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Documentation of Antiobesogenic Plants used by Bodo Community of Assam, India

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ABSTRACT: Ethno-botanical survey was conducted during the month of October to December 2021 in 6 villages (Bhalabari, Simlibari, Khoirabari, Banseria, Angrajuli and Bagchai chuburi) of Udalguri district of BTR for a better understanding of local beliefs, habits and culinary practices regarding the use of medicinal plants for treatment of obesity. During the ethno-medicinal survey period the well known medicinal practitioners called as "Buwidw" were contacted and appraised regarding the purpose of the study and other ethno-medicinal information were gathered. Local healers or buwidw were interviewed using structured questionnaire. Owing to their prior experiences being exploited by business associates of pharmaceutical and drug companies, some respondents were occasionally reluctant to impart their knowledge of medicinal plants and less receptive to being the focus of outsiders' and visitors' investigations. Altogether 12 local healers or buwidw were interviewed from the randomly selected villages. From the survey, 15 medicinal plants were collected that are mainly used for treatmentof obesity. Out of these 15 plants most cited plants were found to be *Alstonia scholaris* (L.) *R.Br.* (Apocynaceae) and *Syzygium cumini* (L.) *Skeels* (Myrtaceae). This explorative survey underscores the importance of preserving and documentation of indigenous plants for further scientific investigations.

Keywords: Antiobesogenic, Bodo tribe, Obesity, Documentation, GC-MS, Phytochemical.

INTRODUCTION

Over the past several decades, there has been a swift rise in the prevalence of obesity across the globe due to radical change in the food habits and lifestyle. Consumption of high fat salt and sugar (HFSS) food products as well as sedentary lifestyle has greatly influenced the increased in the prevalence of obesity (Bhatia *et al.*, 2021).

Obesity has become a serious global health concern since it is associated with major life threatening diseases including cardiovascular diseases (CVD), type 2 diabetes (T2DM) and several cancers (Mazzeo, 2016). Onset of obesity can be attributed to some broad factors such as genetic, socio-demographic, behavioral, and obesogenic environment. These are the factors that synergistically influence obesity and obesity related disorders (Vaidya *et al.*, 2006; Endalifer & Diress, 2020). The most preferred ways to fight weight gain is to adopt physiological interventions such as physical exercise and healthy diet but due to urbanization and demand of luxurious life these interventions appears to be difficult to practice and maintain (Chew *et al*., 2022; Koengkan & Fuinhas 2022).

So, introducing pharmacological interventions have become a very important step for treatment of obesity. Some anti obesogenic drugs and weight reducing therapies had been circulating the market and helped in acceleration of growth of pharmaceutical industries worldwide (Sun *et al.*, 2016). The use of these pharmacological drugs reduces the calorie absorption, alters appetite drive, provides satiety, alters adipogenesis and regulates metabolism of the body leading to reduction of body weight (Chandrasekaran *et al.*, 2012). But use of these drugs were found to be having serious health effects like liver disorder, faulty bowel movements, gastro-intestinal (GI) disorder, sleeplessness, cardiovascular diseases, hypertension, restlessness etc. (Kushner, 2014; Tong *et al.*, 2022; Muller *et al.*, 2022). In this context, use of medicinal plants which have been consumed for hundred years becomes very important because of their minimal or no side effects. Drugs that are being used for the treatment of obesity or weight loss should be able to reduce weight with little or no side effects (Rodgers *et al.*, 2012).

As a result, the emphasis on natural products is increasing currently because of their complete absence of side effects (Venmathi *et al.*, 2022; Brahmi *et al.*, 2023). Since time immemorial herbal plants have been

used for prevention and cure of many diseases and it is considered as a repository of wide variety of bioactive compounds with numerous therapeutic activities (Dattaray, 2022). The medicinal properties of plants have been intensively explored since last few decades. The medicinal activities include antiobesogenic, anti-inflammatory, anti diabetic, antiviral, anticarcinogenic and analgesic etc. (Debbarma *et al.*, 2017).

Since plants are the key source of various bioactive compounds, it plays a crucial role in prevention and cure of many diseases. Around 2/3 rd of the world population depends on the medicinal plants. The better compatibility and adaptability of medicinal plants in human body and cultural acceptability have made it more important in the field of medicine. It is demonstrated that most of the medicines used are developed from plant extract. The discovery of various medicinal and therapeutic activities of plants through many researches only became possible after the detailed study of traditional or ethno medicinal usage of plants since age old times. The traditional knowledge on herbal plants of ethnic community, their claims, beliefs and folklore practices have significant contribution in advancement and development of science and technology (Rehman *et al.,* 2022).

Ethno botanical studies play an important role in preserving the traditional knowledge on herbal plants and revealing indigenous plants species for development of new drugs. Scientific documentation of the indigenous plants of particular community not only preserves the indigenous knowledge but also helps in conservation of biological diversity and gives encouragement to the community (Patil *et al.,* 2023). Since last few decades, it has been observed that the ethnomedical use of plants is rapidly vanishing, and this trend is more pronounced in industrialised nations. Studies have showed that the traditional knowledge on medicinal plants of the ethnic community is decreasing in alarming rate. The main reason behind this loss of traditional knowledge is quick land degradation such as accelerated forest destruction, increase accessibility and affordability of modern drugs, influence of modern culture and adoption of new culture know as acculturation. This indicates that the passing down of community customs and rituals from one generation to another is now on the verge of disappearance creating a threat to protection and preservation of traditional knowledge of an ethnic community. In view of this loss of indigenous knowledge, scientific documentation and greater understanding of ethno botanical roots has appeared to be the crucial task of ethno-allied discipline (Ranil *et al.,* 2021; Borgohain & Borpatra Gohain, 2023).

For documentation of data, information regarding the traditional uses of indigenous plants of Bodo tribe of Bodoland Territorial Region (BTR) possessing antiobesogenic properties was elucidated through household survey and by interacting with *buwidw* 'local healers'. The survey was conducted in 6 villages (Bhalabari, Simlibari, Khoirabari, Banseria, Angrajuli and Bagchai Chuburi) of Udalguri district of BTR for better understanding of local beliefs, habits and folklore practices.

MATERIAL AND METHOD

A. Study area

The Bodo tribe of Assam of Northeastern India comprises as one of the major and oldest tribal communities of Assam. They are early settlers of Assam in northeast India and have a population of around two million according to the 2011 census. The Bodo people are concentrated in the northern areas of Bramhaputra River Valley. This dwelling region of Bodo community is now known as Bodoland Territorial Region (BTR) consisting of 5 districts: Kokrajhar, Chirang, Baksa, Tamulpur and Udalguri (Fig. 1). Large sections of this tribe are economically under-developed and they have traditional believes and knowledge in plants and forests. A wide variety of traditional plants are being used among Bodo tribe for the treatment of mild to severe type of health issues or ailments since time immemorial.

The Bodoland Territorial Region, also known as Bodoland, is an autonomous region in Assam, Northeast India. Bodoland area is consists of 5 administrative districts situated in north bank of the Brahmaputra river down the foothills of Bhutan and Arunachal Pradesh. Geographically BTR region lies between 26° 7'12" N to 26° 47' 50" N Latitude and 89° 47' 40" E to 92° 18' 30" E Longitude and is in the North Western part of Assam. the Administrative Head Quarter is Kokrajhar town that lies between 26° 25' N latitude and 90° 16' 38" E Longitude. BTC has an area about 8970 sq.km with total forest area 3234 sq.km.

The ethno-botanical survey was conducted during the month of October to December 2021 in 6 villages (Bhalabari, Simlibari, Khoirabari, Banseria, Angrajuli and Bagchai Chuburi) of Udalguri district of BTR for a better understanding of local beliefs, habits and culinary practices regarding the use of medicinal plants for treatment of obesity.

B. Data collection

During the ethno-medicinal survey period the well known medicinal practitioners called as "Buwidw" were contacted and appraised regarding the purpose of the study and other ethno-medicinal information were gathered. Rapport establishment was done with local resourceful person and social workers for their suggestion and advice on folklore medicinal practices.

Data were gathered through in-depth interviews with 12 local healers who were selected using the Snowball Sampling technique. The guidance of the previous respondents determined the direction of the subsequent informants. The interview activities were conducted using a semi-structured questionnaire to evaluate traditional practices for the use of medicinal plant species, the part used, and the method of preparation.

The use value (UV) is a quantitative technique that illustrates the relative importance of species known locally, was determined using the following formula: UV=U/N, where UV stands for a species' use value, U for the number of citations per species, and N for the

total number of informants (Tardío & Pardo-de-Santayana 2008).

C. Plants collection and preservation

From the survey, 15 medicinal plants were collected that are mainly used for treatment of obesity. All medicinal plants were collected from 6 different villages. A detailed field notes were recorded of the collected plant specimens including local name, habit, habitat, locality, flower color, parts used and date of collection, etc. Medicinal plants were dried, pressed, and mounted on herbarium sheets and identified with the help of taxonomist from department of Agronomy, Assam Agricultural University, Jorhat.

D. GC-MS analysis

Gas chromatography – mass spectrometry (GC-MS) analysis. Analysis of sample was carried out using GC-MS (7890/5975 Agilent Technologies, Inc., Beijing, China) consisting of a gaschromatography interfaced to a mass spectrometer instrument. The GC-MS was equipped with a HP-5 MS (5% phenyl methyl siloxane) low bleed capillary column of 30m length, 0.25mm diameter and 0.25µm film thickness. For GC-MS detection, an electron ionization system with ionization energy of 70Ev was used. The carrier gas used was helium (99.99%) at a constant flow rate of 1.25 ml/min in split mode. The injector and mass transfer line temperature were set at 250 C and 200 C respectively, and an injection volume of 1 µl was employed. The oven temperature was programmed from 35 C for 5 min, with an increase of 10 °C/min to 280 C for 10.5 min, then 50 °C/min to 285 °C for 29.9 min with a run time of 70 min. The mass spectrometry operating parameters were as follows: ionization energy, 70eV; ion source temperature, 230°C; solvent cut time, 3.3 min; relative detector gain mode; scan speed, 1666 µ/sec; scan range of 40–550 m/z and the interface temperature of 250 °C.

E. Data analysis

Microsoft Excel is used for all the statistical calculations, graphs, etc. The documented data was analyzed by comparing various parameters, including the number of plant species, families, parts used by the plants, preparation methods and habits of the plant species.

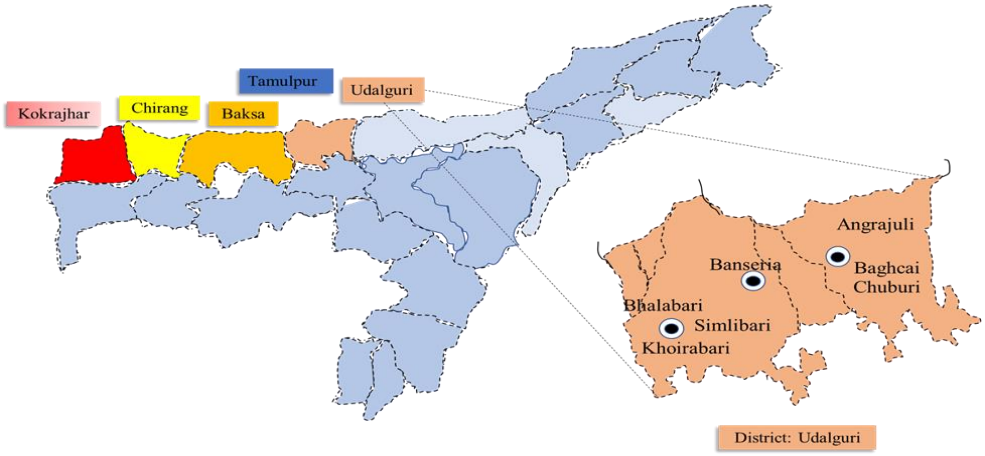

Fig. 1. Map of Bodoland Territorial Region (BTR) of Assam and the study area.

Table 1: Demographic profile of respondents (N=12).

Characteristics	No. of respondents (n)	Percentage of respondents (%)
Gender		
Male	10	83.33
Female	2	16.67
Education level		
Primary	8	66.67
Secondary	3	25.00
Higher education	1	8.33
Age		
45-55 years	1	8.33
55-65 years	3	25.00
65-75 years	2	16.67
>75 years above	6	50.00
Experience		
10-20 years	2	16.67
20-30 years	3	25.00
30-40 years	6	50.00
>50 years	1	8.33
Occupation		
Farming	5	41.67
Employed	3	25.00
Unemployed	4	33.33

Table 2: Plants used for treatment of obesity.

Scientific name	Family	Accession number	Local name	Parts used	Preparation	Dosage	Habit	Village	Times stated (per village)	Use value (per species)
Oroxylum indicum (L.) kurz	Bignoniaceae	AAU WEED HERBARIUM Acc. No. 5463	Kharong khandai	Leaves/ fruit	Fresh Juice	1 cup twice daily	Tree	Simlibari	1	0.08
Phlogacanthus curviflorus (Wall.) Nees	Acanthaceae	AAU WEED HERBARIUM Acc. No. 5465	Basikhor	Flower	Decoction	1-2 tsp once daily	Shrub	Khoirabari	1	0.08
Zingiber officinale Rosc.	Zingiberaceae	AAU WEED HERBARIUM Acc. No. 5467	Jermao	Roots	Fresh Juice	1 cup daily	Herb	Simlibari Angrajuli	1 1	0.16
Syzygium cumini (L.) Skeels	Myrtaceae	AAU WEED HERBARIUM Acc. No. 5464	Gwswm jamboo	Seed	Powder	1-2 tsp twice daily	Tree	Bholabari Angrajuli Simlibari	1 2 2	0.42
Ocimum tenuiflorum (L.)	Lamiaceae	AAU WEED HERBARIUM Acc. No. 5469	Tulsi	Roots	Paste	3-4 tsp daily	Herb	Khoirabari	2	0.16
Terminalia chebula Retz.	Combretaceae	AAU WEED HERBARIUM Acc. No. 5475	Selekha	Fruit	Fresh juice	1 cup twice daily	Tree	Banseria Angrajuli	1 1	0.16
Alstonia scholaris (L.) *R.Br.*	Apocynaceae	AAU WEED HERBARIUM Acc. No. 5468	Sithona	Bark	Decoction	1-2tsp daily	Tree	Banseria Khoirabari Simlibari	2 2 3	0.58
Phyllanthus emblica (L.)	Phyllanthaceae	AAU WEED HERBARIUM Acc. No. 5461	Amla	Fruit	Decoction	1-2 tsp daily	Tree	Khoirabari	1	0.08
Nyctanthes arbor-tristis (L.)	Oleaceae	AAU WEED HERBARIUM Acc. No. 5474	Sewali	Flower	Decoction	2-3 tsp daily	Shrub	Simlibari	1	0.08
Momordica charantia (L.)	Cucurbitaceae	AAU WEED HERBARIUM Acc. No. 5473	Udasi	Seed	Decoction	1-2tsp twice daily	climber	Bholabari	2	0.16
Murraya koenigii (L.) *Spreng,*	Rutaceae	AAU WEED HERBARIUM Acc. No. 5462	Narasingha	Leaves	Fresh Juice	Daily 3-4 tsp	Tree	Angrajuli	1	0.08
Azadirachta indica A. Juss.	Meliaceae	AAU WEED HERBARIUM Acc. No. 5466	Neem	Leaves	Decoction	2-3tsp twice Daily	Tree	Banseria Khoirabari	1 2	0.25
Rosa cymosa Tratt.,	Rosaceae	AAU WEED HERBARIUM Acc. No. 5470	Golabgufur	Flower	Decoction	3-4tsp daily	Shrub	Bholabari	1	0.08
Clerodendrum infortunatum L,	Lamiaceae	AAU WEED HERBARIUM Acc. No. 5471	Mwkhwna	Leaves	Decoction	1 cup once daily	Shrub	Khoirabari	1	0.08
Syzygium Jambo (L.) *Alston*	Myrtaceae	AAU WEED HERBARIUM Acc. No. 5472	Godjaam	Leaves	Decoction	3-4tsp daily	Shrub	Khoirabari Banseria	1 1	0.16
Oroxylum indicum (L.) kurz	Bignoniaceae	AAU WEED HERBARIUM Acc. No. 5463	Kharong khandai	Leaves/ fruit	Fresh Juice	1 cup twice daily	Tree	Simlibari	1	0.08
Phlogacanthus curviflorus (Wall.) Nees	Acanthaceae	AAU WEED HERBARIUM Acc. No. 5465	Basikhor	Flower	Decoction	1-2 tsp once daily	Shrub	Khoirabari	1	0.08
Zingiber officinale Rosc.	Zingiberaceae	AAU WEED HERBARIUM Acc. No. 5467	Jermao	Roots	Fresh Juice	1 cup daily	Herb	Simlibari Angrajuli	1 1	0.16
Syzygium cumini (L.) Skeels	Myrtaceae	AAU WEED HERBARIUM Acc. No. 5464	Gwswm jamboo	Seed	Powder	1-2 tsp twice daily	Tree	Bholabari Angrajuli Simlibari	1 2 2	0.42
Ocimum tenuiflorum (L.)	Lamiaceae	AAU WEED HERBARIUM Acc. No. 5469	Tulsi	Roots	Paste	3-4 tsp daily	Herb	Khoirabari	2	0.16

Terminalia chebula Retz.	Combretaceae	AAU WEED HERBARIUM Acc. No. 5475	Selekha	Fruit	Fresh juice	1 cup twice daily	Tree	Banseria Angrajuli	1 1	0.16
Alstonia scholaris (L.) *R.Br.*	Apocynaceae	AAU WEED HERBARIUM Acc. No. 5468	Sithona	Bark	Decoction	1-2tsp daily	Tree	Banseria Khoirabari Simlibari	2 2 3	0.58
Phyllanthus emblica (L.)	Phyllanthaceae	AAU WEED HERBARIUM Acc. No. 5461	Amla	Fruit	Decoction	1-2 tsp daily	Tree	Khoirabari	1	0.08
Nyctanthes arbor-tristis (L.)	Oleaceae	AAU WEED HERBARIUM Acc. No. 5474	Sewali	Flower	Decoction	2-3 tsp daily	Shrub	Simlibari	1	0.08
Momordica charantia (L.)	Cucurbitaceae	AAU WEED HERBARIUM Acc. No. 5473	Udasi	Seed	Decoction	1-2tsp twice daily	climber	Bholabari	2	0.16
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Azadirachta indica A. Juss.	Meliaceae	AAU WEED HERBARIUM Acc. No. 5466	Neem	Leaves	Decoction	2-3tsp twice Daily	Tree	Banseria Khoirabari	1 2	0.25
Rosa cymosa Tratt.,	Rosaceae	AAU WEED HERBARIUM Acc. No. 5470	Golabgufur	Flower	Decoction	3-4tsp daily	Shrub	Bholabari	1	0.08
Clerodendrum infortunatum L,	Lamiaceae	AAU WEED HERBARIUM Acc. No. 5471	Mwkhwna	Leaves	Decoction	1 cup once daily	Shrub	Khoirabari	1	0.08
Syzygium Jambo (L.) *Alston*	Myrtaceae	AAU WEED HERBARIUM Acc. No. 5472	Godjaam	Leaves	Decoction	3-4tsp daily	Shrub	Khoirabari Banseria	1 1	0.16

RESULTS

A. Socio -demographic details

All 12 traditional healers belong to the Bodo tribe residing in Udalguri dsitrict of BTR region. The majority of traditional healers were male i.e. 83.33%, while only 16.67% were found to be female. The lesser number of female healers was because of illiteracy and cultural norms in the society. Most of them were seen to be unemployed and farmers with primary (66.67%) and secondary level of education (25.00%). Half the respondents were found to be having experience as local healers for 30-40 years. Most of the respondents fell under the age group of 55-65 years (25.00%) and 75 years above (50.00%) (Table 1).

B. Medicinal plants: their diversity and use value

A total of 15 plant species were recorded that are used for obesity and weight loss (Table 2). These plants species were collected and identified with the help of taxonomist from department of Agronomy, Assam Agricultural University, Jorhat.

The 15 identified species comprised of trees (47%), shrubs (33%), herbs (13%) and climbers (7%) that belongs to 13 different families. Almost all the collected plant species used for weight loss belong to different families (Fig. 3). Only Myrtaceae and Lamiaceae family were found to have 13.33% of plant species each. Rest all the families such as Bignoniaceae, Acanthaceae, Zingiberaceae, Combretaceae, Apocynaceae, Phyllanthaceae, Oleaceae, Cucurbitaceae, Rutaceae, Meliaceae and rosaceae have 6.67% of plant species each (Fig. 2). The most cited plant were *Alstonia scholaris (*L.*) R.Br.* (Apocynaceae) and *Syzygium cumini* (L.) *Skeels* (Myrtaceae) with use value (UV) of 0.58 and 0.42 respectively. The use value of other 13 plant species ranged from 0.08 to 0.25.

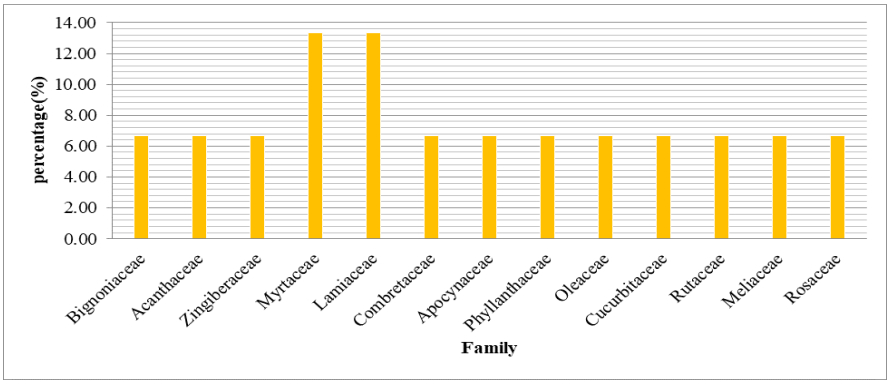

Fig. 2. Percentage of plant species in different family.

C. Plant parts and mode of preparations used for treatment of obesity

In this study, several parts of the plants such as leaves, flower, bark, fruit, seed and root were used for treatment of obesity. Most frequently used plant parts were leaves (34%) followed by flower (20%), root (13%), seed (13%), fruit (13%) and bark (7%) (Fig. 4).

All the parts used for the herbal preparation are administered through oral mode. It was found that mostly used method for herbal preparation was decoction (60.00%). Other modes of preparation used were juice (26.67%) followed by paste (6.67%) and powder (6.67%) (Fig. 5).

Plants such as *Phlogacanthus curviflorus (Wall.) Nees, Alstonia scholaris* (L.) *R.Br., Phyllanthus emblica* (L.), *Nyctanthes arbor-tristis* (L.), *Momordica charantia* (L.), *Azadirachta indica A. Juss., Rosa cymosa Tratt., Clerodendrum infortunatum* L, *and Syzygium Jambo* (L.) *Alston* were mainly used for decoction, where a drink is prepared by steeping the plant parts in water until the water takes up all bioactive compounds and flavors. These decoctions prepared from the plant parts were consumed 1-3 tsp 2-3 times daily for weight loss and obesity. Fresh juice prepared from *Oroxylum indicum* (L.) kurz., *Zingiber officinale Rosc., Terminalia chebula Retz.,* and *Murraya koenigii* (L.) *Spreng.,* were also consumed for treatment of weight loss and obesity. The powder of dried seeds of *Syzygium cumini* (L.) *Skeels* were consumed 1-2 tsp twice daily to reduce obesity and diabetes mellitus. Paste was also prepared from the plant *Ocimum tenuiflorum* (L.), roots and consumed 3-4 tsp daily for treatment.

D. Healer's perceptions on obesity and its complications

In this study, all the 12 traditional healers were aware about obesity. However, only 41.66% of the healers were aware about the complications. Obesity associated complications such as heart diseases, type 2 diabetes mellitus, hypertension, stroke and cancer were not known by most of the healers. Regarding causes of obesity, most of the local healers believed that excess consumption of non vegetarian items like meat fish and egg contribute to weight gain and obesity. The second important cause of overweight and obesity reported by the local healer was idle sitting or lack of physical exercise. Some local healers also mentioned about stress or having tension as cause of excess weight gain or obesity.

Regrading consequences of obesity, some local healers reported excess fatigue, breathlessness, and leg pain as the main symptoms. For prevention and treatment of obesity, most of local healers reported that consumption of herbal medicine, eating less non vegetarian items and physical exercise would help in reducing obesity. All the local healers believed that herbal preparations used for treatment of obesity were more effective than allopathic medicines as it has no or minimal side effects.

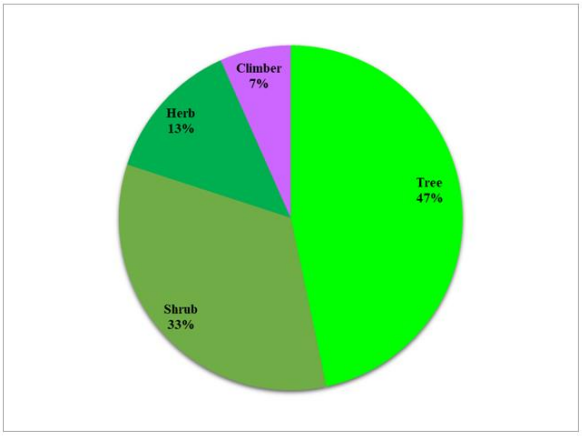

Fig. 3. Growth form of medicinal plants.

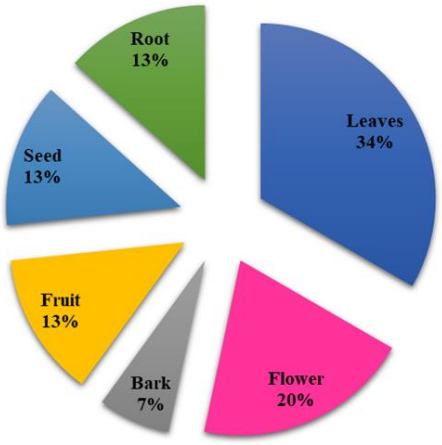

Fig. 4. Percenatge of plant parts used for treatment.

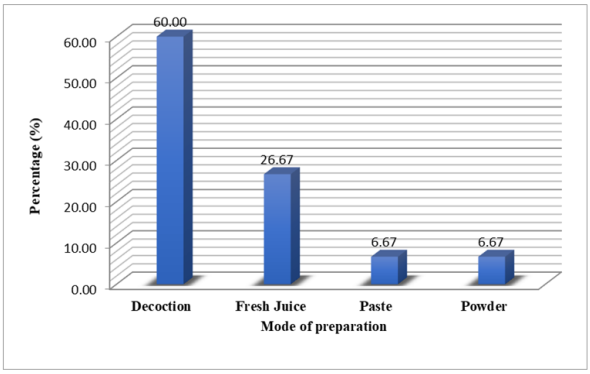

Fig. 5. Mode of preparation for treatment of obesity.

DISCUSSION

The traditional knowledge of medicinal plants is preserved through ethnobotanical studies, which also reveal indigenous plant species that can be used to create new drugs. Native knowledge is preserved through scientific documentation of the local plants, which also aids in the preservation of biological diversity and inspires the community. Studies have shown that the ethnic community's traditional knowledge of medicinal plants is vanishing at an alarming rate. The primary cause of this loss of traditional knowledge is rapid land degradation, including increased deforestation, increased accessibility and affordability of modern drugs, influence of modern culture, and adoption of new cultural norms, also known as acculturation. This shows that the transmission of cultural practices and rituals from one generation to the next is now in danger of disappearing, endangering the protection and preservation of an ethnic group's traditional knowledge. In such a scenario, scientific documentation and a deeper understanding of ethnobotanical roots have emerged as the most important tasks for ethno-allied disciplines.

In this study, 12 traditional healers belong to the Bodo tribe residing in Udalguri district of BTR region. The majority of traditional healers were male i.e. 83.33%, while only 16.67% were found to be female. The lesser number of female healers was because of illiteracy and cultural norms in the society. Similar results were reported by Latif *et al.* (2015) where it was found that Gender wise, most of the respondents were male i.e. 75% while only 25% of respondents were female. The study area's informants were largely illiterate and women were hesitant to converse with people outside of the village area. The same fact was also documented in a previous study on the local knowledge on medicinal plants by Prabhu et al., (2014). Most of the respondents had experience of 30-40 years as traditional healers and fell under the age group of 55-65 years and 75 years above. The number of local healers of the age groups 61–70 years was higher when compared with the other age groups (Latif *et al.*, 2015).

With the help of all the local healers total 15 plant species were recorded that are used for obesity and weight loss. The 15 identified species comprised of trees (47%), shrubs (33%), herbs (13%) and climbers (7%) that belongs to 13 different families. In this study most common growth form found was tree. However previous ethnobotanical studies reported that most common growth form was herb, which was most frequently used for herbal preparation (Silambarasan & Ayyanar 2015; Iqbal *et al.*, 2021).

May be due to its year round presence, tree was used often for treatment and it is also in accordance with the study findings of Kareti *et al.*, 2022; Silambarasan *et al.*, 2023.

Almost all the collected plant species used for weight loss belong to different families (Fig. 3). Only Myrtaceae and Lamiaceae family were found to have 13.33% of plant species each. Rest all the families such as Bignoniaceae, Acanthaceae, Zingiberaceae, Combretaceae, Apocynaceae, Phyllanthaceae, Oleaceae, Cucurbitaceae, Rutaceae, Meliaceae and rosaceae have 6.67% of plant species each (Fig. 2).

The most cited plant were *Alstonia scholaris* (L.) *R.Br.* (Apocynaceae) and *Syzygium cumini* (L.) *Skeels* (Myrtaceae) with use value (UV) of 0.58 and 0.42 respectively. The use value of other 13 plant species ranged from 0.08 to 0.25. The UV is useful in identifying the plants that are most frequently used to treat diseases. When there are numerous reports of a plant's use, UVs are high; when there are fewer reports, UVs are low (Benarba *et al.*, 2015).

In our study, the plants which may be regarded as more important than others are *Alstonia scholaris* (L.) *R.Br.* (Apocynaceae) and *Syzygium cumini* (L.) *Skeels* (Myrtaceae) as they have higher UV value.

Several parts of the plants such as leaves, flower, bark, fruit, seed and root were used for treatment of obesity. Most frequently used plant parts were leaves (34%) followed by flower (20%), root (13%), seed (13%), fruit (13%) and bark (7%). Fig4. Similar results were also reported by Silambarasan & Ayyanar (2015) where it was found that most frequently used plant parts for herbal preparation was leaves (23%) were most frequently used individually or in combination with other plant parts. It was followed by the whole ripe fruit (13%), seed (13%), root (9%), aerial parts (7%) and stem bark (6%). Sureshkumar *et al.* (2017) also reported that leaf (37%) was most commonly used part in preparation of herbal medicine.

Many studies have mentioned that leaves are most extensively used along with other plant parts. Tribal communities across the world used leaves in the preparing of herbal medicines. The main reason leaves were used so frequently was that they were easier to collect than underground flower and fruit parts, and from a scientific standpoint, leaves are active in photosynthesis and metabolite production. (Prabhu *et al.*, 2014; Morvin *et al.*, 2014).

Various method of herbal preparation for treatment of obesity has been reported such as decoction, juice, paste, and powder. Interestingly, most often used was decocotion (60.00%) and it was followed by juice (26.67%) followed by paste (6.67%) and powder (6.67%). All the parts used for the herbal preparation

were administered through oral route. Similarly, number of studies also reported that decoction was the mostly used mode of herbal preparation for treatment of variety of illness (Prabhu *et al.,* 2021; Navia *et al.,* 2022; Mphuthi & Husaini 2022). In fact, Castellanos *et al.* (2022) mentioned that decoction of herbs in traditional medicine was more effective in treatment of metabolic diseases without any adverse health effects.

E. GC-MS ANALYSIS of selected indigenous plants

GC-MS analysis of most two promising plants (*Alstonia scholaris* (L.) *R.Br.* and *Syzygium cumini* (L.) *Skeels)* were carried out for identification of the bioactive compounds present in the plant extract. The bio active compounds along with the retention time (RT), Molecular formula, molecular weight and peak area % (concentration) were presented in Table 3.

GC-MS analysis of *Alstonia scholaris* (L.) *R.Br.* The bioactive compounds present in the methanolic extract of *Alstonia scholaris* (L.) *R.Br.* (bark) was detected by GC-MS. GC-MS analysis shows the presence of 8 bioactive compounds representing different classes (Table 3 and Fig.6).

The major constituents of *Alstonia scholaris (L.) R.Br.* were found to be Eucalyptol (0.143%), Rutin (6.71%), Quercetin 7,3,4-trimethoxy (4.52%), Phenol,2,6-dimethoxy (0.77%), Caffeic acid (8.52%), Catechin (4.49%), Vanillic acid (3.07%), and echitaminic acid (2.81%). *Compounds that were identified by GCMS analysis were found in the NIST mass spectral library.*

GC-MS analysis of flavonoids in *Alstonia scholaris* (L.) *R.Br. Among the identified bioactive compounds* Rutin (6.71%), Quercetin 7,3,4-trimethoxy (4.52%), Catechin (4.49%), were the flavonoid compounds that have antiobesogenic and antidiabetic properties (Table 3 and Fig. 6).

In 2012, Rahul *et al.,* reported that the flavonoids present in the bark may contribute to high antioxidant activity due to the presence of 3 flavonoids such as quercetin 3-O-galactosides, quercetin 3-O-glucosides and kaempferol 3-O-glucosides. Moreover, in 2019 Soni *et al.,* also reported that presence of flavonoid compound in *Alstonia scholaris* such as 6-(2,4-dihydroxyphe nyl)-4-hydroxy-2-prop-1-en-2-yl-2, 3-dihydrofuro [3,2-g] chromen-5-one. In this study, Compounds such as rutin and catehcin have not been reported yet by other studies.

Flavonoids are known for their antioxidant activity and they also have a number of other functions, such as anti-inflammatory, vasorelaxant, anticoagulant, cardioprotective, anti-diabetic, chemoprotective, neuroprotective, antidepressant, and a number of other properties. Additionally, flavonoids found in herbal plants are known to have potential advantages for the management of metabolic disorders and the prevention and treatment of obesity (Rufino *et al.,* 2021).

Several studies revealed that people who consume a high amount of total flavonoids and flavonols are less likely to be obese when exposed to a normal diet. This is demonstrated by a double-blind, randomized, parallel pilot study that found that high consumption of flavonoids, including flavonols, flavan-3-ols, anthocyanins, and flavonoid polymers, is inversely associated with weight gain (Cases *et al.,* 2015; Marranzano *et al.,* 2018; Song *et al.,* 2019). Moreover, Paoli *et al.,* in 2015 also observed that flavonoids have number of potential antiobesity effects or weight loss properties. Flavonoids are responsible for controlling appetite and decrease in food intake. Reduction in the intestinal absorption of fat and modulation of lipolysis, oxidation, and adipocyte differentiation by flavonoids were also observed, which contributes to its antiobesogenic properties.

GC-MS analysis of alkaloids in *Alstonia scholaris* (L.) *R.Br.* Alkaloid such as echitaminc acid (2.81%) and Eucalyptol (0.14%) compound were found in the bark of *Alstonia scholaris* (L.) *R.Br.* (Table 3 and Fig. 6).

Hamdiani *et al.,* in 2018 reported that GC-MS analysis of the base fraction of *Alstonia scholaris* (L.) R. Br. leave shows the presence of four alkaloids such as Sarpagan-16-carboxylic acid, 17-hydroxy-, methyl ester (Akuammidine) as the major alkaloidal compound, Nicotine, Strictamine and Voacristine. In a previous study by Tan *et al.,* 2019 revealed that the methanol crude extracts of *Alstonia macrophylla* Bark were composed primarily of alkaloids such as alstonerine (34.38%), strictamin (5.23%), rauvomitin (4.29%), and brucine (3.66%). Other constituents found in extract were triterpenoids: γ-sitosterol (3.85%) and lupeol (3.00%), 24-methylenecycloartanol (2.81%), campesterol (2.71%), β-amyrin (2.30%), and stigmasterol (2.13%). From the root bark of *Alstonia scholaris* the main constituent echitamine and other alkaloids including echitaminic acid, akuammicine, akuammigine derivative, and echitamidinetype alkaloids have also been isolated. This study reported that the plant *Alstonia scholaris* is crucial in terms of the presence of alkaloids, which are major components with diverse biological activities (Pratyush *et al.,* 2011). Many studies have shown that *Alstonia scholaris* bark is widely used in traditional medical systems in China, the Indian subcontinent, Southeast Asia, Latin America, Africa, and Australia. The species is also known by other names, such as devil's tree, white cheese wood, verbal, milkwood pines, mill wood, kilky pine, and blackboard tree, in addition to Dita bark.

Zaharudin *et al.* (2019) reported that alkaloids have several anti-diabetic properties. Alkaloids reduce blood glucose level by inhibiting the digestive enzymes. Some studies revealed that alkaloids can inhibit the functioning of certain enzymes called aldose reductase and protein tyrosine phosphatase-1B, which results in reduced conversion of glucose to sorbitol that results in excess production of reactive oxygen species (ROS) (Kinoshita *et al.,* 1988; Oates *et al.,* 2008). In 2017, Ruud *et al.,* reported that alkaloids can elevate insulin secretion and suppresses hepatic glucose synthesis and slows down lipolysis. Moreover, it influences the metabolism of fats in adipocytes, activates lipoprotein lipase, regulates the synthesis of fatty acids, and supports the proliferation and survival of -cells. Freitas *et al.,* in 2020 revealed that alkaloids are also

responsible for preventing the production of advanced glycation end products (AGEs) which is associated with several complications of diabetes such as retinopathy, cardiomyopathy and neuropathy.

GC-MS analysis of phenols in *Alstonia scholaris (L.) R.Br.* Phenol,2,6-dimethoxy (0.77%), Caffeic acid (8.52%) and Vanillic acid (3.07%) were the phenolic compounds found in the plant bark extract that also play a crucial role in reducing weight and has anti-diabetic properties (Table 3 and Fig. 6).

Preliminary phytochemical studies have shown that the *A. scholaris* bark contains a variety of chemical constituents, including phenolic compounds, triterpenes, triterpenoids, glucosides, and alkaloids (Khyade *et al.,* 2014). *A. scholaris* has been found to have anti-inflammatory, antimutagenic, anticancer, analgesic, hepatoprotective, wound-healing, antidiarrheal, and antiplasmodial properties (Kanase & Mane *et al.,* 2018).

According to a study, phenolic compounds, which are chemical components extracted from plants, can prevent amylase from being absorbed. Many fruits and vegetables, particularly grapes, berries, and tomatoes, contain phenolic compounds. By lowering the risk of metabolic syndrome and the associated complications of type 2 diabetes, phenolic compounds, such as phenolic acids and flavonoids, may promote health benefits. There is still a need for more research because different phenolic compound groups have different biological properties and little is known about the mechanisms by which they might help prevent disease. (Sales *et al.,* 2012). Several studies reported the benefits of phenolic compounds, including their anti-aging, anti-inflammatory, antioxidant, and antiproliferative properties. There are pertinent antioxidant enzymes to combat oxidants in addition to the aforementioned adjustments. Dietary plant polyphenols and polyphenol-rich foods affect how carbohydrates and lipids are metabolized. They also reduce hyperglycemia, dyslipidemia, and insulin resistance. They also enhance -cell function, stimulate insulin secretion, improve the metabolism of adipose tissue, and reduce inflammation. Long-term complications of diabetes, such as cardiovascular disease, neuropathy, nephropathy, and retinopathy, can also be prevented by polyphenolic compounds. (Shukitt-Hale, *et al.,* 2008; Moo-Huchin *et al.,* 2015).

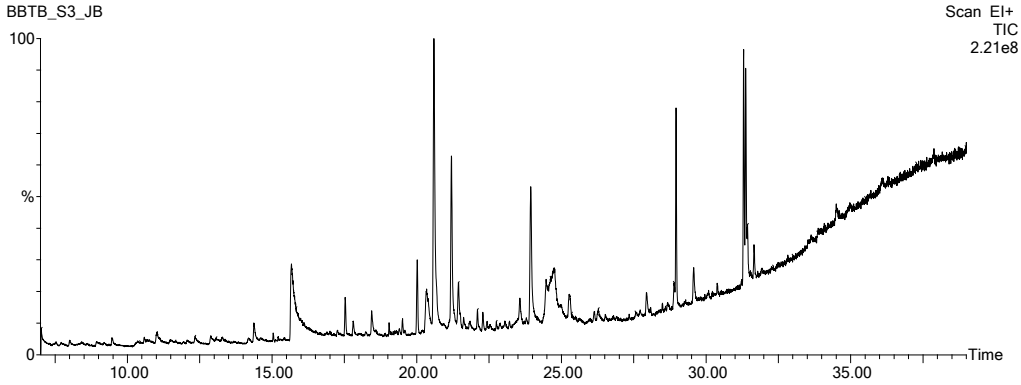

Fig. 6. GC-MS chromatogram of *Alstonia scholaris* (L.) *R.Br.*

Table 3: GC-MS analysis of *Alstonia scholaris* (L.) *R.Br.*

Sr. No.	RT	Name of the compound	Molecular formula	Molecular weight	Peak area (%)	Nature of compound
1.	15.04	Eucalyptol	$C_{10}H_{18}O$	154	0.143	Terpenoids
2.	15.67	Rutin	$C_{27}H_{30}O_{16}$	610	6.704	Flavonoid
3.	18.44	Phenol ,2,6-dimethoxy	$C_8H_{10}O_3$	154	0.765	Phenol
4.	20.59	Caffeic acid	$C_9H_8O_4$	180	8.519	Phenol
5.	21.20	Quercetin 7,3,4-trimethoxy	$C_{18}H_{16}O_7$	344	4.517	Flavonoid
6.	23.94	Catechin	$C_{15}H_{14}O_6$	290	4.491	Flavonoid
7.	28.96	Vanillic acid	$C_8H_8O_4$	168	3.077	Phenol
8.	31.30	Echitaminic acid	$C_{21}H_{27}N_2O_4^+$	371.4	2.809	Alkaloid

B. GC-MS analysis of Syzygium cumini (L.) *Skeels*

The bioactive compounds present in the methanolic extract of shows the presence of 10 bioactive compounds in the methanolic extract of *Syzygium cumini* (L.) *Skeels* seed. The mass spectra of identified compounds from *Syzygium cumini* (L.) *skeels* seed were presented in the Table 4 and Fig. 7.

The major constituents of *Syzygium cumini* (L.) *Skeels* seed were found to be Chloroacetic acid (0.51%), Linolenic acid (0.50%), Retinal (0.71%), P-coumaric acid (1.69%), Germacrene acid (1.11%), Succinic acid (4.62%), Syringic acid (3.21%), Fumaric acid (1.53%), Pentadecanoic acid (3.59%) and Eicosanoic acid (7.30%).

5.2.1 GC-MS analysis of organic acids in *Syzygium cumini* (L.) *Skeels*

Among the identified bioactive compounds, Chloroacetic acid (0.51%), Linolenic acid (0.50%), Retinal (0.71%), Germacrene acid (1.11%), Succinic acid (4.62%), Fumaric acid (1.53%), Pentadecanoic

acid (3.59%) and Eicosanoic acid (7.30%) were the organic acids found in the methanolic extract of *Syzygium cumini* (L.) *Skeels* (Table 4 & Fig. 7).

Organic acids such as Succinic acid, Syringic acid and Fumaric acid have antioxidant, antihyperlipidemic, antimicrobial, antidiabetic properties (Aung *et al.*, 2022; Budak, 2022).

Similarly, Parimala & Salomi (2021) reported that GC-MS analysis of *Syzygium cumini* L *skeels* seed composed of Hexadecanoic acid, Ascorbic acid 2,6-dihexadecanoate, Oleic Acid, Octadecadienoic acid, Isopropyl palmitate, Tetradecanoic acid, 3-Cyclohexadiene, Hydroxymethylfurfura, Furaldehyde and gamma-Sitosterol. Sarma *et al.*, in 2020 found that *Syzygium cumini* (L.) leaf composed of the following compounds: globulol, caryophyllene and α-pinene. While β-eudesmol, β-pinene, γ-cadinene, camphene, αterpineol, camphor, humulene 6,7-epoxide, cubeban-11-ol, α-muurolene, epicubenol, αcopaene, viridiflorene, βguanine, β-bourbonene, terpinen-4-ol, endo-borneol, levoverbenone and isobornyl acetate.

Ah *et al.* (2019) reported that GC-MS analysis of black plum seed extract composed of 10 different compounds such as Oleic acid, n-hexadecanoic acid, Cyclooctasiloxane, hexadecamethyl and 1-monolinoleoylglycerol trimethylsilyl ether.

Recent study on plant secondary metabolites by Sukhikh *et al.* (2023) reported that organic acids are involved in protection of pancreatic beta cells, neurons and many vital organs such as eye, liver, kidney from oxidative damage. Furthermore, it enhances metabolism of glucose and lipid, as well as cardiovascular health. Fattahi *et al.* (2017) reported that phytochemical compound such as organic acids are associated with regeneration of pancreas beta-cells mediated by its proliferation and it has a important role in prevention and treatment of diabetes mellitus.

GC-MS analysis of phenols in *Syzygium cumini* (L.) *Skeels.* Two phenolic compounds: P-coumaric acid (1.69%) and Syringic acid (3.21%) were found in methanolic extract of *Syzygium cumini* (L.) *Skeels* (Table 4 & Fig. 7).

According to Aguilar-Hernández *et al.*, 2017, p-coumaric acid and ferulic acid were important natural phenolic antioxidants. Significant data regarding other qualities like UV protection, anti-carcinogenic and anti-inflammatory properties, as well as cardiovascular protection have been reported due to the potential positive impacts of these compounds on human health.

Compounds such as P-coumaric acid, hexadecanoic acid and Eicosanoic acid has Antioxidant, hypocholesterolemic, and antigenotoxic properties (Kumar *et al.*, 2022; Hamza *et al.*, 2022). Tombozara *et al.*, (2020) also found that organic and phenolic acids have potential antioxidant and antidiabetic properties for treatment of diabetes mellitus.

Kumar *et al.*, in 2022 reported that The pulp and seed which are rich in phenols and other acids showed inhibition of intestinal glucose loading, a notable decrease in blood glucose and glycated hemoglobin concentration, as well as a significant improvement in serum insulin, HOMA-IR, C-peptide levels, and the activity of hexokinase, phosphofructokinase, glucose-6-phosphatase, and fructose-1,6-bisphosphatase in the studied animals. Additionally, it has been demonstrated by Nascimento-Silva *et al.*, in 2022 that higher concentrations of the Jambolan pulp or seed extracts has protective effect on functioning of beta cells of pancreas. The seed extract supplementation has been shown in animal studies to increase HDL-c content while lowering serum levels of triglycerides, total cholesterol, LDL-c, and VLDL-c.

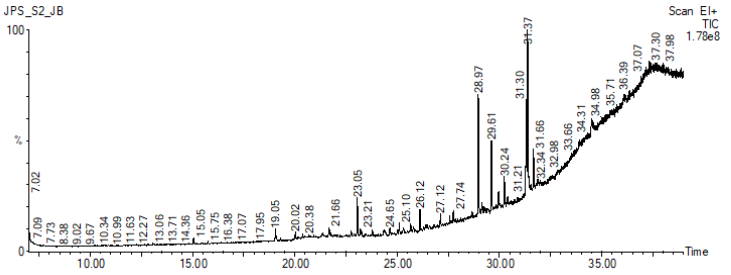

Fig. 7. GC-MS chromatogram of *Syzygium cumini* (L.) Skeels.

Table 4: GC-MS analysis of *Syzygium cumini* (L.) *Skeels.*

Sr. No.	RT	Name of the compound	Molecular formula	Molecular weight	Peak area (%)	Nature of compound
1.	19.05	Chloroacetic acid	$C_2H_3ClO_2$	290	0.505	Acid
2.	20.22	Linolenic acid	$C_{18}H_{30}O_2$	352	0.496	Omega-3 fatty acid
3.	21.66	Retinal	$C_{20}H_{28}O$	284	0.707	Retinaldehyde
4.	23.05	P-coumaric acid	$C_9H_8O_3$	164	1.690	phenolic acid
5.	26.12	Germacrene acid	$C_{15}H_{24}$	204	1.113	Acid (Organic hydrocarbons)
6.	28.97	Succinic acid	$C_4H_6O_4$	350	4.619	Acid
7.	29.61	Syringic acid	$C_9H_{10}O_5$	198	3.217	Phenolic compound
8.	30.24	Fumaric acid	$C_4H_4O_4$	472	1.503	Acid
9.	31.30	Pentadecanoic acid	$C_{15}H_{30}O_2$	320	3.587	Long chain fatty acids
10.	31.37	Eicosanoic acid	$C_{20}H_{40}O_2$	312	7.298	Long chain fatty acids

CONCLUSIONS

In rural regions like BTR where the Bodo tribe makes up the majority of the population, local traditional knowledge and plant-based medicine are still widely practiced, and traditional healers are crucial to primary healthcare. Large sections of this tribe are economically under-developed and they have traditional believes and knowledge in plants and forests. A wide variety of traditional plants are being used among Bodo tribe for the treatment of mild to severe type of health issues or ailments since time immemorial. Obesity has become a serious global health concern since it is associated with major life threatening diseases. It has increased swiftly across all the age group making it serious concern. In fact it is slowly increasing among the tribal population due to radical change in their dietary habit towards HFSS food products. Introducing pharmacological intervention has become very important to combat obesity. Use of medicinal plants which have been consumed for hundred years becomes very important because of their minimal or no side effects. Thus, emphasis on natural products is increasing currently because of their complete absence of side effects. The information acquired from this study could help to identify plant species and extraction techniques for the development of herbal medications to combat obesity and its associated disorders. Most frequently used plants with highest use value for treatment of obesity, as reported in our study such as *Alstonia scholaris* (L.) *R.Br.* (Apocynaceae) and *Syzygium cumini* (L.) *Skeels* (Myrtaceae) should be given importance for fruther *in vivo* studies. Moreover, in our study, the GC-MS analysis has confirmed the presence of antiobesogenic bioactive compounds in the methanolic extract of the two plants species.

FUTURE SCOPE

The information acquired from this study could help to identify plant species and extraction techniques for the development of herbal medications to combat obesity and its associated disorders.

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