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Assessment of Anti-Obesity Potential and Techno-Functional Properties of *Bougainvillea spectabilis* Willd. Bracts

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Abstract: The present research signifies the anti-obesity potential of *Bougainvillea spectabilis* Willd. and its techno-functional properties. *Bougainvillea spectabilis* Willd. is a medicinal plant that belongs to the Nyctaginaceae family. Studies have reported the various bioactive compounds such as flavonoids, phenols, alkaloids, saponins, tannins, etc., in *Bougainvillea spectabilis* Willd., responsible for its biological properties such as antibacterial, antidiabetic, antioxidant, anti-inflammatory, antiviral, antifungal, antipyretic, and anticarcinogenic. In this article, the techno-functional properties of the plant, such as tapped density, bulk density, Hausner ratio, Carr index, angle of repose, water absorption and solubility index, swelling capacity, foaming capacity, foam stability, and oil absorption capacity were discussed. The plant's total phenolic and flavonoid content was 2.9 mg GAE/g and 12.3 mg QE/g, respectively. The plant's antioxidant activity (89.9%) was estimated using the DPPH assay. The components of the plant powder were confirmed by FTIR analysis. Lipase (I_C50: 68.21) and amylase inhibition assay (I_C50: 60.19) significantly confirmed the anti-obesity potential of the plant. The highest glucose retention time (2.1 mg/dL) was observed at 120 min.

Keywords: amylase; *Bougainvillea spectabilis* Willd. bracts; glucose assay; lipase; obesity; techno-functional properties

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Citation: Kumar, M.; Kaushik, D.; Kaur, J.; Proestos, C.; Oz, F.; Kumar, A.; Anjali, A.; Elobeid, T.; Terzioğlu, M.E.; Xiao, J. Assessment of Anti-Obesity Potential and Techno-Functional Properties of *Bougainvillea spectabilis* Willd. Bracts. *Separations* **2022**, *9*, 399. https://doi.org/10.3390/separations9120399

Academic Editor: Małgorzata Starowicz

Received: 31 October 2022
Accepted: 25 November 2022
Published: 30 November 2022

1. Introduction

Obesity is a global health issue that has been increasing worldwide for the past few decades [1]. It is characterized by fat accumulation in different body parts, including the abdomen, hips, thighs, pancreas, kidneys, and liver [2]. It is linked to unhealthy eating habits, a sedentary lifestyle, inconsistent sleep patterns, and genetic factors. It affects people of all ages and is associated with the health risk of several diseases, such as osteoarthritis, type 2 diabetes, asthma, coronary heart disease, cancer, kidney problems, and hypertension. According to the Organisation for Economic Co-operation and Development (OECD) survey (2017), India is ranked third in obesity after the USA and China. Many synthetic drugs to treat obesity are available on the market; however, their consumption causes several side effects [3]. From ancient times, people used to consume medicinal plants. Conventional drugs and medicinal plants have almost similar working mechanisms, but herbal medicine is still considered less potent [4]. In developing countries such as India,

medicinal plants have greater importance because of their easy availability, safety, low cost, and minimum side effects [5]. Medicinal plants have essential applications in various industries, such as food, cosmetics, and pharmaceutical.

Bougainvillea spectabilis Willd. is a medicinal plant belonging to the Nyctaginaceae family, which grows in tropical and subtropical areas throughout the year [6,7]. The most common color of leaves and stems is deep green and dull green-brown [8,9]. The flowers are covered with trilobed bracts with bright colors to attract insects for pollination. *Bougainvillea spectabilis* Willd. have colored bracts ranging from purplish to magenta, varying according to species [10]. The major countries where *Bougainvillea spectabilis* Willd. is grown are America, Mexico, France, Spain, India, Brazil, Italy, Australia, Thailand, China, Pakistan, Madagascar, and the Philippines [6].

Several studies have reported that the phytochemical compounds in *Bougainvillea spectabilis* Willd. are alkaloids, saponins, tannins, phenols, flavonoids, glycosides, quinones, and terpenoids [11,12]. The major bioactive components of *Bougainvillea spectabilis* Willd. bougainvinones, pinitol, quercetagetin, quercetin, and terpinolene are present in leaves, bracts, and stems [13–15]. The plant shows several pharmacological properties such as antibacterial, antihyperlipidemic, antidiabetic, antiobesity, antifertility, antioxidant, anti-inflammatory, antiulcer, antiviral, antifungal, antipyretic, antihelminthic, antidiarrhea, neuroprotective and anticarcinogenic [9,16–19]. The infusion of flowers is used for treating low blood pressure. Bracts are consumed in boiling water to treat cough, relieve upper respiratory tract problems [20], and prevent gastrointestinal infections [21].

In this article, we focus on checking the antiobesity potential of *Bougainvillea spectabilis* Willd. bracts and the techno-functional properties of the powder.

2. Materials and Methods

For the extraction process, ethanol was procured from Poet Biorefining (Lewis Ave Sioux Falls, SD, USA). Lipase, soluble starch, lecithin, sodium cholate, amylase, nutrient agar, hydrochloric acid, dimethyl sulfoxide, glycerol trioleate, and dialysis membrane (MCWO 2000) were procured from Jiangsu Huaxi International (Jiangyin, China). Analytical reagent grade chemicals were used, and the class A certified glassware was washed in triple distilled water throughout the experiments.

2.1. Raw Material

Fresh modified leaves (bracts) were collected from the botanical garden of the Lovely Professional University, Phagwara, Punjab (India).

2.2. Sample Preparation

Fresh bracts were separated from tri-lobed tiny flowers. The magenta-colored modified leaves of *Bougainvillea spectabilis* Willd. were plucked out manually from the botanical garden and carried to the laboratory in a pouch, and kept in hygienic conditions. *Bougainvillea spectabilis* Willd. bracts were cleaned with tap water three to four times and then with distilled water to remove the dirt and pollutants. Afterward, bracts were dried at 45 °C for two days in a tray dryer (PPI FiniX72).

2.3. Moisture Content

The moisture content of *Bougainvillea spectabilis* Willd. bracts powder was measured using the method described by AOAC [22]. The powder of *Bougainvillea spectabilis* Willd. bracts were weighed 10 g and then placed in a tray dryer for drying at 45 °C. From the dried powder, 1 g was taken out after each interval of 1 h, and weight was determined. The same procedure was carried out until the constant weight was achieved. The moisture content on a dry basis was determined using a standard formula:

$$MC = (W - W_d)/W_d$$

where MC = moisture content on a dry weight basis; W = weight of a sample; and W_d = weight of dry material.

2.4. Techno-Functional Properties of Dried Bougainvillea Spectabilis Willd. Bracts Powder

The dehydrated sample was utilized for the analysis of techno-functional properties. The dehydrated sample was taken for the techno-functional analysis. The bulk density of the sample Singh et al. [23] was calculated using the formula:

$$\text{Bulk density (g/mL)} = W_2 - W_1/V$$

where W_1 = weight of container; W_2 = weight of container + sample; and V = volume of container.

The tapped density, Carr index, and Hausner ratio were determined by the procedure given by Tze et al. [24]:

$$\text{Tapped density (g/mL)} = M/V_T$$

where M = mass of powder; V_T = final tapped volume.

The Carr index (CI) expresses the compressibility of the powder and is determined using the formula:

$$\text{Carr Index (CI)} = \text{T.D.} - \text{B.D.}/\text{T.D.} \times 100$$

where T.D. = tapped density and B.D. = bulk density

The Hausner ratio indicates the flowability of granular material or powder and is determined using the formula:

$$\text{Hausner Ratio (HR)} = \text{T.D.}/\text{B.D.}$$

where T.D. = tapped density and B.D. = bulk density.

The angle of repose (φ) was calculated by the formula given by Brar et al. [25]. The height (H) and the diameter of the heap (D) of dried *Bougainvillea spectabilis* Willd. bracts powder were determined using the formula:

$$\varphi = \tan^{-1} 2H/D$$

The water absorption index (WAI) and water solubility index (WSI) were calculated by the procedure described by Mokhtar et al. [26] using the formula:

$$\text{WAI (g/g)} = \text{Weight of hydrated residue}/\text{Weight of sample}$$

$$\text{WSI (\%)} = \text{Weight of dry solids in supernatant}/\text{Weight of sample} \times 100$$

Swelling capacity (SC) was calculated by the procedure described by Ishara et al. [27] using the formula:

$$\text{SC} = V_f\ (\text{mL})/\text{W(g)}$$

where V_f = final volume after 24 h; W = weight of sample.

Foaming capacity (FC) and foam stability (FS) were calculated by the procedure described by Mokhtar et al. [26] using the formula:

$$\text{Foaming capacity (\%)} = V_2 - V_1/V_1 \times 100$$

where V_1 = volume of liquid + foam (mL); V_2 = volume of the mixture before blending (mL):

$$\text{Foam stability (\%)} = V_3 - V_1/V_1 \times 100$$

where V_3 is the foam volume measured one hour after whipping (mL); oil absorption capacity (OAC) was calculated by the procedure given by Baljeet et al. [28] using the formula:

$$\text{OAC (g/g)} = \text{Weight of sample and oil}/\text{Weight of sample}$$

2.5. Extraction Process

Ethanolic extraction was carried out for the *Bougainvillea spectabilis* Willd. bracts powder. An amount of 1 g of *Bougainvillea spectabilis* Willd. bracts powder was dissolved in 10 mL ethanol at 35 °C in an orbital shaker for 24 h at 150 rpm. The extract was then dried under a refrigeration temperature of 4 to 7 °C and stored in airtight glass vials at −18 °C [2].

2.6. Total Phenolic Content

The total phenolic content of *Bougainvillea spectabilis* Willd. bracts extract was estimated using the Folin–Ciocalteu assay. To plot a calibration curve, gallic acid was utilized as a reference standard. An amount of 10 mg of *Bougainvillea spectabilis* Willd. bracts extract was prepared in 10 mL of ethanol. An amount of 250 µL of the sample solution was taken out, and a volume was made using 1 mL of ethanol. Then, 10 µL of fresh Folin–Ciocalteu reagent was dissolved in the prepared solution and incubated for 10 min. An amount of 100 µL of 7.5% Na_2CO_3 aqueous solution was mixed in the solution and incubated at 30 °C for 30 min. The absorbance was taken at 765 nm using an Evolution™ One/One Plus UV–Vis spectrophotometer [29].

2.7. Total Flavonoid Content

The total flavonoid content of *Bougainvillea spectabilis* Willd. bracts extract was estimated using the method given by Sadh et al. [29]. To plot a calibration curve, quercitin was utilized as a reference standard. An amount of 10 mg of *Bougainvillea spectabilis* Willd. bracts extract was prepared in 10 mL of ethanol. Then, 250 µL of the sample solution was taken in a test tube, and using distilled water, the volume was increased to 1 mL. Then, 10 µL of the $NaNO_2$ (5%) aqueous solution was added to the mixture. After 5 min, 10 µL of the AlCl3 (10%) aqueous solution was added and kept at room temperature for 6 min. Then, 100 µL of 1M NaOH aqueous solution was added to the mixture, and absorbance was determined at 510 nm using an Evolution™ One/One Plus UV–Vis spectrophotometer.

2.8. Antioxidant Efficacy Estimation

The antioxidant activity of the bracts extract was measured using the DPPH assay. To plot a calibration curve, ascorbic acid was utilized as the reference standard. An amount of 10 mg of *Bougainvillea spectabilis* Willd. bracts extract was prepared in 10 mL of ethanol, and 250 µL of this solution was dissolved in 2 mL of 0.1 mM DPPH methanol solution and then incubated for 30 min in the dark. Using a spectrophotometer, the solution's absorbance was determined at 517 nm to measure the decrease in the DPPH free radical [2].

2.9. Fourier Transform Infrared Spectroscopy (FTIR)

Functional groups in the dried *Bougainvillea spectabilis* Willd. bracts powder were evaluated, and spectra were recorded using the ATR-FTIR spectrometer (Model–IR Affinity-01, Shimadzu, Japan) [30]. An amount of 5 mg of the sample was used to obtain the results, and spectra were recorded at a spectrum range of the mid-infra-red region, i.e., 4000–400 cm^{-1} [31].

2.10. Lipase and Amylase Inhibition Assay

The lipase and amylase inhibitory activity of the *Bougainvillea spectabilis* Willd. bracts extract was determined using the method given by [32].

2.11. Glucose Uptake Assay

The effect of glucose movement was determined using the glucose uptake assay [33].

2.12. Statistical Analysis

SEM (standard error mean) calculation, one-way, and two-way analysis confirmed the statistical difference in non-significant and significant values. The comparison between

means was conducted using Microsoft Excel, 2019 (Microsoft Corporation, Redmond, WA, USA).

3. Results and Discussion

In the present study, we investigated the *Bougainvillea spectabilis* Willd. bracts powder's techno-functional properties, phytochemical analysis, and in vitro assays to confirm the anti-obesity potential of the plant.

3.1. Techno-Functional Properties of Dried Bougainvillea Spectabilis Willd. Bracts Powder

Techno-functional properties include water and oil absorption, the ability to form and stabilize foams and emulsions, and solubility in food processing. It has an indirect or direct effect on processing applications, the quality of food, and furthers their acceptance and uses in food and food formulations [23]. Techno-functional properties of dried *Bougainvillea spectabilis* Willd. bracts powder are shown in Table 1. The value of bulk density, tapped density, Carr index, and the Hausner ratio was observed to be 0.401 g/cm^3, 0.510 g/cm^3, 21.37, and 1.271, respectively. The angle of repose was found to be 32.09°. The lower the value of the repose angle, the better the fluidity of the material will be. The water absorption and solubility indexes were 9.78 g/g and 20.45%, respectively. The value of foaming capacity and foam stability was observed to be 13.45% and 57.72%, respectively. Foam enhances the texture, appearance, and consistency of the material. The value of the sample's swelling and oil absorption capacity was 6.82 mL/g and 4.03 g/g, respectively.

Table 1. Techno-functional properties of dried *Bougainvillea spectabilis* Willd. bracts powder.

Techno-Functional Properties	*Bougainvillea spectabilis* Willd. Bracts Powder
Bulk density (g/cm^3)	0.401 ± 0.098
Tapped density (g/cm^3)	0.510 ± 0.22
Carr Index (CI)	21.37 ± 0.94
Hausner ration (HR)	1.271 ± 0.17
Angle of repose (°)	32.09 ± 0.92
Water absorption index (WAI) (g/g)	9.78 ± 0.67
Water solubility index (WSI) (%)	20.45 ± 0.94
Swelling capacity (mL/g)	6.82 ± 0.57
Foaming capacity (%)	13.45 ± 0.82
Foam stability (%)	57.72 ± 0.16
Oil absorption capacity (OAC) (g/g)	4.03 ± 0.23

Data are presented as mean ± SD (n = 3).

3.2. Phytochemical Analysis of Bougainvillea Spectabilis Willd. Bracts Powder

Drying of the bracts sample was carried out at each interval of 1 h until the constant value for drying was observed. The maximum time for drying at a temperature of 45 °C was 5 h. The phytochemical analysis of bracts includes moisture content, total phenolics, total flavonoids, antioxidant (DPPH), and FTIR analysis. The percentage of initial and final moisture content of dried *Bougainvillea spectabilis* Willd. bracts powder at different time intervals and temperature of 45 °C varied from (14.75 to 82.5%) as shown in Table 2. The sample dried at 45 °C for 5 h showed a significantly ($p < 0.05$) lower moisture content on drying, i.e., 14.7%. It was compared with the moisture content value reported by Rashid et al. [34].

Table 2. Phytochemical parameters of *Bougainvillea spectabilis* Willd. bracts powder.

Sample	Time (min)	Moisture (%)	TPC (mg GAE/g)	TFC (mg QE/g)	Antioxidant (%)
Bougainvillea spectabilis Willd. bracts powder	60	80 ± 0.002 [a]	3.5 ± 0.002 [a]	23.6 ± 0.002 [a]	87.5 ± 0.002 [a]
	120	63.7 ± 0.002 [a]	3.4 ± 0.007 [b]	21.3 ± 0.002 [a]	88.3 ± 0.006 [b]
	180	47.7 ± 0.002 [a]	3.2 ± 0.001 [a]	14.1 ± 0.002 [a]	86.7 ± 0.005 [b]
	240	30 ± 0.001 [a]	3.0 ± 0.002 [a]	13.0 ± 0.002 [a]	87.5 ± 0.001 [a]
	300	14.7 ± 0.002 [a]	2.9 ± 0.002 [a]	12.3 ± 0.002 [a]	89.9 ± 0.007 [b]

Data are presented as mean ± SD (n = 3); [a,b] Means with the same superscript in a column do not vary significantly ($p < 0.05$) from each other.

The total phenolic content was determined using a gallic acid standard curve at 765 nm, where the equation obtained was y = 0.3396× + 0.009 with a regression coefficient (R^2) = 0.9966. The plot has a slope (m) = 0.3396 and an intercept = 0.009 (Figure 1).

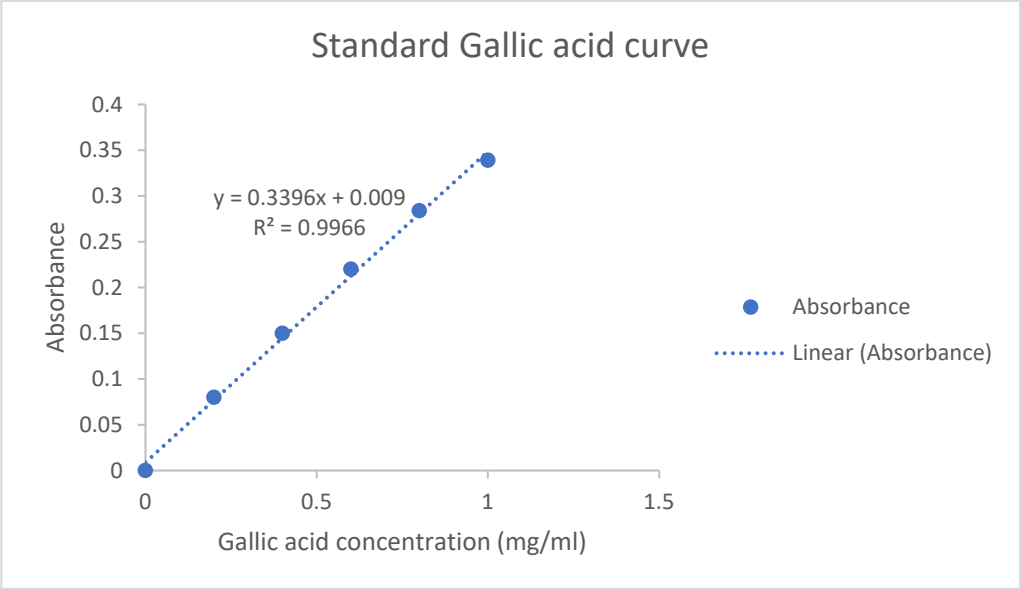

Figure 1. Standard gallic acid curve for total phenolic content.

Similarly, the total flavonoid content was determined using a quercetin standard curve at 510 nm, where the equation obtained was y = 0.4879× + 0.0002 with a regression coefficient (R^2) = 0.9996. The plot has a slope (m) = 0.4879 and intercepts = 0.0002 (Figure 2).

Total phenolic content (TPC) showed a significant ($p < 0.05$) decrease with increasing the time of drying. The range varies from 3.5 to 2.9 mg GAE/g. The value of phenolic content was compared with similar findings reported by Compaore et al. [35]. In addition, the total flavonoid content (TFC) (23.6 to 12.3 mg QE/g) was significantly ($p < 0.05$) higher than the phenolic content. A significant ($p < 0.05$) decrease in flavonoid content was observed during drying at different temperatures. The final value of flavonoid content was 12.3 mg QE/g which was compared with similar findings reported by Singh et al. [36]. Furthermore, antioxidant activity has shown a slight ($p < 0.05$) difference during drying; the range varies from 86.7 to 89.9%. The increase in antioxidant activity is due to the flavonoid content in *Bougainvillea spectabilis* Willd. bracts. This occurs due to the presence of functional hydroxyl groups, which show antioxidant effects by chelating metal ions, scavenging free radicals, and reduction in free radicals formation [37].

Total phenolic content (TPC) and total flavonoid content (TFC) decrease with time on drying due to irreversible chemical changes and alterations in structure. The polyphenolic compounds are more heat-sensible, and higher degradation occurs due to changes in the activity of organic acid content, pH level, the concentration of sugar, and polyphenol oxidase.

However, the reduction in antioxidant activity significantly decreases the level of phenolic compounds present in the product [38]. The phenolic compounds present in *Bougainvillea spectabilis* Willd. bracts target different functions such as regulation occurring in the lipid metabolism process, calorie utilization increase, suppression of the level of adipogenesis, inhibition of the adipocyte cells, and inflammation through changes in signaling pathways [39]. Similarly, the molecular level was affected in metabolic pathways by intaking of flavonoids which control the genes of lipolysis and adipogenesis [40]. However, redox imbalances were improved in obesity, while the intake of antioxidants was responsible for ameliorating fatty cells [41].

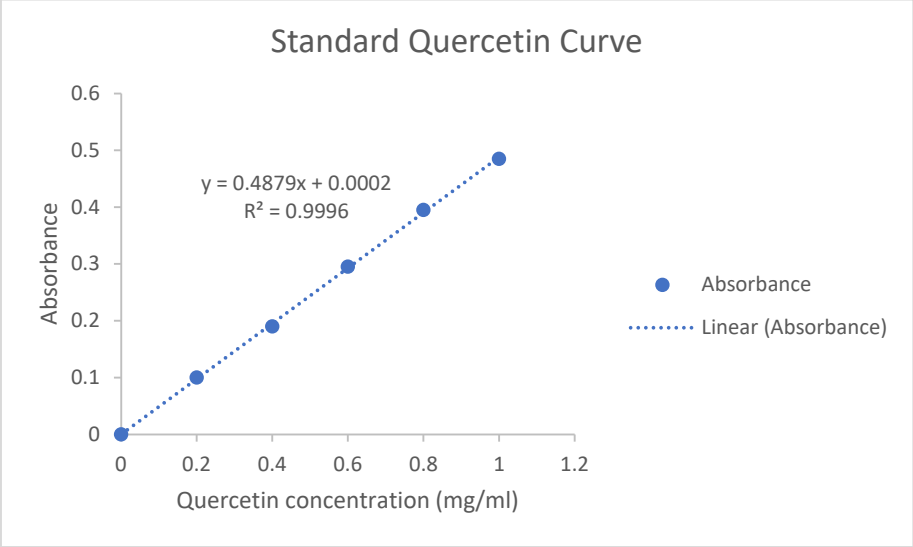

Figure 2. Standard quercetin curve for total flavonoid content.

3.3. FTIR Analysis

Infra-red spectra of the *Bougainvillea spectabilis* Willd. bracts were compared to check the qualitative effect of different variables (time and temperature) on the physicochemical and phytochemical potential of dried *Bougainvillea spectabilis* Willd. bracts by identifying the presence of major peaks. FTIR spectrometer is undoubtedly one of the most crucial analytical methods available today to study any sample's physicochemical and conformational properties [42]. Based on functional properties, the bracts sample was subjected to IR spectroscopy ranging from 4000 to 400 cm^{-1}, and the results obtained are shown in Figure 3. According to the FTIR spectra, the FTIR vibrational frequencies obtained at 3865.48 and 3740.1 cm^{-1} revealed the presence of water molecules, 1687.77 cm^{-1} inferred the oxygen-containing compounds (Aromatic ketone C = O stretching), nitrogen-containing compounds (Oxime C = N–OH stretching), 1653.05 cm^{-1} corresponded to aliphatic hydrocarbons (Alkenes C = C stretching), 1533.46 cm^{-1} indicated the existence of aromatic compounds (C = C stretching), and 1462.09 cm^{-1} can be attributed to boron compounds (B–N stretching). The nitrogen-containing compounds (Azo compound N = N stretching) appeared at 1404.22 cm^{-1}, 1323.21 cm^{-1} indicated aromatic P = O stretching, 1234.48 cm^{-1} was associated with the presence of phosphorus compounds (Aromatic P–O stretching), 1062.81 cm^{-1} indicated silicon compounds (Si–O–C stretching), 989.52 cm^{-1} corresponded to phosphorus compounds (Phosphine P–H wagging), and 675.11 cm^{-1} inferred the aliphatic hydrocarbons (Alkene =C–H bending), alkenes (= C–H out-of-plane bending), amides (Secondary amide N–H wagging), organic halogen compounds (C–X stretching (X = F, Cl, Br or I), phosphorus compounds (P = S stretching), and sulfur compounds (C–S stretching). The results were compared with the findings of Sahu et al. [43].

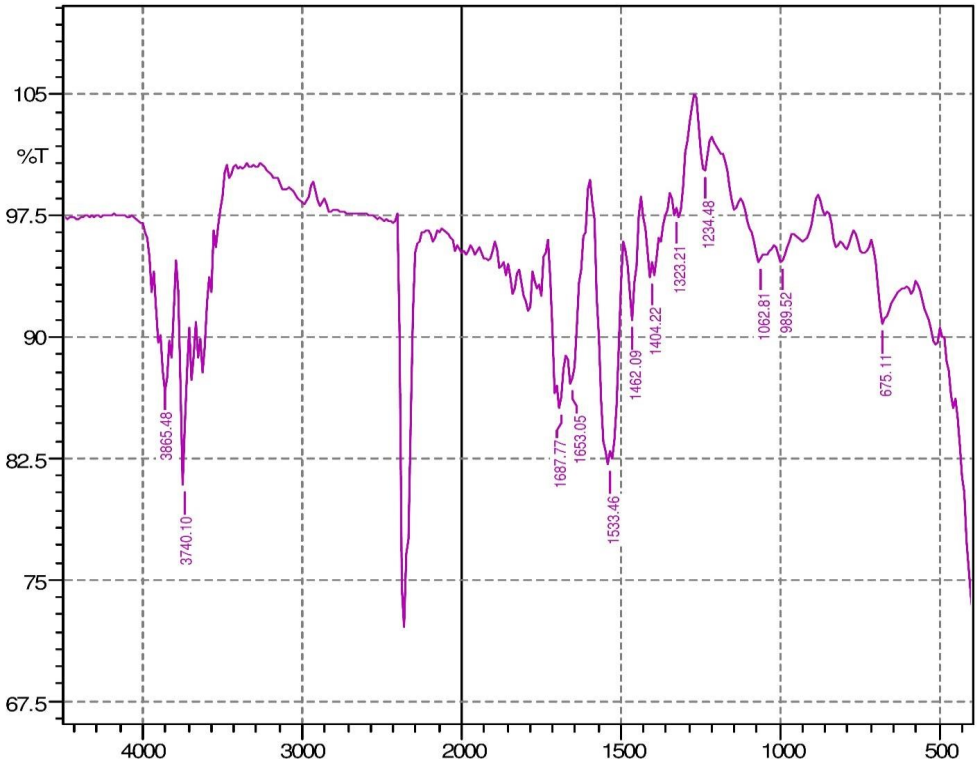

Figure 3. FTIR spectra of *Bougainvillea spectabilis* Willd. bracts.

3.4. Lipase Inhibition Assay

The result of % lipase inhibition and I_C50 of bracts extract is shown in Table 3. The bracts sample (81.09%, 68.21) showed a significant ($p < 0.05$) higher % of lipase inhibition and I_C50. These results were compared with the findings reported by Kumar et al. [2]. The study revealed that *Betula utilis* showed a significant ($p < 0.05$) higher % of lipase inhibition (74.91%) and I_C50 (59.71). Similarly, in *Bauhinia variegate*, the % lipase inhibition and I_C50 were 57.39% and 26.95 respectively. The possible mechanism for lowered lipid levels by the *Bougainvillea spectabilis* Willd. extract may be an insulin-mimicking action, as the primary function of the insulin in adipose tissue is to block the hormone-sensitive lipase activity, lowering the fatty acids and glycerol release. The study revealed that herb extract showed a significant decrease in the elevated levels of total cholesterol, LDL, triglycerides, and VLDL and a significant increase in HDL levels [18,44].

Table 3. Lipase and amylase inhibition assay of *Bougainvillea spectabilis* Willd. bracts extract.

Sample	% of Inhibition of Lipase	I_C50	% of Inhibition of Amylase	I_C50
Bougainvillea spectabilis Willd. bracts extract	81.09 ± 0.92	68.21	74.24 ± 0.88	60.19

Data are presented as mean ± SD (n = 3).

3.5. Amylase Inhibition Assay

The percentage of amylase inhibition and I_C50 of the herb extract is presented in Table 3. The bracts sample (74.24%, 60.19) showed a significant ($p < 0.05$) higher % of amylase inhibition and I_C50. Kumar et al. [2] reported in a study that *Aconitum heterophyllum* showed a significant ($p < 0.05$) higher % of amylase inhibition (63.33%) and I_C50 (34.79), whereas *Bergenia ciliate* showed 18.27% of amylase inhibition and 4.47 I_C50 value. The inhibition effect of the *Bougainvillea spectabilis* Willd. bracts sample could possibly be due to the phenolic content present in the extract. The plant contains D-pinitol (3-O-methyl-chiro

inositol), which is reported to have insulin-like effects. D-pinitol does not directly boost insulin activity, but it may be linked to the mechanism through which insulin links with glucose transport. The study revealed that it could affect glucose uptake by acting through the post-receptor mechanism of insulin action [18,44,45].

3.6. Glucose Uptake Assay

The *Bougainvillea spectabilis* Willd. bracts extract was analyzed for its role in ameliorating high glucose levels. The results of the glucose levels and percentage of glucose movement for the herb extract are shown in Figures 4 and 5. The glucose level and glucose movement percentage were observed at different time intervals (15 min, 30 min, 60 min, 90 min, 180 min, 240 min, 360 min, and 480 min). The highest glucose retention time (2.1 mg/dL) was observed at 120 min, and the herb extract (2.1 mg/dL) showed significantly ($p < 0.005$) higher glucose retention time compared with the control (1.5 mg/dL) at 120 min. Furthermore, the glucose retention decreased at 240 min in both the herb extract (1.6 mg/dL) and control (1.2 mg/dL). Similarly, the percentage of glucose movement was significantly ($p < 0.005$) lower in the herb extract (49%) compared with the glucose control (56%) at 240 min. These results suggest that the herb extract has the property of quenching the glucose molecules, improving glucose uptake as a result of the lower glucose levels, and playing a role in reducing high glucose concentration [2].

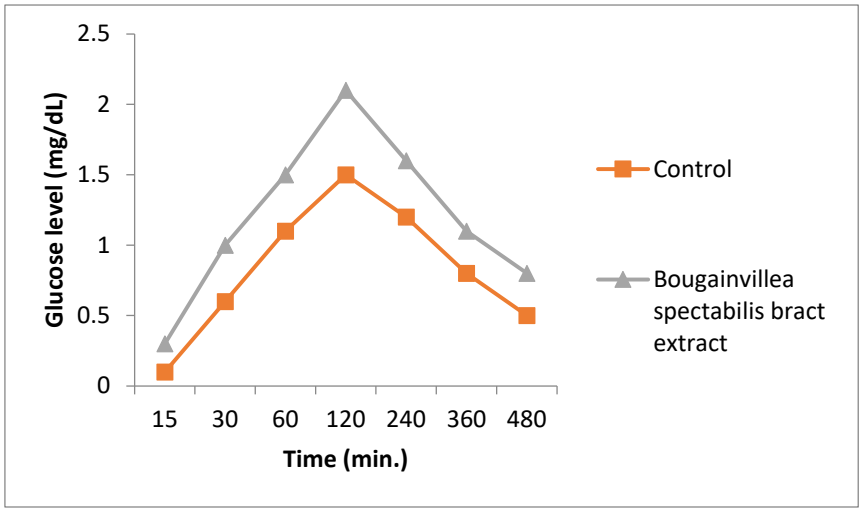

Figure 4. Glucose level (mg/dL) of herb extract.

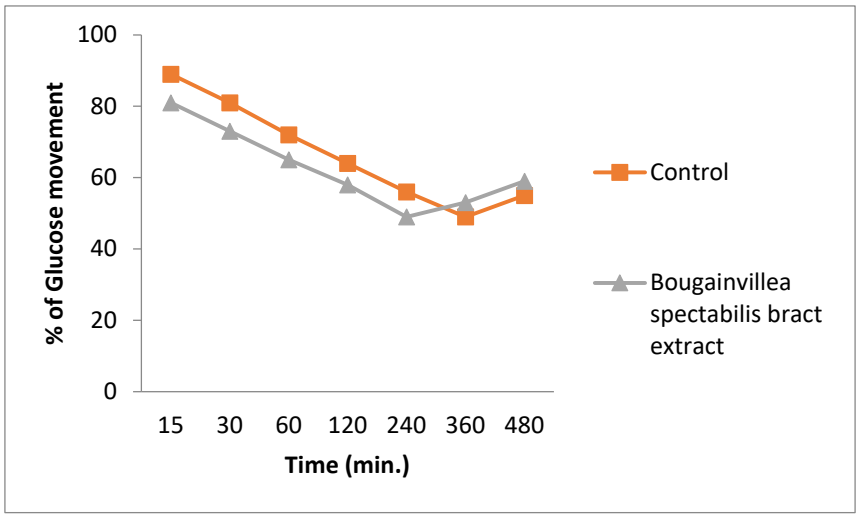

Figure 5. Percentage of glucose movement of herb extract.

4. Conclusions

The data suggest that *Bougainvillea spectabilis* Willd. bracts extract possesses anti-obesity potential and can be used in developing herbal medication. Due to its high polyphenol and flavonoid content and excellent antioxidant activity, the dried *Bougainvillea spectabilis* Willd. bracts powder has a high nutritional potential which shows effective properties to cure obesity by suppressing and controlling the appetite, reducing the level of adipocytes, and proper metabolism function. It also contains an amylase enzyme that works as a catalyst in the digestion process and breaks down the starch into sugar. Furthermore, hormones are also targeted, which affect the pancreas and help to regulate the level of blood sugar. This study also reveals a high water absorption and solubility index, foaming capacity, foam stability, swelling capacity, and oil absorption index in dried *Bougainvillea spectabilis* Willd. bracts powder. This makes the plant significantly valuable for future research as a natural source of bioactive compounds that help in developing functional, value-added food products and provide their benefits to customers.

Author Contributions: Conceptualization, M.K. and D.K.; methodology, M.K.; software, D.K. and A.K.; validation, M.K., C.P. and F.O.; formal analysis, J.X.; investigation, M.K.; resources, J.K.; data curation, A.A.; writing—original draft preparation, M.K., T.E. and M.E.T.; writing—review and editing, M.K. and D.K.; visualization, C.P.; supervision, F.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data already present in the manuscript.

Acknowledgments: The support by the School of Agriculture and Department of Food Technology and Nutrition, Lovely Professional University, Phagwara, Punjab, India, is gratefully acknowledged. The support of Shoolini University, University of Athens, Ataturk University, Rani Lakshmi Bai Central, Agricultural University, Qatar University, Universidade de Vigo, and Jiangsu University is also acknowledged for compeleting the research project.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Fruh, S.M. Obesity: Risk factors, complications, and strategies for sustainable long-term weight management. *J. Am. Assoc. Nurse. Pract.* **2017**, *29*, S3–S14. [CrossRef] [PubMed]
2. Kumar, M.; Guleria, S.; Chawla, P.; Khan, A.; Modi, V.K.; Kumar, N.; Kaushik, R. Anti-obesity efficacy of the selected high altitude Himalayan herbs: In vitro studies. *J. Food Sci. Technol.* **2020**, *57*, 3081–3090. [CrossRef] [PubMed]
3. Kumar, M.; Kaushik, D.; Kaur, J.; Proestos, C.; Oz, F.; Oz, E.; Gupta, P.; Kundu, P.; Kaur, A.; Anisha, A.; et al. A Critical Review on Obesity: Herbal Approach, Bioactive Compounds, and Their Mechanism. *Appl. Sci.* **2022**, *12*, 8342. [CrossRef]
4. Welz, A.N.; Emberger-Klein, A.; Menrad, K. The importance of herbal medicine use in the German health-care system: Prevalence, usage pattern, and influencing factors. *BMC Health Serv. Res.* **2019**, *19*, 952. [CrossRef] [PubMed]
5. Sen, S.; Chakraborty, R. Revival, modernization and integration of Indian traditional herbal medicine in clinical practice: Importance, challenges and future. *J. Tradit. Complement. Med.* **2017**, *7*, 234–244. [CrossRef] [PubMed]
6. Abarca-Vargas, R.; Petricevich, V.L. Bougainvillea genus: A review on phytochemistry, pharmacology, and toxicology. *eCAM* **2018**, *2018*, 9070927. [CrossRef] [PubMed]
7. Nitesh, C.J.; Ambika, N.J.; Alkama, G.F. Efficiency of *Bougainvillea spectabilis* Willd in Monitoring Dust. *Int. J. Appl. Environ. Sci.* **2017**, *12*, 773–785.
8. Ghogar, A.; Jiraungkoorskul, K.; Jiraungkoorskul, W. Paper Flower, *Bougainvillea spectabilis*: Update properties of traditional medicinal plant. *J. Nat. Remedies.* **2016**, *16*, 82–87. [CrossRef]
9. Venkatachalam, R.N.; Singh, K.; Marar, T. *Bougainvillea spectabilis*, a good source of antioxidant phytochemicals. *Res. J. Pharm. Biol. Chem. Sci.* **2012**, *3*, 605–613.
10. Salam, P.; Bhargav, V.; Gupta, Y.C.; Nimbolkar, P.K. Evolution in Bougainvillea (Bougainvillea Commers.)-A review. *J. Appl. Nat. Sci.* **2017**, *9*, 1489–1494. [CrossRef]
11. Jawla, S.; Kumar, Y.; Khan, M.S.Y. Isolation of anti-diabetic principle from *Bougainvillea spectabilis* willd (Nyctaginaceae) stem bark. *Trop. J. Pharm. Res.* **2013**, *12*, 761–765.

12. Dhankhar, S.; Sharma, M.; Ruhil, S.; Balhara, M.; Kumar, M.; Chhillar, A.K. Evaluation of antimicrobial and antioxidant activities of *Bougainvillea spectabilis*. *Int. J. Pharm. Pharm. Sci.* **2013**, *5*, 178–182.
13. Vukovic, N.; Kacaniova, M.; Hleba, L.; Sukdolak, S. Chemical Composition of the Essential oil of *Bougainvillea spectabilis* from Montenegro. *J. Essent. Oil Bear. Plants* **2013**, *16*, 212–215. [CrossRef]
14. Sudipta, K.M.; Lokesh, P.; Rashmi, W.; Vijay, R.; Ssn, K. Phytochemical screening and in vitro antimicrobial activity of *Bougainvillea spectabilis* flower extracts. *Int. J. Phytomedicine* **2012**, *4*, 375–379.
15. Do, L.T.; Aree, T.; Siripong, P.; Pham, T.N.; Nguyen, P.K.; Tip-pyang, S. Bougainvinones A–H, peltogynoids from the stem bark of purple *Bougainvillea spectabilis* and their cytotoxic activity. *J. Nat. Prod.* **2016**, *79*, 939–945. [CrossRef]
16. Mandal, G.; Chatterjee, C.; Chatterjee, M. Evaluation of anti inflammatory activity of methanolic extract of leaves of *Bougainvillea spectabilis* in experimental animal models. *Pharmacogn. Res.* **2015**, *7*, 18–22.
17. Do, L.T.; Aree, T.; Siripong, P.; Vo, N.T.; Nguyen, T.T.; Nguyen, P.K.; Tip-pyang, S. Cytotoxic flavones from the stem bark of *Bougainvillea spectabilis* willd. *Planta Med.* **2018**, *84*, 129–134. [CrossRef]
18. Chauhan, P.; Mahajan, S.; Kulshrestha, A.; Shrivastava, S.; Sharma, B.; Goswamy, H.M.; Prasad, G.B.K.S. *Bougainvillea spectabilis* exhibits antihyperglycemic and antioxidant activities in experimental diabetes. *eCAM* **2016**, *21*, 177–185. [CrossRef]
19. Bhat, M.; Kothiwale, S.K.; Tirmale, A.R.; Bhargava, S.Y.; Joshi, B.N. Antidiabetic properties of Azardiracta indica and *Bougainvillea spectabilis*: In vivo studies in murine diabetes model. *eCAM* **2011**, *2011*, 561625.
20. Killedar, S.; Pawar, A.; Nadaf, S.; Nale, A.; Tamboli, U.; Pishawikar, S. Novel analytical method development for some amide group containing drugs using *Bougainvillea spectabilis* bract extracts. *Asian Pac. J. Trop. Med.* **2014**, *7*, S560–S567. [CrossRef]
21. Hajare, C.N.; Inamdar, F.R.; Patil, R.V.; Shete, C.S.; Wadkar, S.S.; Patil, K.S.; Ghosh, J.S. Anti-bacterial activity of the leaves of *Bougainvillea spectabilis* against E. coli NCIM 2832 and M. aureus NCIM 5021. *Int. J. Pharm. Sci. Rev. Res.* **2015**, *34*, 194–196.
22. AOAC. *Official Methods of Analysis*, 18th ed.; Association of Official Analytical Chemists: Washington, DC, USA, 2005; Method 935.14 and 992.24.
23. Singh, J.; Rasane, P.; Kaur, S.; Nanda, V. Comparative analysis of antioxidant potential and techno-functional properties of selected corn silk varieties at different developmental stages. *J. Food Meas. Charact.* **2022**, *16*, 2685–2698. [CrossRef]
24. Tze, N.L.; Han, C.P.; Yusof, Y.A.; Ling, C.N.; Talib, R.A.; Taip, F.S.; Aziz, M.G. Physicochemical and nutritional properties of spray-dried pitaya fruit powder as natural colorant. *Food Sci. Biotechnol.* **2012**, *21*, 675–682. [CrossRef]
25. Brar, I.S.; Dixit, A.K.; Khurana, R.; Gautam, A. Studies on physical properties of maize (*Zea mays* L.) seeds. *Int. J. Curr. Microbiol. Appl. Sci.* **2017**, *6*, 963–970. [CrossRef]
26. Mokhtar, S.M.; Swailam, H.M.; Embaby, H.E. Physicochemical properties, nutritional value and techno-functional properties of goldenberry (*Physalis peruviana*) waste powder concise title: Composition of goldenberry juice waste. *Food Chem.* **2018**, *248*, 1–7. [CrossRef] [PubMed]
27. Ishara, J.R.; Sila, D.N.; Kenji, G.M.; Buzera, A.K. Nutritional and functional properties of mushroom (Agaricus bisporus & Pleurotus ostreatus) and their blends with maize flour. *Am. J. Food Technol.* **2018**, *6*, 33–41.
28. Baljeet, S.Y.; Ritika, B.Y.; Reena, K. Effect of incorporation of carrot pomace powder and germinated chickpea flour on the quality characteristics of biscuits. *Int. Food Res. J.* **2014**, *21*, 217–222.
29. Sadh, P.K.; Chawla, P.; Duhan, J.S. Fermentation approach on phenolic, antioxidants and functional properties of peanut press cake. *Food Biosci.* **2018**, *22*, 113–120. [CrossRef]
30. Chawla, P.; Kumar, V.; Bains, A.; Singh, R.; Sadh, P.K.; Kaushik, R.; Kumar, N. Improvement of Mineral Absorption and Nutritional Properties of *Citrullus vulgaris* Seeds Using Solid-State Fermentation. *J. Am. Coll. Nutr.* **2020**, *39*, 628–635. [CrossRef]
31. Shashikant, M.; Bains, A.; Chawla, P.; Sharma, M.; Kaushik, R.; Kandi, S.; Kuhad, R.C. In-vitro antimicrobial and anti-inflammatory activity of modified solvent evaporated ethanolic extract of Calocybe indica: GCMS and HPLC characterization. *Int. J. Food Microbiol.* **2022**, *376*, 109741. [CrossRef]
32. Patil, M.M.; Anand, T.; Ilaiyaraja, N.; Khanum, F. Invitro antioxidant and anti-obesity properties of Bauhinia variegate. *Def. Life Sci. J.* **2017**, *2*, 128–132. [CrossRef]
33. Souza, S.D.; Murata, H.; Jose, M.V.; Askarova, S.; Yantsen, Y.; Andersen, J.D.; Edington, C.D.; Clafshenkel, W.P.; Koepsel, R.R.; Russell, A.J. Engineering of cell membranes with a bisphosphonate-containing polymer using ATRP synthesis for bone targeting. *Biomaterials* **2014**, *35*, 9447–9458. [CrossRef] [PubMed]
34. Rashid, S.A.; Rehmani, F.S.; Arman, M.; Ibrahimand, M.; Shafique, S. Estimation of Moisture Content & Metal Ions in White Flowers of *Bougainvillea spectabilis* and Purple Flowers of Bougainvillea glabra in Pakistan. *Pak. J. Chem.* **2011**, *1*, 190–192.
35. Compaore, M.; Bakasso, S.; Nacoulma, A.P.; Meda, R.N.; Kiendrebeogo, M.; Millogo, J.F.; Nacoulma, O.G. Polyphenolic Contents of *Bougainvillea spectabilis* Wild and Bougainvillea glabra Choisy (Nictagynaceae) with Potential Antioxidant and Antiproliferative Activities. *Asian J. Pharm. Biol. Res.* **2013**, *3*, 24–28.
36. Singh, J.; Kaur, S.; Rasane, P. Evaluation of the nutritional and quality characteristics of black carrot fortified instant noodles. *Curr. Nutr. Food Sci.* **2018**, *14*, 442–449. [CrossRef]
37. Panche, A.N.; Diwan, A.D.; Chandra, S.R. Flavonoids: An overview. *J. Nutr. Sci.* **2016**, *5*, e47. [CrossRef] [PubMed]
38. Guiné, R.P.; Barroca, M.J.; Gonçalves, F.J.; Alves, M.; Oliveira, S.; Correia, P.M. Effect of drying on total phenolic compounds, antioxidant activity, and kinetics decay in pears. *Int. J. Fruit Sci.* **2015**, *15*, 173–186. [CrossRef]
39. Yen, G.C.; Cheng, H.L.; Lin, L.Y.; Chen, S.C.; Hsu, C.L. The potential role of phenolic compounds on modulating gut microbiota in obesity. *J. Food Drug Anal.* **2020**, *28*, 195–205. [CrossRef]

40. de la Garza, A.L. The role of flavonoids in the effort to prevent obesity: Nutrition 4.0. *Curr. Res. Nutr. Food Sci. J.* **2018**, *6*, 573–575. [CrossRef]
41. Tun, S.; Spainhower, C.J.; Cottrill, C.L.; Lakhani, H.V.; Pillai, S.S.; Dilip, A.; Chaudhry, H.; Shapiro, J.I.; Sodhi, K. Therapeutic efficacy of antioxidants in ameliorating obesity phenotype and associated comorbidities. *Front. Pharmacol.* **2020**, *11*, 1234. [CrossRef]
42. Singh, J.; Inbaraj, B.S.; Kaur, S.; Rasane, P.; Nanda, V. Phytochemical Analysis and Characterization of Corn Silk (*Zea mays*, G5417). *Agronomy* **2022**, *12*, 777. [CrossRef]
43. Sahu, N.; Saxena, J. Phytochemical analysis of Bougainvillea glabra Choisy by FTIR and UV-VIS spectroscopic analysis. *Int. J. Pharm. Sci. Rev. Res.* **2013**, *21*, 196–198.
44. Saikia, H.; Lama, A. Effect of *Bougainvillea spectabilis* leaves on serum lipids in albino rats fed with high fat diet. *Int. J. Pharm. Sci. Drug Res.* **2011**, *3*, 141–145.
45. Lim, T.K. Bougainvillea spectabilis. In *Edible Medicinal and Non-Medicinal Plants*, 1st ed.; Lim, T.K., Ed.; Springer Dordrecht: Berlin/Heidelberg, Germany; New York, NY, USA; London, UK, 2014; Volume 8, pp. 489–496.