and anti-inflammatory properties[5].

INCREASING DEMAND FOR NATURAL SWEETNERS:

Monk fruit contains essential oil, saccharides, proteins, vitamins and flavones. It is also rich in several triterpene glycosides, commonly known as **mogroside** which is responsible for high biological effects and sweet taste. A group of mogroside contains mogroside IV, V and

VI[6]. The non-nutritive sweeteners are increasing the demand from the natural sources are also increased in the popularity of monk fruit in international market including nutraceutical, food and beverage industries[7]. The monk fruit are cultivated in other areas and restricted only in limited area of China andIndonesiatherefore, availability of monk fruit is insufficient. Only small amount monk fruits in the form of dried and extract are exported to other countries. Low production rate and high market demand leads are also the reason for higher trade price for monk fruits and its products. In Several studies reported that monk fruit is one of the best natural sweeteners for the alternatives of sucrose, but owing to unaffordable price, it is restricted to only pharmacological uses. But yet, 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[8].

HEALTH CONCERNS WITH ARTIFICAL SWEETNERS

Sweetener Type	Name	Comparison with Sucrose	Health Benefits	Health Risks
Artificial	Aspartame[9]	~170 times	Low-calorie Sweetener	✓ Obesity ✓ Glucose intolerance ✓ Mood disorders ✓ Pre-mature birth ✓ Neurodegenerative effects[9]
	Sucralose[10]	~200 times	Low-calorie Sweetener	✓ Metabolic syndrome ✓ Type 2 diabetes ✓ Hypertension ✓ Obesity ✓ Potential Carcinogenic effect[10]
	Saccharin[11]	~400 times	Low-calorie Sweetener	✓ Obesity ✓ Diabetes ✓ Liver and renal impairment ✓ Brain carcinogenesis[11]
	Acesulfame potassium[12]	~120 times	Low-calorie Sweetener	✓ Increased body weight ✓ Metabolic disturbance ✓ Chronic inflammation in male rats[12]
	Neotame[13]	~7000 -13000 times	Low-calorie Sweetener	✓ Metabolic and ✓ Inflammatory disorders[13]
	Erythritol[14]	~ 1times	Low-calorie Sweetener	✓ Increases risk of heart attack ✓ Stroke ✓ Digestive issues[14]
	Xylitol[15]	~ 1 time	Low-calorie Sweetener	✓ Cardiovascular disease ✓ Increase risk of blood clot[15]

Natural	Yacon[16]	0.5 time	✓ Antioxidant ✓ Antimicrobial ✓ Antidiabetic, anti-cancer ✓ anti-obese weight management	✓ Digestive issues and ✓ Abdominal problems[16]
	Stevia[17]	✓ Rebaudioside A is 150–320 times ✓ Stevioside is 100–270 times	✓ Antioxidant ✓ Antibacterial ✓ Chemotherapeutic ✓ Immune modulating properties ✓ Helps in weight management by reducing appetite	✓ No known side effects but stevia may leave a slightly bitter or metallic aftertaste due to stevioside, while rebaudioside A is reported to lack this aftertaste.
	Monk Fruit [18]	~100 -250 times	✓ Antioxidant ✓ Anti-inflammatory ✓ Anti-obese ✓ Anti-carcinogenic ✓ Anti-diabetic	✓ No known side-effects

MONK FRUIT AND ITS TRADITIONAL USES

The fruits of Siraitia grosvenorii have a history with a display of wide range of biological activities, especially their therapeutic effects on throat disorder including tuberculosis and whooping cough. The fruits of Siraitiagrosvenorii have been used medicinally for over 300 years since where recorded, have a high nutritional value. Here Chinese herbs the first valuable to be included in medicine and food. Siraitiagrosvenorii was first recorded in the Chinese medical classic “Xiu Ren Xian Zhi” (Qing dynasty). Siraitia grosvenorii was described as herbal medicine with a diuretic effect, and function for alleviate the heat and treating coughs. Based on “Chong Xiu Lin Gui Xian Zhi” (Qing dynasty), Siraitia grosvenorii was described as a therapy for coughs caused by tuberculosis. In traditional Chinese medicine (TCM) therapy, Siraitia grosvenorii, widely used in TCM with few side effects, is sweet, slightly cold, and goes to the lung and large intestine meridian. The Chinese Pharmacopoeia recommends a dose of 9-15 g for Siraitiagrosvenorii, which has the properties of clearing away heat and moistening the lungs, relieving sore throat to restore voice, and loosening the bowel to relieve constipation. Clinically, the fruits of Siraitia grosvenorii a pharmaceutical preparation had similar effect.[19, 20, 21]

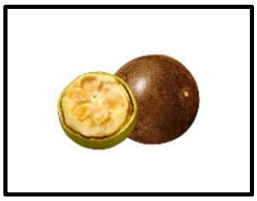
IMPORTANCE OF MOGROSIDES AS BIOACTIVE

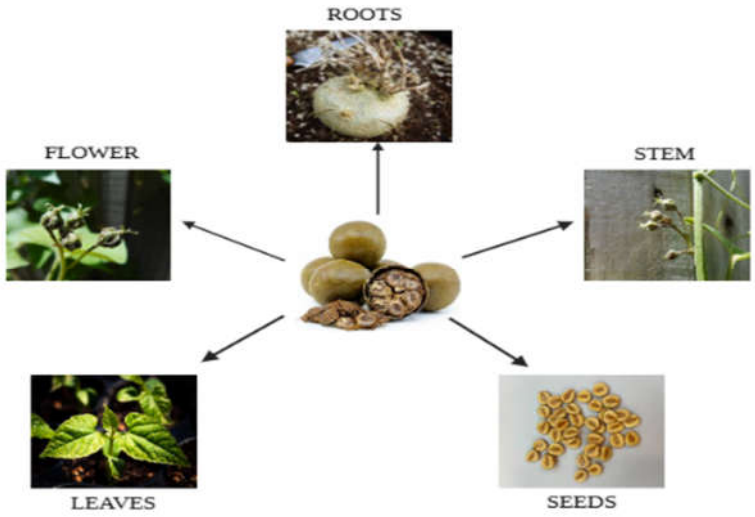
Fruits parts	Bioactive compound	Bioactivities	Reference
Dried fruits	✓ Siamenoside I ✓ Group of mogrosides comprising of IIe, III,	✓ Anti-carcinogenic Activity	[22]

	IIIe, IV, V ✓ Iso mogroside V		
Fresh fruit	✓ Grosvenorine I Grosvenorine Il ✓ Kaempferol-7-O-a-Lrhamnopyranoside ✓ 11-O-mogroside VI ✓ 7-O-mogroside III ✓ Mogroside VI/Neomogrosided ✓ Kaempherol ✓ Rutin ✓ Quercetin ✓ Kaemferol3O-b - rutinoside in addition to predominant group of mogrosides, i.e. IIa, IIe, III, IIIe, IVa, IVe, V ✓ 11-O-mogroside V	✓ Hypoglycaemic activity ✓ Antioxidant properties ✓ Anti-microbial properties ✓ Anti-inflammatory properties	[23]
Dried fruits	✓ Mogroside III ✓ mogroside IV siamenoside I ✓ mogroside V ✓ 11-oxomogroside V	-	[24]
Dried fruits	✓ Grosvenorine I grosvenorine II mogroside IIE/isomer ✓ 11-O-mogroside III mogroside III/isomer ✓ 11-Dehydroxy-mogroside IIImogroside/siamenoside I/isomer ✓ mogroside V isomer other similar compounds	-	[25]
Commercial monk fruit extract	✓ Mogroside Iva,IVe ✓ Mogroside V ✓ Iso mogroside V ✓ Mogroside VI ✓ 11- oxomogroside V ✓ Siamenoside I	-	[26]
Commercial monk fruit extract	✓ Mogroside III A2 ✓ 11-deoxymogroside III	-	[27]
Fresh unripe fruit	✓ Cucurbitane ✓ Triterpene glycosides ✓ Group of mogrosides Flavonoids	-	[28]

BOTANICAL PROFILE OF MONK FRUIT[29, 30]

PARTS	CHARACTERISTICS	PICTURE
ROOTS	✓ They havethick roots	
STEM	✓ Strong but flexible and spread along other plants for support.	
LEAVES	✓ Shape – Large & heart shape ✓ Length – 12 to 33 cm ✓ Width – 5 to 17 cm ✓ Tips – Pointed ✓ Texture – Soft ✓ Leaf stalks – 3 to 10 cm long	
FLOWERS	**FEMALE:** ✓ They are single and seen in small groups. ✓ They are slightly larger than the male flower and have a oblong, velvety ovary covered with yellow-brown hairs **MALE:** ✓ They are grown in clusters of 6-10 on long stalks (7-13). ✓ They are yellow with a bell-shaped base and small pointed tips.	

FRUITS	✓ Shape –Round & oval ✓ Length –6 to 11cm ✓ Width –4 – 8 cm ✓ Its hairs are covered with fine yellow-brown hairs and small blank scales. ✓ In younger's plant it becomes smooth when ✓ Mature	
SEED	✓ Color – Pale yellow ✓ Shape – Flat & Oval ✓ Length – 15 to 18 mm ✓ Width – 10 to 12 mm ✓ Edges – Wavy edges	



PHYTOCHEMICAL PROFILE OF MONK FRUIT:

Monk fruit Contains:

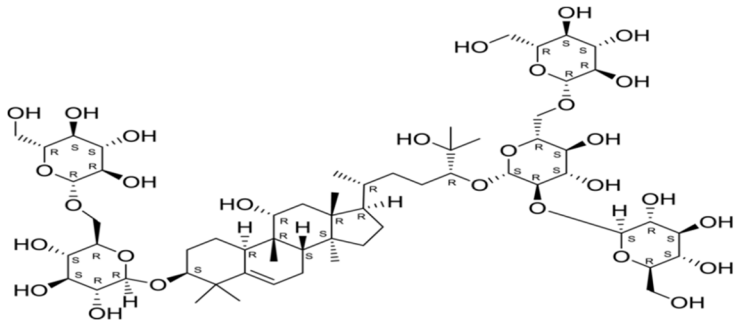
1. Carbohydrates
2. Protein
3. Fat
4. Vitamin
5. Minerals

The fruit is made up of polysaccharide and sugar like glucose and fructose[31]. It promotes the crude protein include all fundamental amino acid including Lysine, Valine, Methionine, Leucine, Isoleucine, Phenylalanine, Threonine and Histidine[32] on the other hand, seed kernels of monk fruit have been reported to contain 48.5% of fat[33]. Monk fruit contain ascorbic acid, thiamin and riboflavin[34]. The ripe monk fruit also accept with 14 essential traces Element with the highest amount of potassium, calcium and magnesium and other such as Fe, Zn, P, Mn, Cu, Al, Pb, I, Cd, Ni and Se[35].Monk fruit consists of various bioactive constituents. The major bioactive compound present in monk fruit are glycosides that have cucurbitane-type

Triterpenes[36]. In Cucurbitane it types has 26 Form of triterpene Glycoside has identified, among these, 3 types are Triterpene were aglycone, 2 types of pentacyclic triterpene alcohol and 3 types triterpenes were benzoates,further two types of cucurbitane triterpene including Siraitic acid C and Siraitic acid F were identifier from the roots of monk fruit. In case of Cucurbitane-type triterpene aglycone, identified mogrosides IV, V and VI that share Morgrol aglycon structure [(10α,24R)-9β-Methyl-19-norlanosta-5-ene-3β,11α24,25-tetrol] with two to six glycose units attached.Phytochemical components inmonk fruit included [37, 38, 39, 40, 41]

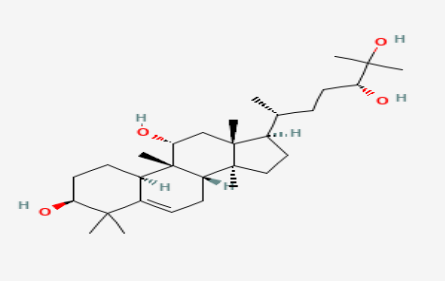
1. Phenolic acid
2. Anthraquinone
3. Sterols
4. Alkaloids
5. Aliphatic acids
6. Flavonoids(Kaempferol, quercetin and vanillic acid)
7. Rhamnopyranoside
8. Kaempferol 3,7-di-O-Lrhamnopyranoside (kaempferitrin)

CHEMISTRY AND STRUCTURAL CHARCTERISTICS OF MOGROSIDE:



Mogroside

The first crude mogrosides were extracted from Siraitia grosvenorii in 1974 by American Lee Chihong. In 1977, Japanese researcher Takemoto Tsunematsu was start studying how to isolate the pure mogrosides and figured out the corresponding chemical structures. After that more than 40 analogues were isolated one after the other. And then it was founded that all the mogrosides has different number of glucose units. The morgrol, [10-cucurbit-5-ene-3, 11, 24R, 25-tetraol], backbone[20].



STRUCTURE OF MORGROL

Examples: [21]

1. Triterpenoids and Glycosides
2. Flavonoids
3. Miscellaneous Compounds
4. Polysaccharides
5. Amino Acids and Proteins

NATURAL SWEETING PROPERIES:

Monk fruit sweeteners are extremely sweet in nature, almost 100-250 times sweeterthan sugar. It contains glucose and fructose. The sweetness of monk fruit is not only because of natural sugars compared to other fruits. Its sweetness comes from the compounds called mogrosides which have mogrol as the backbone and glucose units attached to glycosides. The Mogrosides are present in the juice extracted from the fruit and which are rich in antioxidants. They are separated from the juice during their processing and therefore the sweetener has no traces of the sugars like fructose and glucose. Mogroside V is the main mogroside amongst the monk fruit sweeteners. Mogroside V at 1/10000 concentration is about 425 times sweeter than 5% sucrose. Sometimes the mogrosides are the Basic chemical structure of all steviol glycosides mixed with other products like insulin or erythritol to balance the intense sweet taste of the sweetener. But now it is mostly being used alone as a sweetener or as a component of the mixture of sweetener blends to enhance the taste of food products. The monk fruit extract has a subtle fruity caramelized taste and it does not give much of an aftertaste. However, it is quite likely that the foods containing the monk fruit sweeteners taste different than those having sugar because sugar apart from providing sweetness also plays a role in enhancing the taste and texture of the food. It is also noteworthy that monk fruit sweeteners remain stable at higher temperatures and therefore can be used in baked foods with Ease.[42]

THERAPUEITC APPLICATION:

Monk Fruit has traditionally been used for the treatment of sore throat, tonsillitis, and asthma. [43, 44.] It has also been found that the fruit S. grosvenorii possesses expectorant, antioxidant, [45] antimicrobial, antitussive, hypoglycaemic, immunologic, hepatoprotective and anti-inflammatory activities. Mogroside is also suggested to treat obesity as well as non-alcoholic fatty liver disease. In addition, Mogroside V is said to have anti-cancer activities particularly for pancreatic cancer [46] and also produce antihyperglycemic [47].

SAFETY AND TOXICOLOGY OF MONK FRUIT:

Monk fruit has been recognized as safe (GRAS) status by United States Food and Drug Administration (USFDA, 2015).Government of several countries such as Australia, New Zealand, China and Japan have approved its use in only table-top packets and food products. According to the FDA, monk fruit sweetener is safe to be consumed by children, pregnant women and individuals with diabetes [48]. The studies in animals have illustrated no detrimental reproductive or developmental effects on mother or offspring, despite of animals being exposed to high levels of mogrosides daily over long periods [49,50]. There is a lack of toxicological analysis of monk fruit extract examined through animal studies, [51,52,53,54,55] observed that a beverage containing monk fruit had no effect on total daily energy consumption, glucose and insulin responses in healthy human males. Food Standards

Australia, New Zealand reported that mogroside V (about 30–40% of the total extract) was a major constituent of the commercial monk fruit extract. The metabolism of mogroside V indicated its degradation in the intestinal lumen along with the formation of several metabolites. These metabolites could be measured through urine, plasma, liver and other organs, which indicated the systemic absorption; however, the excretion was also through faeces, which indicated the partial systemic absorption of the mogroside V

INDUSTRIALAND NEUTRACEUTICAL APPLICATION

S.no	Product type	Product name	LHK role	Key ingredients	Sensory characteristics	Reference
1.	Compound beverage	✓ Sour carambola ✓ LHK compound beverage	Major ingredient	✓ Sour carambola juice ✓ 9% LHK Extract ✓ 4% Aspartame 0.03% ✓ Table salt 0.05%	Light yellow liquid, uniform and stable colour & body, no impurities and precipitation, no off-taste, possess unique sour carambola flavour, moderately sweet & sour taste	[56]
2.		✓ Anti-haze Qingfei Drink	Minor ingredient	✓ Astragalus membranaceus 9% ✓ LHK 2% ✓ pear 50% ✓ Xanthan gum 0.1%	Uniform & translucent body, possess pear fruit & medicinal aroma, appropriate sour & sweet taste with proper mouth perception; Significant improvement on haze mice's pathological lung damage after mice test were proved	[57]
3.		✓ Purple Sweet potato residue functional beverage	Major ingredient	✓ Purple sweet potato residue anthocyanins extract 70 ml ✓ LHK extract 30 ml ✓ sucrose 6 g/100 mL	Bright purple liquid with unique flavour and aroma of purple sweet potato & LHK, liquid exhibit uniform & stable state, no phase separation or precipitation, no impurities and suspended matter, sour & sweet taste with palatability, no off-odour. Anthocyanin	[58]

4.	Wine	✓ Sweet glycosidesfree fruit wine	Major ingredient	✓ Sweet Glycosides-free LHK juice (residue after glycosides extraction), diluted at 1:60 ratio, fermentation temperature 28 °C with 7%.	Golden yellow wine, clear, translucent, and shiny wine body, slightly darker than LHK juice. The wine taste is fresh and soft, with obvious LHK fruity aroma & new	[59]
5.		✓ LHK tea fermented wine	Major ingredient	✓ LHK tea extract: bean sprout juice = 6:1, yeast 5% (v/v), inoculation time 12 h, fermentation time 6 d at 30 °C	The wine has a yellowish-brown colour, transparent and shiny body, with mellow and soft sensation. The wine possesses slight sweet taste with harmonious fruity & wine aroma, where LHK flavour is obvious. The alcohol content 6.5% vol	[60]
6.	Tea beverage	✓ Hawthorn leaf tea beverage with LHK flavour	Flavour ingredient	✓ Hawthorn leaf extract 80 ml/100 ml, LHK concentration 6 g/100 ml, Vc 0.08 g/100 m	Moderate sweet & sour taste, soft sensation with intense aroma, low-calorie	[61]
7.		✓ Sugar-free LHK & Chrysanthemum tea beverage	Major ingredient	✓ LHK extract ✓ chrysanthemum extract5:5, ✓ citric acid 0.02% stevioside 0.003% xanthan gum 0.15%	Bright reddish-brown liquid with uniform and clear body, no impurities visible to the naked eye; with LHK & chrysanthemum unique scents and flavours; The beverage possess sweet and sour taste, with harmonious scent and without peculiar smell, as well as cool & refreshing sensation	[62]

8.	Fermented beverage	✓ Sweet glycoside free LHK vinegar	Major ingredient	✓ Sweet glycoside-free dilution at 1:40 ratio using water, fermented at 30°C where the kombucha culture is 15% addition	The acid content could reach 17.04 g/kg after 11 d fermentation, which the highest content	[63]
9.		✓ Low-sugar fermented beverage with rose residue.	Minor residue	✓ Rose residue extract: LHK extract = 1:2, LAB ferment powder (culture) 3%, ferment time 12 h, xanthan gum 0.04%, CMC-Na 0.03%, glucose 2.4 g/100 g	Light-red liquid with delicate fragrance of rose and LHK. Appropriate stickiness and fluidity, proper sweet & sour taste, no peculiar smell, and impurities. Sugar content less than 5 g/100 ml which is lowsugar beverage	[64]
10	Solid beverage	✓ LHK solid beverage	Major ingredient	✓ LHK Solid/liquid ratio 1:20 (kg/L), extract temperature 80 °C, extract time 30 min	Dark-brown powder or granules, reddishbrown liquid after resolution. Transparent liquid body with the unique flavour and smell of LHK, combined with appropriate sweet taste.	[65]

CONCLUSION

The main bioactive components of Siraitia grosvenorii, or monk fruit, are called mogrosides. They belong to a special class of naturally occurring, high-intensity sweeteners that combine remarkable sweetness with low calorie content. Mogrosides are potentially beneficial substitutes for sugar and artificial sweeteners.Traditionally, monk fruit has been used to treat sore throat and is known for antioxidant, anti-inflammatory, and antimicrobial properties. Mogrosides may also help with obesity, fatty liver disease, and even show anti-cancer potential. The U.S. FDA and several other countries recognize monk fruit as safe, including for children, pregnant women, and people with diabetes which is compared to artificial sweeteners.In conclusion, the natural sweetness and health-promoting qualities of mogrosides from monk fruit provide a desirable combination.Further comprehensive research addressing pharmacokinetics, precise molecular targets, innovative formulation and delivery systems, and well-designed large-scale clinical trials is imperative to firmly establish the efficacy, safety, and translational potential of mogrosides for clinical and functional food applications.

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