ORIGINAL ARTICLE

Subacute Toxicity of Microgranulated *Myrmecodia platytyrea* Aqueous Tuber Extract (gMPAE)

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ABSTRACT

Introduction: *Myrmecodia platytyrea*, locally known as 'Sarang Semut', is an epiphytic plant native to Asia and the Asia Pacific. The tubers were traditionally used to manage cancer, hyperuricemia, and coronary heart diseases. Scientifically, the aqueous tuber extract has potential pharmacological benefits, including anti-cancer, anti-diabetic, and anti-inflammatory properties. Since the extract had no acute or subacute toxic effects, it might be used as a supplement to reduce inflammation and improve physiological functioning with better bioavailability than conventional preparations. This study aims to investigate the subacute toxicity of the microgranulated aqueous extract of *M. platytyrea* tuber (gMPAE). Methods: The formulation of the microgranules was established and analysed using a scanning electron microscope (SEM). The subacute oral toxicity study was carried out. The female nulliparous and non-pregnant ICR mice were divided into three groups (n=5), a group treated with normal saline (control group), a group treated with a placebo (blank microgranules), and a group treated with gMPAE, orally once daily for 28 days. **Results:** The gMPAE was produced using a spray-dry method and displayed micro-particles with irregular shapes typical for spray-dried formulations. The sub-acute toxicity study showed no physical or behavioural changes in both placebo or gMPAE-treated mice compared to the control mice, with no mortality observed after 28 days of treatment and no signs of delayed occurrence of toxic effects 14 days post-treatment. **Conclusion:** Standardised spray-dried microgranules of *M. platytyrea* tuber aqueous extract were successfully developed to enhance the extract's efficacy and are safe to be used as health supplements.
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Keywords: *Myrmecodia platytyrea*; Microgranules; Subacute toxicity; Spray dry; Supplement

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INTRODUCTION

Rubiaceae is in a large Angiosperm group, belongs to the madder family, and orders Gentianales. Rubiaceae, which includes 611 genera with 13,150 species of herbs, trees, and shrubs, is dispersed mainly in tropical countries (1). Myrmecodia is native to Southeast Asia countries such as Indonesia and Malaysia, Vietnam, Thailand, Philippines, Indochina, The Cape York Peninsula, and Northern Queensland in Australia (2-6).

Ant colonies used Myrmecodia plants as their nest because it is very specified tuber and modified stems. According to Orhan et al. (2010), Myrmecodia sp has anti-inflammatory, antibacterial, anti-allergic, anti-viral, anti-mutagenic, anti-carcinogenic, and antioxidant activity due to flavonoids (7). However, only a few studies were done on a particular species of Myrmecodia, *M. platytyrea*. The uniqueness of this tuber is the red hypocotyl rich with polyphenols. The aqueous extract of *M. platytyrea* tuber has many pharmacological properties, including anti-cancer, anti-diabetic, and anti-inflammatory properties, to name a few (4-6, 8). Moreover, the extract showed no oral acute and subacute toxic effects, thus safe for consumption (9, 10). *M. platytyrea* tubers are mostly ingested traditionally as a decoction from dried tubers or encapsulated grounded powder of the tubers. However, the decoction method or the crude powder has poor bioavailability and low shelf life. Instead of using the tuber as a decoction, the extract can be standardised to optimise efficacy and absorption. Pharmaceutical microgranulation uses spray drying to create homogeneous microparticles for better distribution (11). Microgranulation optimises and evenly delivers drugs and nutraceuticals, such as vitamins or phytonutrients, to systemic circulation, improving bioavailability. This technique can increase pharmaceutical and nutraceutical efficacy and product performance (11). Thus this study aimed to formulate *M. platytyrea* aqueous tuber extract into microgranules that can

protect the active ingredients in the plant extract and improve their bioavailability. Subacute oral toxicity was also conducted to ensure the safety of the formulation.

Therefore, transforming the extract into a microgranulated health supplement would result in increased bioavailability, enhanced stability, and improved efficacy, ultimately leading to an enhancement in the overall quality of life.

MATERIALS AND METHODS

Preparation of *M. platytyrea* crude extract

M. platytyrea tubers were collected from the highlands of Sulawesi and identified by botanist Prof. Dr. Eko Baroto Walujo from the Herbarium Bogoriense at the Research Center for Biology of the Indonesian Institute of Sciences in Bogor, Indonesia. The dried tubers of *M. platytyrea* were ground into powder form. The powder was boiled with distilled water (1:9) for 15 min and filtered using filter paper (Whatman No.1). The solvent in the filtrate was eliminated using a rotary evaporator (Heidolph, Germany) under reduced pressure at 100 mbar, 40°C. This step is crucial to ensure the final product after lyophilisation is a fine and more soluble powder. The concentrated filtrate was then stored at -80°C for three days and freeze-dried (AAPPTec, USA) to obtain the dried powder of the aqueous extract. The extract was kept at -20°C until further use. The decoction method used was a modified method for the preparation of the aqueous extract (12).

Development of the microgranulation process of *M. platytyrea* aqueous extract (MPAE)

Standardised MPAE was formulated using a fluidised bed spray granulation (spray-dried granulation), a method for making free-flowing granulate from liquids (NR FB-5, Thailand) (13). MPAE was dissolved with distilled water and sprayed into a spray dryer chamber containing maltodextrin and lactose (various ratios of 1:1, 1:2, 1:3, 1:4, 1:5, 1:6, 1:7 and 3:1) to produce stable dried microgranules. The volume of binder, drying time and spray jet speed were optimised to allow the production of very fine granules. The spray-dried microgranules were collected in a reservoir connected to a cyclone, cooled to room temperature (24°C). The microgranules were seived using a 100 µm test mesh (Buch & Holm, Denmark) to obtain the desired diameter granules and then kept in sealed vials before being characterised and put to use.

Determination of surface morphology of the microgranulated *M. platytyrea* aqueous extract

The size, shape, and structure of microgranules were examined using a scanning electron microscopy (SEM) (FEI Quanta 450 FEG, Netherlands). Before analysis, a platinum coating (50s) was applied to the microgranule samples. SEM magnification of 100x was used for the 100 µm granules to examine the morphology of the particles and the micrographs were acquired at room temperature and analysed using an acceleration voltage of 5 kV. The method used was from the previously described method (14).

Experimental mice

The female nulliparous and non-pregnant ICR mice (18-25 g, 8 weeks) were provided by Laboratory Animal Facility and Management (LAFAM), Faculty of Pharmacy, Universiti Teknologi MARA. They were housed in individually ventilated cages (Alternative Design, USA) with a 12:12 h light/dark cycle, a temperature of 22°C (3°C), and relative humidity of 50–60%. Mice were given access to a commercial meal pellet (Gold Coin Sdn. Bhd., Malaysia) and unlimited filtered tap water. The study received approval from the Committee on Animal Research and Ethics Universiti Teknologi MARA(UiTM CARE) UiTM CARE: 339/2021 (2 April 2021).

Determination of subacute oral toxicity of the microgranulated *M. platytyrea* aqueous extract

The female ICR mice (18-25 g, 8 weeks) were divided randomly into three groups (n=5), consisting of a group treated with normal saline (control group), a group treated with a placebo (blank microgranules), and a group treated with gMPAE (consisting 400 mg/kg of extract). The mice were given the treatments orally using an oropharyngeal cannula once daily for 28 days. The study was done following established guidelines for repeated dosage 28-day oral toxicity, with necessary modifications made to suit the experimental requirements (15). Behavioural and physical changes were observed daily for 28 days and two weeks post-administration (satellite group; without placebo or gMPAE administration) for late-onset. The mice were also observed for signs of toxicity on their skin, hair, pupils, mucous membrane, salivation, lethargy, gait, sleep, coma, convulsions, tremors, diarrhoea, oral activity, abdominal, and external genitalia. The body weight of the mice was recorded throughout the experiment. Blood collection was done to determine the blood biochemistry after the administration of anaesthesia, followed by cardiac puncture and subsequent diaphragm incision to assure the cessation of life. Then, a gross necropsy was carried out by an in-house veterinarian.

RESULTS

Microgranulation process of *M. platytyrea* aqueous extract

The microgranules were prepared using a spray-dried granulation process, and the results of the different formulations are presented in Table IA-B. Specifically, the ratio of the diluents, inlet temperature, spray rate, and spray frequency were varied to observe their effects on process yield. Maltodextrin and lactose (1:6) were

Table I : A) Process parameters for the blank granule formulation; B) Process parameters for the granulated *Myrmecodia platytyrea* aqueous extract (gMPAE) formulation.

Trial	Ratio (Maltodextrin: Lactose)	Weight (g)	Binder	Binder (%)	Peristaltic pump speed	Volume of binder ml (10% - 15%)	Time of spray (sec)	Inlet temperature ± (°C)	Drying time (Min)	Speed (RPM)	Results
1	1:1	400	PVP K90 ($EtOH:dH_2O$)	1	20	60	60	70-80	3-5	165	• Clump and sticky • No granules were produced • Solvent of binder evaporated • The entire binder was used.
			PVP K90 (dH_2O, 60 °C)	1	20	60	60	70-80	3-5	165	• Clump and sticky • No granules were produced • Small amount of binder remained
			PVP K90 (isopropanol:dH_2O)	1	20	60	60	70-80	3-5	165	• Clump and sticky • No granules were produced. • Solvent of binder evaporated • The entire binder was used.
	1:3	400	PVP K90 ($EtOH:dH_2O$)	1	15	60	60	70-80	3-5	165	• Granules were produced. • Solvent of binder evaporated • Binder was sufficient • Low yield of granules produced
			PVP K90 (dH_2O, 60 °C)	1	15	60	60	70-80	3-5	165	• Granules were produced. • Binder was sufficient • Low yield of granules produced • Small amount of binder remained
			PVP K90 (isopropanol:dH_2O)	1	15	60	60	70-80	3-5	165	• Granules were produced. • Solvent of binder evaporated • Binder was sufficient • Low yield of granules produced
	3:1	400	PVP K90 ($EtOH:dH_2O$)	1	10	60	60	70-80	3-5	165	• Clump and sticky • No granules were produced • The entire binder was used. • Solvent of binder evaporated
			PVP K90 (dH_2O, 60 °C)	1	10	60	60	70-80	3-5	165	• Clump and sticky • No granules were produced • Small amount of binder remained
			PVP K90 (isopropanol:dH_2O)	1	10	60	60	70-80	3-5	165	• Clump and sticky • No granules were produced • The entire binder was used. • Solvent of binder evaporated

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	1:1			1	10	70	60	70-80	3-5	165	• Clump and sticky • No granules were produced • 11 ml of binder remained
	1:3	400	PVP K90 (dH_2O, 60 °C)	1	10	70	60	70-80	3-5	165	• Big size granules were formed • 8 ml of binder remained • Low yield of granules produced
	3:1			1	10	70	60	70-80	3-5	165	• Clump and sticky • No granules were produced • 7 ml of binder remained
	1:2									190	• Big size granules were formed • Low yield of granules produced
2	1:4									185	• Big size granules were formed • Granules were produced and smaller than 1:5 • Low yield of granules produced • Clumping
	1:5	400	PVP K90 (dH_2O, 60 °C)	1	6	60	30	70-80	3-5		• Big size granules were formed • Granules formed were smaller than 1:6 • Low yield of granules produced
	1:6									184	• Big size granules were produced. • Granules formed were bigger than 1:5 • Low yield of granules produced • 6 ml of binder remained
	1:6 (1)										• No binder remained • Low yield of granules produced • The size was slightly bigger
	1:6 (2)										• 3 ml of binder remained • Low yield of granules produced • The size was slightly bigger and almost the same as 1:6(1)
	1:6 (3)										• No binder remained • Higher yield of granules produced • Size of granules were smaller than 1:6(1) and 1:6(2)
3	1:6 (4)	400	PVP K90 (dH_2O, 60 °C)	1	4	60	30	70-80	3-5	159	• 7 ml of binder remained • Yield of granules produced was higher than 1:6(3) • Size of granules were smaller than 1:6(1) and 1:6(2)
	1:6 (5)										• 6 ml of binder remained • Higher yield of granules produced • Size of granules were smaller than 1:6(3) and 1:6(4)
	1:6 (6)										• No binder remained • Higher yield of granules produced • Size of granules were smaller than 1:6(3) and 1:6(4)

Note: Optimum parameters chosen in this study were bold.

Trial (% concentration of MPAE)	Ratio (Maltodextrin: Lactose)	Weight (g)	Binder	Binder (%)	Peristaltic pump speed	The volume of binder ml (10% - 15%)	Time of spray (sec)	Inlet temperature ± (°C)	Drying time (Min)	Speed (RPM)	Results
1 (1%)	1:6(1)	400	PVP K90 (dH_2O, 60 °C)	1	4	60	30	70-80	3-5	161	• The intensity of granule colour was higher than 0.25% • The production yield was higher • The size of the granule was small
	1:6(2)										• The intensity of granule colour was higher than 0.25% • The production yield was higher • The size of the granule was small
2 (1%)	1:6 (1)	400	PVP K90 (dH_2O, 60 °C)	1.5	4	60	30	70-80	3-5	161	• The intensity of granule colour was the same as 1% • The production yield was higher • Desirable size of the granule was produced.
	1:6 (2)										• The intensity of granule colour was the same as 1% • The production yield was higher than 1:6(1) • Desirable size of the granule was produced
	1:6 (3)										• The intensity of granule colour was the same as 1% • The production yield was lower than 1:6(2) • Desirable size of the granule was produced
	1:6 (4)										• The intensity of granule colour was the same as 1% • The production yield was higher than 1:6(2) • Desirable size of the granule was produced
3 (3%)	**1:6 (1)**	**400**	**PVP K90 (dH_2O, 60 °C)**	**1.5**	**4**	**60**	**30**	**70-80**	**3-5**	**161**	• **The intensity of granule colour was higher than 0.25% and 1%** • **The production yield was high** • **Desirable size of the granule was produced**
	1:6 (2)										• **The intensity of granule colour was higher than 0.25% and 1%** • **The production yield was higher than 1:6(1)** • **Desirable size of the granule was produced**
	1:6 (3)										• **The intensity of granule colour was higher than 0.25% and 1%** • **The production yield was lower than 1:6(1)** • **Desirable size of the granule was produced**
	1:6 (4)										• **The intensity of granule colour was higher than 0.25% and 1%** • **The production yield was higher than 1:6(2)** • **Desirable size of the granule was produced**

Note: Optimum parameters chosen in this study were bold

chosen as diluents, whilst polyvinylpyrrolidone (PVP), also known as K90 was used as a binder. The optimum specification for this spray-drying process was as follows: peristaltic pump speed of 4 min/ml with 60 ml of binder (K90) with 30 min time of spray with an inlet temperature of 70-80 C, drying time of 3-5 min, speed of 161 rpm.

The final product was leather brown-coloured microgranules with a particle diameter of 100 µm with a process yield of 36.55% (blank) and 28.31% (gMPAE), respectively. The microgranules (blank and gMPAE) were readily soluble in water at room temperature. Blank and gMPAE produced an off-white and dark brown solution, respectively.

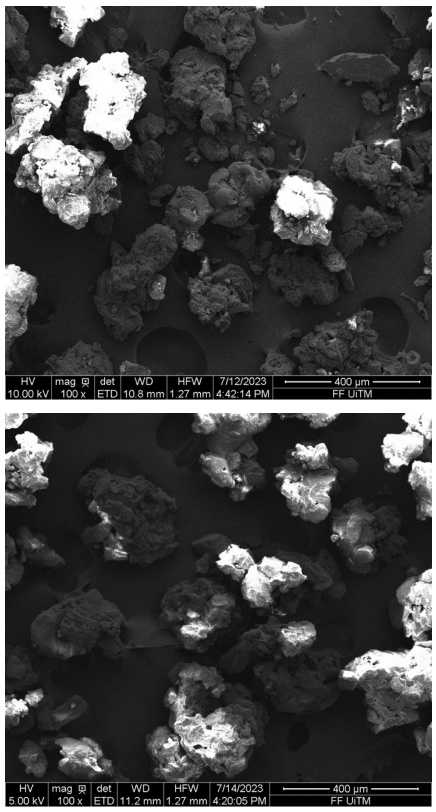
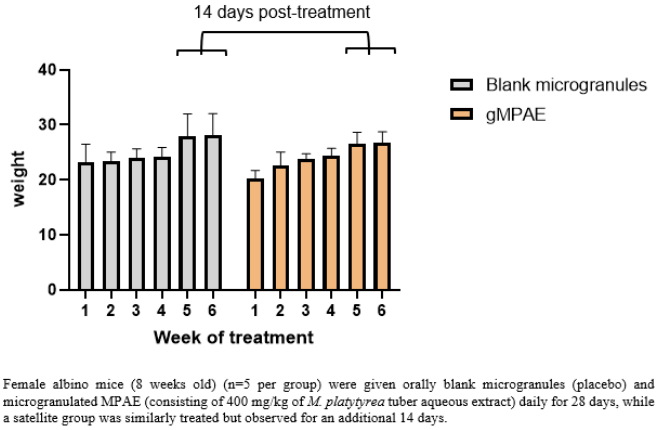


Figure 1 : A) SEM micrograph of spray-dried powder particles (blank microgranules), 100x magnification; **B)** SEM micrograph of spray-dried powder particles (microgranules containing *Myrmecodia platytyrea* tuber extract), 100x magnification.

Surface morphology analysis of the microgranulated *M. platytyrea* aqueous extract

Micrograph analysis evaluated by SEM displayed in Fig. 1A–B, revealed the morphology of the particles. The microparticles had a somewhat atypical morphology, which is commonly observed in spray-drying formulations. The particles exhibited a continuous wall with predominantly irregular amorphous formations, and indentations on the surface that displayed a wrinkled appearance were detected. The absence of visible cracks is evidence of the encapsulation's high quality. During atomisation within the spray dryer chamber, the liquid droplets undergo rapid expansion, forming hollow particles characterised by a matrix-type structure.



Female albino mice (8 weeks old) (n=5 per group) were given orally blank microgranules (placebo) and microgranulated MPAE (consisting of 400 mg/kg of *M. platytyrea* tuber aqueous extract) daily for 28 days, while a satellite group was similarly treated but observed for an additional 14 days.

Figure 2 : Body weight of mice recorded throughout 28 days of the daily oral administration of gMPAE and 14 days post-administration.

Subacute oral toxicity of the microgranulated *M. platytyrea* aqueous extract

The female mice in this subacute oral toxicity study received repeated doses of gMPAE consisting of 400 mg/kg of the extract, daily for 28 days. No signs of toxicity and mortality were observed in the treated group compared to the placebo group (Table II). Furthermore, the consumption of gMPAE for 28 days did not elicit significant changes in physical appearance, gross examination, and body weight compared to the control groups (Figure 2). Blood biochemistry such as levels of ALP, ALT, creatinine and blood urea nitrogen

Table II: Effects of the daily oral administration of gMPAE for 28 days on mortality, behavioural and physical changes, and symptoms of toxicity

Group	Treatment	Effects				
		Death/ Total	Mortality latency (h)	Behavioral changes	Physical changes	Symptoms of toxicity
Placebo	Sub-acute 28 days	0/5	No	No	No	None
gMPAE		0/5	No	No	No	None
Placebo	Sub-acute satellite 42 days	0/5	No	No	No	None
gMPAE		0/5	No	No	No	None

Female albino mice (8 weeks old) (n=5 per group) were given orally blank microgranules (placebo) and microgranulated MPAE (consisting of 400 mg/kg of *M. platytyrea* tuber aqueous extract) daily for 28 days, while a satellite group was similarly treated but observed for an additional 14 days.

Table III : Blood biochemistry of mice after 28 days of the daily oral administration of gMPAE

Group	Treatment	Blood biochemistry (mean±SD)			
		ALP (U/L)	ALT (U/L)	Creatinine (µmol/L)	Urea (mmol/L)
Placebo	Sub-acute 28 days	61.6±11.7	82.5±51.8	11.9±4.0	8.3±0.5
gMPAE		63.6±8.5	26.0±2.8	9.0±2.4	8.7±1.3
Placebo	Sub-acute satellite 42 days	26.4±8.3	45.5±28.7	64.3±40.0	6.5±0.9
gMPAE		34.0±1.5	111.9±93.8	67.2±30.0	7.8±2.1
*Normal range		13-88	7-227	35.36-141.44	5.36-21.07

Female albino mice (8 weeks old) (n=5 per group) were given orally blank microgranules (placebo) and microgranulated MPAE (consisting of 400 mg/kg of *M. platytyrea* tuber aqueous extract) daily for 28 days, while a satellite group was similarly treated but observed for an additional 14 days.

*Normal range: Loeb, WF and Quimby, FW. 1999. The Clinical Chemistry of Laboratory Animals, 2nd ed. Philadelphia: Taylor & Francis USA.

were analysed. All the tested values fall within the normal range in all groups (Table III). These results indicated that oral administration of gMPAE did not elicit deleterious effects in the mice. Hence, the blank microgranules and gMPAE were considered non-toxic.

DISCUSSION

Granulation methods are broadly divided into two categories: dry granules and wet granulation, depending on the method that facilitates the accumulation of dry particles. The extract was formulated using a microgranulation process. This process improves bioavailability, prolongs the release of active forms for up to 6 hours, and enhances shelf-life compared to crude powder (13). In addition, granulation provides stability and uniformity. The method transforms one or more soluble or insoluble powders, aqueous or oily liquids, or previously micronised minerals and/or plant extracts into a collection of granules resulting from a homogenous aggregation of particles (granulate).

The pharmacological properties shown by many medicinal plants are attributed to the presence of phenolic compounds (16). However, due to their diverse structural makeup and bioactivities, phenolic compounds in plant extracts cannot be fully utilised for their therapeutic benefits. Plants and their extraction, the complexity of the plant matrix, and potential synergistic interactions between phenolic compounds and other components can all reduce bioavailability (17). As a result, the encapsulation method can be utilised to increase the bioavailability of bioactive substances like phenolic compounds by using different wall materials to enable target delivery and controlled release (delayed or long-acting release) (18).

In this study, spray-dried microgranulation was selected, and the desired characteristics of the microgranules, such as their morphology and size, were considered. Optimising these variables can significantly improve the effectiveness of encapsulation (18, 19). This technique can improve the bioavailability of these bioactive compounds by reducing their particle size (19). Depending on the route of administration, the optimal particle size for a drug varies. For example, intravenous delivery often employs particles within the size range of 0.1–0.3 µm, whereas inhalation delivery utilises particles ranging from 1–5 µm. On the other hand, oral drug delivery encompasses particles with sizes ranging from 0.1–100 µm. The optimal range for inhalable medication particle sizes is typically between 3 and 5 µm (20). Hence, the 100 µm particle size for the microgranulated MPAE in this study.

The carrier agents used in this study were maltodextrin and lactose. Maltodextrin has been proven beneficial for encapsulating anthocyanins and other phenolic compounds by improving their bioavailability (21). Lactose is a typical encapsulation agent or carrier during spray drying because of its relatively high glass transition temperature compared to other monosaccharides/disaccharides (22). Polyvinylpyrrolidone (PVP), also known as polyvidone or povidone, was chosen as the binder for this formulation. The water-soluble polymer, PVP, is created from the monomer N-vinylpyrrolidone offered in various molecular weights and associated viscosities. PVP can also increase bioavailability and has been proven safe as a food-grade additive and a pharmaceutical excipient (23).

A significant constraint in the therapeutic application of herbal medicines is their poor solubility, and these products have garnered substantial criticism in light of their perceived lack of standardisation and apparent low quality (17). Numerous chemicals in the plant extracts can undergo degradation when exposed to the strongly acidic pH environment of the stomach (24). Other compounds can undergo hepatic metabolism before entering the systemic circulation. Furthermore, it is worth noting that herbal extracts frequently exhibit suboptimal compressibility and high

hygroscopicity, resulting in powders with inadequate flowability (25). Numerous researchers are currently engaged in the exploration of innovative drug delivery systems, including solid dispersion, fast-dissolving tablets, sustained and extended-release formulations, microparticles, microcapsules, nanoparticles, and mucoadhesive systems, to harness the potential of these medicinal plants (26). Therefore, the spray-dry microgranulation technique and maltodextrin as a carrier agent can improve the powder flowability and hygroscopicity of dry plant extracts, which is essential for the development of herbal products (26, 27).

The morphology of microgranules produced through spray drying is influenced by various factors, which encompass the drying conditions (specifically, air flow, temperature, and partial pressure of the solvent), the properties of the aerosol (including droplet size, temperature, and the mass fraction of solid or solute), and the processing parameters such as nozzle temperature, gas flow, salt concentration, and solution feed rate (27). Many studies have been conducted on the formulation of herbal extracts in tablet form. According to a study on the extracts from the leaves of *Morus alba*, the hygroscopic and low flowability properties of extracts derived from herbal plants provide challenges in developing pharmaceutical formulations (28). Hence, they designed a tablet formulation using wet granulation of fermented herbal extracts with Viscozyme®, an enzyme that facilitates the hydrolysis of carbohydrates and releases proteins from plant materials (28).

For the sub-acute oral toxicity study, the group of mice given a placebo and microgranulated *M. platytyrea* aqueous extract (gMPAE) showed no mortality and symptoms of toxicity after 28 days of oral administration. The satellite groups also demonstrated the same trend. These findings supported a previous study on the same extract (9). An acute oral toxicity study and a 28-day repeated dose toxicity study of MPAE did not cause any toxic effects or physical and behavioural changes to the mice. Moreover, MPAE at 400 mg/kg (p.o.) displayed an involvement in the regulation of fatty metabolism, precursors of inflammation, endogenous antioxidant system (GSH), and exogenous metabolites (9). *M. platytyrea* tubers contain bioactive compounds such as stigmasterol, morindolide, and phenolic compounds, which have the high antioxidant capacity (2, 3). MPAE has also demonstrated a potent analgesic effect may be due to the presence of bioactive compounds in the extract (4). Furthermore, the tuber extract could also reduce blood sugar levels of diabetic rats as early as seven days after extract administration (8). A previous study on the leaves of *M. platytyrea* showed strong anti-cancer and anti-metastatic properties against hepatocellular carcinoma that may be due to the compounds described earlier (29). Hence, 400 mg/kg dosage was chosen as the optimum dose in this study. When considering the dose conversion between animals and human and the safety factor of 10, 200 mg/day of MPAE is suggested for human consumption (30). About 3% MPAE was then incorporated into the formulation to ensure the efficacy of the improved product.

CONCLUSION

The *M. platytyrea* tuber aqueous extract was successfully formulated into a microgranulated form (gMPAE) to improve the efficacy of its potent pharmacological benefits. In addition, the sub-acute toxicity revealed no toxic effect suggesting gMPAE is safe to be developed as a health supplement. The standardised spray-dried microgranules of *M. platytyrea* tuber aqueous extract may enhanced its bioavailability better than the conventional preparation. Thus, the outcome of this study, plus the scientific evidence of the therapeutic benefits of *M. platytyrea* tuber extract, gMPAE can be commercialised as a nutritional product with better bioavailability to improve quality of life.

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