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Potential effects of phyto-bioactive and aversive compounds in some plant parts on obesity complications in rats

التأثيرات المحتملة للمركبات الحيوية النباتية والمنفرة لبعض الأجزاء النباتية على مضاعفات السمنة فى الفئران

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Abstract:

The present study aims to explore the effect of three by-products that result from food processing processes, namely onion and bananas peels, and apricot seeds, on obesity disease and its complications in rats. Feeding of rats on diet induced obesity (DIO) leads to increase the BW than the control group. At the end of the experiment (8 weeks), rats of the normal group recorded 171.89% of baseline for the BW while obese group was 252.83% of baseline. Replacement of diets starch with apricot seeds powder (ASP),, red onion skin powder

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(ROSP), banana peel powder (BPP) and their mixture (ASP + ROSP + BPP by equal parts) induced significant decreasing on BW of the obese rats which recorded 223.10, 206.19, 227.99 and 193.52% of baseline, respectively. The higher effect on weigh decreasing was recorded for the plant parts mixtures followed by ROSP, BPP and ASP, respectively. On the other side data has demonstrated the potency of the tested plant parts including ASP, ROSP and BPP to ameliorate liver, blood lipids profiles disorders and hyperglycemia in obese rats. Additionally, tested plant parts improve the oxidant/antioxidant status in obese rats. These findings provide a basis for the use of selected plant parts and also have important implications for the prevention and early treatment of obesity. Also, the data support the benefits of dietary modification, including bioactive compounds supplementation, in alleviating oxidative stress associated obesity.

Keywords: apricot seeds powder, red onion skin powder, banana peel powder, serum lipid profile, serum glucose, glutathione fractions, oxidative stress.

الملخص بالعربي :

تهدف الدراسة الحالية إلى استكشاف تأثير ثلاثة منتجات ثانوية ناتجة عن عمليات التصنيع الغذائي وهي قشر البصل والموز وبذور المشمش على أمراض السمنة ومضاعفاتها في الفئران. أوضحت النتائج أن تغذية الفئران بالسمنة التي يسببها النظام الغذائي المحث للسمنة ((DIOإلى زيادة وزن الجسم مقارنة بمجموعة الضابطة السالبة. وفي نهاية التجربة (٨ أسابيع) ، سجلت الفئران من المجموعة الضابطة السالبة زيادة مقدارها ١٧١,٨٩٪ من خط مقارنة بخط الأساس، بينما سجلت المجموعة الضابطة الموجبة نسبة ٢٥٢,٨٣٪ من خط الأساس. أدى استبدال نشا الوجبات بمسحوق بذور المشمش ((ASP، ومسحوق قشر البصل

الأحمر (ROSP)، ومسحوق قشر الموز(BPP)ومخلوطهم (ASP + ROSP + BPP بأجزاء متساوية) إلى انخفاض كبير في وزن الجسم للفئران التي تعاني من السمنة المفرطة وذلك بنسبة ٢٢٣,١٠ ، ٢٠٦,١٩، ٢٢٧,٩٩ ، ١٩٣,٥٢٪ من خط الأساس على التوالي. تم تسجيل التأثير الأعلى على انخفاض الوزن للمجموعة التى تغذت على المخلوط من أجزاء النبات تليها ROSP، BPP، ASP على التوالي. على الجانب الآخر، أظهرت البيانات فاعلية أجزاء النبات المختبرة بما في ذلك ASP و ROSP و BPP فى تحسين وظائف الكبد واضطرابات صورة الدهون وارتفاع السكر في الدم في الفئران البدينة. بالإضافة إلى ذلك ، أظهرت أجزاء النبات المختبرة كبيرة على تحسين حالة الأكسدة / مضادات الأكسدة في الفئران البدينة. لذا.. تعد هذه النتائج أساسًا لاستخدام أجزاء نباتية مختارة ولها أيضًا آثار مهمة للوقاية والعلاج المبكر للسمنة. أيضًا ، تدعم البيانات فوائد تعديل النظام الغذائي ، بما في ذلك مكملات المركبات النشطة بيولوجيًا ، في التخفيف من الإجهاد التأكسدي المرتبط بالسمنة.

الكلمات المفتاحية: مسحوق بذور المشمش ، مسحوق قشرة البصل الأحمر ، مسحوق قشر الموز ، صورة دهون الدم ، جلوكوز الدم ، جزيئات الجلوتاثيون ، الإجهاد التأكسدي.

Introduction

Epidemiological studies have pointed out that consumption of plant parts imparts health benefits, e.g. reduced risk of coronary heart disease, stroke, diabetics, obesity and certain types of cancer (Elhassaneen *et al.*, 2016 a-d; and Elmaadawy *et al.*, 2016). Apart from dietary fiber, these health benefits are mainly attributed to many organic micronutrients including phytochemicals, vitamins and others. Therefore, the study of Heimendinger and Chapelsky (1996) reported that a minimum of five servings a day of vegetables and fruits, especially of green and yellow vegetables and citrus fruits, is recommended. Although consumers are increasingly aware of diet related

health problems, a large group of the population lacks a generous intake of fruits and vegetables. Thus, dietary supplements and food fortification may be an alternative route to the consumption of minor plant components that may have health benefits. Since synthetic additives are more and more rejected by consumers, functional ingredients should preferably originate from natural sources. This is particularly valid for terpenoids, phenolic compounds etc which, in contrast to most carotenoids and vitamins, are not chemically synthesized and need to be extracted from plant material. The preparation of food diets and supplements from by-products has already been summarized (Ali, 2008), and residual sources of natural antioxidants were the subject of many studies (Hegazy, 2009; and El-wazeir, 2011).

Food processing in the Arab world represent a large proportion of waste was estimated at 18.14 million tonnes per year and represent remnants of fruit and vegetables manufacture about 6.14% of this amount (http://elasaala.blogspot.com/2012/01/blog-post_2703. html). Waste in the food processing is characterized by a high ratio of product-specific waste/by-products. Food processing by-products/plant parts could be considered a good source of phytochemicals. They are a large group of plant-derived compounds such as phenolic compounds (phenolic acids and flavonoids), terpenes, volatile oils and nitrogen compounds (indoles), organo- sulphur contanning compounds and aversive compounds hypothesized to be responsible for much of the disease protection such as cancer, cardiovascular disease,

diabetes mellitus, cataracts, aging and rheumatoid arthritis provided by diets high in plant parts peels/by-products of fruits, vegetables, herbs, beans, cereals, plant-based beverages etc (Arts and Hollman, 2005; Elhassaneen *et al.,* 2016 a-d; and Emam *et al.*, 2018). We will limit our study here to three of the by-products that result from food processing operations, which are onion and banana peels, and apricot kernels for the following reasons: 1) these by-products are produced in large quantities, which cause great pollution to the manufacturing environment if they are not disposed of, 2) these by-products cause the most serious damage when dumped into the environment without treatment, and 3) the treatment of these wastes, which is represented in converting them into organic fertilizers, requires a great cost.

Apricot (*Primus armeniaca* L.; *Rosacea* family) is mostly grown in Mediterranean countries, Pakistan, Russia, USA and Iran. Bitter apricot seeds are by-products of the apricot processing industry. Apart from the use of apricot seed oil in cosmetics, peeled seeds serve as a raw material for the production of persipan (reviewed in Schieber *et al*., 2001). Apricot kernel oil is a rich source of MUFA and PUFA, including mainly oleic (about 70%) and linoleic acids, respectively. In addition, apricot kernel oil could be considered as a good source of bioactive compounds such as tocopherols and phytosterols consisting mainly of the α-isomer and β-sitosterol, respectively (Hassan, 2011 and Tahoon, 2019).

Onion (*Allium cepa* L.) belongs to family, *Alliaceae* and represent one of the most important crop aroud the world

including Egypt. The amount of onion waste produced annually in the European Union is estimated at approximately 450,000 tons. Onion skins are a source of flavour components and fiber compounds and particularly rich in quercetin glycosides, phenolics, carotenoids (Hertog, *et al*., 1992; Waldron, 200, Elhassaneen and Sanad, 2009, and Hassan, 2015). Banana (*Musa sapientum*) belongs to the family *Musaceae* which has already provided human with food, tools and shelter prior to recorded history (Ngwang, 2015) .Its play an important role in the economy and food security of many wet tropical regions in the world (Coulibaly *et al*., 2007). Peels represent about 30 – 40 g / 100 g of fruit weight. Significant quantities of banana peels equivalent to 40% of the total weight fresh banana are generated as a waste product in industries producing banana based products (Ragab *et al*., 2016). Banana fruit peel has a broad spectrum of biological activities and include be used as a good source of antioxidant and antitumor agent (Kumar *et al*., 2012). In addition to banana peels extracts are promising sources of natural antioxidants total phenol (Kumar, 2015) and Bioactive compounds such as alkaloids, anthocyanin, flavonoids, glycosides, phlobatannins, tannins and terpenoids.

Obesity is a complex disease that results from the inappropriate control of the body's energy balance due to overfeeding and/or a sedentary way of life. It is a state of excess adipose tissue mass. Body weights are distributed continuously in populations, so that choice of a medically meaningful distinction between lean and obese is somewhat arbitrary.

Obesity is therefore more effectively defined by assessing its linkage to morbidity or mortality. Although not a direct measure of adiposity, the most widely used method to gauge obesity is the *body mass index* (BMI), which is equal to weight/height^2 (in kg/m^2). Other approaches to quantifying obesity include anthropometry (skin-fold thickness), densitometry (underwater weighing), CT or MRI, and electrical impedance. Using data from the Metropolitan Life Tables, BMIs for the midpoint of all heights and frames among both men and women range from 19–26 kg/m^2; at a similar BMI, women have more body fat than men (Elhassaneen and Salem, 2015). Based on data of substantial morbidity, a BMI of 30 is most commonly used as a threshold for obesity in both men and women. Large-scale epidemiologic studies suggest that all-cause, metabolic, cancer, and cardiovascular morbidity begin to rise (albeit at a slow rate) when BMIs are ≥25, suggesting that the cut-off for obesity should be lowered. Most authorities use the term *overweight* (rather than obese) to describe individuals with BMIs between 25 and 30. A BMI between 25 and 30 should be viewed as medically significant and worthy of therapeutic intervention, especially in the presence of risk factors that are influenced by adiposity, such as hypertension and glucose intolerance.

Over half of adults are overweight and 19.5% of the adult population are obese in Organisation for Economic Co-operation and Development member countries (OECD, 2017). According to the World Health Organization (WHO), there are more than one billion overweight adults in the world. At least

300 million of them are clinically obese (WHO, 2006) and of these about 115 million come from developing countries (WHO and Dini , 2006).). Egypt, a developing country, is undergoing rapid urbanization changes. This has a direct impact on its people's dietary habits and physical activity patterns. According to national studies, it is common to skip meals and to replace them with daily snacks, and most of these snacks are high in calories and low in nutrients. So, Egypt appeared in No. 8 ranking among the countries of the world where obesity - adult prevalence rate, 30.3% (http://www.indexmundi.com/egypt/ obesity adult_ prevalence rate. html).

Also, obesity is a risk factor for several malignancies including colon, pancreatic, thyroid, hepatic, and uterine cancer and for cardiovascular diseases, and diabetes mellitus (Na and Myung; Gukovsky *et al.*, 2013; Alzahrani *et al.*, 2014; and Mokdad, 2003). Furthermore, obesity is due to a loss of the balance between energy intake and expenditure over long periods of time, and the brain plays a critical role in controlling and inhibiting the pre-potent responses to foods (Morton *et al.*, 2014). According to the our knowledge available, there are very few studies dealing with phytochemicals, especially those aversive compounds and their relationship to obesity. Therefore, the present study aims to explore the effect of three food processing processing by-products, namely onion and

bananas peels, and apricot seeds, on obesity disease complications in rats.

Materials and Methods

Materials

Food by-products: Red onion skin (ROS) (*Allium cepa* L.) was obtained from the New Beni Suef company for Preservation, dehydration and Industrialization of Vegetables, Beni Suef Elgudida City, Nile East, Beni Suef, Egypt; banana (*Musa sapientum*) peels and Apricot (*Primus armeniaca* L.) seeds was obtained from Benha City market, Benha Governorate, Egypt during the 2019 harvesting period. The collected samples was transported to the laboratory and used immediately for peels and seeds preparation.

Chemicals, solvents and buffers: All chemicals, solvents and buffers (except mentioned on site) were purchased from Al-Gomhoryia Company for Trading Drugs, Chemicals and Medical Instruments, Cairo, Egypt. Serotonin, dihydroxybenzylamine (internal standard, (DHBA), perchloric acid ($HClO_4$), Na_2HPO_4, citric acid, Na_2EDTA, and heptanesulfonic acid (HSA) were purchased from Egyptian agent of Sigma Chemical Co. (St. Louis, MO). The water employed in all solutions and in the mobile phase was purified through a Nanopure II system (National Liver Institute, Shebin El-Kom, Egypt) before use.

Methods

Preparation of food by-products peel powder

Banana (BPP) peels powder

Banana (BPP) peels powder were washed and then dried in a hot air oven (Horizontal Forced Air Drier, Proctor and Schwartz Inc., Philadelphia, PA) at 55 0C for 14. The dried skins were ground into a fine powder in high mixer speed (Moulinex Egypt, Al-Araby Co., Egypt). The material that passed through an 80 mesh sieve was retained for use.

Red onion peel powder (ROPP)

Red onion skin peel were washed and then dried in a hot air oven (Horizontal Forced Air Drier, Proctor and Schwartz Inc., Philadelphia, PA) at 55 ^{0}C for 14. The dried peels were ground into a fine powder in high mixer speed (Moulinex Egypt, Al-Araby Co., Egypt). The material that passed through an 80 mesh sieve was retained for use.

Aprocot seed powder (ASP)

Unripe apricot fruits were washed, sliced and seeds extracted. The seeds were cleaned and dried at 60 ^{0}C for 6 in hot air oven (AFOS Mini Smoker, England). This is followed by milling with grinder (Retsch Micro Universal Bench Top Grinder, Germany) to produce the respective flour type. The material that passed through an 80 mesh sieve was retained for use.

Biological Experiments

Animals

Animals used in this study, adult male albino rats (130-150 g per each) were obtained from Research Institute of Ophthalmology, Medical Analysis Department, Giza, Egypt.

Basal Diet

The basic diet prepared according to the following formula as mentioned by (AIN, 1993) 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 diet induced obesity (DIO) prepared according to Research Diets, Inc. NJ, as follow: casein, 80 mesh (23.3%), L-cystine (0.35%), corn starch (8.48%), maltodextrin (11.65%), sucrose (20.14%), soybean oil (2.91%), lard fat (20.69%), mineral mixture (1.17%), dicalcium phosphate (1,52%), calcium carbonate (0.64%), potassium citrate.1 H_2O (1.92%), vitamin mixture (1.17%), choline bitartrate (0.23%). The used vitamins and salt mixtures components were formulated according to Campbell, (1963) and Hegested, (1941), respectively.

Experimental design

All biological experiments performed a complied with the rulings of the Institute of Laboratory Animal Resources, Commission on life Sciences, National Research Council (NRC, 1996). Rats (n= 36 rats), 160-170g per each, were housed individually in wire cages in a room maintained at 25 ± 2 ^{0}C and kept under normal healthy conditions. All rats were fed on basal diet 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) (Research Diets, Inc. NJ) for 8 weeks which classified into sex sub groups as follow: group (2), fed on DIO as a positive control; group (3), fed on DIO containing 5 % ASP; group (4), fed on DIO containing 5 % ; ROSP, group (5), fed on DIO containing 5 % BPP and

group (6): fed on DIO containing 5 % mixture, ASP + ROSP + BPP by equal parts. Body weight gain (as percent of initial weight) was assayed every week in rats.

Blood sampling

At the end of experiment period, 8 weeks, blood samples were collected after 12 hours fasting using the abdominal aorta and rats were scarified under ether anesthetized. Blood samples were received into clean dry centrifuge tubes and left to clot at room temperature, then centrifuged for 10 minutes at 3000 rpm to separate the serum according to Drury and Wallington, (1980). Serum was carefully aspirate, transferred into clean covet tubes and stored frozen at -20 ^{o}C until analysis.

Hematological analysis

Blood lipids profile

Triglycerides (TG), Total cholesterol (TC) and HDL-Cholesterol were determined in serum using specific kits purchased from El-Nasr Pharmaceutical Chemicals Company, Cairo, Egypt. Low density lipoprotein cholesterol (LDL-c) and very low density lipoprotein cholesterol (VLDL-c) were assayed according to the equations of Fniedewald *et al.,* (1972) *as* follow:

Very low density lipoprotein (VLDL cholesterol) = TG/5

LDL cholesterol = Total cholesterol – HDL cholesterol – V LDL cholesterol

Liver functions

Aspartate aminotransferase (AST), alanine aminotransferase (ALT) were determined according to Yound, (1975) and Tietz,

(1976) respectively by using specific kits supplied by Biocon Company, Cairo, Egypt.

Serum glucose

Enzymatic determination of serum glucose was carried out colorimetrically according to Yound, (1975).

Nitrite determination

Nitrite was determined flourometric such as described by Misko *et al*., (1993).

Nitrite/nitrate detection

Plasma is filtered through an ultrafree microcentrifuge filter unit (14000 rpm for 15 min) to remove the hemoglobin resulting from cell lysis. The filtrate should contain mostly nitrate (recovery greater than 90%) due to the reaction of NO with the iron-heme center of the protein. Nitrate is converted to nitrite by the action of nitrate reductase (from *Aspergillus niger*, Sigma Chemical Co., St. Louis, MO, USA) such as follow: the sample is incubated with 40 μM NADPH (to initiate the reaction) and 14 mU of enzyme in a final volume of 50 μl of 20 mM Tris buffer (pH, 7.6). The reaction is terminated after 5 min at 20 ^{0}C by dilution with 50 μl of water followed by addition of the DNA reagent for determination of nitrite. Nitrite levels in samples are then calculated by first subtracting the value of the enzyme blank (i.e., nitrate reductase plus NADPH) from the experimental and then calculating the value using a standard curve for nitrite to which NADPH has been added.

Thiobarpituric acid reactive substances (TBARS) content

TBARS were measured as described by Buege and Aust, (1978). In brief, 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 FeSO4.7H2O was added and the mixture was heated for 20 min in boiling water. The samples were centrifuged at 1000 xg 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 malonicdialdehyde.

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).

Results and Discussion

The effect of plant parts (phyto-bioactive and aversive compounds) on body weight of obese rats

The effect of plant parts (phyto-bioactive and aversive compounds) on body weight (BW, g) of obese rats was shown in Table (1) and Figure (1). From such data it could be noticed that feeding of rats on diet induced obesity (DIO) leads to increase the BW than the control group. At the end of the experiment (8 weeks), rats of the normal group recorded 171.89% of baseline for the BW while obese group was 252.83% of baseline. Replacement of diets starch with apricot

seeds powder (ASP), , red onion skin powder (ROSP), banana peel powder (BPP) and their mixture (ASP + ROSP + BPP by equal parts) induced significant decreasing on BW of the obese rats which recorded 223.10, 206.19, 227.99 and 193.52% of baseline, respectively. The higher effect on weigh decreasing was recorded for the plant parts mixtures followed by ROSP, BPP and ASP, respectively. The effect of different plant parts including ASP, ROSP and BPP in the control of obesity is the main subjects of many studies (Bedawy, 2008; El-Safty, 2012; Bonet *et al.*, 2015; Elmaadawy *et al.*,, 2016; Sayed Ahmed, 2016; Saad *et al.,* 2018 and Emam *et al.*, 2018).

The positive effects of such plant parts regarding the control of the obesity could be attributed to their high level content of different classes phytochemical/aversive compounds including flavonols, phenolic acids, anthocyanins, alkaloids, carotenoids, phytosterols and organosulfur compounds (**Onyeneho and Hettiarachchy, 1993;** Rodriguez *et al*., 1994; Velioglu *et al*., 1998; Beattic *et al.,* 2005; Bedawy, 2008; Hassan, 2011; and Edenta *et al*., 2017). Also, Erdogan-orhan and Kartal, (2010) reported that apricot kernel oil is a rich source of MUFA and PUFA, including mainly oleic (about 70%) and linoleic acids, respectively. In addition, apricot kernel oil could be considered as a good source of bioactive compounds such as tocopherols and phytosterols consisting mainly of the α-isomer and β-

sitosterol, respectively. Due to its high content of oleic acid, apricot kernel oil is considered as a healthy supplement in diet.

Table 1. The effect of plant parts (phyto-bioactive and aversive compounds) on body weight gain (g) of obese rats *

Groups	Feeding period (weeks)								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Control (-) Std diet	140.12	155.76	204.71	248.10	272.58	315.97	347.11	370.06	380.97 [e]
Control (+) Obese	140.12	180.38	224.13	283.62	330.73	425.86	469.00	462.68	494.38[a]
SP	140.12	169.55	211.85	268.08	312.60	383.61	437.05	456.77	466.73 [b]
ROSP	140.12	154.56	195.10	246.88	287.88	353.28	374.87	411.44	429.04 [c]
BPP	140.12	165.31	208.67	264.05	307.91	377.85	400.95	430.07	459.58 [b]
Mix	140.12	167.50	222.11	263.67	298.93	355.07	376.78	393.54	411.27 [d]

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts. Means in the same row with different superscript letters are significantly different at $p \leq 0.05$.

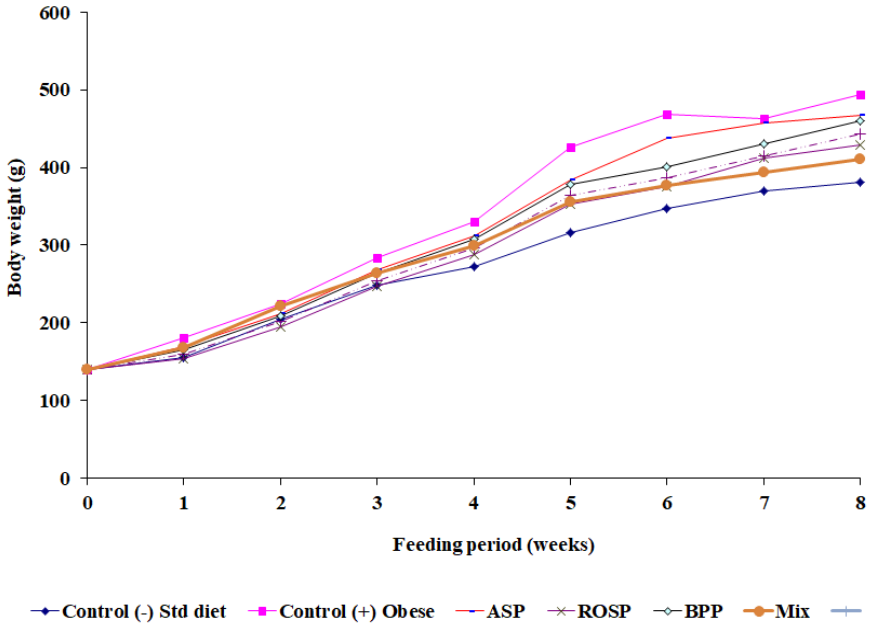

Figure 1. The effect of plant parts (phyto-bioactive and aversive compounds) on body weight gain (g) of obese rats*
*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts. Means in the same row with different superscript letters are significantly different at $p \leq 0.05$.

Such phytochemical/aversive compounds and their conversion products (metabolites) have been shown to impact gene expression and cell (including adipocyte) function through multiple mechanisms, including: 1) interacting with several transcription factors of the nuclear receptor superfamily, 2) interfering with the activity of other transcription factors, 3)

modulating signaling pathways which are associated with inflammatory and oxidative stress responses, and 4) through extragenomic actions including scavenging of reactive species, retinoylation (Constance *et al.,* 2003; Bonet *et al.,* 2015, Elmaadawy *et al.,* 2016 and Sayed Ahmed, 2016) . All of these mechanisms participate to their action control of adipocyte function, adiposity and obesity (reviewed in Bray, 2004; and Bonet *et al.,* 2015).

The effect of plant parts (phyto-bioactive and aversive compounds) on blood lipids profile of obese rats

The effect of plant parts (phyto-bioactive and aversive compounds) on some blood lipid profile parameters in plasma of obese rats were shown in Table (2) and Figure (2). It could be noticed that obesity (DIO group) induced a significant increased ($p \leq 0.05$) in TG (33.11%), TC (75.41%) and LDL (33.11%) while significant decreased ($p \leq 0.05$) in HDL (-29.85%) compared to normal controls. At the end of the experiment (8 weeks), replacement of diets starch with apricot seeds powder (ASP), red onion skin powder (ROSP), banana peel powder (BPP) and their mixture (ASP + ROSP + BPP by equal parts) induced significant improvements on blood lipid profile through decreasing the TG, TC and LDL by the ratio of 18.90, 14.30, 16.13 and 8.44; 42.62, 28.02 and 37.80 and 17.57; 33.80, 25.22, 30.81 and 17.54; and 18.90, 14.30, 16.13, and 8.44, respectively. The opposite direction was observed for the HDL levels. The higher effects in improving of the blood lipid profile disorders induced by obesity in rats were recorded for the plant oarts mixtures followed by ROSP, BPP and ASP,

respectively. In similar studies, modeling based on systematic reviews of RCTs suggests that modest and sustained weight loss (5-10 kg) in patients with overweight or obesity is associated with reductions in low density lipoprotein, total cholesterol and triglycerides and with increased levels of high density lipoprotein. (Neter *et al,* 2003; Avenell *et al.,* 2004; Poobalan *et al.,* 2004; Christensen *et al.,* 2007; Bales and Buhr, 2008; Williamson *et al.,* 2009; and Elbasouny *et al.,* 2019).

In this mode, coronary heart disease (CHD) is a major health problem in both industrial and developing countries including Egypt. Many studies have now shown that blood elevated concentrations of total or low density lipoprotein (LDL) cholesterol in the blood are powerful risk factors for CHD, whereas high concentrations of high density lipoprotein (HDL) cholesterol or a low LDL (or total) to HDL (reviewed in Bedawy, 2008 and ElMaadawy *et al.,* 2016). The composition of the human diet plays an important role in the management of lipid and lipoprotein concentrations in the blood. Reduction in saturated fat and cholesterol intake has traditionally been the first goal of dietary therapy in lowering the risk for cardiovascular disease. In recent years, however, the possible hypocholesrerolemic effects of several dietary (phyto-bioactive and aversive compounds) such as found in our selected plant parts (ASP, ROSP and BPP) including, flavonols, phenolic acids, anthocyanins, alkaloids, carotenoids, phytosterols and organo-sulfur compounds, vitamins, trace minerals etc. have attracted much interest.

Also, phenolic compounds found in such plant parts exerts its beneficial effects on cardiovascular health by antioxidant and anti-inflammatory activities *(*Anonymous, 1998 and Kuhlmann *et al., 1998;* Elbasouny *et al.,* 2019 and Sayed, 2020*).* LDL oxidation and endothelial cell damage is believed to be involved in the early development of atherosclerosis *(*Kaneko *et al.,* 1994; and Bedawy, 2008*).* Researchers found that presence of phenolics such quercetin significantly reduced LDL oxidation *in vitro* from various oxidases including 15-lipoxygenase, copper-ion, UV light, and linoleic acid hydroperoxide *(*Aviram *et al.,* 1999 and Kaneko *et al.,* 1994*).*

Table (2). The effect of selected plant parts (phyto-bioactive and aversive compounds) on serum on blood lipids profile concentration of obese rats*

Value	Control (-) Std diet	Control (+) Diabetic	Plant parts (5%, w/w)			
			ASP	ROSP	BPP	Mix
Triglycerides (TG, mg/dL)						
Mean	79.63	105.99	94.67	91.01	92.47	86.35
SD	4.56	6.87	9.43	3.90	6.43	6.34
% of Change	0.00	33.11[a]	18.90 [b]	14.30 [bc]	16.13 [b]	8.44 [d]
Total cholesterol (TC, mg/dL)						

Mean	2.96	5.19	4.22	3.79	4.08	3.48
SD	0.65	1.02	0.76	1.10	1.40	1.11
% of Change	0.00	75.41 [a]	42.62 [b]	28.02 [d]	37.80 [c]	17.57 [e]
High density lipoprotein (HDL, mg/dL)						
Mean	46.23	32.43	36.89	40.05	37.73	42.35
SD	5.33	2.21	4.52	10.66	7.32	5.98
% of Change	0.00	-29.85 [a]	-20.19 [b]	-13.36 [c]	-18.37 [b]	-8.38 [d]
Low density lipoprotein (LDL, mg/dL)						
Mean	74.64	114.69	99.87	93.46	97.64	87.73
SD	5.54	4.44	3.65	4.32	7.84	5.76
% of Change	0.00	53.65 [a]	33.80 [b]	25.22 [c]	30.81 [b]	17.54 [d]
Very low density lipoprotein (VHDL, mg/dL)						
Mean	15.93	21.20	18.93	18.20	18.49	17.27
SD	5.76	3.99	5.76	8.45	6.76	3.56
% of Change	0.00	33.11 [a]	18.90 [b]	14.30 [bc]	16.13 [b]	8.44 [d]

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts. Means in the same row with different superscript letters are significantly different at $p< 0.05$.

Besides the direct antioxidant effect, quercetin also inhibited consumption of *alpha*-tocopherol *(*Hertog *et al.*, 1992 and Kaneko *et al.*, 1994*)* and protected human serum paraxonase (PON 1) activities *(*Aviram *et al., 1999).* Also, McAnlis *et al., 1999)* suggested that quercetin, having a high affinity for protein, was bound to albumin and never incorporated into the LDL particle. Also, Prakash *et al*., (2007) reported that onion a rich source of quercetin (5110 µg/g) with high antioxidant activity and also showed significant protection of DNA damage caused by free radicals. Furthermore, Edenta *et al*., (2014) revealed that the *M.sapientum* peel extract has antihyperlipidemic properties and reduces the risk of cardiovascular diseases. Consumption of the pulp of 2 ripe bananas in the morning and evening for 4 weeks taking into account the back and leg strength and exercise time under the antioxidant condition in addition possibly controls the triglyceride, cholesterol level, and pro-inflammatory.

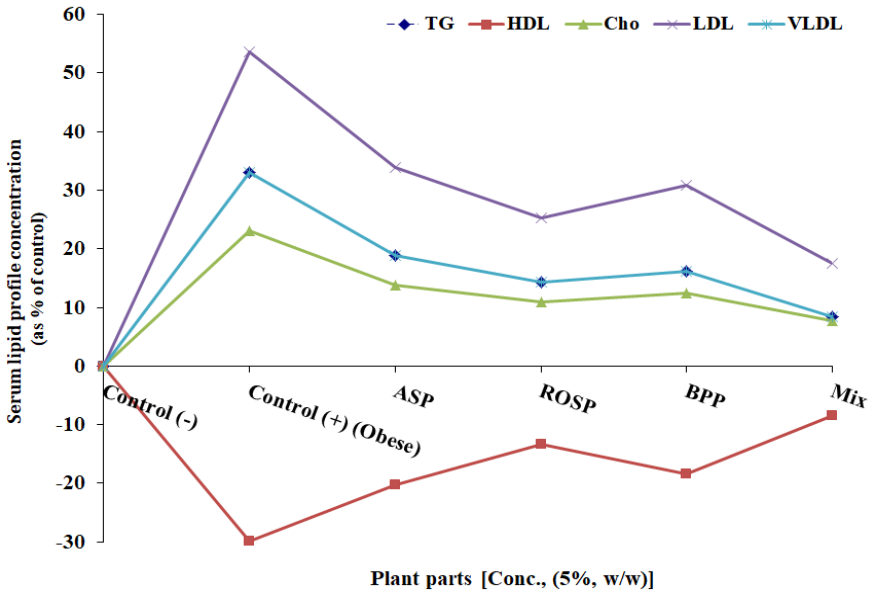

Figure 2. The effect of selected plant parts (phyto-bioactive and aversive compounds) on serum on blood lipids profile concentration of obese rats*

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts.

The effect of plant parts (phyto-bioactive and aversive compounds) on liver functions enzymes activity in serum of obese rats

The effect of plant parts (phyto-bioactive and aversive compounds) on serum Liver functions enzyme of obese rats were shown in Table (3) and Figure (3). It could be noticed that obesity (DIO group) induced a significant increased ($p \leq 0.05$) in

ALT (19.77%), AST (35.28%) and ALP (26.39%) compared to normal controls. At the end of the experiment (8 weeks), replacement of diets starch with apricot seeds powder (ASP), red onion skin powder (ROSP), banana peel powder (BPP) and their mixture (ASP + ROSP + BPP by equal parts) induced significant improvements on the ALT, AST and ALP by the ratio of 4.39, 4.16, 6.69 and 2.85; 12.53, 9.23, 12.53 and 4.73; and 16.39, 13.72, 18.70 and 10.19%. The higher effects in manipulation of the liver enzymes disorders induced by obesity in rats were recorded for the plant parts mixtures followed by ROSP, ASP, and BPP, respectively. By other meaning, the rate of suppression was increased with the mixture treatment gave maximum reduction yield of liver functions enzymes activities when compared with the tested plant parts separated. It could be mean that a combination of different plant parts may be more efficient for reducing serum level of AST, ALT and ALP, the biomarkers of liver functions stress, because the interactive effects occurred by different catagories of bioactive compounds of plant parts used.

In general, aminotransferases are normally intracellular enzymes. Thus, the presence of elevated levels of aminotransferase in the plasma indicates damage to cells rich in these enzymes. For example, physical trauma or a disease process can cause cell lysis, resulting release of intracellular enzymes into the blood. Two amino transferases were found in plasma are of particular diagnostic value AST, ALT and ALP. AST enzyme is one of the enzymes tested in the cardiac enzyme series. This

Table 3. The effect of selected plant parts (phyto-bioactive and aversive compounds) on serum Liver functions enzyme of obese rats*

Value	Control (-) Std diet	Control (+) Obese	Vegetables processing by-product powder (5 %, w/w)			
			ASP	ROSP	BPP	Mix
Serum alanine aminotransferase (ALT) activity (U/L)						
Mean	49.16	58.88	51.32	51.21	52.45	50.56
SD	2.78	6.23	5.23	4.01	3.78	7.01
% of Change	0.00	19.77 [a]	4.39 [c]	4.16 [c]	6.69[b]	2.85 [d]
Serum Aspartate aminotransferase (AST)activity (U/L)						
Mean	26.54	35.91	29.87	28.99	32.23	27.80
SD	2.34	5.76	3.78	4.06	2.56	7.43
% of Change	0.00	35.28 [a]	12.53 [b]	9.23 [c]	12.53 [b]	4.73 [d]
Serum alkaline phosphatase (ALP,U/L)						
Mean	100.05	126.45	116.45	113.78	118.76	110.25
SD	12.76	7.87	11.43	6.67	4.99	9.36
% of Change	0.00	26.39 [a]	16.39 [bc]	13.72 [c]	18.70 [b]	10.19 [d]

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts. Means in the same row with different superscript letters are significantly different at $p \leq 0.05$.

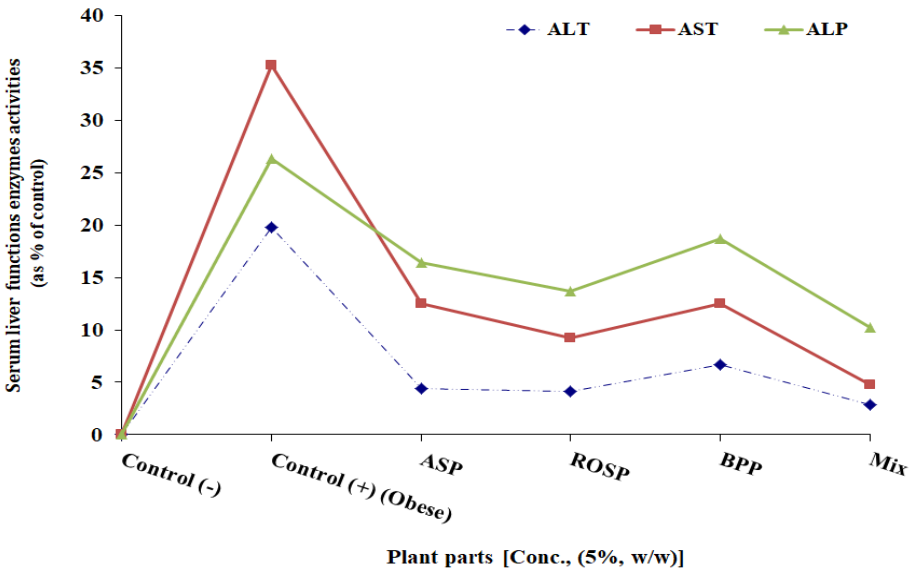

Figure 3. The effect of selected plant parts (phyto-bioactive and aversive compounds) on serum Liver functions enzyme of obese rats *

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts

enzyme is found in very high concentration within the heart muscles, skeletal muscle cells, and to a leaser degree in the kidney and panaceas. ALT is found predominately in the liver leaser quantities are found in the kidneys, heart and skeletal

muscles (Pagana and pagana, 1997). Alkaline phosphatatse (ALP) is an enzyme which catalyzes the hydrolysis of phophate esters at an alkaline pH to give pi and the corresponding alcohol, phenol or sugar. Although ALP is found in many tissues, the highest concentrations are found in the liver, biliary tract, epithelium and bone. The intestinal mucosa and placenta also contain ALP (Pagana and pagana, 1997). However, practically every body tissue contains at least a small amount of ALP. Elevated serum and leukocytic ALP leaves in patients with Hodgkin`s and non-Hodgkin`s lymbhoma were reported by several investigators (Aiba *et al*., 1980 and Thyss *et al*., 1985).

Aminotransferases (AST and ALT) and alkaline phosphatase (ALP) enzymes are elevated in nearly all liver diseases, but are particularly high in conditions that the causes extensive cell necrosis, such as severe viral hepatitis and prolongated circulatory collapse. Serial enzyme measurments are often useful in determining the course of liver damage (Abd El-Aziz, 1990; Pagana and pagana, 1997 and Hong *et al.*, 2002). Also, aminotransferases may be elevated in nonhepatic disease, such as myocardial infraction and muscle disorders; however, these disorders can usually be distingushed clinically from liver disease (Champe and Harvey, 1994). Data of the present study with the other reported that aminotransferases may be elevated significantly in additionally nonhepatic disease such as obesity in human and experimental animals (Elhassaneen and Salem, 2014).

Such as reviewed in many studies plant parts including ASP, ROSP and BPP are rich sources of different classes of phyto-bioactive and aversive compounds including flavonols, phenolic acids, anthocyanins, alkaloids, carotenoids, phytosterols, organosulfur compounds, trace minerals, vitamin etc. (Rodriguez *et al*., 1994; Mahran et al.,2018-b; Elbasouny *et al.,* 2019; and Sayed, 2020). The present study with others reported that the effect of many plant parts on decreasing the serum liver function enzymes activity could be attributed to their high level content of that phytochemical/aversive compounds (Hassan, 2011; Abd El-Fatah, 2013, Elhassaneen *et al.,* 2013; and Mahran 2018-b). The possible mode of action of liver serum enzymes-lowering activity of the diets supplemented with selected plant products including ASP, ROSP, BPP and their mixture could be explained by one or more of the following process: 1) flavonoids found in all the tested plant parts are known to block the hepatocellular uptake of bile acids (Dawson, (1998); 2) flavonoids pretreatment improved the antioxidant capacity of the liver, diminished the bilirubin concentration compared with the groups without treatment (Beattic *et al.*, 2005); 3) flavonol glycosides (found in all tested plant parts) reduced the elevated levels of the following serum enzymes, AST, ALT and ALP. 4) pre-treatment with flavonoids were not only able to suppress the elevation of AST and ALT but also reduce the damage of hepatocytes *in vitro* was reported by El-Nashar, (2007); 5) it was found that flavonoids have exhibited strong antioxidant activity against reactive oxygen species (ROS) *in vitro* and the

hepatoprotective activity of flavonoids was possibly due to its antioxidant properties, acting as scavengers of reactive oxygen species (ROS); and 6) pre-treatment with apricot kernel extract rich in phytochemicals were able to reduce the damage of liver i.e. suppresses the elevation of AST, ALT and ALP through the improvement of antioxidant defense system in red blood cells (Hassan, 2011). Take in our consideration all of these mode of actions, the higher improvement in liver function parameters recorded in rats feeding tested plant parts mixture bread samples could be attributed to the antagonism effects induced by their content of different phyto-bioactive and aversive compounds categories.

The effect of plant parts (phyto-bioactive and aversive compounds) on serum glucose of obese rats

The effect of plant parts (phyto-bioactive and aversive compounds) on serum glucose of obese rats were shown in Table (4) and Figure (4). It could be noticed that obesity (DIO group) induced a significant increased ($p \leq 0.05$) in serum glucose (37.20%) compared to normal controls. At the end of the experiment (8 weeks), replacement of diets starch with apricot seeds powder (ASP), red onion skin powder (ROSP), banana peel powder (BPP) and their mixture (ASP + ROSP + BPP by equal parts) induced significant improvements on the serum glucose by the ratio of 20.55, 9.36, 15.07 and 7.15%. The higher amelioration effects in serum glucose level raising induced by obesity in rats was recorded for the plant parts mixtures followed by, ROSP, BPP and ASP, respectively. By other meaning, the rate of decreasing with the mixture

treatment gave maximum reduction of serum glucose levels when compared with the tested plant parts separated. It could be mean that a combination of different plant parts may be more efficient for decreasing serum glucose level, the biomarkers of pancreas functions stress, because the interactive effects occurred by different categories of bioactive compounds or aversive effects of plant parts used.

Table (4). The effect of selected plant parts (phyto-bioactive and aversive compounds) on serum glucose concentration (mg/dl) of obese rats*

Value	Control (-)	Control (+)	Plant parts (5%, w/w)			
			ASP	ROSP	BPP	Mixture
Mean	96.77	132.78	116.66	105.84	111.35	103.70
SD	6.21	6.7	3.32	6.31	4.11	6.43
% of Change	0.00	37.20 [a]	20.55 [b]	9.36 [d]	15.07 [c]	7.15 [e]

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts. Means in the same row with different superscript letters are significantly different at $p \leq 0.05$.

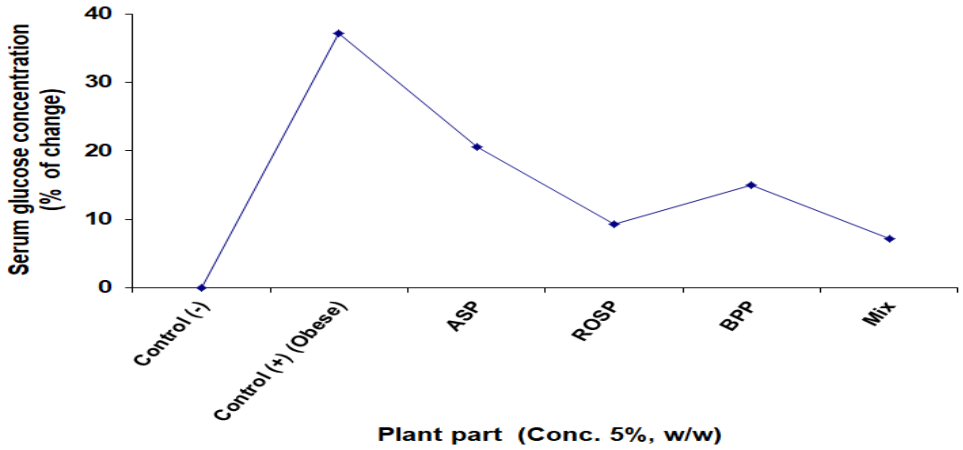

Figure (4). The effect of selected plant parts (phyto-bioactive and aversive compounds) on serum glucose concentration (as % of control) of obese rats*

* ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts

In similar studies, Avenell *et al.*, (2004) and Vettor *et al.*, (2005) reported that in patients with type 2 diabetes, weight loss of around 5 kg is associated with a reduction in fasting blood glucose of between 0.17 mmol/L to 0.24 mmol/L at 12 months. The decreasing in serum glucose as the result of feeding plant parts including PSP, ROSP and BPP and their mixture was the subject of many studies. For example, significant research has been done on the effect of onion/onion skin consumption on diabetic conditions. The organosulfur compounds S-methylcysteine sulfoxide and S-allylcysteine sulfoxide were linked to significant amelioration of weight

loss, hyperglycemia, low liver protein and glycogen, and other characteristics of diabetes mellitus in rats (Sheela *et al.*, 1995). Onion peel extract (OPE) might improve glucose response and insulin resistance associated with type-2 diabetes by alleviating metabolic dysregulation of free fatty acids, suppressing oxidative stress, up-regulating glucose uptake at peripheral tissues, and/or down-regulating inflammatory gene expression in liver which was reported by Jung *et al.*, (2011). Moreover, in most cases, OPE showed greater potency than pure quercetin equivalent. These findings provide a basis for the use of onion peel to improve insulin insensitivity in type-2 diabetes. OPE might improve glucose response and insulin resistance associated with type-2 diabetes by alleviating metabolic dysregulation of free fatty acids, suppressing oxidative stress, up-regulating glucose uptake at peripheral tissues, and/or down-regulating inflammatory gene expression in liver. Moreover, in most cases, OPE showed greater potency than pure quercetin equivalent. These findings provide a basis for the use of onion peel to improve insulin insensitivity in type-2 diabetes.

Banana peel extract shows significant reduction in the elevated serum fasting glucose levels in the body (Sayed, 2020). Banana flower and stem can be incorporated in the diet of diabetic patients to make them more tolerant to hyperglycemia. Also, Sayed (2020) showed that the effect of methanolic extract of (Musa sapientum Linn. Sucker) banana on fasting blood glucose, body weight and pancreas histology of alloxan induced hyperglycemic rats. It was observed that the extract at

all tested does significantly lowered fasting blood glucose level in the treated rats; it was efficient in reducing blood glucose level. On the other side, apricot kernel oil is a rich source of MUFA and PUFA, including mainly oleic (about 70%) and linoleic acids, respectively. In addition, apricot kernel oil could be considered as a good source of bioactive compounds such as tocopherols and phytosterols consisting mainly of the α-isomer and β-sitosterol, respectively. Due to its high content of oleic acid, apricot kernel oil is considered as a healthy supplement in diet. These compounds are known for their properties in scavenging free radicals, inhibiting lipid oxidation *in vitro* and improve glucose response and insulin resistance associated with type 2 diabetes (Noda *et al.*, 2002; Jung *et al.*, 2011; El-Safty, 2012; and Elhassaneen *et al.*, 2016-d). Additionally, the mixture treatment gave maximum hypoglycemic yield when compared with the tested by-products separated. It could be mean that a combination of different plant parts may be more efficient for decreasing the serum glucose level because the interactive effects occurred by different categories of phyto-bioactive and aversive compounds of plant parts used.

Effect of plant parts (phyto-bioactive and aversive compounds) on glutathione fractions concentration in plasma of obese rats

Biological antioxidant macromolecules i.e. glutathione (GSH) fractions concentration in plasma of obese rats consumed food processing by-products applied in bread were assessed (Table 5 and Figure 5). From such data it could be noticed that obesity

by DIO induced a significant decreased ($p \leq 0.05$) in GSH and GSSG concentrations and GSH/GSSG ratio in plasma by -30.83, 11.27 and 22.04% compared to normal controls, respectively. Adding 5% (w/w) of ASP, ROSP, BPP and their mixture to the rat diets induced significant ($p \leq 0.05$) increasing on these parameters concentration in plasma by the ratio of 21.35, 12.86, 20.17 and 11.17; 9.86, 7.04, 8.45 and 7.04; and 12.75, 6.26, 12.81 and 4.44% , respectively. The higher amelioration effect in plasma GSH and GSSG concentrations and GSH/GSSG ratio rising induced by obesity in rats was recorded for the by-product mixtures treatment followed by ROSP, BPP and ASP, respectively.

Reduced glutathione (GSH) has received more attention in terms of its biosynthesis, regulation, and various intracellular functions (Reed and Beatty, 1980; and Elhassaneen, 1996). Among of these functions are two roles regarding to detoxifications process as follow: 1) as a key conjugate of electrophilic intermediates, principally via glutathione-*s*-transferase activities in phase II metabolism, and 2) as an important antioxidant. The last function, antioxidant, of GSH include its role in the activities of GSH enzymes family i.e. glutathione peroxidase (GSH-Px) and peroxiredoxins (PRXs). also, GSH can apparently serve as a nonenzymatic scavenger of oxyradicals (Halliwell and Gutteridge, 1985; Elhassaneen *et al.*, 2016; and Mahran *et al.*, 2018-b). The antioxidant defense

systems status in obese rats feeding some plant parts is the subject of many studies. For example, ElMaadawy *et al.*, (2016) indicated that obesity induced a significant decreased ($p \leq 0.05$) in plasma non-enzymes antioxidant (GSH, 30.83% and GSSG, 11.27%), plasma antioxidant vitamins (vitamin A, 27.43%; vitamin C, 20.98% and vitamin E, 31.50%) as well as RBC's antioxidant enzymes (GSH-Px, 37.66%; GSH-Rd, 28.66%; CAT, 19.51% and SOD, 25.26%) as a percent of normal group. Also, Feeding on 5% of potato, cauliflower, onion and mango peels and their mixture induced significant exhibited a significant improvement ($p \leq 0.05$) in all of these parameters by different rates.

Table 5. The effect of selected plant parts (phyto-bioactive and aversive compounds) on plasma glutathione fractions concentration of obese rats*

Value	Control (-) Std diet	Control (+) Obese	Plant parts (5 %, w/w)			
			ASP	ROSP	BPP	Mix
Reduced glutathione concentration (GSH, µmol /L)						
Mean	8.27	5.72	6.50	7.20	6.60	7.34
SD	1.11	0.45	2.11	1.21	0.49	0.76
% of Change	0.00	-30.83 [a]	-21.35 [b]	-12.86 [c]	-20.17 [b]	-11.17 [c]
Oxidized glutathione concentration (GSSG, µmol /L)						

Mean	0.73	0.65	0.66	0.68	0.67	0.68
SD	0.11	0.21	0.10	0.09	0.11	0.20
% of Change	0.00	-11.27 [a]	-9.86 [b]	-7.04 [c]	-8.45 [b]	-7.04 [c]
			GSH/GSSG ratio			
Mean	11.37	8.87	9.92	10.66	9.92	10.87
SD	2.02	1.54	1.11	0.99	2.05	1.43
% of Change	0.00	-22.04 [a]	-12.75 [b]	-6.26 [c]	-12.81 [b]	-4.44 [d]

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts. Means in the same row with different superscript letters are significantly different at $p \leq 0.05$.

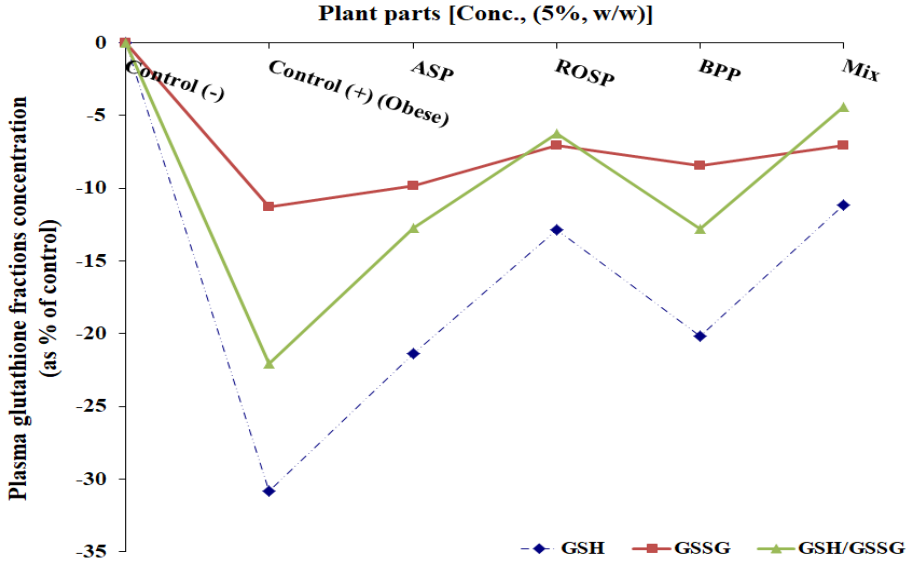

Figure 5. The effect of selected plant parts (phyto-bioactive and aversive compounds) on plasma glutathione fractions concentration of obese rats*

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts. Means in the same row with different superscript letters are significantly different at $p \leq 0.05$.

A decreasing in glutathione fractions observed in obese rats group generally accompanied by a concomitant decreased in the ratio of GSH/GSSG. Several studies reported that a more fundamental effect of oxyradical-generating compounds as the obesity development, however, is their effect on what can be referred to as the redox status (GSH/GSSG) of cells or tissues (Mahran *et al.*, 2018; and Rdwan *et al.*, 2018). Few studies have been addressed directly the issue of effects of pro-oxidants on redox status. For example, Elhassaneen *et al*., (2004) mentioned that increased fluxes of oxyradicals might be decreased in the GSH/GSSG ratio, due either to direct radical scavenging or to increased peroxidase activity. This effect could also occur indirectly due to reduced NADPH availability [necessary for glutathione reductase (GSH-Rd) activity] resulting, for example, from oxidations in the first step of the redox cycle (Champe and Harvey, 1994). In this context, Bedard and Krause (2007); Elmaadawy *et al.*, 2016 and others reported that various enzymes inside the cells including adipocytes can also produce ROS. Particularly, the family of NAPDH oxidases (NOX) is considered to be an important

source of ROS generation. Such effect could be one of the most important reasons for reducing the GSH/GSSG ratio in obese rats. The tested plant parts in the present study and their mixtures feeding are rich in phyto-chemicals/ aversive compounds which exhibited antioxidant effects against ROS formation as the obesity development through several mechanism of action including the raising of redox status (GSH/GSSG ratio) in different sites of the body.

Effect of plant parts (phyto-bioactive and aversive compounds) on serum oxidants concentration of obese rats

Oxidative stress (OS) status in obese rats feeding some tested plant parts was assessed by measuring some oxidants concentration parameters in plasma including thiobarbituric acid reactive substances (TBARS) and nitric oxides (nitrite, NO_2 and nitrate, NO_3) (Table 6 and Figure 6). From such data it could be noticed that obesity by DIO induced a significant ($p \leq 0.05$) increased in TBARS, NO_2 and NO_2/NO_3concentration in plasma by rate of 33.58, 26.53 and 26.36% compared to normal controls, respectively.

Adding 5% (w/w) of ASP, ROSP, BPP and their mixture to the rat diets induced significant ($p \leq 0.05$) increasing on these parameters concentration in plasma by the ratio of 17.36, 7.55, 13.58 and 5.28; 19.59, 10.61, 16.73 and 7.35; and 18.60, 14.32, 17.85 and 10.04%, respectively. The higher amelioration effect in plasma TBARS, NO_2 and NO_2/NO_3concentration rising induced by obesity in rats was recorded for the by-product

mixtures treatment followed by ROSP, BPP and ASP, respectively, respectively. For example, ElMaadawy *et al.*, (2016) indicated that obesity induced a significant increased ($p \leq 0.05$) in plasma oxidants concentration (TBARS, 41.95%; NO_2, 31.02% and NO2/NO3, 26.45%).

In similar studies, clinical evidences for obesity-associated OS have been provided by measurement of either biomarkers or end-products of free radical-mediated oxidative processes (Elhassaneen and Salem, 2014; Sayed Ahmed, 2016; and Rdwan *et al.*, 2018). For example, lipid peroxidation markers such as malondialdehyde (MDA), one of the most important compounds in TBARS and major products of the oxidation of polyunsaturated fatty acids (PUFA), lipid hydroperoxides and conjugated dienes are found to be increased in plasma from obese subjects in many clinical studies (Vincent and Taylor, 2006; and Elmaadawy *et al.*, 2016; and Emam *et al.*, 2018). Systemic metabolic alterations associated with obesity contribute to the increase in OS have been reported by many authors. For example, hyperglycemia as a hallmark of type II diabetes, a metabolic complication of obesity, induces OS through activation of the polyol and hexosamine pathways, production of advanced glycation end-products (AGE), and increase of diacylglycerols (DAG) synthesis (DCCTRG, 1993 and Le Lay *et al.*, 2014). Excess of circulating lipids induces ROS formation pathways, which contribute to the increase in

lipid oxidation and protein carbonylation (Jensen *et al.,* 1989). Leptin and angiotensin II, secreted at high levels by adipocytes, are inducers of ROS generation and might therefore promote inflammation and lipid peroxidation (Bouloumie *et al.,* 1999). Altogether, dysregulation of metabolic parameters occurring with fat mass expansion will contribute to inducing OS damages notably at the vascular level (Brandes and Kreuzer, 2005). Regarding the RNS, Endothelial NO synthase- (eNOS-) and inducible NO synthase- (iNOS-) dependent NO are abundant in adipocytes. iNOS expression has been shown to be increased in white adipose tissue (WAT) derived from diet-induced or genetic models of obesity (Perreault and Marette, 2001). Similarly, both eNOS and iNOS are expressed at higher levels in WAT from obese patients compared to lean controls (Elizalde *et al.,* 2000 and Engeli *et al.,* 2004).

On the other side, interest in the possible significance of MDA on human health has been stimulated by reports that are mutagenic and carcinogenic compound (Shamberger *et al*., 1974). Nitric oxide synthase catalyzes the conversion of L-arginine to citrulline and highly reactive free radical species, nitric oxide (NO) (Manahan, 1989). Nitric oxide, in turn, can react with molecular oxygen and water to form nitrite and nitrate; with hemoglobin to form iron-nitrosyl adducts and/or nitrate in blood, with superoxide anion to make nitrate, and with the amino and thiol groups of protein to

Table 6. The effect of selected plant parts (phyto-bioactive and aversive compounds) on plasma oxidants concentration of obese rats*

Value	Control (-) Std diet	Control (+) Obese	Plant parts (5 %, w/w)			
			ASP	ROSP	BPP	Mix
Thiobarbituric acid reactive substances (TBARS, nmol/mL)						
Mean	2.79	3.72	3.27	3.00	3.16	2.93
SD	0.65	1.01	1.04	0.67	0.69	0.52
% of Change	0.00	33.58 [a]	17.36 [b]	7.55 [c]	13.58 [b]	5.28 [d]
Nitrite (NO_2, nmol/L)						
Mean	2.54	3.21	3.03	2.81	2.96	2.72
SD	0.29	1.05	0.79	0.47	0.61	0.54
% of Change	0.00	26.53 [a]	19.59 [b]	10.61 [d]	16.73 [c]	7.35 [e]
Nitrite/Nitrate (NO_2/NO_3, nmol/L)						
Mean	3.87	4.89	4.59	4.42	4.56	4.26
SD	1.65	0.65	0.91	1.00	1.21	0.97
% of Change	0.00	26.36 [a]	18.60 [b]	14.32 [c]	17.85 [b]	10.04 [d]

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by

equal parts. Means in the same row with different superscript letters are significantly different at p≤ 0.05

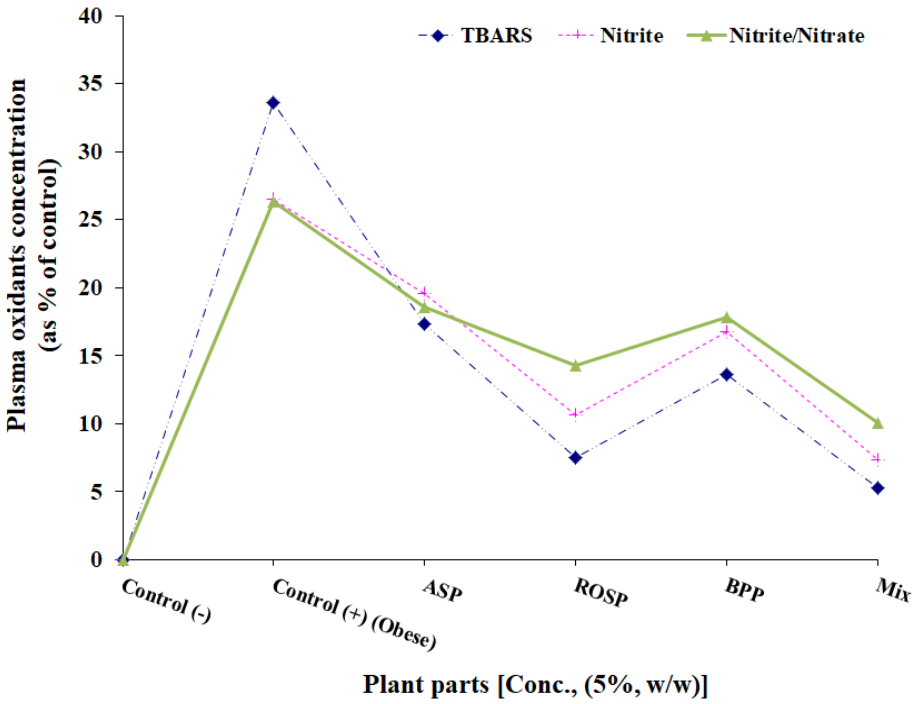

Figure 6. The effect of selected plant parts (phyto-bioactive and aversive compounds) on plasma oxidants concentration of obese rats*

*ASP, apricot seeds powder; ROSP, red onion skin powder; BPP, banana peel powder and Mixture, ASP + ROSP + BPP by equal parts. Means in the same row with different superscript letters are significantly different at $p \leq 0.05$.

produce nitrosylated species (Manahan, 1989; Misko *et al*., 1993). The excess production of nitric oxides has been implicated in the pathogenesis and tissue destruction of a growing number of immunological and inflammatory diseases including septic shock, arthritis, graft rejection and diabetes (Jacob *et al*., 1992).

The positive effects of plant parts on oxidants formation/ concentration of obese rats could be attributed to several mechanisms induced by their phyto-chemical/bioactive components content. In this context, Coskun *et al.,* (2005) found that quercetin, dominant flavonoid such as found in ROSP have anti-oxidative and anti-inflammatory activities. Such dietary phenolics are metabolized in liver, inhibiting liver injury induced by diabetes i.e. enhancing lipid metabolism, reducing OS may be particularly effective, consequently. Also, ASP is determining radical scavenging power (RSP), anti-lipid peroxidative activity (ALPA), reducing power (RP), total phenolic content (TPC) related to reduce the OS (Durmaz *et al.,* 2009). Furthermore, the banana peels extracts are promising sources of natural antioxidants total phenol and bioactive compounds such as alkaloids, anthocyanin, flavonoids, glycosides, phlobatannins, tannins and terpenoids related to reduce the OS (Kumar, 2015; and Edenta *et al*., 2017). Additionally, the mixture treatment gave maximum reduction yield of plasma OS/oxidants when compared with the tested plant parts separated. It could be mean that a combination of different plant parts may be more efficient for reducing plasma MDA and nitric oxides level, the biomarkers

of OR and inflammation in the body, because the interactive effects occurred by different categories of bioactive compounds of different plant parts used.

In conclusion, the present study has demonstrated the potency of the tested plant parts including ASP, ROSP and BPP to ameliorate liver, kidney, blood lipids profiles disorders and hyperglycemia in obese rats. Also, ASP, ROSP and BPP improved the immunological functions i.e. increasing the albumin level and protease activity in serum. Furthermore, tested plant parts improve the oxidant/antioxidant status and neurological disorders in obese rats. These findings provide a basis for the use of selected plant parts and also have important implications for the prevention and early treatment of obesity. Also, the data support the benefits of dietary modification, including bioactive compounds supplementation, in alleviating oxidative stress and conventional neurological disorders associated obesity. Finally, more research must be done on the future to elucidate the realized benefits from dietary plant parts intake on obesity disease and its complications.

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