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The proximate composition and phytochemical screening of *Momordica Balsamina* (balsam apple) fruit and leaves

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Abstract

Malnutrition is a global issue that affects both children and adults irrespective of their socio-economic status. It is therefore important to find various means to tackle malnutrition. This is especially important as undernutrition and overnutrition can be linked to a variety of non-communicable diseases (NCDs). Therefore, this study aimed to gather more insight into the nutritional and phytochemical quality of *Momordica balsamina* leaves and fruit (fruit pericarp, fruit flesh and seeds). The results showed that *M. balsamina* had a nutritional composition that would be advantageous to the human diet. The nutritional quality was verified by the presence of a high protein percentage across all samples (19.72–29.08%), with the leaves containing the highest protein content (29.08% ± 0.77). There was also a low-fat content present across all samples which ranged from 1.03% to 2.40%. The ash content indicated the presence of total minerals to be adequate (2.93–21.16%), where the pericarp had the highest ash quantity (21.16% ± 0.09). Overall, the moisture levels were low (7.11–13.40%); with *M. balsamina* seeds containing the highest carbohydrate content (67.84% ± 0.30).

Moreover, rich in the major phytoconstituents, *M. balsamina* extracts were found to contain alkaloids, saponins, cardiac glycosides, steroids and triterpenoids. Based on these findings, it can be deduced that the incorporation of *M. balsamina* into an individual's diet could prevent diseases associated with malnutrition and could be used to supplement the human diet in managing certain NCDs.

Keywords: *Momordica balsamina*; malnutrition; nutrients; proximate composition; bioactive compounds.

Practical Application: Validating the consumption of *Momordica balsamina* to maintain a healthy diet while also identifying the major phytoconstituent group that could also contribute to the management of various diseases.

1 INTRODUCTION

The World Health Organisation has recognised malnutrition as a global issue that affects both children and adults. Notably, 462 million adults have been identified as underweight and 52 million children (under 5 years) suffer from wasting (having low weight for height) (WHO, 2019). Therefore, the elimination of malnutrition would result in a 32% decrease in the global disease burden. Due to the prominence of malnutrition in developing countries, there has been little progress in tackling this health condition. Ultimately, malnutrition can be defined as an imbalance of nutrients in the body, where the nutrients that are needed and the amount used are not balanced (Dukhi, 2020).

There are various forms of malnutrition with two broad categories, namely, undernutrition and overnutrition. Udernutrition is present as wasting or acute malnutrition (low weight for height) and chronic malnutrition (stunting or low height for age). Overnutrition includes overweight, obesity and diet-related non-communicable diseases (NCDs) (e.g., diabetes mellitus, heart disease, different types of cancers and strokes). Notably, malnutrition transcends geography, socio-economic status, sex and gender. This allows households, communities and countries to overlap. Hence, it is necessary to note that anyone is susceptible to malnutrition, although there are groups who are more at risk (such as children, adolescents, women, immuno-compromised individuals or those facing poverty) (Dukhi, 2020). It is therefore important to understand nutrients and their role in the human body.

Ultimately, for the human body to function, it is dependent on the energy obtained from food combustion. Protein and allied nutrients are utilised in both the growth and the endless repairing process in the human body. Every cell requires both oxygen and water to survive; however, it is the haemoglobin (iron-porphyrin-protein) that allows oxygen to be carried to the cell. Moreover, water is supplied via the breakdown of carbohydrates as well as inter-related nutrients, along with the fluids that are consumed. It can thus be concluded that for a functioning body, the ingestion of substances is necessary (Waif, 2003). Therefore, nutrition can be defined as the quality and quantity of food that is received by the body and the processes carried out to provide energy for tasks to be conducted in one's daily life (Khan et al., 2018).

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Even though it is understood that food delivers energy, and nutrients are food components that are essential in human health, as further research is conducted, other compounds present in food are continuously being identified. This allows for a deeper understanding of these compounds and their health benefits. Additionally, the nutritional composition of foods varies significantly, and there remains a gap in the comprehensive understanding of certain nutritional compounds that have yet to be thoroughly studied. Ultimately, this leads to the deduction that synergistic interactions occur between food components, allowing for good health. Notably, this is reflected in the daily dietary patterns of an individual. Hence, this has resulted in the recognition of the crucial inter-relationship between dietary patterns, foods and nutrients and a means to develop dietary guidelines for the improvement of health and disease prevention (Tapsell et al., 2016).

Furthermore, researchers have found that if there are continuous disturbances of nutrient metabolism along with disturbances of energy homeostasis on its own (caused by excess or deficient nutrients), cellular stress is promoted which results in tissue damage and metabolic dysregulation. This eventually leads to the development of various acquired metabolic syndromes. Notably, extrinsic factors together with intrinsic factors and host/microbiota interactions influence the metabolism and the associated risk with metabolic disease development (Chen et al., 2018).

Moreover, there has been a rise in the prevalence of metabolic syndromes acquired in the past few decades. Overall, there has been a striking increase in the number of those contracting diseases (diabetes, obesity and fatty liver disease) in developing countries; based on the adaption of modern diets and lifestyles. As a means of prevention, health organisations have determined dietary recommendations to reduce public health complications arising from altered nutrition practices. It should be noted that interventions in the past have been successful in reducing single nutrient deficiencies. Furthermore, data from previous studies indicated that a more informative approach to formulating effective dietary recommendations may result from thoroughly analyzing the foods consumed along with the eating pattern; rather than solely focusing on individual nutrients present in those foods (Chen et al., 2018; Hawkes, 2006).

Additionally, studies have indicated that individuals following a Mediterranean diet tend to be in good health with positive outcomes. This can be seen in the reduced risk of various chronic diseases, overall mortality as well as an increased chance of aging healthily when following a Mediterranean diet. These results can be attributed to the high consumption of vegetables in Mediterranean diets (Ülger et al., 2018). Ultimately, this has created a link between leafy green vegetables and a reduced risk of death caused by lifestyle diseases (Chacha & Laswai, 2020).

Jansen van Rensburg et al. (2003) examined leafy vegetables found in South Africa. Seven groups of leafy vegetable species were selected as a priority. These species include *Amaranthus* spp., *Brassica rapa* subsp. *chinensis*, *Cleome gynandra*, *Corchorus olitorius*, *Corchorus tridens*, *Solanum retroflexum*, *Vigna unguiculata*, *Cucurbita pepo*, *Cucurbita maxima, Cucurbita moschata*, *Citrullus lanatus*, *Cucumis melo* and *Momordica balsamina*. It was determined that the knowledge of health benefits associated with leafy vegetables could be lost as interest in the growth and consumption of indigenous leafy vegetables, especially in rural areas, is slowly decreasing. Therefore, when taking the potential nutritional value of leafy green vegetables into consideration, both indigenous and indigenised leafy vegetables could be a major contributor to the control of food security and a balanced diet, particularly in rural as well as urban households. It was then concluded that further research on the presence of the nutrients available and their bioavailability is dire and should be urgently answered.

The *Momordica* plant has since then been categorised as a vegetable crop. Belonging to the *Cucurbitaceae* family, *Momordica* (balsam apple) can be classified as either a member of the melon, gourd, pumpkin or cucumber family. Known to be medium in size as well as to thrive in warm regions, this plant species was believed to have been domesticated in Eastern Asia (India/Southern China). In terms of consumption, Africa and Asia have been reported to have the most consumption of *Momordica* variations (Nagarani et al., 2014). Even though *Momordica charantia* is the most cultivated and therefore the most consumed species, there are other wild African species that can be obtained and are regularly consumed. *M. balsamina, Momordica foetida* and *Momordica rostrata* are just a few types of the many types of *Momordica* variations that are popular (Alam et al., 2015). Noteworthy, *M. balsamina* is a tendril-bearing, wild climber that has a valuable medicinal and nutritional composition that is commonly used as traditional folk medicine around the world (Thakur et al., 2009).

Both African and Asian countries (especially the rural communities) have integrated the fruit and leaves of *M. balsamina* into their daily diets. Unripe fruits/leaves are generally consumed after being cooked. However, in Namibia, the red fruit pulp is also eaten (Ramalhete et al., 2022). For centuries, the *Momordica* species has been noted for its importance in traditional and folk medicines. It has also been used in a range of medicinal treatments such as hypertension, cancer and obesity (Bortolotti et al., 2019). *M. balsamina* (fruits, leaves and/or seeds) is no exception, as it also has a range of traditional medicinal applications in the form of decoctions, infusions, poultices and/or as herbal teas (Omokhua-Uyi & Van Staden, 2020). Different plant parts have also been noted to exhibit anti-diabetic, anti-plasmodial, anti-viral, anti-inflammatory, analgesic, shigellocidal, anti-diarrhoea, anti-septic and anti-microbial activities (Ramalhete et al., 2022).

Apart from its uses in treating aliments, balsam apple has been considered a wonder plant in nutraceutical sciences. This is due to the *M. balsamina* leaves containing 17 amino acids, an adequate mineral composition, with a high protein (288 g/kg) and fat (54 g/kg) value as well as a low fibre content (37 g/kg) (Thakur et al., 2009). Furthermore, Aberoumand and Deokule (2009) conducted proximate analysis on *Momordica dioica* fruit and detected the presence of ash (9.10%), crude protein (5.44%), crude lipid (3.25%), carbohydrate (59.31%) as well as a high energy content (288.25 kcal/100 g). However, *M. balsamina* leaves were found to contain 127.00 g/kg ash, 53.70 g/kg fat, 287.70 g/kg protein and 37.20 g/kg crude fibre. It was

then determined that the protein and fat content was higher than the average for vegetables on the database of the South African Food Composition Database. The ash content was also an indication of a high mineral content, which would be ideal to be used as a potential source of essential minerals in the human diet (Flyman & Afolayan, 2007). Additionally, the seeds of *M. charantia* were found to contain close to 35–40% oil, of which 3.33% is monounsaturated fatty acid and 36.71% is saturated fatty acids (Saheed *et al*., 2018).

Importantly, considerations should also be made regarding the phytoconstituents (alkaloids, flavonoids, glycosides, steroids, terpenes, cardiac glycosides and saponins) found in the *Momordica* species. The importance of studying the presence of these chemical compounds lies in their potential to manage cardiovascular disease, diabetes and hypertension (Thakur et al., 2009). Furthermore, the increase in healthcare costs and negative side effects of pharmaceutical drugs underscores the need for natural alternatives (Ekor, 2014). Hence, for the advancement of human medicine, it is crucial to investigate the nutritional composition and chemical compounds present in *M. balsamina*.

2 MATERIALS AND METHODS

2.1 Sample Preparation

The leaves and fruit (pericarp, seeds and flesh) of *M. balsamina* were obtained from market stalls and field samples in Durban, South Africa. Each part was cleaned, washed and dried as explained below.

• Leaves: The stems, discoloured and damaged leaves were removed. Thereafter, the leaves were rinsed and dried at 30°C (Thermo incubator) and ground into a fine powder;

• Fruit pericarp: The outer covering of the fruit was removed, rinsed and dried at 30°C (Thermo incubator) and ground into a fine powder;

• Fruit: The flesh of the fruit was rinsed and dried at 30°C (Thermo incubator) and ground into a fine powder;

• Seeds: Seeds were sorted, rinsed and dried at 30°C (Thermo incubator) and thereafter ground into a fine powder.

2.2 Nutritional Analysis

Proximate composition analysis was conducted to measure moisture, protein (N×6.25), fat, ash, crude fibre and carbohydrate (by difference) in triplicate, according to the Association of Official Analytical Chemists (AOAC) standard procedures (AOAC, 1990).

2.3 Sample Extraction

Soxhlet extraction is a technique preferred for extraction as it allows for an intimate interaction between the sample and the solvent. This ensures that the targeted compounds are exposed to the solvent. Therefore, Soxhlet extraction was applied, and the method explained by Redfern et al. (2014) with slight modifications was used. The dried powder (8–10 g) (leaves, fruit flesh, pericarp and seeds) was placed into Whatman No. 1 filter paper which was tightly bound and placed into the extraction chamber. Each sample was extracted with three different solvents of different polarities (distilled water, ethyl acetate and hexane) at a constant temperature of 60°C. Approximately, 200 mL of the solvent was placed into the round bottom and 50 mL was added to the sample in the extraction chamber. The solvent from the round bottom was then evaporated and condensed into the extraction chamber which then refluxed back into the round bottom. This extraction process was run for 4 h with the resulting extracts collected from the round bottom and concentrated as explained below.

The resulting extracts of hexane and ethyl acetate were then evaporated using a Buchi rotary evaporator (at 60°C), where the resulting concentrated extracts were further air-dried in a dark cupboard, whereas the distilled water extracts were stored overnight in a bio-freezer and freeze-dried (SP VirTis). The air-dried samples (ethyl acetate/hexane crude extracts) were then kept in an air-tight container and placed in a dark, dry cupboard, whereas the freeze-dried samples (distilled water crude extracts) were stored in a dark, air-tight container at 4°C until required for testing.

2.4 Phytochemical Screening

2.4.1 Alkaloids—Dragendorff's Test

Extracts (100 mg) were boiled with 5 mL of methanol and thereafter filtered. A few drops of 1% hydrochloric acid followed by Dragendorff's reagent was added. The presence of a brownish-red colour precipitate indicated a positive result. If there was no change, it was considered to be an absence of alkaloids (Mujeeb et al., 2014).

2.4.2 Saponins—Froth Test

Distilled water (10 mL) was added to 100 mg of the extract and was then vigorously shaken. The presence of froth was monitored. A positive result was determined if the height (height above surface liquid level) remained at or greater than 3 cm after 30 min. A negative result was determined if extracts exhibited an absence of froth/froth lower than 3 cm after 30 min (Auwal et al., 2014; Bulugahapitiya & Chandani, 2002).

2.4.3 Steroid/Triterpenoids—Salkowski Test

Chloroform (1 mL) was shaken with 100 mg of the extract and concentrated sulphuric acid (1.5 mL) was then added to the side of the tube. The presence of a red-brown colour showed a positive result for steroids. Thereafter, the tube was shaken and allowed to stand, and if the lower level turned/was turning yellow, it was taken as a positive result for triterpenoids (Yadav et al., 2010).

2.4.4 Cardiac Glycosides—Keller-Kiliani Test

Approximately 1.25 mg of the extract was carefully mixed with chloroform (0.5 mL) and allowed to react with 0.5 mL of

concentrated sulphuric acid. The formation of reddish-brown colour depicted a positive result, and a negative result showed no change in colour upon the addition of the sulphuric acid (Kebede et al., 2021).

2.4.5 Flavonoids—Alkaline Test

Extracts were treated with a few drops of 2 M sodium hydroxide solution, and the formation of an intense yellow colour which turned colourless upon the addition of 1% hydrochloric acid indicated a positive for flavonoids, whereas no change indicated a negative result (Ushie et al., 2016; Yadav et al., 2010).

2.5 Statistical Analysis

To evaluate the differences, a one-way analysis of variance (ANOVA) (Graph Pad Prism) followed by Bonferroni post-tests was conducted, with values expressed as mean ± standard deviation ($p < 0.05$).

3 RESULTS AND DISCUSSION

3.1 Nutritional Analysis

Moisture content is known to affect the safety, quality and shelf-life of food products (Appoldt & Raihani, 2017). The properties of water affect the physical, chemical and microbial stability of foods (Bell & Labuza, 2000; Joslyn, 1970). Therefore, moisture analysis is an important and widely employed determination used during the formulation, processing and testing of food products (Park & Bell, 2004). Dehydration moisture removal is used for the improvement of the stability of a food's storage. A small increment of moisture can affect foods with low to intermediate moisture levels as it significantly reduces the product's shelf-life (Bell & Labuza, 2000). In the *M. balsamina* samples, the fruit pericarp was found to have the highest moisture content (13.40%) and the seeds had the least moisture (7.11%) (Table 1). The fruit flesh and leaves had a similar moisture content of 11.08 and 11.28%, respectively.

Sulaiman and Yakubu (2018) found that the leaves of *M. charantia* have a moisture content of 15.00%, whereas Bakare et al. (2010) reported a moisture content of 17.97%. The moisture content of *M. charantia* leaves by Bakare et al. (2010) and Sulaiman and Yakubu (2018) were both higher than the results depicted in Table 1 (11.28%). Kumar et al. (2016) noted the moisture content present in the leaves of *Solanum nigrum* L. (72.00%), *Celosia argentea* L. (69.60%) and *Alternanthera sessilis* (L.) R. Br. Ex DC. (71.40%) were also greater than the result obtained in Table 1.

Salvi (2015) noted *M. dioica* fruits to have 87.00% moisture and *M. dioica* Roxb. ex Willd (Fruit) had 75.80% moisture (Kumar et al., 2016). The fruits of *Carpobrotus edulis, Englerophytum magalismontanum* and *Pappea capensis* contained 19.61, 88.11 and 45.63% moisture (Sibiya et al., 2021), whereas the fruit of *M. charantia* was found to be 10.74% (Bakare et al., 2010). The moisture results of Kumar et al. (2016), Salvi (2015) and Sibiya et al. (2021) were higher in comparison with the 11.08% indicated in Table 1. However, the results of Bakare et al. (2010) were similar, with a 0.34% difference.

Yerima and Umar (2019) analysed the nutritional properties of *M. balsamina* seeds and documented a moisture content of 5.25%, which was lower than the moisture in *M. charantia* (20.69%) (Bakare et al., 2010; Kumar & Khurana, 2016). The seeds of *Emblica officinalis*, *Terminalia belerica* and *Terminalia chebula* were found to contain 34.12, 32.35 and 17.27% moisture. The results obtained by Yerima and Umar (2019) were similar to the result obtained in Table 1 (7.11%). Based on the result from Table 1, it can thus be said that *M. balsamina* seeds have a lower moisture content when compared with *M. charantia*, *E. officinalis*, *T. belerica* and *T. chebula*.

The moisture content in the pericarp of *M. charantia* fruit was found to be 14.42% in mature samples and 13.34% in immature samples (Horax et al., 2010). Saeed et al. (2010) also investigated the nutritional value of *M. charantia* fruit pericarp and reported the moisture to be 4.15%. Four different *Cucurbitaceae* species were examined by Osuagwu and Edeoga (2014) who determined the moisture of the fruit pericarp for *M. charantia, Trichosantes cucumerina, Cucurbita ficifolia* and *Luffa cylindrica* to be 0.38, 0.74, 1.00 and 0.34%, respectively. Ripe *Roystonea regia* fruit pericarp had been recorded to contain 7.58% moisture and 7.10% in unripe fruit pericarp (Aleshinloye et al., 2017). The 13.34% moisture obtained by Horax et al. (2010) for *M. charantia* fruit pericarp was in accordance with the result obtained in Table 1 (13.40%), with a mere 0.06% difference. However, the moisture content as reported by Saeed et al. (2010) as well as Osuagwu and Edeoga (2014) for *M. charantia* fruit pericarp was much lower than the moisture content in Table 1 (13.40%) for *M. balsamina*.

The ash content is the representation of the total minerals present (Fraizer, 2009). Ash is considered to be the residue of inorganic substances that occur when organic matter is completely incinerated. This occurs when samples are exposed to elevated temperatures (500–600°C) and complete oxidation occurs via the combustion and volatilisation of organic materials. The loss in weight is used to determine the ash content in a sample (Harbers, 1988). The pericarp had the greatest ash content (21.16%) followed by the leaves (15.18%), fruit flesh (10.62%) and seeds (2.93%) (Table 1).

Table 1. The nutritional profile of the leaves, pericarp, fruit flesh and seeds of *Momordica balsamina*.

	Fruit flesh	Pericarp	Seeds	Leaves
Moisture (%)	11.08 ± 0.13^{ab}	13.40 ± 0.14^{b}	7.11 ± 0.20^{b}	11.28 ± 0.06^{ab}
Ash (%)	10.62 ± 0.51^{b}	21.16 ± 0.09^{b}	2.93 ± 0.03^{b}	15.18 ± 0.21^{b}
Fat (%)	1.96 ± 0.23^{cad}	1.18 ± 0.11^{c}	2.40 ± 0.33^{c}	1.03 ± 0.17^{ba}
Protein (%)	26.73 ± 0.75^{abc}	21.35 ± 1.89^{a}	19.72 ± 0.06^{a}	29.08 ± 0.77^{b}
Carbohydrates (%)	49.61 ± 0.70^{b}	42.91 ± 1.95^{b}	67.84 ± 0.30^{b}	43.44 ± 0.73^{ba}

Data denote mean ± standard deviation ($n = 3$). Values with different superscript letters are significantly different ($p < 0.05$).

Leaves of *M. charantia* were noted to have an ash content of 15.42% (Kumar & Khurana, 2016) which was slightly lower than the 17.93% obtained by Sulaiman and Yakubu (2018). Bakare et al. (2010) also reported the total ash of *M. charantia* to be 15.42%. These results coincide with the ash percentage obtained for the leaves of *M. balsamina* in Table 1 (15.18%). However, the ash content of *M. balsamina* leaves (15.18%) is much greater in comparison with the ash content present in the leaves of *S. nigrum* L. (3.80%), *C. argentea* L. (3.60%) and *A. sessilis* (L.) R. Br. Ex DC. (1.50%) (Kumar et al., 2016).

Both Bakare et al. (2010) and Kumar and Khurana (2016) reported *M. charantia* fruit to have a total ash of 7.36%. Salvi (2015) determined the ash content of *M. dioica* fruit to be 14.00%. The findings of Kumar et al. (2016) showed a 2.40% ash content in *M. dioica* Roxb. ex Willd (Fruit), which was lower than the amount present in the fruit of *C. edulis* (8.76%) and *P. capensis* (3.42%) but similar to *E. magalismontanum* (2.05%) (Sibiya et al., 2021). Fruits of *Ficus capensis* were found to have 7.66% ash (Okoroh et al., 2019). Overall, the ash of *M. balsamina* fruit flesh obtained in Table 1 (10.62%) was closer to the ash content identified by Bakare et al. (2010), Kumar and Khurana (2016), Okoroh et al. (2019) and Sibiya et al. (2021).

Momordica balsamina seeds have been reported to have an ash content of 2.25 and 4.50% (Uchegbu et al., 2017; Yerima & Umar, 2019). This was lower than the amount present in *M. charantia* (9.73%) (Kumar & Khurana, 2016). Rathnayake et al. (2018) examined six cultivars of *M. charantia* seeds and found the ash content to range from 2.8 to 4.2% in mature seeds and 2.1 to 2.8% in ripe seeds. The ash results for *E. officinalis* (11.28%), *T. belerica* (11.75%) and *T. chebula* (8.56%) were higher than those reported for *M. balsamina* and *M. charantia* (Malik et al., 2020). Table 1 depicts an ash content of 2.93% for *M. balsamina* seeds. These results were aligned with the findings of Rathnayake et al. (2018), Uchegbu et al. (2017) and Yerima and Umar (2019).

In *M. charantia*, the fruit pericarp was detected to have 14.99% ash by Saeed et al. (2010). This was higher than the 0.06% in *M. charantia* fruit pericarp as reported by Osuagwu and Edeoga (2014). *Xylopia aethiopica* fruit pericarp was found to have 8.70% ash (Fategbe et al., 2021). Aleshinloye et al. (2017) noted *R. regia* to have an ash content of 11.14% in ripe and 10.46% in unripe fruit pericarp samples. The ash content of *Tamarindus indica* pericarp was recorded as 3.40% by Dàvila-Hernàndez et al. (2020). *T. cucumerina*, *C. ficifolia* and *L. cylindrica* had 0.15, 0.42 and 0.90% of ash content (Osuagwu and Edeoga, 2014). Based on the results mentioned, *M. balsamina* fruit pericarp contained the highest percentage of ash (21.16%) (Table 1). *M. charantia* as reported by Saeed et al. (2010) had the closest percentage of ash to the result in Table 1 with the fruit pericarp of *T. cucumerina*, *C. ficifolia* and *L. cylindrica* having the lowest percentage of ash in comparison.

Fats from food provide an important energy source for the human body whereby saturated and monosaturated fatty acids are synthesised in the human body for various functions that are physiological, energetic and structural in nature (Jéquier, 1994; Liu et al., 2017). It should also be noted that vitamins A, D, E and K can only be absorbed in the intestine when fat is present and have therefore been termed as fat-soluble vitamins (Albahrani & Greaves, 2016). Overall, the fat percentage was low and similar in quantities across all four samples of *M. balsamina* (Table 1), with the seeds containing the largest fat content (2.40%). The fruit flesh was the second highest (1.96%), in comparison with the fruit pericarp (1.18%) and leaves (1.03%).

The leaves of *M. charantia* have been found to have a fat content of 3.68% (Kumar & Khurana, 2016). Sulaiman and Yakubu (2018) also investigated *M. charantia* leaves and depicted the fat to be 3.03%. *Rumex crispus* L. leaves had a fat content of 2.01% (Idris et al., 2019). The result obtained in Table 1 (1.03%) for *M. balsamina* was slightly lower than the percentages that were reported for *M. charantia* and *R. crispus* L. However, the fat results for the leaves of *S. nigrum* L. (1.90%) and *C. argentea* L. (0.50%) were similar with a 0.87% and 0.53% difference (Kumar et al., 2016).

Fruits of *M. dioica* were found to have a fat content of 4.00% (Salvi, 2015). However, the fruit of *M. dioica* Roxb. ex Willd was lower with a 1.30% (Kumar et al., 2016). In comparison with the results of Kumar et al. (2016) and Salvi (2015), *M. charantia* fruits were found to have a higher fat content of 6.11% (Kumar & Khurana, 2016). Based on the results obtained in Table 1 for *M. balsamina* (fruit flesh 1.96%), *M. dioica* Roxb. ex Willd fruit had the closest fat percentage (1.30%). It can be said that the fruits of *C. edulis* (0.21%) and *E. magalismontanum* (0.31%) have a lower fat content than that of *M. balsamina*, as shown in Table 1 (Sibiya et al., 2021). However, the fruits of *P. capensis* (5.11%) and *F. capensis* (4.47%) have a greater fat percentage than the 1.96% depicted in Table 1 (Okoroh et al., 2019; Sibiya et al., 2021).

Yerima and Umar (2019) evaluated *M. balsamina* seeds and the results showed that the seeds had a high percentage of crude lipids (38.77%). The fat content of *M. charantia* seeds was reported as 11.50%. Mature seeds of *M. charantia* contained fat which ranged from 28.90 to 41.90% and 39.20 to 45.20% in ripe seeds across six cultivars (Rathnayake et al., 2018). These findings were dramatically greater than the result obtained in Table 1 (2.40%). Although Uchegbu et al. (2017) recorded *M. balsamina* seeds to have a fat content of 1.45%, as well as *E. officinalis* (2.95%), *T. belerica* (3.44%) and *T. chebula* (2.97%) as described by Malik et al. (2020) had a fat content that coincided or was close to the 2.40% reported in Table 1.

In the fruit pericarp of *M. charantia*, 9.70% of fat was detected in both mature and immature pericarp samples (Horax et al., 2010). Saeed et al. (2010) reported that there was 0.18% fat in *M. charantia* fruit pericarp. When determining the fat content of *M. charantia, T. cucumerina, C. ficifolia* and *L. cylindrica*, Osuagwu and Edeoga (2014) noted that all species had 0.006% fat. The ripe fruit pericarp (9.80%) of *R. regia* was determined to be slightly higher in fat than the unripe fruit pericarp (7.40%) (Aleshinloye et al., 2017). The result of Saeed et al. (2010) for *M. charantia* fruit pericarp was the closest to the result obtained in Table 1 (1.18%) for the fat content of *M. balsamina* fruit pericarp. Based on the 1.18% obtained from Table 1, it can be said that *M. balsamina* fruit pericarp has a lower fat content than *R. regia and M. charantia* as depicted by Aleshinloye et al. (2017) and Horax et al. (2010) but a higher fat content than *M.*

charantia, T. cucumerina, C. ficifolia and *L. cylindrica* as reported by Osuagwu and Edeoga (2014).

Protein has been classified as an essential macronutrient that is required for the growth and maintenance of the human body (Delimaris, 2013). Proteins are responsible for a wide range of functions in cells. Importantly, proteins have been noted to contribute to the function, structure and regulation of the body's organs and tissues (Sudhakararao et al., 2019). The leaves of *M. balsamina* (Table 1) contained the most protein content (29.08%), followed by the fruit flesh (26.73%), fruit pericarp (21.35%) and seeds (19.72%). All four *M. balsamina* samples (Table 1) exhibited a higher protein content than the leaves of *Aspilia africana* (Asteraceae) C.D Adams which were reported to contain a high concentration of crude protein (15.62%) (Adegbesan, 2019).

The protein of *M. charantia* leaves was found to be 27.46% by Bakare et al. (2010) as well as by Kumar and Khurana (2016). *M. balsamina* leaves were recorded to have 11.29% of protein (Thakur et al., 2009). In comparison, Sulaiman and Yakubu (2018) showed 10.25% protein in *M. charantia* leaves which was the lowest but closer to Thakur et al. (2009) with a mere 1.04% difference. Idris et al. (2019) noted 26.37% protein in the leaves of *R. crispus* L. which was higher than the 15.62% in *A. africana* leaves as reported by Adegbesan (2019). The result in Table 1 (29.08%) depicts a high protein content of *M. balsamina* leaves that is in accordance with the results exhibited by Bakare et al. (2010) as well as Kumar and Khurana (2016). It should also be noted that the protein content result from Table 1 is greater than the protein content present in the leaves of *S. nigrum* L. (4.40%), *C. argentea* L. (5.00%) and *A. sessilis* (L.) R. Br. Ex DC. (4.50%) (Kumar et al., 2016).

Nagarani et al. (2014) identified the protein content of *M. dioica*, *M. balsamina* and *M. charantia* fruit, which were found to contain 19.38, 27.88 and 11.29% of protein, respectively. There was 6.50% protein noted in the fruits of *M. dioica* (Salvi, 2015). However, a low protein content in *M. dioica* Roxb. ex Willd (fruit) was recorded (2.00%) by Kumar et al. (2016) and *M. charantia* L. fruit (2.10%) by Upadhyay et al. (2015). In *M. charantia* fruit, there was a protein content of 27.88% reported by both Bakare et al. (2010) and Kumar and Khurana (2016). Table 1 depicts the fruit flesh of *M. balsamina* to have a protein content of 26.73% which was in accordance with the results exhibited by Nagarani et al. (2014) (*M. dioica* and *M. balsamina),* Bakare et al. (2010) as well as Kumar and Khurana (2016). Notably, the fruits of *C. edulis* (3.45%) and *P. capensis* (4.33%), *E. magalismontanum* (0.83%) and *F. capensis* (1.40%) had a low protein content in comparison with the result in Table 1 (26.73%) (Okoroh et al., 2019; Sibiya et al., 2021).

The crude protein of *M. balsamina* seeds was found to be 20.25% (Yerima & Umar, 2019). There was 19.50% protein in the seeds of *M. charantia* as expressed by Bakare et al. (2010). From six different cultivars, the protein in mature *M. charantia* seeds ranged from 12.00 to 26.20% and 14.40 to 31.50% in ripened seeds (Rathnayake et al., 2018). The results mentioned above are in consensus with the protein result obtained from Table 1 (19.72%) for the seeds of *M. balsamina*. However, the protein content represented by Uchegbu et al. (2017) for the seeds of *M. balsamina* (8.75%) is low in comparison with Table 1. The seeds of *T. belerica* (18.29%) and *T. chebula* (18.45%) were similar to the result obtained in Table 1 for the seed protein content (Malik et al., 2020).

In mature and immature *M. charantia* fruit pericarp, there was a protein content of 8.80 and 11.50%, respectively (Horax et al., 2010). Osuagwu and Edeoga (2014) determined the protein content of four *Cucurbitaceae* species, viz. *M. charantia*, (0.25%) *T. cucumerina* (0.30%), *C. ficifolia* (0.40%) and *L. cylindrica* (0.25%). *R. regia* fruit pericarp was found to have a protein content of 8.07% in ripe samples and 6.93% in unripe samples (Aleshinloye et al., 2017). A high percentage of protein of 20.37% was reported by Saeed et al. (2010) in the fruit pericarp of *M. charantia*. Overall, the fruit pericarp of *M. balsamina* as shown in Table 1 (21.35%) demonstrated the highest protein content. The result of Table 1 was greater than *M. charantia*, *T. cucumerina*, *C. ficifolia, L. cylindrica* and *R. regia* fruit pericarp. However, it should be noted that the fruit pericarp of *M. balsamina* (Table 1) was only greater by 0.98% than the protein percentage reported by Saeed et al. (2010).

Foods that contain carbohydrates and dietary fibre play a significant role in allowing for a healthy and well-balanced diet to be maintained (Slavin & Carlson, 2014). Foods that are of plant origin exclusively produce carbohydrates, as they are manufactured from the energy obtained from the sunlight along with water and carbon dioxide. Carbohydrates in the human diet can be categorised into three main groups, which are sugars, starch and non-starch polysaccharides. These carbohydrates are responsible for being the primary source of energy as it provides around 50–70% of energy intake (Lunn & Buttriss, 2007). The seeds of *M. balsamina* (Table 1) were found to contain the greatest percentage of carbohydrates (67.84%) in comparison with the fruit flesh, leaves and fruit pericarp which contained 49.61, 43.44 and 42.91%, respectively.

Leaves of *M. charantia* were examined and found to have a carbohydrate content of 32.34% (Kumar & Khurana, 2016). The carbohydrate content of *M. charantia* leaves was recorded as 28.52% by Sulaiman and Yakubu (2018). Thakur et al. (2009) determined the leaves of *M. balsamina* to have 39.05% carbohydrates. In *M. balsamina* L. leaves, there were 39.05% available carbohydrates as reported by Hassan and Umar (2006). The carbohydrate content present in the leaves of *S. nigrum* L. (11.10%), *C. argentea* L. (10.60%) and *A. sessilis* (L.) R. Br. Ex DC. (16.30%) was lower than the percentage recorded in Table 1 (43.44%) (Kumar et al., 2016). Overall, the percentage of carbohydrates obtained from Table 1 was higher than those depicted by Hassan and Umar (2006), Kumar and Khurana (2016), Kumar et al. (2016), Sulaiman and Yakubu (2018), and Thakur et al. (2009), but lower than the carbohydrate content of *A. africana* leaves (61.64%) (Adegbesan, 2019).

Momordica dioica fruits were shown to have a carbohydrate content of 14.58% (Salvi, 2015). Both Bakare et al. (2010) and Kumar and Khurana (2016) noted 34.31% carbohydrate in *M. charantia fruit*, whereas, in *M. dioica* Roxb. ex Willd (Fruit), there was 16.90% of carbohydrates (Kumar et al., 2016). Upadhyay et al. (2015) determined that there was a 10.60% carbohydrate content in the fruit of *M. charantia* L. The fruits of *C.*

edulis, P. capensis and *E. magalismontanum* had the following carbohydrate contents of 10.97, 25.00 and 3.10%, respectively (Sibiya et al., 2021). It can be said that the fruit flesh carbohydrate content in Table 1 (49.61%) was higher than the fruits of *M. dioica*, *M. charantia, M. dioica* Roxb. ex Willd Fruits, *C. edulis, P. capensis* and *E. magalismontanum* but similar to the fruit of *F. capensis* (49.58%) (Okoroh et al., 2019).

The seeds of *M. balsamina* was reported to have a carbohydrate content of 31.46% (Yerima & Umar, 2019). Kumar and Khurana (2016) quantified a low carbohydrate content (9.18%) when compared with the carbohydrate content determined in *M. balsamina* seeds (83.40%) by Uchegbu et al. (2017). Karaye et al. (2013) examined five species of seeds of the *Cucurbitaceae* family. The carbohydrate content was determined to be as follows: *Luffa aegyptiaca* (Mill.) (31.38%), *C. lanatus* (Thunb. Matsum and Nakai) (34.46%), *C. maxima* (Duchesne, ex Lam) (28.68%), *Cucumis metuliferus* (E. Mey. Ex Naudin) (27.88%) and *M. balsamina* (Linn.) (28.19%). The result of the seeds of *M. balsamina* obtained from Table 1 (67.84%) was higher with the exception being for the carbohydrate content in *M. balsamina* seeds (83.40%) as reported by Uchegbu et al. (2017).

Saeed et al. (2010) depicted the fruit pericarp of *M. charantia* to contain 42.54% of carbohydrates which was lower than the result reported by Osuagwu and Edeoga (2014) for *M. charantia* fruit pericarp (83.68%). Osuagwu and Edeoga (2014) also demonstrated the carbohydrate content of *T. cucumerina* (70.05%), *C. ficifolia* (70.17%) *and L. cylindrica* (71.84%). The ripe fruit pericarp (39.86%) had a higher carbohydrate content than the unripe fruit pericarp (37.55%) of *R. regia* (Aleshinloye et al., 2017). Fategbe et al. (2021) recorded *Xylopia aethiopica* fruit pericarp to contain 56.77% of carbohydrates. Table 1 depicts the fruit pericarp of *M. balsamina* to have a carbohydrate content of 42.91% which was similar to the result of Saeed et al. (2010), who looked at the fruit pericarp of *M. charantia*. There was a difference of 0.37% between the result obtained from Table 1 and that of Saeed et al. (2010). Even the ripe fruit pericarp of *R. regia* had a close carbohydrate content to that of Table 1. It should be noted that the results of Osuagwu and Edeoga (2014) did not correspond with the result obtained in Table 1 and instead were much greater.

3.2 Phytochemical Screening

Table 2 indicates the major phytochemical groups that can be identified in plants. Alkaloids were detected in all plant parts irrespective of the extract and sample type, whereas flavonoids were recorded as undetected in all sample extracts. Saponins were found to be positive in only the distilled water extracts. However, both cardiac glycosides and steroids were undetected in distilled water extracts but were detected in the hexane as well as ethyl acetate extracts. Triterpenoids were detected in all extracts except for the leaves extracted with ethyl acetate.

Biosynthetically derived from amino acids, alkaloids are present in small quantities in plants. This group of compounds has been acknowledged to have great therapeutic potential, especially in drug discovery (Heinrich et al., 2021). Alkaloids are diverse in both their structures and pharmacological action, allowing them to be present in various extraction procedures as well as solvents of different polarities (Dey et al., 2020). The variation in compound structure is evident in Table 2 as all extracts irrespective of plant part indicated a positive reaction for alkaloids. This is supported by the detection of alkaloids in methanolic extracts of *M. charantia* seeds, ethanolic fruit extracts of *M. dioica* as well as in the leaf powders of both *M. charantia L.* and *Morinda lucida Benth* (Chokki et al., 2020; Hassan et al., 2022; Zahan et al., 2020). Ethyl acetate and hexane extracts of *Calotropis gigantean* plant parts (combined) also depicted a positive reaction for alkaloids (Seniya et al., 2011). Based on these findings, it can be deduced that *M. balsamina*

Table 2. Phytochemical screening of various *Momordica balsamina* plant part extracts.

		Fruit flesh	Pericarp	Seeds	Leaves
Alkaloids	Hex	+	+	+	+
	EA	+	+	+	+
	$D.H_2O$	+	+	+	+
Saponins	Hex	-	-	-	-
	EA	-	-	-	-
	$D.H_2O$	+	+	+	+
Cardiac glycosides	Hex	+	+	+	+
	EA	+	+	+	+
	$D.H_2O$	-	-	-	-
Flavonoids	Hex	-	-	-	-
	EA	-	-	-	-
	$D.H_2O$	-	-	-	-
Steroids	Hex	+	+	+	+
	EA	+	+	+	+
	$D.H_2O$	-	-	-	-
Triterpenoids	Hex	+	+	+	+
	EA	+	+	+	-
	$D.H_2O$	+	+	+	+

Data indicates +: detected/-: undetected (n = 3) of different phytochemical groups in each crude extract (Hex: hexane, EA: ethyl acetate and $D.H_2O$: distilled water) (n = 3).

fruit parts (pericarp, fruit flesh and seeds) and leaves contain a range of alkaloids that vary in polarities and should also differ structurally.

In comparison with alkaloids, saponins were only noted in distilled water extracts as seen in Table 2. These findings are corroborated by the polar nature of most saponin compounds that foam into a 'soap-like' consistency in aqueous mixtures. These desirable emulsifying/foaming properties can be attributed to the very hydrophobic aglycone and hydrophilic sugar chains present in saponin structures (Shi et al., 2004). Therefore, the saponins present in *M. balsamina* distilled water extracts exhibited polar qualities which can be attributed to the hydrophilic sugar chains. The presence of hydrophobic aglycone structures would explain the immiscible nature of all ethyl acetate and hexane extracts which resulted in a negative outcome in Table 2. The froth test conducted on both *Thaumatococcus danielli* (ethyl acetate extracts) and *Bauhunia semibifida* ROXB leaves (hexane extract) produced a negative result (Alaekwe et al., 2023; Ushie et al., 2022). In contrast to these findings, aqueous extracts from *Acacia nilotica*, *Rumex abyssinicus* (root) and *Polysphaeria aethiopica* (leaves) had reported a positive result for saponins (Auwal et al., 2014; Kebede et al., 2021). Saponins were also detected in both ethanol and methanolic extracts of *Goniothalamus velutinus* (leaf and bark) (Iqbal et al., 2015). These studies are in accordance with the results obtained in Table 2 where polar solvents (aqueous/ethanol/methanol) extracts tested positive for saponins and the non-polar/moderately non-polar solvents (hexane/ethyl acetate) produced a negative result.

All plant parts of *M. balsamina* hexane and ethyl acetate extracts had detected cardiac glycosides. The distilled water samples produced a negative result (Table 2) and is considered the most desirable outcome. This is based on the toxicity associated with cardiac glycosides in humans and wild animals. Therefore, to avoid the detrimental toxic effects of cardiac glycosides in high concentrations, identifying this group of compounds is of great importance (Botelho et al., 2019). *Azadirachta indica* seeds were reported to exhibit a positive colour change for ethyl acetate and hexane extracts (Awode et al., 2023). The root bark of *Securidaca longipedunculata* extracts was in compliance with the findings of Table 2, where ethyl acetate/hexane extracts tested positive and distilled water extracts tested negative for cardiac glycosides (Osinubi et al., 2023). Methanolic *M. balsamina* leaf extract was identified to contain cardiac glycosides (Mabasa et al., 2021).

Despite the adverse effects experienced with the consumption of plants containing high concentrations of cardiac glycosides, there have been developments in its applications for the treatment of heart disease and arrhythmia. This has led to Food and Drug Administration (FDA) approved clinical drugs on the market. Such a shift has created interest in the presence of cardiac glycosides in plants and their therapeutic potential (Botelho et al., 2019; Osman et al., 2017). This implies that the cardiac glycoside-containing extracts (hexane and ethyl acetate) of *M. balsamina* (leaves, fruit flesh, pericarp and seeds) could be considered in future studies to test its viability as a plant-based alternative in treating heart ailments.

The presence of flavonoids remained undetected in all *M. balsamina* plant parts, irrespective of the solvent used in the extraction process (Table 2). These findings correspond with the data reported by Abdulhamid et al. (2023) who analysed *M. balsamina* leaf (hexane, ethyl acetate, aqueous and butanol) extracts/fractions for flavonoids. However, it should be noted that this conflicts with the results reflected in similar studies conducted on the *Momordica* genus and other plant species, as seen in methanolic *M. balsamina* (leaf), ethanolic *M. dioica* (fruit) and ethyl acetate/hexane *T. daniellii* (leaf) extracts which had indicated a positive result for flavonoids (Azuaga et al., 2022; Hassan et al., 2022; Mabasa et al., 2021).

The disparity in the results obtained for flavonoids in Table 2 and other similar studies can be attributed to the diversity of the compound form which varies according to the *Momordica* plant type as explained by Madala et al. (2016). Ultimately, such differences would stem from the solvent systems/extraction techniques employed, and handling and storage would also cause compound degradation/transformation leading to flavonoids producing a negative result in a sample. Another important factor is the geographical region of sample origination and the time of harvest which dictates the compounds that are present and their concentrations (Awad et al., 2021). Therefore, these considerations should be made to allow for specificity in the compounds extracted when examining the presence of flavonoids in *M. balsamina* samples. Alternatively, it could be theorised that there is an absence of flavonoids in all plant parts no matter the type of extract (hexane, ethyl acetate and distilled water). However, due to the role of flavonoids in plants (contributes to the colour, flower aroma and attraction of pollinators), this theory is highly unlikely (Samanta et al., 2011).

Plant steroids have been identified to reduce the risk of heart disease and oxidative stress (Kopylov et al., 2021). Studies have also confirmed a link between steroid hormones and their role in growth, development as well as reproduction in the human body (Adhya et al., 2018). Therefore, it can be speculated that detected steroids in *M. balsamina* extracts (all hexane and ethyl acetate extracts) would positively impact human health and should be examined for their presence. In contrast to these results, all distilled water extracts tested negative for the presence of steroids (Table 2). These findings were validated by the presence of steroids in *M. dioica Roxb.* Ex Willd hexane and ethyl acetate extracts, whereas distilled water extracts produced a negative result (Johns et al., 2022). A positive result was also obtained in *Azadirachta indica* hexane, ethyl acetate and methanol seed extracts (Awode et al., 2023). Steroids were also undetected in distilled water *M. charantia Linn.* fruit extracts but were detected in chloroform and petroleum ether extracts (Patel et al., 2011). Therefore, it can be said that the steroids detected in *M. balsamina* tend to have more non-polar characteristics.

Triterpenoids produced a positive result in all extracts except for ethyl acetate leaves. However, due to the diversity and wide distribution of triterpenoids in plants, it is thought that the presence of triterpenoids in low concentrations is what prevented the formation of the yellow colour (a negative result) (Sawai & Saito, 2011). Literature supports the variety of triterpenoids in different plant types as well as solvents. This can be seen in

the positive result obtained from methanolic *M. dioica* fruit extracts, *Ficus religiosa* seeds (hexane, ethyl acetate and aqueous extracts) as well as in *M. charantia* L. hexane leaf extracts (Haimed et al., 2019; Pinipay et al., 2022; Rasmi et al., 2023). Triterpenoids were also identified in hexane, butanol, ethyl acetate and distilled water fractions of *Mormodica balsamina* leaves (Abdulhamid et al., 2023).

The data reported in Table 2 indicate *M. balsamina* fruit parts (pericarp/fruit flesh/seeds) and leaves to have a diverse range of phytochemicals. The presence of these constituents has been attributed to the hypoglycaemic effects of the *Momordica* species. It is therefore vital to identify the mode of action that allows for these compounds to be effective in the management as well as treatment of diabetes (Oyelere et al., 2022).

4 CONCLUSION

Based on the findings discussed above, it can be said that *M. balsamina* has a nutritive profile that could be used not only to supplement the human diet but also as a means of protection from diseases that arise from malnutrition. This can be attributed to the high protein content amongst all samples (19.72–29.08%). It should also be noted that the leaves presented the highest protein content (29.08% ± 0.77) and were higher than other *Momordica* species. Overall, there was a low-fat content which ranged around 1.03–2.40%. Notably, the fruit pericarp was found to contain the greatest ash percentage (21.16% ± 0.09) and therefore contains the highest total minerals. Present as plant secondary metabolites, alkaloids, saponins, cardiac glycosides, steroids and triterpenoids were detected in *M. balsamina* extracts. Alkaloids and triterpenoids were deduced to have the most structural diversity as they were detected in a range of extracts, irrespective of the solvent polarity and should be considered accordingly for their health benefits. It can thus be said that this study verified the traditional consumption of the leaves and fruit (fruit pericarp, fruit flesh and seeds) of *M. balsamina* as its consumption would have a positive impact on the human diet. Even though there were a number of bioactive compounds detected, further studies that would correlate the phytochemical constituents detected in *M. balsamina* and its effectiveness in treating various diseases are recommended.

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