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Orange Fleshed Sweet Potato: A Depression Alleviating Functional Food

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Abstract

Oxidative stress induces depression. This article reports depression alleviation of Orange Fleshed Sweet Potato (OFSP) on experimental rat model. Depression was developed by confining the animal in physical constraint condition (restrained cages and exposing to light in night) and oral administration of 0.38 mg reserpine /kg body weight daily; reserpine at a dose of 30-50 mg/kg/day induces oxidative stress leading to depression due to depletion of monoamine. A 20 g raw OFSP was given orally daily to the animal for the 14 days consecutively. Development and alleviation of depression were assessed by behavioural test, atrophy of brain and adrenal gland, and analysis of stress biomarker. Reserpine induced a better depression than the physical constraint. In behavioural test- Tail suspension and Forced swim tests, OFSP showed a lowering of immobility time in tail suspension and increase of climbing time in forced swimming as compared to the negative control, but it was almost similar to that of the antidepressant clomipramine. OFSP also made a significant decrease of serum malonaldehyde (MDA) and an increase of superoxide dismutase (SOD) and nitric oxide (NO). This study revealed that orange fleshed sweet potato have depression alleviating potential in experimental animal model. The dietary intake of antioxidant carotene rich orange flesh sweet potato could fade out the oxidative stress, and thus the depression.

Keywords

Orange Fleshed Sweet Potato, Chemophysical Depression, Depression Alleviation, Behavioural Assessment, Stress Biomarkers, Animal Model

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1. Introduction

Oxidative stress induces depression [1], which may result in inflammation and neurodegeneration [2]. Cellular metabolism generates reactive oxygen species such as superoxide anion (O^{2-}), hydrogen peroxide (H_2O_2), and hydroxyl radical ($HO\cdot$) and hydrogen radical ($H\cdot$) develops oxidative stress [3-5] affecting cellular structures including cell membranes, DNA [3]. Oxidative stress is responsible for develop several chronic diseases including diabetes, cardiovascular disorders, neurological diseases, cancers [6-8]. Brain is highly sensitive to oxidative stress as compare to other organs or systems. It is because of its high levels of membrane lipids, excitotoxic amino acids, weak antioxidant capacity, high energy demand, high oxygen consumption, and autoxidizable neurotransmitters [9-13]. The adrenal gland is also an essential stress-responsive organ, which is part of both the hypothalamic-pituitary-adrenal axis and sympatho-adrenomedullary system. Chronic stress, thus, affects function of brain and of adrenal gland [14]. Stress also makes change in oxidative biomarkers- malondialdehyde and antioxidant enzyme system.

Reserpine at certain dose induces stress [9]. Reserpine depletes monoamine which result in irreversible blocks of vesicular monoamine transporter (VMAT) for neuronal transmission or storage, and promotes dopamine-autoxidation and oxidative catabolism by monoamine oxidase (MAO); this

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leads to form dopamine-quinones and hydrogen peroxide [9, 15, 16]. Sustained or chronic stress decreases monoamines leading to develop depression [17]. It has been reported that some plant products have antidepressant activity on experimental stress [18-20].

Antioxidant rich food has been suggested to reduce depression. The Orange Fleshed Sweet Potato (OFSP), a carotene dense functional food [21, 22], scavenges reactive oxygen species and thus, reduces oxidative stress, consequently depression [23, 24]. This study aimed to investigate the depression alleviation potential of orange fleshed sweet potatoes in rat model.

2. Materials and Methods

2.1. Potato Sample

Three varieties of orange fleshed sweet potatoes were collected from the Tuber Crops Research Centre (TCRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur-1701; Bangladesh.

2.2. Experimental Animal

Rat model was used. A total of 50 healthy Wister albino rats of 100-150 g weight and age 50-60 days were collected from animal house of Pharmacy department, Jahangirnagar University, Savar. Prior to experimentation, rats were acclimatized with basal diet and water in the animal house at the Institute of Nutrition and Food Science (INFS), University of Dhaka for 14 days.

Ethical permission was taken from the Ethical Committee of the Faculty of Biological Sciences, University of Dhaka.

2.3. Stress Development and Experimentation

The acclimatised animal was divided into ten groups, each containing five rats; five groups (A_1, B_1, C_1, D_1, and E_1) were in physical stress, and five groups (A_2, B_2, C_2, D_2, and E_2) for chemical stress model.

2.4. Physical Stress [15]

Neurological stress (depression) was developed into the animals of group A_1, B_1, C_1 and D_1 by putting the rats in restrained cages and exposing to light during night for 14 days. Each cage housed 3 rats in a 9"× 3" × 6" dimension space for each rat. Group A_1, B_1, C_1 were given three varieties of orange fleshed sweet potato containing rich content of carotene, namely BARI_SP 2, BARI_SP 4 and BARI_SP 5, at dose of 20 g raw. Group D_1, which received an antidepressant, clomipramine at a dose of 12.65 mg/kg body weight, was used as positive control.

2.5. Chemical Stress [17]

Chemical stress was induced into the rats (A2, B2, C2, D2 and E2 group) by Reserpine (0.38 mg/kg body weight daily) given orally for consecutive 14 days. Orange fleshed sweet potato named BARI_SP 2, BARI_SP 4 and BARI_SP 5 were given orally at dose of 20 g raw respective to the group A_2, B_2 and C_2. Group D_2, which received the clomipramine at the same dose, was used positive control. E group rat receive only the basal diet and was used as negative control.

After 14 days of experimentation, on the 15th day, the Behavioural tests- Tail Suspension and Forced Swimming were performed, and animals were then sacrificed to collect the blood, brains and adrenal glands.

2.6. Tail Suspension Test

Rats were individually suspended on the edge of a table, 50 cm above the floor by adhesive tape placed approximately 11 cm from the tip of the tail. Each animal was visually and acoustically isolated from other animals during the test. The total period of immobility was recorded manually for five minutes as described by Steru et al; Nishizawa et al [20, 25].

2.7. Forced Swim Test

Rats of all groups were systematically subjected to forced swimming individually. Rat was placed in a cylinder (40 cm height and 15 cm diameter) containing fresh water (26°C) up to a height of 30 cm. The total time of swimming, climbing and immobility in 4 minutes of the test were recorded as described by Porsolt et al [26].

2.8. Collection of Blood Specimen

On the 16th day one drop of blood was taken from each rat by tail bleeding for estimation of fasting blood glucose. Rats were then sacrificed to collect the blood, which was processed to separate serum to be stored in eppendorf tubes at -20°C for biochemical analysis.

2.9. Estimation of Fasting Blood Glucose and Stress Biomarkers

Fasting blood glucose was estimated with the use of a standard glucometer (AccuChek, Germany). Serum malondialdehyde content was estimated by thiobarbituric acid assay method as described [27]. TCA-TBA-HCl reagent (15% w/v trichloroacetic acid (TCA), 0.375% w/v thiobarbituric acid (TBA) and 0.25 N hydrochloric acid) were used. Five hundred micro litre (500 µl) serum was combined with 1 ml of TCA-TBA-HCL, mixed thoroughly and heated for 15 minutes in a boiling water bath. After cooling, the flocculent precipitate was removed by centrifugation at 3000 rpm for 10 minutes. The absorbance of the sample was read at 535 nm against blank (only reagent without serum). Serum MDA was measured by using the following formula:

MDA concentration, C= OD/bε

Where, extinction coefficient ε= 1.56×10^5 M^{-1} cm^{-1}, width of tube b= 1 cm, OD=Optical density at 535 nm.

Cu-Zn containing superoxide dismutase activity was measured by the method (28) as described. For test sample, 25 µl of serum was added to 500 µloftris-EDTA buffer at pH 8.2 prepared by mixing 2.85 g of tris and 1.11 g of EDTA in 1 litre of deionized water. The absorbance was measured at 420 nm at zero time and after one minute of the addition of 500 µl of pyrogallol solution (0.2 mM) prepared by dissolving 0.252 g of pyrogallolina solution of 0.6 ml of concentrated HCl acid diluted in 1 lite of deionized water relative to tris –EDTA buffer. For control, 25 µl of deionized water was used rather than serum.

$$\%\ \text{Inhibition of pyrogallol autoxidation} = \frac{\Delta A \text{ for test}}{\Delta A \text{ for control}} \times 100$$

$$(Cu-Zn)\ \text{SOD Activity (U/ml)} = \frac{\%\ \text{Inhibition of pyrogallol autoxidation}}{50\%}$$

Where,

$$\Delta A = \text{Absorbance after one minute of the addition of pyrogallol} - \text{Absorbance at zero time}$$

For determination of NO (29), 150 µl of serum was added to 1.3 ml of deionized water, then 50 µl of Griess reagent prepared (by mixing equal volume of N-(1-naphthyl) ethylenediamine dihydrochloride solution (0.1%) and sulphanilamide solution (1%) in 5% phosphoric acid) was added. The mixture was incubated for 30 minutes at room temperature and the absorbance was recorded at 548 nm relative to reference prepared by mixing 50 µl of Griess reagent and 1.45 ml of deionized water. A standard curve of nitrite concentration (x-axis) against absorbance (y-axis) was plotted. Nitrite concentrations corresponding to the absorbance of experimental samples were calculated from the plot.

2.10. Collection of Brain and Adrenal Gland Sample

Brain was removed from each of the rats by meticulous dissection, washed in saline, wiped in tissue paper, weighed and recorded. The weight was measured by electric balance analyzer (Mettler Toledo, Switzerland). The brain samples were preserved in 10% formalin. Similarly, one adrenal gland from each of the rats was extracted, washed in saline, wiped in tissue paper, weighed and recorded, and preserved.

Data analyses and figure preparation were carried out using the Statistical Package for Social Sciences (SPSS, version 20.0 for Windows) and Microsoft Excel 2013. ANOVA and Post hoc Tukey test were done to analyse the data and the p value of <0.05 was considered significant.

3. Results

3.1. Effect on Behavioural Test (TST, FST)

In tail suspension test, the orange fleshed sweet potatoes (OFSP) showed a lowering of immobility, and increase of climbing in forced swimming insignificantly as compared to the negative control, but it was almost similar that of the antidepressant clomipramine (Table 1, Figure 1). Swimming and immobility time have had no effect.

Table 1. Behavioural changes physical[1] and chemical[2] stressed rat models.

Groups			Tail Suspension Immobility (s) $\pm sd$	Forced Swim Test		
				Climbing (s) $\pm sd$	Swimming (s) $\pm sd$	Immobility (s) $\pm sd$
Physical stress model BARI_SP2 (Kamalasundari)^{OFSP}		A_1	32.4 ± 3.65	121.2 ± 3.21	86.8 ± 3.65	32.0 ± 3.55
BARI_SP 4^{OFSP}		B_1	32.8 ± 4.51	116.6 ± 10.92	87.2 ± 6.08	32.2 ± 4.38
BARI_SP 5 ^{OFSP}		C_1	32.0 ± 4.69	118.8 ± 7.87	89.0 ± 5.81	33.2 ± 4.49
Clomipramine		D_1	34.8 ± 6.35	119.8 ± 6.34	88.4 ± 3.421	33.2 ± 6.20
Chemical stress model BARI_SP 2 (Kamalasundari)^{OFSP}		A_2	28.8 ± 3.42	122.6 ± 3.14	87.6 ± 3.78	29.8 ± 3.271
BARI_SP 4^{OFSP}		B_2	29.4 ± 3.28	121.0 ± 4.35	88.2 ± 2.95	31.00 ± 3.67
BARI_SP 5 ^{OFSP}		C_2	30.4 ± 7.70	120.4 ± 11.10	89.0 ± 5.09	30.60 ± 8.14
Clomipramine		D_2	31.80 ± 3.70	121.4 ± 6.77	88.2 ± 5.02	30.40 ± 4.16
Negative Control		E	35.40 ± 5.76	114.4 ± 5.98	88.80 ± 4.26	36.60 ± 7.73
Significance (p<0.5)						
Physical1	ANOVA		F = 0.812 P = 0.532	F = 1.161 P = 0.358	F = 0.846 P = 0.513	F = 0.872 P = 0.498
	Tukey test		D1vs A1, B1, C1; p=0.632, 0.705, 0.555	D1vs A1, B1, C1; p=0.390, 1.00, 0.861	D1vs A1, B1, C1; p=0.989, 0.843, 0.873	D1vs A1, B1, C1; p=0.739, 0.774, 0.400
Chemical2	ANOVA		F = 0.812 P = 0.532	F = 1.186 P = 0.347	F = 0.087 P = 0.986	F = 1.156 P = 0.359
	Tukey test		D2 vs A2, B2, C2; p=0.359, 0.534, 0.790	D2 vs A2, B2, C2; p=0.528, 0.617, 0.470	D2 vs A2, B2, C2; p=0.999, 1.00, 0.999	D2 vs A2, B2, C2; p=0.556, 0.492, 1.00

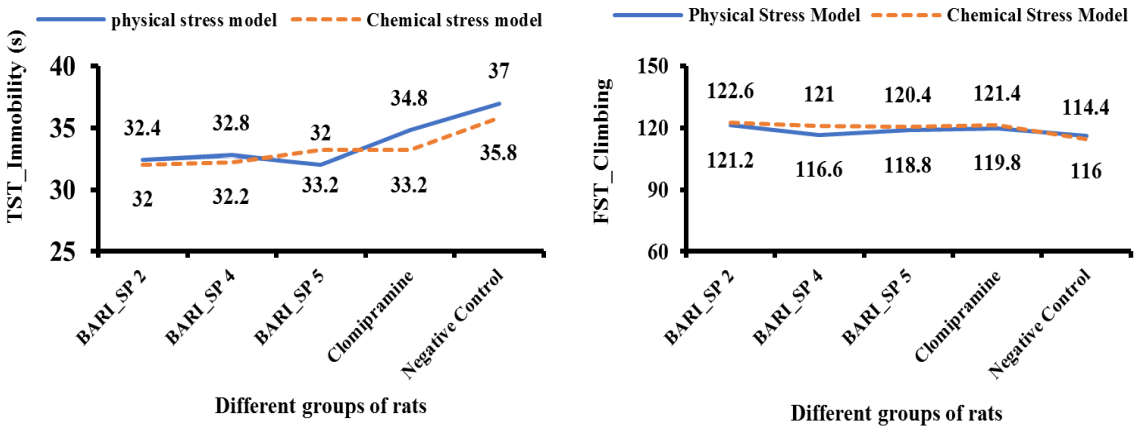

Figure 1. behavioural changes in different groups of rats.

3.2. Stress Biomarkers

Effect on Fasting Blood Glucose and Malondialdehyde Level

Treatment with OFSP made an insignificant effect on fasting blood glucose level, but decreased serum MDA level, which was found similar to that of the antidepressant clomipramine (Table 2, Figure 2). OFSP SP 4 and 5 were found to be significantly effective on serum MDA level.

Table 2. Fasting blood glucose and malonaldehyde in different groups of rats in physical and chemical stress.

Groups		Fasting Blood Glucose (mmol/L)±*sd*	Malonaldehyde (nmol/ml)±*sd*
Physical stress BARI_SP 2 (Kamala sundari)^{OFSP}	A_1	5.44 ± 0.57	2.45 ± 0.03
BARI_SP 4 ^{OFSP}	B_1	5.18 ± 0.67	2.71 ± 0.37
BARI_SP 5 ^{OFSP}	C_1	5.32 ± 0.239	2.28±0.01
Clomipramine	D_1	4.92 ± 0.934	1.69 ± 0.23
Chemical stress BARI_SP 2 (Kamala sundari)^{OFSP}	A_2	5.1 ± 1.175	1.99 ± 0.26
BARI_SP 4 ^{OFSP}	B_2	5.3 ± 0.235	1.73 ± 0.08
BARI_SP 5 ^{OFSP}	C_2	5.18 ± 0.531	1.62±0.31
Clomipramine	D_2	5.64 ± 0.358	1.93 ± 0.32
Negative Control	E	6.72 ± 2.72	2.23 ± 0.29

Physical ANOVA	F = 0.555 P = 0.698	F = 16.16 P = 0.0001
Tukey Test	D1vs A1, B1, C1; p=0.995, 0.998, 1.000	D1vs A1, B1, C1; p=0.214, 1.00, 0.017
Chemical ANOVA	F = 2.428 P = 0.194	F = 3.906 P = 0.017
Tukey Test	D2vs A2, B2, C2; p=0.359, 0.486, 0.407	D2vs A2, B2, C2; p=0.645, 0.05, 0.015

Significance ($p<0.05$).
OFSP: Orange Fleshed Sweet Potato.
Values were expressed in mean ± standard deviation.

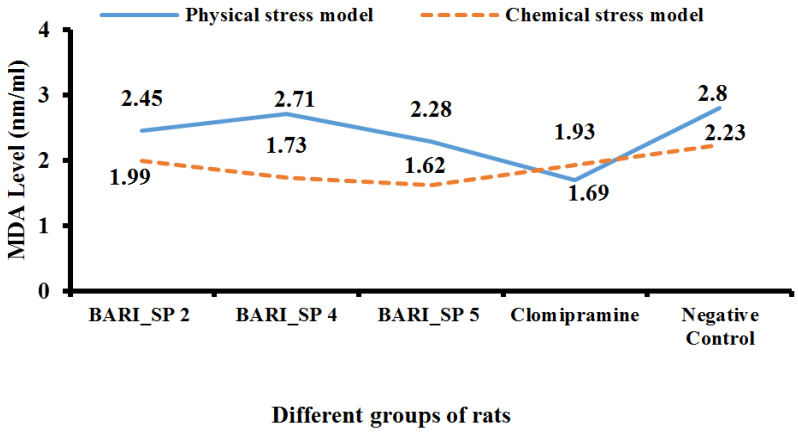

Figure 2. MDA level in different groups of rats.

3.3. Effect on Cu-Zn Superoxide Dismutase (SOD) Activity and Nitric Oxide (NO) Level

The OFSP treatment indicated a significant increase in SOD activity and NO level, which was fund higher than that of the clomipramine (Table 3, Figure 2). In case of SOD, BARI SP 2 showed higher activity than the SP 4 and SP 5 in physical stress model, but BARI SP 5 showed stronger activity in chemical stress model. On the other hand, the SP 4 and SP 5 showed stronger effect on serum nitric oxide level in physical stress model, and the SP 4 gave higher effect in chemical stress model. ANOVA analysis among groups indicated a significant effect on nitric oxide level in physical stress model.

Table 3. Change in SOD activity and serum NO in different groups of physical and chemical stress.

Groups		(Cu-Zn) SOD Activity (U/ml) $\pm sd$	NO Level (µM) $\pm sd$
Physical stress[1] BARI_SP 2 (Kamala sundari)^{OFSP}	A_1	3.43±0.45	12.05±4.22
BARI_SP 4 ^{OFSP}	B_1	2.43±0.46	21.79±1.92
BARI_SP 5 ^{OFSP}	C_1	2.44±0.15	16.92±6.77
Clomipramine	D_1	2.90±0.31	9.89±4.61
Chemical stress[2] BARI_SP 2 (Kamala sundari)^{OFSP}	A_1	2.38±0.49	10.62±3.06
BARI_SP 4 ^{OFSP}	B_1	2.34±0.12	14.72±5.60
BARI_SP 5 ^{OFSP}	C_1	2.78±0.79	10.93±4.04
Clomipramine	D_1	2.43±0.58	9.99±3.38
Negative Control	E_1	1.95±0.75	7.33±3.60

Physical ANOVA	F = 0.555 P = 0.698	F = 9.543 P = 0.0001
Tukey Test	D1vs A1, B1, C1: p=0.0001, 0.574, 0.559	E1vs A1, B1, C1: p=0.334, 0.0001, 0.01
Chemical ANOVA	F = 1.243 P = 0.325	F = 2.175 P = 0.111
Tukey Test	D2vs A2, B2, C2;: p=0.359, 0.486, 0.407	D2vs A2, B2, C2: p=0.645, 0.05, 0.015

Significance ($p<0.05$);
OFSP: Orange Fleshed Sweet Potato;
Values were expressed in mean ± standard deviation.

Table 4. Change in adrenal gland and brain weight in different groups of rats in physical and chemical stress.

Groups		Weight of Adrenal gland (mg) $\pm sd$	Weight of Brain (g) $\pm sd$
Physical stress BARI_SP 2 (Kamala sundari)^{OFSP}	A_1	7.8 ± 2.5883	1.527 ± 0.0775
BARI_SP 4 ^{OFSP}	B_1	7.4 ± 4.00	1.5092 ± 0.066
BARI_SP 5 ^{OFSP}	C_1	10.6 ± 5.595	1.552 ± 0.0478
Clomipramine	D_1	10.4 ± 3.71	1.481 ± 0.119
Chemical stress BARI_SP 2 (Kamala sundari)^{OFSP}	A_2	10.2 ± 1.483	1.591 ± 0.086
BARI_SP 4 ^{OFSP}	B_2	9.40 ± 2.509	1.583 ± 0.0986
BARI_SP 5 ^{OFSP}	C_2	10.80 ± 3.19	1.564 ± 0.0563
Clomipramine	D_2	10.6 ± 2.701	1.51 ± 0.0786
Negative Control	E	11.2 ± 1.340	1.542 ± 0.0666

Physical ANOVA	F = 2.272 P = 0.097	F = 1.021 P = 0.420
Tukey Test	D_1vs A_1, B_1, C_1; p=0.146, 0.104, 0.766	D_1vs A_1, B_1, C_1; p=0.891, 0.709, 0.993
Chemical ANOVA	F = 0.219 P = 0.925	F = 0.767 P = 0.559
Tukey Test	D_2vs A_2, B_2, C_2; p=0.960, 0.746, 0.999	D_2vs A_2, B_2, C_2; p=0.862, 0.918, 0.961

Significance ($p<0.05$);
OFSP: Orange Fleshed Sweet Potato;
Values were expressed in mean ± standard deviation.

3.4. Effect on Adrenal Gland and Brain Function

An apparent decrease in adrenal gland and a increase in brain weight were noted with OFSP treatment, which was almost similar that of the clomipramine (table 4, figure 4). SP 2 and SP 4 showed stronger activity than the SP 5.

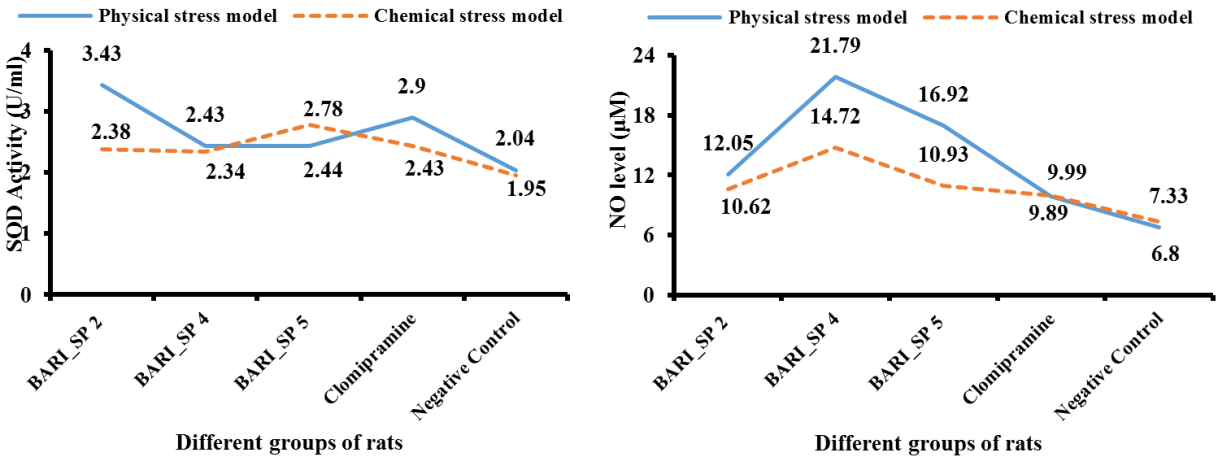

Figure 3. (Cu-Zn) SOD activity and NO level in different groups of rats.

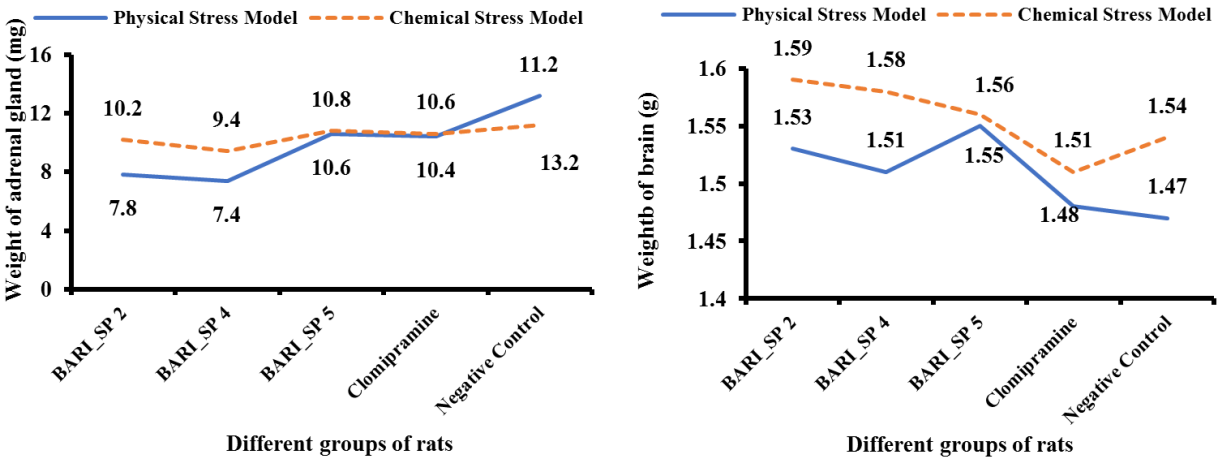

Figure 4. Weight of adrenal gland and brain.

4. Discussion

Oxidative stress induces chronic disorders including neurodegeneration like depression, which is characterized by changes of muscle tone [30, 31], stress biochemicals [32], weight of brain and adrenal gland [33] In the present study, behavioural tests, stress marker, antioxidant enzymes, and organ atrophy were investigated to assess muscle tone, stress level and organ function. Use of Orange Flesh Sweet Potato (OFST) was shown to improve the stress-induced depression.

Orange Flesh Sweet Potato is a carotene dense functional food. It has been widely used to combat micronutrient deficiency, particularly vitamin A and malnutrition [21, 22, 34]. In this study, OFSP was used as antioxidant, which made an apparent improvement in some of the depression characteristics such muscle tone like the antidepressant, clomipramine. OFSP treatment also showed a significant decrease of MDA value, and also noted an increased level of SOD and NO demonstrating a lowering of depression or stress by the OFSP. The apparent decrease of adrenal gland and increase of brain weight by the OFSP suggested up regulation of function of these organs, which was comparable to the antidepressant, clomipramine. In a previous study with nutraceuticals- omega-3 fatty acid, vitamin C, zinc revealed a significant relieve of depression in experimental stress model [35], but the present work did not make significant relieve of depression, which might be because of that the β-carotene could not release from the raw OFSP [21]. However, a large number of studies with plant products [18-20] has reported alleviation of some depression characteristics like this study.

5. Conclusion

The Orange Flesh Sweet Potato indicated to have depression alleviating potential in experimental depression. Regular dietary consumption of antioxidant carotene rich orange flesh sweet potato could reduce stress, and thus depression. However, further researches on its antioxidative potential in vivo activity should be undertaken.

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Conflict of Interest

Authors do not have any conflict of interest.

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