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Strawberry and Cauliflower Leaves are Rich in Bioactive Compounds and Antioxidant Activity: Application on Obese Rats

Yousif A. Elhassaneen[1,*], Ghada M. ElBassouny[2], Omar A. Emam[2], Horia E. Ammar[2]

[1]Department of Nutrition and Food Science, Faculty of Home Economics, Menoufia University, Shebin El-Kom, Egypt
[2]Home Economics Department, Faculty of Specific Education, Benha University, Benha, Egypt
*Corresponding author: yousif12@hotmail.com

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Abstract The present study aims to investigate the bioactive compounds content and antioxidant activity of the agricultural remnants (strawberry and cauliflower leaves). This study will also see if eating strawberry and cauliflower leaves powder can help with the complications associated with obesity in rats. Data indicated that the bioactive compounds assayed content was ranged as follow: total phenolics from 189.15 to 233.94 mg EGA.100 g^{-1}, total carotenoids from 39.56 to 47.21 mg.100 g^{-1}, total flavonoids from 42.83 to 52.06 mg RE.100 g^{-1}, lutein from 53.17 to 56.4 mg.100 g^{-1}, total anthocyanin's from 19.21 to 23.96 mg.100 g^{-1}, total chlorophylls from 306.32 to 349.73 mg.100 g^{-1}, and dietary fiber from 23.44 to 28.06 g.100g^{-1}. Also, the hydro-ethanolic extract of strawberry and cauliflower leaves demonstrated a wide range of antioxidant activity. For the all plant parts tested and their mixture, a positive and highly significant ($p \leq 0.05$) relationships between total bioactive compounds assayed and antioxidant activity was recorded. Normal rats fed diet-induced obesity (DIO) (model control) had higher body weight than the control/normal group. At the end of the experiment (8 weeks), rats of the normal group recorded increasing on body weight rate by 77.57% from the starting point of the experiment while obese group was 1114.60%. Dietary intervention with the tested plant parts and their mixture on the diet by 10% induced significant ($p \leq 0.05$) decreasing on body weight, improving of the serum lipid profile parameters, decreasing of the oxidative stress and positively manipulated obesity-related histopathological changes in adipose tissues of the obese rats. These data support the use of strawberry and cauliflower leaves for obesity treatment and prevention. Furthermore, the findings suggest the benefits of dietary changes, such as strawberry and cauliflower leaves supplementation, in reducing the complications linked with obesity, such as oxidative stress problems.

Keywords: *Chemical composition, nutritional evaluation, body weight, serum lipid profile, oxidative stress, histology, adipose tissues*

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1. Introduction

The agricultural sector is one of the main sectors generating the largest quantities of agricultural solid wastes, which may be allowed to accumulate indiscriminately and constitute nuisance to global health and threat to food security or used as raw materials for bio-economy. The benefits of recycling of agricultural solid wastes include reduction of greenhouse gas emissions and use as fossil fuel as well as contributing significantly to the development of new green markets, creation of jobs, production of bio-energy and bio-conversion of agricultural solid wastes to human and animal feed [1,2]. Thus new aspects concerning the use of these wastes as by-products for further exploitation on the production of food additives or supplements with high nutritional value have gained increasing interest because these are high-value products and their recovery may be economically attractive. It is well known that agro-industrial by-products are rich in dietary fibers, some of which contain appreciable amounts of colorants, antioxidant compounds or other substances with positive health effects, while some of them, like the oilseed meals, are rich in proteins [2,3,4].

Strawberry (*Fragaria* × *ananassa*, Family, *Rosaceae*) is an evergreen plant that typically cultivates in the Mediterranean region [5]. The plant leaves are nutritionally valuable raw material contain protein, fat, ash, moisture, fiber and carbohydrate at 13.45, 5.38, 9.22, 3.80, 12.35 and 55.80%, respectively [6] Also, Strawberry leaves are a rich source of bioactive compounds such as polyphenolic compounds, terpenoids, essential oils, tocopherols, etc., [7,8]. In general, young strawberry leaves contain much more polyphenolic compounds than

the fruits and mature leaves and are a rich source of flavonoids and procyanidins [9,10,11]. For such reasons, a number of biological benefits including significant antioxidant activity, antibacterial and antifungal effects, anti-carcinogenic and anti-inflammatory action were exhibited for such plant part [12,13,14]. Thus, strawberry leaves represent a potent source of biologically active compounds and have been used for a long to alleviate symptoms of several health impairments and diseases. For example, reported that a comprise of various phenolic compounds with health beneficial effects was found in strawberry leaves, two major compounds related to their beneficial activities in animals and humans are arbutin and hydroquinone. Results of previous studies suggested that arbutin is a potent antioxidative and cytoprotective agent [15,16] Also, aquatic extract of strawberry leaves has positive effects in the treatment of diabetes, hypertension, and inflammation, chiefly due to its diuretic, uroantiseptic and astringent properties [17,18]. Furthermore, strawberry leaves are considered to be an excellent source of compounds, with high antioxidant capacity, high biological activities and potential health benefits such as reducing myocardium ischemia, reduction of thrombosis risk and anti-cancer activity [19]. Additionally, flavonoids found in his plant part seem to play an important role in human health and to possess beneficial effects in the prevention of human diseases [20,21,22]. Finally, several pigments from different categories were determined in the strawberry leaves including chlorophylls and carotenoids [23,24]. Given the high content of such bioactive compounds high values of antioxidant capacity were determined [25,26].

Cauliflower (*Brassica oleracea*) belongs to family *Cruciferae* (*Brassicaceae*), which comprises also: cabbage, broccoli, Brussels sprouts, turnip, Swedish turnip. Cauliflower leaves considered as a waste by-product which obtained it during processing (freezing and cooking) of cauliflower, huge amount of leaves is generated, and its disposal is a major problem and causes environmental pollution. Leaves constitutes about 40-50% of cauliflower fruit and have a high content of different nutrients including protein, ash, fiber and carbohdrates [27]. Also, they are rich sources of bioactive compounds (polyphenols, carotenoids, glycoalkaloids, anthocyanins, dietary fiber etc [27,28]. Furthermore, cauliflower leaves which are generally thrown away as waste are also rich source of iron and β-carotene and thus can be utilized in various value added products [29]. For example, reported that cauliflower leaves considered as waste were dried, powdered and used for preparing namakpara, kurmura, biscuit and cake. Protein content was maximum in kurmura (12.25%) and minimum in biscuit (7.42%) when evaluated nutritionally. Ascorbic acid and β-carotene contents of all the products, ranged from 2.21 to 4.29 and 2.04 to 4.98 mg/100 g, respectively. Total iron content was highest in cake (9.90 mg/100 g) whereas ionizable iron content was maximum in biscuit (2.83 mg/100 g). On another side, varied bioactive components found in cauliflower leaves may be responsible for the offered health protection. A number of experiments indicate that such plant part added to laboratory animals' diet had positive effects on complete blood count (CBC), serum lipid profile, liver and kidney functions and serum glucose [28,30,31].

Obesity is "an excess of body fat frequently resulting in a significant impairment of health and longevity [32]. It is most commonly assessed by body mass index (BMI) which is calculated by dividing an individual's weight measured in kilogrammes by their height in metres squared. Overweight is generally defined as a BMI greater than 25; individuals with a BMI greater than 30 are classified as obese [33]. In general, obesity results from inherited, physiological and environmental factors, combined with diet, physical activity and exercise choices. Obesity can be described as the "New World Syndrome". Its prevalence is on continuous rise in all age groups of many of the developed countries in the world. Annually, about 4.7 million premature deaths occur due to obesity. It was ranked fifth among the leading preventable causes of death, making up 12.3% of all *deaths* worldwide and *8.4*% of total disability-adjusted life years (DALYs) lost to non-communicable diseases. In Egypt, obesity is a major public health issue and its repercussions are not only limited to the health dimension, but also extend to affecting the productive capacity of the citizens. This adversely affects the overall fundamentals of the Egyptian economy. According to the "100 million Seha" initiative, 39.8% of Egyptian adults suffer from obesity [34]. Obesity prevalence can vary according to the geographical location, gender, and socioeconomic class. In addition, obesity is a risk factor for numerous Non-Communicable Diseases (NCD) such as diabetes. Also, obese patients have been associated with increased risk of morbidity and mortality relative to those with ideal body weight [35]. Even modest weight reduction in the range of 5–10% of the initial body weight is associated with significant improvements in a wide range of co-morbid conditions [36]. In this context, several authors stated that the medical complications of obesity constitute a large portion of health care expenditures, and also generate additional economic costs on the public budgets of countries through loss of worker productivity, increased disability, and premature loss of individuals. Perhaps the main reason for such financial and social problems is the complications of obesity, which means that obesity is linked to many different diseases, the most important of which are cardiovascular diseases, type 2 diabetes, obstructive sleep apnea, certain types of cancer, osteoarthritis, asthma, and neurological and immunological disorders [4,24,37,38,39,40,41,42].

In recent years, through the strategies used to treat/prevent obesity, a number of pharmacological approaches have been studied. However, only a small number of effective and safe drugs have been developed from a therapeutic stand point Drug treatment throughout the ages has been considered expensive, and was often associated with multiple side effects, which leads to patient non-compliance with this type of treatment. Hence the urgent need to search for alternative treatments, especially from natural sources, that are cost-effective and have few side effects. In this regard, several plant parts in the form of crude drugs such as powders, extracts and other herbal formulations have been applied in numerous studies as anti-obesity agents [4,24,26,40,42,43,44,45]. Almost of such plant parts have been exhibited positively effects in preventing and/or treating obesity and its complications in different experimental animals. The results of these studies represented an encouraging factor

for expansion in this field, in addition to searching for different plant parts that have the anti-obesity effect and are available in various local and global environments.

Various countries of the world including Egypt, still grow strawberries for their fruits only and cauliflower for the flowers only, while the vegetative part, which represents the majority of green leaves, is left as waste thrown into the environment without use causing many harmful environmental effects. Therefore, in an attempt to take advantage of this important plant parts, strawberry and cauliflower leaves, which is present in Egypt in huge quantities, the present study was carried out to investigate the to explore their bioactive compounds content and their biological activities of such plant parts. Also, potential protective effects of such plant parts on obesity and its complications in experimental rats will be in the scope of this study.

2. Materials and Methods

2.1. Materials

2.1.1. Plant Parts

Cauliflower (*Brassica oleracea*) leaves were obtained in November, 2023 by special arrangement with some village farmers, Ashmoun City, Menoufia Governorate, Egypt. Strawberry (*Fragaria ananassa*) leaves were obtained in February 2023 by special arrangement with some village farmers lived in Badr Center, Menoufia Governorate, Egypt. The collected samples was transported to the laboratory and used immediately for peels and pomace powders preparation.

2.1.2. Chemicals

Bioactive compounds standard [gallic acid (GA), catechine (CA), linalool, ursolic acid], butylated hydroxytoluene (BHT), DDPH (2,2-diphenyl-1-picrylhydrazyl) and dimethyle sulfoxide (DMSO) were purchased from Sigma Chemical Co., St. Louis, MO. All other chemicals (Except as otherwise stated), reagents and solvents were of analytical grade were purchased from El-Ghomhorya Company for Trading Drug, Chemicals and Medical Instruments, El-Amiria, Cairo, Egypt.

2.1.3. Kits

Kit's assays for Alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), malondialdehyde (MDA), serum lipids profile (triglycerides, TGs; total cholesterol, TC; high density lipoprotein cholesterol, HDL-c) and serum glucose were purchased from BIODIAGNOSTIC, Dokki, Giza, Egypt. Reduced glutathione (GSH) and oxidized glutathione (GSSG) were assayed by the kits provided by MyBioSource, Inc., San Diego, CA, USA.). Casein was obtained from Morgan Chemical Co., Cairo, Egypt. Vitamins and salts mixtures in food grade, organic solvents and other chemicals in analytical grade were purchased from El-Ghomhorya Company for Trading Drugs, Chemicals and Medical instruments, Cairo, Egypt.

2.1.4. Instruments

Absorbance (Abs) and fluorescence (FL) for different assays were measured using Labo-med. Inc., spectrophotometer, CA and Schematzu fluorescence apparatus, Japan, respectively. Also, Micro-Kjeldahl semiautomatic apparatus, Velp company, Italy was used for total nitrogen determination. Soxhelt semiautomatic apparatus Velp company, Italy, was used for crude fat determination.

2.2. Methods

2.2.1. Preparation of Agricultural Ruminant's Powder

Strawberry and cauliflower healthy leaves were collected and immediately taken to the laboratory. The harvested leaves were cleaned and washed with water to remove impurities. Leaves were dried in a hot air oven (Horizontal Forced Air Drier, Velp Inc., Italy) at 60 ^{0}C for 8 h (moisture final, 8%). The dried product were ground into a fine powder in high mixer speed (Moulinex Egypt, ElAraby Co., Benha, Egypt). The material that passed through an 80 mesh sieve was retained for packing in polyethylene pages and storing at 4°C for using in chemical and biological experiments. for their aqueous extracts according to the method mentioned in [48]. In brief, 20 g from sample plus 180 ml water were homogenized and transferred to a beaker and stirred at 200 rpm in an orbital shaker (Unimax 1010, Heidolph Instruments GmbH & Co. KG, Germany) for 1 h at room temperature (23±3°C). The extract was then separated from the residue by filtration through Whatman No. 1 filter paper. The remaining residue was re-extracted twice, and then the two extracts were combined. The residual solvent of was removed under reduced pressure at 55°C using a rotary evaporator (Laborata 4000; Heidolph Instruments GmbH & Co. KG, Germany). All aqueous extracts could be ready for analytical studies.

2.2.2. Analytical Methods

2.2.2.1. Chemical Analysis of the Selected Plant Parts Powder

Plant parts powders were analyzed for moisture, protein (T.N. × 6.25, micro-kjeldahl method), fat (soxhelt method, petroleum ether solvent), ash, fiber and dietary fiber contents were determined using the methods described in the A.O.A.C. [46]. Carbohydrates calculated by the differences.

2.2.2.2. Determination of Nutritional Value of Agricultural Ruminant's Powder

Total energy value

Total energy (Kcal/100 g) of agricultural ruminant's powder samples was calculated according to the following equation: Total energy value (Kcal/100 g) = 4 (Protein % + carbohydrates %) + 9 (Fat %)

Satisfaction of the daily needs of adult man (25-50 year old) in protein

Grams consumed (G.D.R., g) of food (wet weight basis) to cover the daily requirements of adult man (63 g) in protein was calculated using the [47] values. Percent satisfaction of the daily requirement of adult man in

protein (P.S./80 g,%) when consuming the possibly commonly used portions in Egypt i.e. one loaf (80 g weight), was also calculated.

Satisfaction of the daily requirements of adult man (25-50 year old) in energy

Grams consumed of food (wet weight basis) to cover the daily requirements of man in energy (G.D.R., g) were calculated using the RDA (Recommended dietary allowances) which are 2900 Kcal /day for man as given by RDA [47] The percent of satisfaction (P.S., %) of the daily needs of adult man (25 -50 year old, 79 Kg weight and 176 cm height) in energy upon consumption the commonly used portion at homes in Egypt, i.e. i.e. one loaf (80 g weight), was also calculated.

2.2.2.3. Bioactive Compounds Determination

For the bioactive compounds determination in agricultural ruminant's powder, their ethanolic extracts were prepared according to the method mentioned in Gharib et al., [48] Total phenolic compounds in agricultural ruminant's powder were determined using Folin-Ciocalteu reagent according to Singleton and Rossi, [49] and Wolfe et al., [50]. Results are expressed as gallic acid and equivalents (GAE). The total carotenoids in 80% acetone extract were determined by using the method reported by Litchenthaler, [51] and were expressed as µg of carotenoid/g of dry extract. Total flavonoids contents were estimated using colorimetric assay described by Zhishen et al., [52] and expressed as catechin equivalent, mg of CA/g of dry extract. Lutein was extracted from the molokhia leaves according to the methods described by Bangbang et al., [53] and expressed as µg.100 g^{-1}. Total content of anthocyanin's in the sample was measured spectrophotometrically such as described by Sukwattanasinit et al., [54] using molar extinction coefficient of cyanidin-3,5-diglucoside (26 300 M^{-1} cm^{-1}). The total chlorophyll (a+b) concentration was determined spectrophotometrically according to the method of] Zilha et al., [55] by measuring the absorbance of the extract at 662 nm and 644nm, respectively. The resulting absorbance measurements are then applied to a standard equation.

2.2.2.4. Antioxidant Activity (AA)

Antioxidant activity (AA) of the selected agricultural ruminant's and standards (α-tocopherol and BHT) was determined according to the BCB assay following a modification of the procedure described by Marco, [56]. For a typical assay, 1mL of *β*-carotene solution, 0.2 mg/mL in chloroform, was added to round-bottom flasks (50 mL) containing 0.02 mL of linoleic acid and 0.2 mL of Tween 20. Each mixture was then dosed with 0.2 mL of 80% MeOH (as control) or corresponding plant extract or standard. After evaporation to dryness under vacuum at room temperature, oxygenated distilled water (50 ml) was added and the mixture was shaken to form a liposome solution. The samples were then subjected to thermal auto-oxidation at 50 ^{0}C for 2 h. The absorbance of the solution at 470 nm was monitored on a spectrophotometer (Beckman DU-50) by taking measurements at 10 min intervals, and the rate of bleaching of *β*-carotene was calculated by fitting linear regression to data over time. All samples were assayed in triplicate. Various concentrations of BHT and α-tocopherol in 80% methanol were used as the control. Antioxidant activity was calculated in four different ways as follow: 1) absorbance was plotted against time, as a knit curve, and the absolute value of slope was expressed as antioxidant value (AOX) [57], 2) antioxidant activity (AA) was all calculated as percent inhibition relative to control using the equation of Marinova, et al., [58] AA= ($R_{control}$ - R_{sample}) / $R_{control}$ x 100 where: $R_{control}$ and R_{sample} were the bleaching rates of β-carotene in reactant mixture without antioxidant and with plant part extract, respectively, 3) this method of expression based on the oxidation rate ratio (ORR) was calculated according to the method of Marinova, et al., [58] using the equation [ORR = R_{sample} / $R_{control}$] where: $R_{control}$ and R_{sample} are the same in the previous method, and 4) the antioxidant activity coefficient (AAC) was calculated as described by Mallett et al., [59] [AAC = (Abs_{S120}- Abs_{C120})/ Abs_{C0}- Abs_{C120}) x 100] where: $Abs_{S\ 120}$ was the absorbance of the antioxidant mixture at time 120 min, $Abs_{C\ 120}$ was the absorbance of the control at time 120 min, $Abs_{C\ 0}$was the absorbance of the control at zero time.

2.2.2.5. β-carotene Bleaching (BCB) Assay

For *β*-carotene bleaching (BCB) assay, antioxidant activity (AA) against time (every 10 min thereafter for 120 min) for the all tested agricultural ruminant's extracts was measured/constructed according to Marco., [56]. The AA was all calculated as percent inhibition (bleaching rates of *β*-carotene in reactant mixture of plant part extracts) relative to control (bleaching rates of *β*-carotene in reactant mixture of without plant part extracts) such as described by Al-Saikhan *et al*., [57].

2.2.3. Biological Experiments

2.2.3.1. Animals

Animals used in this study, adult male albino rats (150±5.52g per each) were obtained from Research Institute of Ophthalmology, Medical Analysis Department, Giza, Egypt.

2.2.3.2. Basal Diet (BD)

The BD prepared according to the following formula as mentioned by AIN., [60] as follow: protein (10%), corn oil (10%), vitamin mixture (1%), mineral mixture (4%), choline chloride (0.2%), methionine (0.3%), cellulose (5%), and the remained is corn starch (69.5%). The used vitamin mixture component and the salt mixture used was formulated according to Reeves et al., [61].

2.2.3.3. Experimental Design

All biological experiments performed a complied with the rulings of the Institute of Laboratory Animal Resources, Commission on life Sciences, NRC, [62]. Rats (n=36 rats), were housed individually in wire cages in a room maintained at 23 ± 2°C and kept under normal healthy conditions. All rats were fed on BD for one-week before starting the experiment for acclimatization. After one week period, the rats were divided into two main groups, the first group (Group 1, 6 rats) still fed on basal diet and the other main group (30 rats) was feed with diet-induced obesity (DIO, product no.D1245, Research Diets,

Inc. NJ for 8 weeks which classified into sex sub groups as follow: group (2), fed on diet-induced obesity (DIO) as a positive control; groups (3, 4 and 5), fed on BD containing 10% cauliflower powder (CLP), 10% strawberry leaves powder (SLP) and Mix (CLP + SLP by equal parts) respectively. The diet consumed was recorded every day and body weight was recorded every week during the experimental period (8 weeks days). The body weight gain (BW, %), food intake (FI) and food efficiency ratio (FER) were determined using the following equations: BWG (%)= (Final weight – Initial weight)/ Initial weight×100, FER= Grams gain in body weight (g/28 day)/ Grams feed intake (g/28 day).

2.2.3.4. Blood and Adipose Tissue Sampling

At the end of experiment period (8 weeks), after 12 hours fasting, rats were scarified under ether anesthetized and blood samples were collected using the abdominal aorta. Samples were received into clean dry centrifuge tubes and left to clot at room temperature, then centrifuged for 15 minutes at 3000 rpm to separate the serum according to Drury and Wallington, [63]. Serum was carefully aspirate, transferred into clean covet tubes and stored frozen at -20^{o}C until analysis. Specimens of the adipose tissue were taken immediately after sacrificing rats and immersed in 10% neutral buffered formalin for the histological examination.

2.2.4. Hematological Analysis

2.2.4.1. Serum Lipid Profile

Triglycerides (TGs), total cholesterol (TC), HDL-Cholesterol, and LDL-cholesterol and VLDL-cholesterol were determined in serum according to the methods of Fossati and Prenape, [64], Richmond, [65], Lopes-Virella et al., [66] and Ahmadi et al., [67].

2.2.4.2. Glutathione Content

GSH content was measured colorimetrically in serum samples such as described by Ellman, [68].

2.2.4.3. Thiobarbituric Acid Reactive Substances (TBARS)

TBARs content were measured as thiobarbituric acid reactive substances (TBARS) as described by Buege and Aust, [69]. Half milliliter of plasma were added to 1.0 ml of thiobarbituric acid reagent, consisting of 15% TCA, 0.375% thiobarbituric acid (TBA) and 0.01% butylated hydroxytoluene in 0.25 N HCl. Twenty-five microliters of 0.1 M $FeSO_4.7H_2O$ was added and the mixture was heated for 20 min in boiling water. The samples were centrifuged at 1000 rpm for 10 min and the absorbance was read at 535 nm using Labo-med. Inc., spectrophotometer against a reagent blank. The absorbance of the samples was compared to a standard curve of known concentrations of malondialdehyde.

2.2.5. Histological Examination

Specimens of adipose tissues were taken immediately after sacrificing rats and immersed in 10% neutral buffered formalin. The fixed specimens were then trimmed and dehydrated in ascending grades of alcohol, cleared in xylene, embedded in paraffin, sectioned (4-6 µm thickness), stained with hematoxylin and eosin and examined microscopically Carleton., [70].

2.3. Statistical Analysis

All measurements were done in triplicate and recorded as mean ±SD. Statistical analysis was performed with the Student *t*-test and MINITAB 12 computer program (Minitab Inc., State College, PA).

3. Results and Discussion

3.1. Proximate Chemical Composition of the Selected Plant Parts from Agricultural Remnants

Table 1. Proximate chemical composition (g/100) of selected plant parts from agricultural remnants

Factor	Cauliflower leaves powder (CLP)	Strawberry leaves Powder (SLP)	Mixture (Mix)
Moisture	7.84 ± 0.25 [a]	8.09 ± 0.33 [a]	7.95 ± 0.56 [a]
Total protein	11.86 ± 0.32 [a]	4.87 ± 0.14 [c]	8.77 ± 0.22 [b]
Crude fat	2.73 ± 0.14 [a]	1.23 ± 0.09 [b]	2.04 ± 0.09 [a]
Crude fiber	11.56 ± 0.76 [a]	6.74 ± 0.42 [c]	9.53 ± 0.44 [b]
Ash	2.97 ± 0.12 [a]	3.84 ± 0.21 [a]	3.29 ± 0.26 [a]
Carbohydrates (by difference)	63.04 ± 2.15 [c]	75.23 ± 3.13 [a]	68.42 ± 1.94 [b]

Values represent the mean ±SD (n=3). Means in the same raw with the different superscript letters were significantly ($p \leq 0.05$). Mix, mixture of CLP and SLP by equal parts.

Proximate chemical composition of the selected plant parts from agricultural remnants and their mixture were shown in Table 1. Such data indicated that the moisture content was ranged 7.84 ± 0.25 to 8.09 ± 0.33%, total protein ranged 4.87 ± 0.14 to 11.86 ± 0.32%, crude fat ranged 1.23 ± 0.09 to 2.73 ± 0.14, crude fiber ranged 6.74 ± 0.42 to 11.56 ± 0.76%, ash content ranged 2.97 ± 0.12 to 3.84 ± 0.21%, and carbohydrates content ranged 63.04 ± 2.15 to 75.23 ± 3.13%. The CLP was recorded the highest content of protein, crude fat and crude fiber while the highest values of ash and carbohydrates were recorded for SLP. Such data are partially match with that investigated by Elhassaneen et al., [28] and Sayed Ahmed., [27] who found that the proximate composition of food by-products including CLP were ass follow: the moisture content was ranged 3.62- 6.12%, total protein was 3.07-12.57%, crude fat was 0.99-9.95%, crude fiber was 10.38-24.89%, ash content was 2.92-6.89% and total carbohydrate content was 49.74 – 74.64%. Also, Badwy, [23] and Elhassaneen et al., [24] showed that the proximate chemical composition, of strawberry leaves powder (SLP) were recorded 4.49, 1.02, 5.61, 3.6, 85.2% for the protein, fat, fiber, ash and carbohydrates as (D/W) respectively. Furthermore, Zhang and Zhou [71] reported that the leaves contained the high crude fiber, carbohydrate and ash with low fat and essential oil. Finally, Nourelhouda *et al.*, [72] showed that strawberry leaves contained protein, fat, ash, moisture, fiber and carbohydrate at 13.45%,

5.38%, 9.22%, 3.80%, 12.35% and 55.80%, respectively and ascorbic acid at 113.15 mg/100g. From the data of the present study and the others it could be noticed that the proximate chemical composition of plant parts from agricultural remnants were varied according to the type of plant part, verity, agricultural management, climate, region etc., [3,27,73,74].

3.2. Nutritional Evaluation of the Selected Plant Parts from Agricultural Remnants

The nutritional evaluation of the selected plant parts from agricultural remnants powder and their mixture are shown in Table 2. From such date it could be noticed that the total energy was ranged 324 ± 3.89 to 331 ± 4.01Kcal/100g, G.D.R. (g) for protein (63 g) was 531.20 ± 5.22 to 1293.63 ± 9.34g, G.D.R. (g) for energy (2900 Kcal) was 874.89 ± 5.38 to 894.59 ± 6.11%, P.S./ 100 g for protein (63g) was 7.73 ± 0.95 to 18.83 ± 1.77 and P.S./100 g for energy (2900 Kcal) was 11.18 ± 0.71 to 11.28 ± 0.66%. The nutritional evaluation reported was partially accordance with that observed by several authors [23,27,28]. Although selected plant parts from agricultural remnants represents low-calorie foods i.e. consumption of 100 g powder cover only 11.18 to 11.48% of the daily requirement of the adult person for energy (2900 Kcal). This is due to their fat content, the high calories component, is generally low. Such data confirm the possibility of successfully using of the selected plant parts from agricultural remnants in nutritional applications for obese and overweight patients.

Table 2. Nutritional evaluation of selected plant parts from agricultural remnants

Factor	Cauliflower leaves powder (CLP)	Strawberry leaves Powder (SLP)	Mixture (Mix)
Energy (Kcal/100g)	324 ± 3.89 [a]	331 ± 4.01 [a]	327 ± 2.98 [a]
G.D.R. (g) for protein (63 g)	531.20 ± 5.22 [c]	1293.63 ± 9.34 [a]	718.36 ± 7.81 [b]
G.D.R. (g) for energy (2900 Kcal)	894.59 ± 6.11 [a]	874.89 ± 5.38 [a]	886.52 ± 8.02 [a]
P.S./100 g (%) for protein (63g)	18.83 ± 1.77 [a]	7.73 ± 0.95 [c]	13.92 ± 0.82 [b]
P.S./100 g (%) For energy (2900 Kcal)	11.18 ± 0.71 [a]	11.43 ± 0.29 [a]	11.28 ± 0.66 [a]

Values represent the mean ±SD (n=3). Means in the same raw with the different superscript letters were significantly ($p \leq 0.05$). Mix, mixture of CLP and SLP by equal parts.

3.3. Some Bioactive Compounds Content of Selected Plant Parts from Agricultural Remnants

Some bioactive compounds content of selected plant parts from agricultural remnants were shown in Table 3. From such data it could be noticed that the total phenolics was ranged 189.15 ± 17.69 to 233.94 ± 13.32mg EGA.100 g-1, total carotenoids content was ranged 39.56 ± 5.15 to 47.21 ± 6.14.100 g-1; total flavonoids was ranged 42.83 ± 6.14 to 52.06 ± 3.21 mg RE.100 g-1), lutein was ranged 53.17 ± 8.15 to 56.4 ± 9.17 mg.100 g-1, total anthocyanins was ranged 19.21 ± 3.45 to 23.96 ±3.09 mg.100 g-1, total chlorophylls was ranged 306.32 ± 22.17 to 349.73 ± 19.65 mg.100 g-1, and dietary fiber was ranged 23.44 ± 0.98 to 28.06 ± 2.19 g/100g. The CLP was recorded the highest content of all assayed bioactive compounds compared to the rest of the selected plant parts. In similar study, Elhassaneen et al., [28] found that the total dietary fiber, carotenoids and phenolic contents of food by-products including CLP were ranged 27.15- 42.71 $g.100g^{-1}$, 92.43-412.14 $mg.100g^{-1}$ and 1104-7129 mg EGA.100 g^{-1}, respectively. Badwy, [23] and Elhassaneen, et al., [24] noticed that the total phenolic, and chlorophyll A contents of SLP were 125.6 (mg GAE/100g), and 44.8 (mgl^{-1}), respectively. Furthermore, several authors reported that the total amounts and percentages of different groups of strawberry leaves of phenolic compounds are Twenty-one different compound, ellagitannins constituted the largest group of the compounds in the leaves representing 47.0−54.3% of the total phenolic compounds and flavonoids were found to be the second largest group of polyphenols and their percentage of the total phenolic compounds in different SLP was 36.4−41.4% [75,76]. In general, phenolics, carotenoids and anthocyanins are playing several important biological roles including antioxidant and scavenging activities and inhibiting the low density lipoprotein oxidation [4,24,48,77,78,79,80]. Also, phenolic compounds and carotenoids shows several of pharmacological and nutritional effects such as growth-inhibition of tumor and microbial cells, immunostimulatory properties, improving the growth performance, reduction of cancer risk, and protection against diabetes, ageing and cardiovascular diseases [23,26,27,77,80,81,82]. Polysaccharides play significant roles in different therapeutic and medical applications through using as they exhibited different biological activities such anti-mutagenicity, anticoagulant, anti-inflammatory, anti-obesity, anti-osteoporosis, antioxidant and antimicrobial activities [24,41,80,84,85,86,87]. Also, polysaccharides absorb cholesterol which are then eliminated from the digestive system i.e. hypocholesterolemic and hypolipidemic agents [88,89]. Chlorophyll provides nutritional benefits to the body and helps keep the healthy right including right bones, strong muscles, maintaining normal blood pressure and needs for the blood to clot properly through its different biological roles i.e. antioxidant, ant scavenging and antimicrobial activities [26,90,91,92]. Lutein is an oxygenated carotenoid found naturally in high quantities in green leafy vegetables such as spinach, kale and yellow carrots [26,92,93]. Several studies have shown that higher dietary intake of lutein is associated with a reduced risk of age-related cataract [94,95]. Also, low risk of coronary heart disease, stroke, and metabolic syndrome were also recorded. Such physiological roles of lutein due to its acts as an antioxidant, protecting cells against the damaging effects of free radicals such as inhibit peroxidation of membrane phospholipids and reduce lipofuscin formation [62,92,93,96]. Data of the current study indicated that such selected plant parts from agricultural remnants could be played a good position in food sciences and nutritional applications through their

high content of bioactive compounds.

3.4. Antioxidant Activities (AA) of Selected Plant Parts from Agricultural Remnants

The AA of the selected food processing by-products are illustrated in Table 4.Such data indicated that the selected plant parts from agricultural remnants showed slightly differences in antioxidant activity ranged 75.29± 4.11 to 81.43±4.15%. All of the selected agricultural remnants plant parts showed strong activity because of their high bioactive compounds content. The current data are partially in accordance with that observed by several authors who reported that plant parts including food processing by-products and agricultural remnants are high in their antioxidant activity due to their high bioactive compounds content [24,27,28,42,81]. For example, Also, Badwy., [23] noticed that the total phenolic, total antioxidants and chlorophyll A contents of SLP were 125.6 (mg GAE/100g), 83.86(mg CE/100g), and 44.8 (mgl^{-1}), respectively. Also, several authors mentioned that SLP possess high antioxidant capacity and inhibit free radicals due to the presence of polyphenol compounds such as anthocyanin, flavonols, ellagitannins and fistein [97,98,99,100]. Furthermore, Jaganath *et a*l., [101] reported that SLP extracts contain a number of biologically active compounds such as assayed in the present study which either protect the organism against the toxic effect of various physicochemical agents or enhance treatment of many diseases.

3.5. *β*-Carotene Bleaching Activity of the Selected Plant Parts from Agricultural Remnants

β -carotene bleaching assay are depending on determination the ability of an antioxidant to inhibit lipid peroxidation. The decrease in absorbance of β-carotene in the presence of different tested plant parts extract (BHT and α–tocopherol were used as a reference) with the oxidation of β-carotene and linoleic acid is illustrated in Table 5 and Figure 1. Such data indicated that mixture of the selected plant parts powder (Mix) exhibited the lowest decreasing followed by CLP and SLP. The values of Mix, CLP and SLP absorbance's through 120 min are coming well i.e. very closing the line of 50 mg /L of butyhydroxy toluene (BHT) and relatively closing to the lines of 50 mg α-tocopherol and 100 mg /L of butyhydroxy toluene (BHT). Such data confirmed that the high stability of the all selected plant parts from agricultural remnants when comparing with that most common standards, α-tocopherol and BHT. The obtained data are match well with that noticed by several authors who tested the AA stability of many plant parts including food processing by-products and agricultural remnants commonly distributed in Egypt [23,24,27,73,81,102,103]. The Mix sample gave maximum antioxidant activity when compared with the rest tested plant parts separated. It could be mean that a combination of the selected plant parts from agricultural remnants may be more efficient for antioxidant activity level due to the synergistic effects occurred by the different categories of bioactive compounds found in all plant parts.

Table 3. Some bioactive compounds content of selected plant parts from agricultural remnants

Factor	Cauliflower leaves powder (CLP)	Strawberry leaves Powder (SLP)	Mixture (Mix)
Total phenolics (mg gallic acid.100 g^{-1})	233.94 ± 13.32	189.15 ± 17.69	204.34 ± 9.61
Total carotenoids (mg catechin.100 g^{-1})	47.21 ± 6.14^{a}	39.56 ± 5.15^{b}	42.99 ± 3.05^{ab}
Total flavonoids (mg RE.100 g^{-1})	52.06 ± 3.21^{a}	42.83 ± 6.14^{b}	49.14 ± 5.10^{a}
Lutein (mg.100 g^{-1})	56.4 ± 9.17^{a}	53.17 ± 8.15^{a}	53.04 ± 4.12^{a}
Total anthocyanins (mg.100 g^{-1})	23.96 ± 3.09^{a}	19.21 ± 3.45^{b}	22.14 ± 1.98^{ab}
Total chlorophylls (mg.100 g^{-1})	349.73 ± 19.65^{a}	306.32 ± 22.17^{c}	319.56 ± 18.23^{b}
Dietary fiber (g.100g^{-1})	28.06 ± 2.19^{a}	23.44 ± 0.98^{b}	24.98 ± 1.33^{ab}

Values represent the mean±SD (n=3). Means in the same raw with the different superscript letters were significantly (p≤0.05). Mix, mixture of CLP and SLP by equal parts.

Table 4. Antioxidant activity of the selected plant parts from agricultural remnants

Samples	Antioxidant value[a] AOX (A/h)		Antioxidant activity[b] AA (%)		Oxidation rate ratio[c] (ORR)		Antioxidant activity coefficient[d] (AAC)	
Strawberry leaves powder (SLP)	0.140±	0.013	75.29±	4.11^{C}	0.246±	0.025	481.20±	40.09
Cauliflower leaves powder (CLP)	0.105±	0.011	81.43±	4.15^{B}	0.185±	0.021	587.94±	25.87
Control	0.565±	0.011	0.00±	0.00	0.998±	0.025	0.00±	0.00
BHT, 50 mg/L	0.068±	0.01	88.04±	1.09^{B}	0.119±	0.013	702.85±	9.90
BHT, 100 mg/L	0.022±	0.004	96.03±	1.32^{A}	0.039±	0.007	841.75±	10.65
a-tocopherol, 50 mg/L	0.015±	0.004	97.27	2.10^{A}	0.027±	0.005	863.31±	8.54

[a]Antioxidant value (AOX, A/h) = The absolute value of slope (Abs was plotted against time). [b]Antioxidant activity (AA, %) = (R control - R sample) / R control x 100 where: R control and R sample were the bleaching rates of beta-carotene in reactant mixture without antioxidant and with plant extract, respectively. [c]Oxidation rate ratio (ORR) = R sample / R control. [d] Antioxidant activity coefficient (AAC) = (Abs S 120 - Abs C 120) / Abs C 0 - Abs C 120) x 1000 where:.Abs S 120 was the absorbance of the antioxidant mixture at time 120 min, Abs C 120 was the absorbance of the control at time 120 min, Abs C0 was the absorbance of the control at zero time. [e] Each value represents mean ±SD. Means in the same raw with the different capital superscript letters were significantly (p≤0.05).

Table 5. Antioxidant activity of the selected plant parts from agricultural remnants assayed by the β-carotene bleaching method

Samples	Time (min)												
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Strawberry leaves powder (SLP)	0.899	0.898	0.881	0.857	0.855	0.838	0.772	0.760	0.738	0.737	0.730	0.725	0.721 [c]
Cauliflower leaves powder (CLP)	0.899	0.898	0.882	0.861	0.860	0.852	0.795	0.793	0.770	0.755	0.745	0.741	0.740 [bc]
Mixture (Mix)	0.899	0.898	0.882	0.880	0.875	0.865	0.835	0.801	0.793	0.778	0.760	0.753	0.748 [bc]
Control	0.899	0.581	0.552	0.504	0.458	0.427	0.400	0.361	0.310	0.244	0.211	0.172	0.150
BHT, 50 mg/L	0.899	0.898	0.896	0.885	0.879	0.865	0.836	0.821	0.795	0.788	0.774	0.771	0.769 [b]
BHT, 100 mg/L	0.899	0.899	0.899	0.890	0.886	0.884	0.881	0.880	0.874	0.869	0.865	0.861	0.860[a]
α -tocopherol, 50 mg/L	0.899	0.899	0.899	0.893	0.892	0.891	0.889	0.889	0.888	0.880	0.877	0.875	0.873[a]

BHT, butylated hydroxyltoluene; α-Toc, alpha-tocopherol; Mix, mixture of CLP and SLP by equal parts.

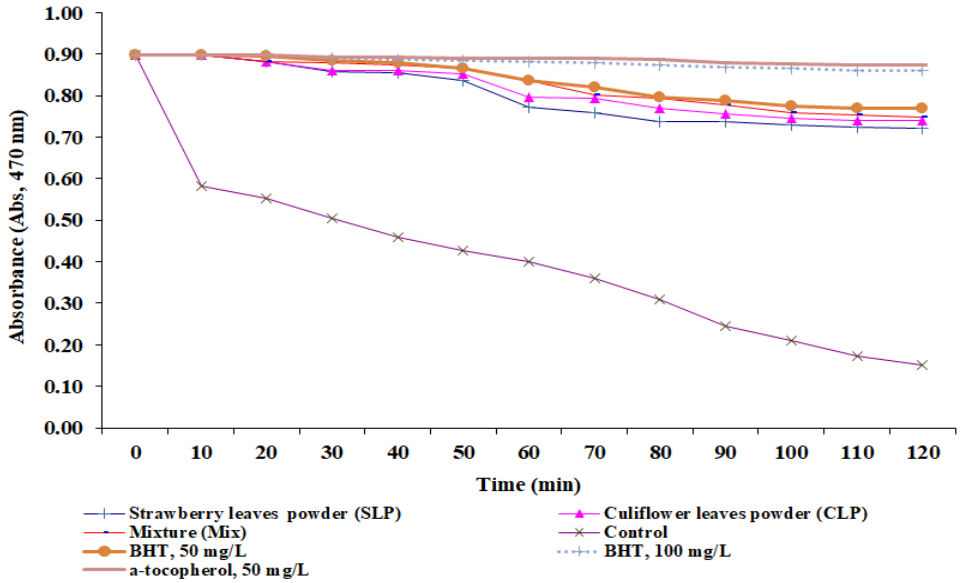


Figure 1. Antioxidant activity (AA, Abs at 470 nm) of the selected plant parts from agricultural remnants assayed by the β-carotene bleaching method (BHT and α–tocopherol were used as a reference). BHT, butylated hydroxyltoluene; a-Toc, alpha-tocopherol; CLP, cauliflower leaves powder; SLP, strawberry leaves powder and Mix, mixture of CLP and SLP by equal parts

3.6. Relationship Between Total Determined Bioactive Compounds and Antioxidant Activity (AA) of the Selected Plant Parts from Agricultural Remnants Assayed by the β-Carotene Bleaching Method

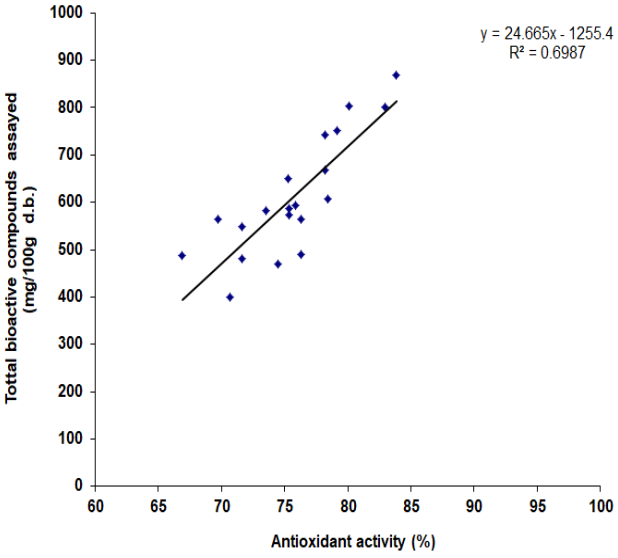
The relationship between total determined bioactive compounds and the AA of the selected plant parts from agricultural remnants were shown in Table 6 and Figure 2. From such data it could be noticed that when all the selected plant parts from agricultural remnants and their mixture were taken in the statistical analysis, there were positive and highly significant ($p \leq 0.05$) relationships between total bioactive compounds assayed and AA. The relationships were recorded $r^2 = 0.6987$, $r^2 = 0.7528$ and $r^2 = 0.8093$ at $p \leq 0.05$ for SLP, CLP and their mixture, respectively. These data indicates that the assayed bioactive compounds could play a major role in the AA of tested food processing by- products. The current data are partially in accordance with that observed by several authors in different plant parts including food processing by-products and agricultural remnants in Egypt [23,24,27,28] [42,48] [73,77,80,81] [102,103,104] [105,106,107,108] Also, Velioglu *et al.*, [108] reported that a highly significant correlation between total phenolics content and antioxidant activity of 28 plant products, including agricultural by-products. Data of the present study confirmed the significances of the selected plant parts from agricultural remnants as natural antioxidants in therapeutic nutrition. with this context, Majid *et al.*, [109] found that the intervention by phenolics (such as found in the tested plant parts) significantly increased the levels of biological antioxidant defense system [reduced glutathione (GSH) and the antioxidant enzymes] and inhibited the lipid peroxidation in liver and lungs of the experimental animals. Also, antioxidants help protect cells from the potentially damaging physiological process known as "oxidative stress" i.e. damage the healthy cells by free radicals. Such phenomena is thought to be associated with the development of several diseases including cancer, heart, bone, immunodeficiency, diabetes, obesity, aging, neurological and diseases [4,73,81,110,111,112,113,114]. Also, antioxidant phytochemicals found in the several plant parts such as including in the present study inhibited or delayed the oxidation of biological molecules i.e. lipids, proteins, nucleic acid, and carbohydrates by inhibiting the initiation or propagation of oxidizing chain reactions [113,115]. The Mix sample exhibited the maximum correlation when compared with the rest of the tested plant parts separated. It could be mean that a combination of the selected plant

parts from agricultural remnants may be more efficient for the correlation level due to the synergistic effects occurred by the different categories of bioactive compounds found in all plant parts.

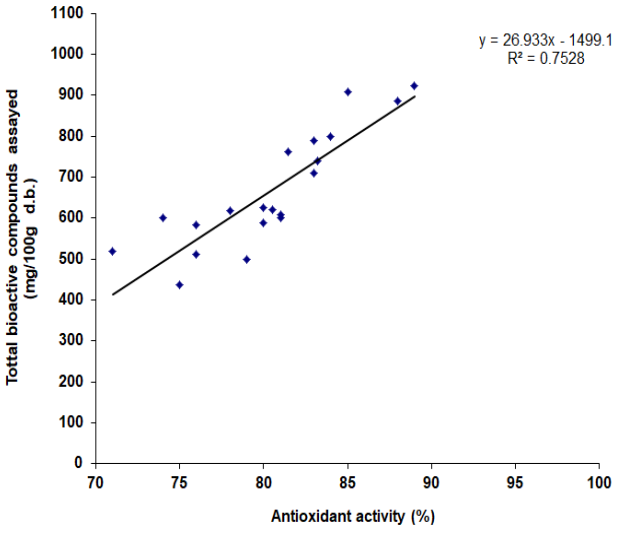
Table 6. Relationship between total assayed bioactive compounds and antioxidant activity (AA) of the selected plant parts from agricultural remnants assayed by the β-carotene bleaching method (n=20)

Relationship between antioxidant activities (AA) and total bioactive compounds assayed content		r^2
Strawberry leaves powder (SLP)	y = 24.665x - 1255.4	0.6987*
Cauliflower leaves powder (CLP)	y = 26.933x - 1499.1	0.7528**
Mixture (Mix)*	y = 26.979x - 1466.5	0.8093*

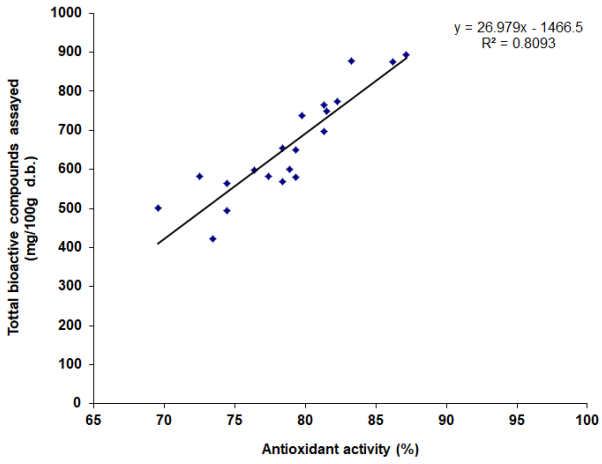
* Mix, mixture of CLP and SLP by equal parts; y, total bioactive compounds assayed content; x, antioxidant activity; * P ≤ 0.05; ** P ≤ 0.05



SLP



CLP



Mix

Figure 2. Relationship between total assayed bioactive compounds versus antioxidant activity (AA) of the selected plant parts from agricultural remnants assayed by the β-carotene bleaching method (n=20)

3.7. Biological Experiments

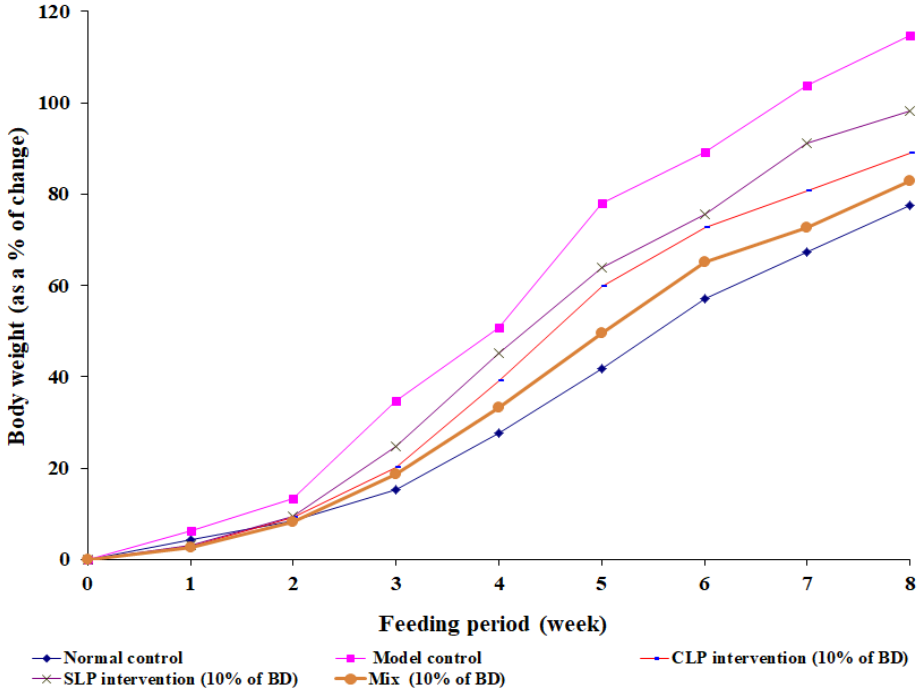
3.7.1. Effect of Dietary Intervention with Selected Plant Parts from Agricultural Remnants on Body Weight of Obese Rats

Effect of dietary intervention with selected plant parts from agricultural remnants on body weight of obese rats was shown in Table 7 and Figure 3. Such data indicated that at the end of the experiment (8 weeks), rats of the normal group recorded increasing on body weight rate by 77.57% from the starting point of the experiment while obese group was 1114.60%. Dietary intervention with CLP, SLP and their mixture (Mix) on the diet by 10% induced significant decreasing on body weight of the obese rats by the rate of 88.92, 98.19 and 82,78% from the starting point, respectively. Thus, the highest effect on body weight decreasing was recorded for the Mix followed by CLP and SLP, respectively. Such data are in accordance with that observed by Sayed Ahmed [27] and Elhassaneen et al., [24] as the result of feeding intervention with CLP and SLP, respectively. Also, several authors reported a significant control/treatment of obesity by feeding intervention with the different part parts [4,24,26,27] [37,41,42] [74,81,83] [87,116]. All of these studies with the present date confirmed that the positive effects of all such plant parts regarding the prevention and/or treatment of the obesity could be attributed to their high level content of different classes of bioactive constituents including phenolics, carotenoids, flavonoids, anthocyanins, alkaloids, terpenoids, phytosterols, essential oils and organosulfur compounds etc. Such bioactive constituents could manage/control the obesity by impress gene expression and adipocyte function through several mechanisms as follow: 1) work alongside with several transcription factors of the nuclear receptor superfamily, 2) interfere with the activity of other transcription factors, 3) modify the signaling pathways which are associated with the oxidative stress responses; and 4) epigenetic effects including scavenging of the reactive species, inhibition of the lipid moieties oxidation etc., [24,26,27,42,83,116].

Table 7. Effect of dietary intervention with selected plant parts from agricultural remnants on body weight (g) of obese rats

Groups	Feeding period (weeks)								
	0	1	2	3	4	5	6	7	8
Normal control	157.64	164.45	170.82	181.84	201.15	223.68	247.65	263.86	279.92 ^{d}
Model control	157.64	167.52	178.62	212.22	237.84	280.55	298.19	321.36	338.30 ^{a}
CLP intervention (10% of BD)	157.64	162.03	172.08	189.19	219.28	251.98	272.08	284.64	297.82 ^{c}
SLP intervention (10% of BD)	157.64	162.43	172.58	196.67	228.73	258.27	276.68	301.32	312.43 ^{b}
Mix intervention (10% of BD)	157.64	161.92	170.71	187.03	209.95	235.57	260.46	272.31	288.13 ^{cd}

Each value represents the mean of six rats. Means with different superscript letters in the same row are significantly different ($p \leq 0.05$). Normal control, healthy rats without intervention; Model control, diet induced obesity (DIO) rats without intervention; BD, basal diet; CLP, cauliflower leaves powder; SLP, Strawberry leaves powder; Mix, mixture powder of CLP and SLP by equal parts



Each value represents the mean of six rats. Normal control, healthy rats without intervention; Model control, diet induced obesity (DIO) rats without intervention; BD, basal diet; CLP, cauliflower leaves powder; SLP, Strawberry leaves powder; Mix, mixture powder of CLP and SLP by equal parts

Figure 3. Effect of dietary intervention with selected plant parts from agricultural remnants on body weight (as a percent of control) of obese rats

3.7.2. Effect of Dietary Intervention with Selected Plant Parts from Agricultural Remnants on Blood Lipids Profile Concentration of Obese Rats

Effect of dietary intervention with selected plant parts from agricultural remnants on blood lipids profile concentration of obese rats was shown in Table 8. From such data it could be noticed that obesity induced a significant increased ($p \leq 0.05$) in TG (68.20%), TC (50.75%) and LDL (132.43%) while significant decreased ($p \leq 0.05$) in HDL (-38.26%) compared to normal control group. Dietary intervention with CLP, SLP and their mixture (Mix) on the diet by 10% induced significant decreasing on serum lipid profile, TG, TC and LDL by the ratio of -24.40, -19.64 and -28.87%; -13.79, -11.44 and -19.02%; and -22.26, -17.89 and -31.15% from the model control, respectively. The opposite direction was observed for the HDL levels. The highest effects in manipulating of the blood lipid profile disorders induced by obesity in rats were noticed for the Mix treatment followed by CLP and SLP, respectively. Such data are in partially according with that recorded by several authors where control/treatment of obesity by feeding intervention with different plant parts [4,24,26,27] [39,40,74] [81,87,116]. Generally, weight loss in patients with obesity is associated with the decreasing in TG, TC and LDL concurrently with increasing the levels of HDL [37,118,119]. Also, Bedawy, [120] found that blood elevated concentrations of TC and LDL are powerful risk factors for cardiovascular disease. With this context, the composition of the diet plays an important role in the management of blood lipid profile parameters. The possible hypocholesrerolemic effects of several dietary phytochemicals such as found in the selected plant parts (CLP and SLP) including, phenolics, alkaloids, carotenoids, anthocyanins, volatile constituents and organosulfur compounds have considered much interest. Such compounds exert their beneficial effects on cardiovascular health through the different biological activities including antioxidant, scavenging and anti-inflammatory activities as well as inhibition of the lipid peroxidation [26,27,80,83,84,114,121]

Table 8. Effect of dietary intervention with selected plant parts from agricultural remnants on blood lipids profile concentration of obese rats

Value	Normal control	Model control	Agricultural remnants (10%, w/w)		
			CLP	SLP	Mix
(TG, mg/dL)					
Mean	44.40 ^{d}	74.68 ^{a}	56.46 ^{bc}	60.01 ^{b}	53.12 ^{c}
SD	3.05	5.13	3.88	4.12	3.65
% of Change	0.00	68.20	-24.40	-19.64	-28.87
Total cholesterol (TC, mg/dL)					
Mean	99.04 ^{d}	149.30 ^{a}	128.71 ^{bc}	132.2 ^{b}	120.90 ^{c}
SD	6.88	10.38	8.95	9.19	8.40
% of Change	0.00	50.75	-13.79	-11.44	-19.02
Low density lipoprotein (LDL, mg/dL)					
Mean	44.07 ^{c}	102.43 ^{a}	79.63 ^{b}	84.11 ^{b}	70.52 ^{bc}
SD	3.48	8.09	6.29	6.64	5.57
% of Change	0.00	132.43	-22.26	-17.89	-31.15
High density lipoprotein (HDL, mg/dL)					
Mean	44.04 ^{a}	27.19 ^{b}	36.27 ^{ab}	37.00 ^{a}	39.93 ^{a}
SD	4.20	2.59	3.46	3.53	3.81
% of Change	0.00	-38.26	33.41	36.08	46.86

Means with different superscript letters in the same row are significantly different ($p \leq 0.05$). Normal control, healthy rats without intervention; Model control, diet induced obesity (DIO) rats without intervention; BD, basal diet; CLP, cauliflower leaves powder; SLP, Strawberry leaves powder; Mix, mixture powder of CLP and SLP by equal parts

3.7.3. Effect of Dietary Intervention with Selected Plant Parts from Agricultural Remnants on Plasma Reduced Glutathione (GSH, µMol /L) Level of Obese Rats

Effect of dietary intervention with selected plant parts from agricultural remnants on plasma reduced glutathione (GSH) level of obese rats was shown in Table 9. From such data it could be noticed that obesity induced a significant decreased ($p \leq 0.05$) in serum GSH (-31.79%) compared to normal control group. Dietary intervention with CLP, SLP and their mixture (Mix) on the diet by 10% induced significant ($p \leq 0.05$) increasing on serum GSH concentration by the ratio of 19.57, 17.68 and 32.30% from the model control group, respectively. Thus, the highest effect in manipulation of the GSH decline induced by obesity in rats was noticed for the Mix followed by CLP and SLP, respectively. Such data are in partially match with that reported by several authors where control/treatment of obesity by feeding intervention with the various plant parts [4,26,39,74,81,87,116]. Generally, GSH is a tripeptide-thiol that has attended more attention related to its biosynthesis, regulation, and various intracellular functions [122]. Related to its roles in detoxifications, it is known as a key conjugate of reactive metabolites in phase II metabolism and is considered as an important biological antioxidant. The antioxidant functions of GSH includes its role in the activities of GSH enzymes family including glutathione peroxidase (GSH-Px) and glutathione reductase (GSH-Rd). Also, it can apparently serve as a nonenzymatic scavenger of free/oxy radicals [28,122,123]. With the same context, several studies found that different enzymes in various cells including adipocytes can also produce reactive oxygen species (ROS) and reactive nitrogen species (RNS). The selected plant parts used in the present study are rich in bioactive compounds which exhibited antioxidant activities against ROS/RNS formation as the obesity development through several mechanism of action including the raising of redox status including GSH in the body. Similar watching's were reported in several studies which was covered the oxidative stress and antioxidant defense systems status in obese rats feeding some plant parts such tomato, eggplant, pomegranate, onion and potato peels, and Ashwagandha roots [26,41].

Table 9. Effect of dietary intervention with selected plant parts from agricultural remnants on plasma reduced glutathione (GSH, µmol /L) level of obese rats*

Value	Normal control	Model control	Agricultural remnants (10%, w/w)		
			CLP	SLP	Mix
Mean	10.98 ^{a}	7.49 ^{b}	8.96 ^{ab}	8.82 ^{ab}	9.91 ^{a}
SD	0.75	0.51	0.61	0.60	0.67
% of Change	0.00	-31.79	19.57	17.68	32.30

Means with different superscript letters in the same row are significantly different ($p \leq 0.05$). Normal control, healthy rats without intervention; Model control, diet induced obesity (DIO) rats without intervention; BD, basal diet; CLP, cauliflower leaves powder; SLP, Strawberry leaves powder; Mix, mixture powder of CLP and SLP by equal parts

3.7.4. Effect of Dietary Intervention with Selected Plant Parts from Agricultural Remnants on Oxidative Stress/Lipid Oxidation (Thiobarbituric Acid Reactive Substances, TBARS, Nmol/Ml) Level of Obese Rats

Effect of dietary intervention with selected plant parts from agricultural remnants on oxidative stress/lipid oxidation (thiobarbituric acid reactive substances, TBARS) level of obese rats was shown in Table 10. Such data indicated that obesity induced a significant ($p \leq 0.05$) increased in serum TBARs (54.57%) compared to normal control group. Dietary intervention with CL, SLP and their mixture (Mix) on the diet by 10% induced significant ($p \leq 0.05$) decreasing on blood TBARs concentration by the ratio of -27.98, -25.77 and -30.70%, from the model control group, respectively. Thus, the highest effect in manipulation of the TBARs elevation induced by obesity in rats was observed for the Mix followed by CLP and SLP, respectively. Such data are in partially match with that reported by several studies where control/treatment of obesity by feeding intervention with the various part parts [4,24,26,39] [40,42,81], [87,116]. Many clinical studies have proven the association of oxidative stress with obesity by measuring some biomarkers that estimate some of the end products of fat oxidation processes that are mediated by free radicals [27,37,84]. For example, final lipid peroxidation markers such as TBARS, the major products of the oxidation of polyunsaturated fatty acids,

lipid hydroperoxides and conjugated dienes are found to be elevated in plasma of obese patients [37,123]. Systemic metabolic alterations such as hyperglycemia as a principal mark of type II diabetes, a metabolic complication of obesity, induce oxidative stress [116]. Also, increase of circulating lipids leads to ROS formation pathways, which contribute to elevate the lipid oxidation and protein carbonylation. Interest in the significance of TBARs including malonaldehyde (MDA) on human health has been reports that some of them are mutagens and carcinogens. The positive effects of the selected plant parts in the present study on oxidants formation/level of obese rats could be attributed to several mechanisms initiated by their various phytochemicals content. For example, several authors found that phenolics and carotenoids such as found in our selected plant parts have antioxidant, scavenging and anti-inflammatory activities as well as inhibition of the lipid peroxidation [48,73,77,80,125]. They also reported that such bioactive compounds are metabolized in liver and lead to enhance the lipid metabolism and reduce the oxidative stress. Finally, the Mix treatment exhibit the highest reduction yield of plasma TBARs when compared with the tested plant parts individually because the synergistic effects occurred by various categories of bioactive compounds of different plant parts used.

Table 10. Effect of dietary intervention with selected plant parts from agricultural remnants on oxidative stress/lipid oxidation (thiobarbituric acid reactive substances, TBARS, nmol/mL) level of obese rats*

Value	Normal control	Model control	Agricultural remnants (10%, w/w)		
			CLP	SLP	Mix
Mean	2.81 ^{c}	4.34 ^{a}	3.13 ^{b}	3.22 ^{ab}	3.01 ^{b}
SD	0.15	0.23	0.17	0.17	0.16
% of Change	0.00	54.57	-27.98	-25.77	-30.70

Means with different superscript letters in the same row are significantly different ($p \leq 0.05$). Normal control, healthy rats without intervention; Model control, diet induced obesity (DIO) rats without intervention; BD, basal diet; CLP, cauliflower leaves powder; SLP, Strawberry leaves powder; Mix, mixture powder of CLP and SLP by equal parts

3.8. Histological Examination of Adipose Tissue

Effect of dietary intervention with selected plant parts from agricultural remnants on adipose tissue histopathological examination of obese rats was shown in Figure 4. Microscopically, adipose of rat from group 1 revealed normal unilocular adipocytes, polygonal in shape and having signet ring appearance (Photo 1). In contrast, adipose tissue of rats from group 2 showed histopathological alterations characterized large size unilocular adipocytes and inflammatory cells infiltration (Photo 2). Meanwhile, some sections from group 3 exhibited normal size unilocular adipocytes (Photo 3). Otherwise, some sections from group 4 revealed few large size unilocular adipocytes and some small size adipocytes (Photo 4). Furthermore, most examined sections from groups 5 exhibited apparent histologically normal unilocular adipocytes (Photos' 5). Such observation are in accordance partially with that Elhassaneen et al., [26] who Found that adipose tissue of rats feeding high fat diet (HFD) showed histopathological alterations characterized by large size unilocular adipocytes and inflammatory cells infiltration. Meanwhile, intervention with *Silybum marianum* extract (SME) on adipose tissue leads exhibit apparent histologically normal unilocular adipocytes. Also, Alsaggar et al., [126] showed that fat accumulation in major fat white adipose tissues, WAT, (tissues (epididymal WAT and inguinal WAT), and the expansion of adipocytes were both suppressed by silibinin, main bioactive compound in SME, treatment. Suppressed fat accumulation and adipose tissue hypertrophy was investigated of white and brown adipose tissues (WAT and BAT). Data of the present study with the other indicated that selected plant parts from agricultural remnants contains several bioactive compounds including phenolics, carotenoids, flavonoids, lutein and chlorophyll. Such compounds have the capacity to diminish oxidative stress and subsequent cytotoxicity, thus protecting intact adipocytes tissue or cells that have not yet sustained irreversible damage [127]. Also, several authors proved that CLP and SLP bioactive compounds acts as a scavenger of free radicals and inhibition the lipid peroxidation linked to the progression of cellular injury through elevation of intracellular GSH content, regulation of membrane permeability and enhancement of membrane stability in the face of xenobiotic damage (Elhassaneen et al., [26,127].

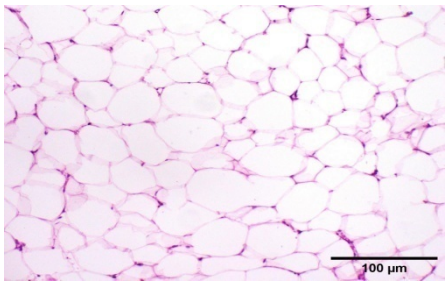


Photo 1. Normal control

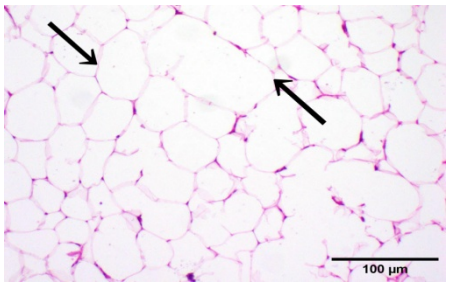


Photo 2. Model control

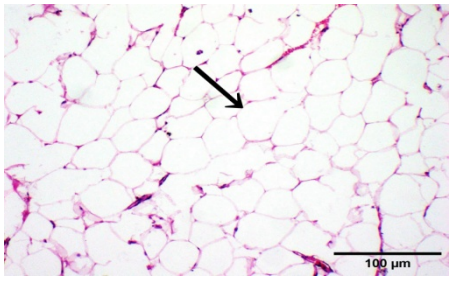


Photo 3. CLP intervention (10% of BD)

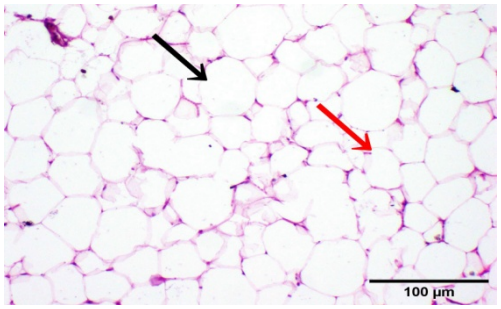


Photo 4. CLP intervention (10% of BD)

Photo 1. Photomicrograph of adipose tissue of rat from group 1 showing normal unilocular adipocytes, polygonal in shape and having signet ring appearance. **Photo 2.** Photomicrograph of adipose tissue of rat from group 2 showing large size unilocular adipocytes (black arrow). **Photo 3.** Photomicrograph of adipose tissue of rat from group 3 showing normal size unilocular adipocytes (black arrow). **Photo 4.** Photomicrograph of adipose tissue of rat from group 4 showing few large size unilocular adipocytes (black arrow) and some small size adipocytes (red arrow). **Photo 5.** Photomicrograph of adipose tissue of rat from group 6 showing apparent histologically normal unilocular adipocytes (H & E, scale bar 100 µm, X 100). Normal control, healthy rats without intervention; Model control, diet induced obesity (DIO) rats without intervention; BD, basal diet; CLP, cauliflower leaves powder; SLP, Strawberry leaves powder; Mix, mixture powder of CLP and SLP by equal parts.

Figure 4. Effect of dietary intervention with selected plant parts from agricultural remnants on adipose tissue histopathological examination of obese rats

4. Conclusion

The study's findings validated our hypothesis that CLP, SLP and their mixture include a variety of bioactive components such as phenolics, carotenoids, anthocyanin's, lutein, flavonoids, total chlorophylls and dietary fiber. These phytochemicals have antioxidant activities which leading role(s) in such plant parts therapeutic effects. Such therapeutic effects include those related to the prevention or treatment of obesity and its related complications, which include decrease on body weight, enhance the serum lipid profile parameters, minimize the oxidative stress, and positively manipulate the obesity-related histopathological changes in adipose tissues of the obese rats. These findings support the benefits of dietary modification, CLP and SLP supplementation, in alleviating the complication associated obesity including oxidative stress.

Ethical Approval

All the experiments of the present study were ethically approved by the Scientific Research Ethics Committee, Faculty of Home Economics, Menoufia University, Shebin El-Kom, Egypt (Approval # 12-SREC-04-2023).

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Conflict of Interest

The authors declare that they have no conflict of interest in publishing this paper.

Authors' Contribution

Yousif Elhassaneen participated in preparing and developing the study protocol, following up on the practical experimental part, retrieving conceptual information, reviewing and verifying the results and statistical analyses, and preparing and reviewing the manuscript. Horia Ammar conducted the practical experiments, collected, tabulated and interpreted the results. It also contributes to retrieving the basic information and concepts as well as preparing the draft of the manuscript. Ghada ElBassouny participated in preparing the study protocol, following up on conducting the practical experiments, retrieving conceptual information, validating the study results, and preparing a draft of the manuscript. Omar Emam participated in retrieving information and concepts, contributing to the concept and design of the work, and participating in reviewing the draft of the manuscript.

Abbreviations

AA, antioxidant activity; BCB, β -Carotene Bleaching; BD, basal diet; BHT, butylated hydroxyltoluene; CA, catechine; CLP, cauliflower leaves powder; DMSO, dimethylsulfoxide; DNA, deoxyribonucleic acid; GA, gallic acid; GSH, reduced glutathione; Mix, mixture of cauliflower and strawberry leaves powder by equal parts; ROS, reactive oxygen species; SLP, strawberry leaves powder; TBARs, thiobarbituric acid reactive substances.

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