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IN VIVO STUDY OF GLYCEMIC RESPONSE OF PRODUCTS INCORPORATED WITH SELECTED SEAWEEDS

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Seaweeds can block multiple enzymes involved in glucose metabolism, including glucosidase, and dipeptidyl peptidase – 4 (DPP-4). Glycemic response is the impact of food on blood sugar levels after ingestion. The Glycemic index is the ranking of carbohydrate foods based on the rise in postprandial blood glucose. Post-prandial hyperglycemia is the sudden increase in blood glucose immediately after the ingestion of food. This study aims to investigate the glycemic response and glycemic index of formulated seaweeds (*Sargassum wightii* and *Ulva lactuca*) incorporated products bread and chapati. The seaweed incorporation highly influences all the sensory attributes of the products bread and chapati. The glycemic response of seaweed incorporated products was lower than the glycemic response of standard bread. Their test food glycemic response has a highly significant difference ($p<0.05$) and the mean incremental area under the curve (*Sargassum wightii:* 11.80 ±0.45), (*Ulva lactuca:* 11.60 ±0.45) was lower than standard bread. Also, control in glycemia is seen in *Sargassum wightii* incorporated bread as stabilization in blood sugar is observed. Both the products incorporated with seaweeds *Sargassum wightii* (84.5) *and Ulva lactuca* (87.6) have a similar glycemic index. Hence it can be used for the control, prevention and treatment of postprandial hyperglycemia as it has control over the sudden rise in blood glucose.

Keywords: Glycemic response, Seaweeds, Brown seaweeds *Sargassum wightii*, Postprandial hyperglycemia, *In vivo* study, oral glucose tolerance test.

The Glycemic index is the quantitative assessment of foods, which classifies the food based on the physiological effect of the post-prandial glucose response of carbohydrates and the type of sugar constituents in the food, given in the percentage of response to an equivalent carbohydrate portion of reference food. The rapid glucose spikes after the ingestion of food refer to the high glycemic index food, which involves high demand for insulin. Though enough insulin is present in the blood, due to insulin insensitivity and resistance, it results in the condition of hyperinsulinemia which is a basic characteristic of diabetes mellitus[1]. Postprandial hyperglycemia refers to the sudden peak of glucose in the bloodstream after the ingestion of food, it depends on various factors such as time taken for gastric emptying, rate of absorption of glucose in the intestine, insulin insensitivity, production of glucose from non-carbohydrate substances (gluconeogenesis), rate of insulin secretion and nerve imbalance. This post prandial hyperglycemia results in various metabolic abnormalities such as insufficient or inactive secretion of insulin from β cells due to its deterioration[2]

The hyperglycemic condition refers to the higher concentration of glucose in blood vessels, it plays a central role in various diabetic micro and macro vascular complications that include retinopathy, neuropathy, and nephropathy and is also associated with other non-communicable diseases such as obesity, cardiovascular diseases and cancer. Hence the management of hyperglycemia could be a primary diabetic care therapy[3]. Glucotoxicity is a condition where there is decreased insulin secretion and in turn increase in insulin resistance due to prolonged hyperglycemia. This is due to the rapid increase in oxidative stress, as reactive oxygen species (ROS) are produced through the non-enzymatic glycation and mitochondrial electron transfer system. Hyperglycemic condition plays a central role in various pathological conditions including micro and macrovascular complications. Hence strict glycemic control and glucose monitoring are necessary to reduce the mortality rate and improve patient outcomes [4].

Postprandial glycemic responses are important to achieve glycemic control, when spikes and elevated rapidly after ingestion, it is considered an independent disease risk factor. The individualized nutritional intervention helps in improving the quality of life (QoL) and gives great practical value. Good glycemic control results in the growth and maintenance of a beneficial microbiome while poor control results in the growth of non-beneficial bacteria[5].

The anti-diabetic potential of seaweeds (*Sargassum wightii*, *Sargassum polycystum*) by inhibiting the enzymes was studied by Unnikrishnan et al(6). The study shows that the natural compounds present in these seaweeds could prevent postprandial hyperglycemia, and prevent oxidative damage as it exhibits powerful inhibition towards a-amylase, a glucosidase, dipeptidyl peptidase – 4 (DPP-4). The anti-diabetic and anti-inflammatory effect of water extracts of seaweeds including *Undaria pinnatifida, Codium fragile* and *Gracillaria verrucosa* on *in vitro* model. These inhibit enzymes such as glucosidase, the brush border enzyme in the intestine, which take part in the final digestion. Thus its inhibition regulates the absorption. Also, it involves the upregulation of the signalling of insulin and glucose absorption. It proves that these seaweeds can modulate glucose absorption and its utilization[7].

These functional foods have been touted as a promising strategy for managing and treating degenerative diseases like diabetes, cardiovascular disease, and cancer. Excessive levels of reactive oxygen species (ROS) have previously been identified as a contributing factor in the development of such disorders[8]. Incorporating seaweeds into the bakery and farinaceous foods such as bread, chapati pasta, noodles, biscuits, cake, and cookies offers significant nutritional, texture, and functional features such as the ability to retain water and oil, as well as a long shelf life[9].

The baking industry is one of the large segments of the food processing sector. It offers a wide range of opportunities for growth, innovation and job generation. The most popular baked products are bread, cookies and biscuits. As these baked products are made majorly from refined flour which is high in simple sugars and turn low in protein and fibre and may influence metabolism. The non-communicable diseases such as constipation, obesity, diabetes and heart diseases find their way when there are poor dietary practices. Low glycemic approaches and value addition on bread and cookies can help to overcome these metabolic disturbances[10]. The objective of this study is to formulate the products incorporated with seaweeds *Sargassum wightii* and *Ulva lactuca* and analyse the chemical, physical and glycemic response of developed products and investigate the glycemic index of foods.

Materials and methods

Materials:

The incorporation of brown seaweeds of family *Rhodophyta* (*Sargassum wightii*) was collected from Mandapam coastal area of Rameswaram, Ramanathapuram district, Tamil

Nadu, India in the month of December – January 2022. It is handpicked and cleaned with seawater to remove epiphytes, dust and impurities.

Experimental animals:

Wistar albino rats were bought with the approval of the institutional Animal Ethical Committee AUM : IAEC . 2022 . FSMD : 01; AUM : IAEC. 2022. FSMD : 02 .

Five male Wistar albino rats of 150 to 300g per group (experimental group 1 and experimental group 2) were housed in the cage and maintained under standard laboratory conditions of temperature (22 ± 2), humidity (45 ± 5) and 12 hours of light and 12 hours of the dark cycle. The rats were allowed to adapt to the new environment with free access to food and water for four days. After four days of adaptation, it was reweighed and an oral glucose tolerance test (OGTT) was performed[11].

The experimental group 1 rat were fed with standard bread and test bread incorporated with *Sargassum wightii* and the experimental group 2 rats were fed with standard bread and test chapati incorporated with *Ulva lactuca.*

Methods:

Processing of seaweeds:

Seaweeds (*Sargassum wightii* and *Ulva lactuca*) were collected from the mandapam coastal area and washed in the laboratory two to three times with potable water and made into dried powder by drying the fresh seaweeds under the sun for one to two days till all of its moisture got evaporated and become crisp and sound. It was then finely powdered in the mixer grinder and collected in a zip lock covered, stored at room temperature.

Incorporation of seaweeds Sargassum wightii in bread:

Bread is an important staple food in the human diet as they are cheap, easily available and flavour full. Maida is the major ingredient for the preparation of bread but it is only rich in simple sugars and lacks protein, fibre and other nutrients, hence the baking industry undergoes various attempts to improve the nutritional quality of bread(9). Seaweeds are rich in protein, fibre, vitamins, minerals and other phytochemicals which can be incorporated into foods to meet the daily requirements[12].

The formula of bread consists of maida and wheat flour in the ratio of 50:50, dry yeast of 3g, butter of 5g, Palm sugar of 5g, 5g of sodium chloride and 60 ml of water. The incorporation of dry seaweed powder (*Sargassum wightii*) at different ratios (five per cent, six per cent, seven per cent and ten per cent) was done by deducting the amount of wheat flour concentration. The preparation of bread was done by hand kneading, the dry ingredients are well sieved and mixed. The dry yeast is activated in lukewarm water and allowed to stand for 10 minutes and added to dry ingredients. To this, butter is added and kneaded for 20 to 30 minutes and allowed for proofing in a dark, warm area for about one hour. After one hour, the bread dough was allowed for second proofing for 30 to 40 minutes in the well-greased bread pan. This bread dough is baked in the convection oven at the temperature of 200*C for 30 minutes

Incorporation of seaweeds Ulva lactuca in chapati:

Wheat (*Triticumaestivum L.*) chapatti is popular in South Asia and the Middle East. Chapattis are unleavened flatbreads that are a staple food in Indian households. Chapati is made primarily from whole wheat flour. It contains all of the nutrients found in the wheat endosperm, germ, and bran, such as dietary fibre, proteins, vitamins, and minerals and food made from wheat flour is becoming more popular because it is good for people's health, such as lowering the risk of cancer, cardiovascular disease and obesity [13] By supplementing whole wheat flour with flour made from various legumes, the protein and mineral content of chapatis is increased, as is the nutritional content [14].

The control sample was prepared by using 90g of whole wheat flour and 10g of soy flour. To develop innovative sample with different variations, the ingredients were used in varied proportions. The formulated sample was prepared in various variations. For variation I, 4 g seaweed powder, 86g wheat flour, and 10g soy flour was used; variation II with 8g seaweed powder, 82g wheat flour, and 10g soy flour; whereas variation III with 12g seaweed powder, 78g wheat flour, and 10g soy flour; and variation IV with 16g seaweed powder, 74g wheat flour, and 10g soy flour. The chapati dough was made by combining the composite flour with the necessary amount of water and salt. The dough was covered with a damp towel and let to rest at room temperature for 30 minutes. The dough was split into equal portions and rolled into a circular sheet (12cm in diameter and around 2 mm in thickness) using a rolling pin before being roasted in a tawa for a few seconds on each side.

Nutritional analysis:

The nutritional analysis of seaweeds (*Sargassum wightii, Ulva lactuca*) incorporated bread and chapati were determined by standard procedures of association of official analytical chemists (AOAC, 2005)

Organoleptic evaluation:

The formulated seaweeds (*Sargassum wightii, Ulva lactuca*) incorporated products such as bread, chapati has undergone sensory analysis for the determination of acceptability. The sensory attributes such as appearance, colour, flavour, taste, texture and overall acceptability were analysed by the human senses. Appearance or look of food influences its doneness and quality. Colour, a food quality indicator, indicates visual attractiveness. The temperature of food contributes to the flavour of the food, which influences the perception of food. Ten semi-trained panel members in the age group 18 to 25 from Avinashilingam University, Coimbatore were selected for the sensory evaluation, Panel members scored the formulated product using a five-point hedonic scale score card in the laboratory. Safe water was provided to rinse their mouth during analysis.

Physical analysis:

Texture analysis:

The texture is the major criterion to judge the quality and freshness of foods. The formulated seaweeds *Sargassum wightii* incorporated products such as bread and *Ulva lactuca* incorporated chapati were analysed in texture analyser model – SHIMADZU EZ-XS, to know its hardness, adhesiveness, cohesiveness, springiness, resilience, elasticity and chewiness.

Colour analysis:

Colour is an important quality attribute governed by the presence of pigments and chemical, biochemical, microbial and physical changes that occur during the processing of food. The colour measurement a simpler, and faster, used to characterise maturity and an indirect measure of quality attributes. Appearance and colour of food surface is the first sensation that consumer perceives, used to either accept or reject the food product.

Oral glucose tolerance test:

On the first day of the test, All ten rats were allowed to fast for 5 to 6 hours, 5µl of blood was taken from the lateral tail vein of Wistar albino rats, and fasting blood glucose was measured with a glucometer. Then they were fed with standard bread and their post-prandial blood glucose was taken after 30 minutes, 60 minutes, 90 minutes, 120 minutes. Formulated seaweeds incorporated bread and chapati of 1 to 2g/kg of available carbohydrates were given and their post prandial glycemic response was measured [15].

Glycemic index:

It was determined by dividing the Incremental Area Under Curve (IAUC) of Formulated seaweeds incorporated in baked products such as bread by the Incremental Area Under Curve (IAUC) of glucose. The incremental area under the curve (IAUC) was calculated by trapezoidal rule in every rat of each group (Control and Experimental). Hence the glycemic index of the bread is calculated by the formula [16].

t-test was applied to investigate the significant difference between the incremental area under the curve of the test food and standard food at a level of 95% level of confidence.

RESULTS AND DISCUSSION

The incorporation of seaweeds (*Sargassum wightii*) in bread and *Ulva lactuca* in a chapati with the main motto to make it a special food with functional properties beyond its nutritional value, to utilize the underexploited seaweeds and to know its glycemic response after incorporation. The formulated seaweed incorporated products such as bread and chapati have undergone several analysis and their glycemic response and glycemic index were investigated *In vivo* method. The incorporation of seaweeds was in different percentages, the standard and variations of bread and chapati are shown in figure 1 and 2

Organoleptic evaluation:

The prepared bread of standards and their three variations are kept for organoleptic evaluation, the mean score for appearance, colour, texture, flavour, taste and overall acceptability of all panellists was calculated.

From table 1, the mean score of sensory attributes of seaweed bread can be observed, comparing with the standard, the variation I of six per cent incorporation has the highest acceptability. The bread on the incorporation of seaweeds has a great impact on all sensory attributes. Variations II and variation III have fishy smell and give an aftertaste after ingestion of bread. The appearance of the seaweeds bread was compared with standard bread, the difference in porosity, thickness and the length of the loaf, the crust of the bread hardens and the colour of the bread and smell increased with the level of incorporation of seaweeds. The incorporation of seaweeds at ten per cent in bread results in brown colour, a fishy flavour with puckering effect in the throat.

Table 2, shows the acceptability of the formulated chapati in which the average score is calculated. For appearance, variation III has the highest score (5±0) whereas variation II has the least score (4.8±0.4). For colour, variation II has the highest score (4.8±0.4) and the least score was a variation I (4.5±0.5). For texture, variation II has the highest score (4.5±0.7) whereas variations III and IV have the lowest score (4±0). For flavour, the variation I have the highest score (4.5±0.5) followed by variation II. For taste, the variation I have the highest acceptability (4.5±0.5) whereas variation IV (3±0.6) has the least acceptability. For overall acceptability, variation II has the highest score of 22.9±1.5.

Nutritional analysis:

On chemical analysis of highly acceptable variation of seaweed bread six per cent is given in table 3, the proximate principles such as carbohydrates, proteins, fats, moisture and ash content of Variation II are given in the table, the proximate principles of seaweed bread can be seen, it contains 48.30g of carbohydrate, 7.27g of protein and 2.93g of fat per 100g of bread.

Among the different variations of the formulated product, the variation with 8 per cent seaweed was highly acceptable by the panel members and the proximate analysis of the formulated product is given below in table 4, the proximate principles of seaweeds incorporated chapati. It contains 50.42 g of carbohydrates, 9g of protein and 8.92 g of fat per 100g.

Texture analysis:

Hardness is the force required to deform the product to a given distance, the force compress or bites between tongue and palate. Where table 5 shows that the bread has a hardness of (2.4N) and a hardness of (4.10N). Adhesiveness is the force required to remove the material that adheres to a specific surface. It is required for lips, teeth and palate. The formulated bread and chapati were found to require the adhesive force of 0.011 N and 0.01081 N. The graph plotted for the texture profile of the formulated products are shown in figure 3

Colour analysis:

The colour of formulated seaweeds *Sargassum wightii* incorporated bread was majorly influenced by the incorporation of seaweeds. It imparts the colour in formulated products, also change in colour was majorly due to the addition of other ingredients and processing of the formulated products. The colour values of formulated products are given in table 6, which shows that the colour and greenness were imparted from the incorporated seaweeds *Ulva lactuca.* figure 4 depicts the colour value of formulated bread and chapati.

Glycemic response of experimental group 1 Wistar albino rats:

The oral glycemic tolerance test was performed for experimental group1 rats (C1, C2, C3, C4, C5) their weights and the average weight of experimental group 1 rat are shown in table 7, it was fed with standard bread and their glycemic response over 2 hours were recorded, after 3 days of washout period, they were fed with test bread incorporated with seaweeds *Sargassum wightii* and its response was also recorded. The amount of bread and chapati to be fed in relation to the body weight was calculated, correspondingly 1-2g of carbohydrates per kilogram of the rat was fed, calculation was given in tables 8 and 9. Figure 5 depicts the weighing and collection of blood from the lateral tail vein of Wistar albino rats by the venipuncture method.

Table 10, depicts the glycemic response of experimental group 1 rat. The glycemic response for test bread mostly stabilizes and gradually decreases. For experimental group 1 rat when fed with test bread, C1 the blood glucose level at 30 minutes and 60 minutes were the same and it increases only at 90 minutes, similarly for experimental group 1 rat C3 stabilizes at 107 mg/dl between 30 and 60 minutes and increases to 127 mg/dl at 90 minutes and gradually decreases to 120mg/dl. For experimental rat group 1 C4, the blood glucose stabilizes between 121mg/dl and 120mg/dl and increases at 90 minutes. But for experimental group 1 rat C2 and experimental rat C3 the blood glucose spikes at 30minutes after ingestion of standard bread.

The stabilization in post-prandial blood glucose depicts that slower rate of glucose release from the ingested test food. Hence the test bread incorporated with seaweeds *Sargassum wightii* has glycemic control characteristics.

Glycemic index of test bread incorporated with *Sargassum wightii*:

The glycemic index of formulated test bread incorporated with seaweeds *Sargassum wightii* can be calculated by dividing the incremental area under test bread with standard bread and multiplying it by 100. The incremental area under curve the was calculated by plotting the glycemic response in the graph (figure 6) and measuring the area under the glucose curve, it was given in table 12

t test was applied to investigate the significance of the difference between the incremental area under the curve for standard and test bread. the t value (2.7735) and p value (0.0242) depict that the p value was less than 0.05, hence experimental rats fed with standard bread and test bread incorporated with seaweeds *Sargassum wightii* have a highly significant difference. The average area covered by the experimental rats for test bread was lower (11.80±0.45) than the area covered when it is fed with standard bread (14±1.22). The formulated bread incorporated with seaweeds *Sargassum wightii* was calculated in table 14 and it resulted as 84.52 which comes under the range of high glycemic index foods. Where the standard bread is also high glycemic food.

Glycemic response of experimental group 2 Wistar albino rats:

From table 11, the experimental group 2 rat Z1 when fed with test chapati incorporated with *Ulva Lactuca* has a spike in blood glucose level at 30 minutes which may be due to the weight of the albino rat (222g). For experimental group 2 rat Z2 when fed with test chapati, the glycemic response gradually increases and reaches its peak at 90 minutes but when it is fed with standard bread, it reaches its peak by 30 minutes itself. When the experimental group rat Z3 was fed with standard bread, it shows a higher glycemic response compared to the test chapati in all intervals. Whereas the experimental group rat Z4 shows lower glucose levels when fed with test chapati incorporated with seaweed *Ulva lactuca*. The glycemic response of standard bread for experimental group rat Z5 reaches the spike at 30 minutes itself but when fed it stabilizes at 123 – 126 mg/dl between 2 hours.

Glycemic index of test bread incorporated with *Ulva lactuca*:

The glycemic index of formulated test chapati incorporated with seaweeds *Ulva lactuca* can be calculated by dividing the incremental area under test chapati with standard bread and multiplying it by 100. The incremental area under the curve was calculated by plotting the glycemic response in the graph (figure 7) and measuring the area under the glucose curve as given in table 13.

In table 13, t value (2.9673) and p value (0.0179) show the highly significant difference between incremental area when it is fed with standard bread and test chapati incorporated with seaweeds *Ulva lactuca*. The average area covered by the experimental rats was lower (11.6±1.14) when it is fed with test chapati than the area covered when it is fed with standard bread (13.5±0.86). The formulated chapati incorporated with seaweeds *Ulva lactuca* was calculated and it resulted in 87.6 which comes under the range of high glycemic index foods as tabulated in table 15.

The incorporation of different seaweeds in daily consumable food matrices could enhance the utilization of therapeutic properties. The control over post prandial hyperglycemia is observed in 6 per cent and 8percent of incorporation of seaweeds *Sargassum wightii* and *Ulva lactuca* respectively in bread and chapati which is highly acceptable among semi-trained panellists. The test bread undergoes various processing methods, where the processing, type and structure of starch also determine the glycemic index. Test chapati was only incorporated with 8% seaweeds *Ulva lactuca*, if we increase the percentage of incorporation of seaweeds, the glycemic index of chapati can be lowered further

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TABLES

TABLE - 1

COMPARISON OF ACCEPTABILITY MEAN SCORE OBTAINED FOR DIFFERENT VARIATIONS OF FORMULATED *Sargassum wightii* BREAD

Attributes	**Standard**	**Variation I**	**Variation II**	**Variation III**
Appearance	5±0	4.8±0.42	4.6±0.5	2.8±0.4
Color	4.6±0.5	4±0	3.8±0.4	2.5±0.5

Texture	4.9±0.3	4±0.5	3.6±1.03	Flavour
Flavour	4.7±0.48	4±0.8	3.2±1.03	1.9±0.5
Taste	4.9±0.3	4.2±0.75	2.7±1.05	1.2±0.4
Overall acceptability	23.9±0.8	21±2.1	17.9±3.14	11±1.2

TABLE - 2

COMPARISON OF ACCEPTABILITY MEAN SCORE OBTAINED FOR DIFFERENT VARIATIONS OF FORMULATED *Ulva lactuca* CHAPATI

Attributes	**Variation I**	**Variation II**	**Variation III**	**Variation IV**
Appearance	4.9±0.3	4.8±0.4	5±0	4.9±0.3
Colour	4.5±0.5	4.8±0.4	4.7±0.4	4.7±0.4
Texture	4.1±0.5	4.5±0.7	4±0	4±0
Flavour	4.6±5	4.4±0.5	4.2±0.6	4.2±0.4
Taste	4.5±0.5	4.3±0.4	4.2±0.6	3±0.6
Overall acceptability	22.6±1.0	22.9±1.5	22.3±0.8	20.7±1.3

TABLE - 3

CHEMICAL ANALYSIS OF FORMULATED *Sargassum wightii* BREAD (VARIATION I)

Nutrients	**Composition of nutrients**
Moisture (%)	39.38
Ash (g)	2.12
Protein (g)	7.27
Fat (g)	2.93
Carbohydrate (g)	48.30

TABLE - 4

CHEMICAL ANALYSIS OF FORMULATED *Ulva lactuca* CHAPATI (VARIATION II)

Nutrients	**Composition of nutrients**
Moisture (%)	28.67
Ash (g)	2.99
Protein (g)	9.00
Fat (g)	8.92
Carbohydrate (g)	50.42

TABLE - 5

TEXTURE PROFILE OF FORMULATED PRODUCTS

Formulated products	**Hardness (N)**	**Adhesive force (N)**
Bread (Variation I)	2.46294	0.01105
Chapati (Variation II)	4.10406	0.01081

TABLE - 6

COLOR VALUES OF FORMULATED BAKED PRODUCTS

Formulated baked products	**L*a*b***		
	L*	**a***	**b***
Bread (Variation I)	51.04	3.06	18.19
Chapati (Variation II)	61.31	-0.31	24.81

TABLE - 7

WEIGHT OF WISTAR ALBINO RATS OF EXPERIMENTAL GROUP 1

Wistar Albino rats	**Experimental group 1**					**Experimental group 2**				
	C1	**C2**	**C3**	**C4**	**C5**	**Z1**	**Z2**	**Z3**	**Z4**	**Z5**
Weight (g)	209	224	288	264	208	222	155	172	164	165
Average weight (g)	224					175.6				

TABLE - 8

RELATION TO BODY WEIGHT, AMOUNT OF FEED FED TO EXPERIMENTAL GROUP 1 WISTAR ALBINO RATS

Experimental group 1	**Weight of the albino rats (g)**	**Amount of carbohydrate to be fed (g)**	**Amount of standard bread to be fed (g)**	**Amount of test bread to be fed (g)**
C1	209	0.418	0.8	0.86
C2	224	0.448	0.86	0.92
C3	288	0.57	1.10	1.19
C4	264	0.52	1	1
C5	208	0.416	0.78	0.86

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TABLE - 9

RELATION TO BODY WEIGHT, AMOUNT OF FEED FED TO EXPERIMENTAL GROUP 2 WISTAR ALBINO RATS

Experimental Group 2	**Weight of the wistar albino rats(g)**	**Amount of carbohydrate (g)**	**Amount of standard bread to be fed (g)**	**Amount of test chapati to be fed (g)**
Z1	222	0.44	0.85	0.87
Z2	155	0.31	0.59	0.61
Z3	172	0.34	0.66	0.67
Z4	164	0.32	0.63	0.63
Z5	165	0.33	0.63	0.65

TABLE - 10

GLYCEMIC RESPONSE OF EXPERIMENTAL GROUP 1 WISTAR ALBINO RATS

Time of blood with drawl over 2 hour	**Glycemic response of experimental group (mg/dl)**									
	Fed with standard bread (g)					**Fed with test bread incorporated with seaweeds *Sargassum wightii* (g)**				
	C1	**C2**	**C3**	**C4**	**C5**	**C1**	**C2**	**C3**	**C4**	**C5**
Fasting	119	107	119	130	115	111	107	124	119	109
30 minutes	121	129	132	140	141	126	138	107	121	133
60 minutes	129	133	125	142	147	126	128	107	120	127
90 minutes	124	126	121	120	127	132	107	127	123	124
120 minutes	116	130	117	96	122	100	113	120	123	113

TABLE - 11

GLYCEMIC RESPONSE OF EXPERIMENTAL GROUP 2 WISTAR ALBINO RATS

Time of blood with drawl over 2 hour (mg/dl)	**Control group**					**Positive control group**				
	X1	**X2**	**X3**	**X4**	**X5**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Fasting	116	103	85	99	123	115	93	119	120	102
30 minutes	125	130	104	100	110	109	112	99	106	122
60 minutes	103	125	93	107	126	145	124	126	120	126
90 minutes	102	124	96	123	131	119	91	92	151	148
120 minutes	99	125	90	110	109	117	111	135	115	144

TABLE - 12

INCREMENTAL AREA UNDER CURVE (IAUC) OF EXPERIMENTAL GROUP 1 RATS

INCREMENTAL AREA UNDER CURVE (IAUC)				
Wistar albino rats (Experimental group)	**Standard bread**	**Test bread**	**t value**	**p value**
C1	13	12	2.7735	0.0242 (p<0.05)
C2	14	12		
C3	13	11		
C4	12	12		
C5	16	12		
Mean±SD	14±1.22	11.80±0.45		

(p<0.05 – highly statistically significant, p<0.01 – statistically significant p>0.05 – not statistically significant)

TABLE - 13

INCREMENTAL AREA UNDER CURVE (IAUC) OF EXPERIMENTAL GROUP 2 RATS

INCREMENTAL AREA UNDER CURVE (IAUC)				
Wistar albino rats (Experimental group)	**Standard bread**	**Test chapathi**	**t value**	**p value**
Z1	13.5	13	2.9673	0.0179 (p<0.05)
Z2	12	12		
Z3	14	11		
Z4	14	10		
Z5	14	12		
Mean±SD	13.5±0.86	11.6±1.14		

(p<0.05 – highly statistically significant, p<0.01 – statistically significant p>0.05 – not statistically significant

TABLE - 14

GLYCEMIC INDEX OF TEST BREAD INCORPORATED WITH SEaWEEDS
Sargassum wightii

Wistar albino rats (Experimental group)	**Glycemic index**
C1	92.3
C2	85.7
C3	84.6
C4	85
C5	75
Mean glycemic index	422.6/5 **= 84.52**

Table - 15

GLYCEMIC INDEX OF TEST CHAPATI INCORPORATED WITH SEAWEEDS
Ulva lactuca

Wistar albino rats (Experimental group)	**Glycemic index**
Z1	96.2
Z2	100
Z3	85
Z4	71.4
Z5	85.7
Mean glycemic index	438.3/5**= 87.6**

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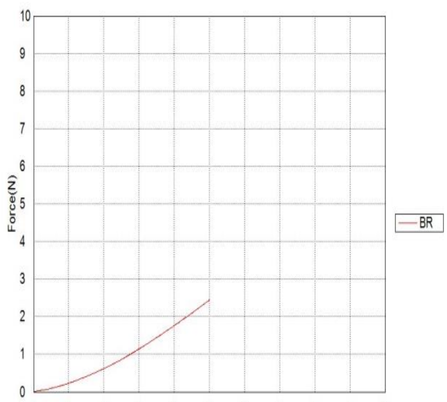
Figures

Variation I **Variation II** **Variation III** **Variation IV**

Figure 1: Variations of formulated seaweeds (*Ulva lactuca*) incorporated chapati

STANDARD **VARIATION I** **VARIATION II** **VARIATION III**

Figure 2: Variations of formulated seaweeds (*Sargassum wightii*) incorporated bread



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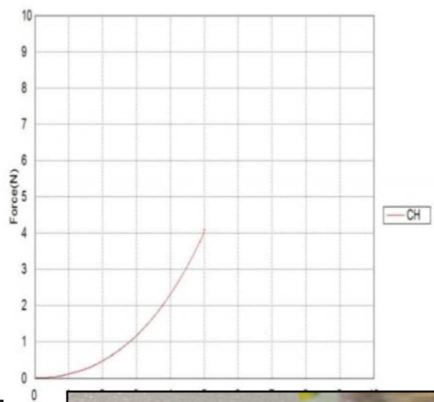
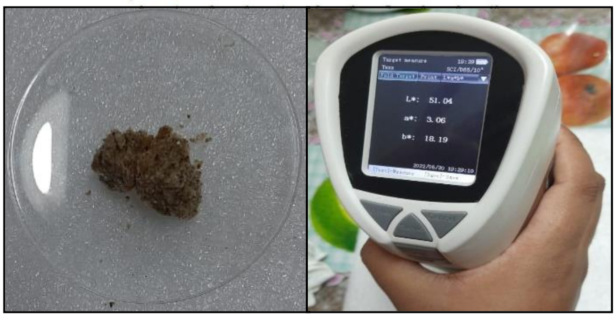
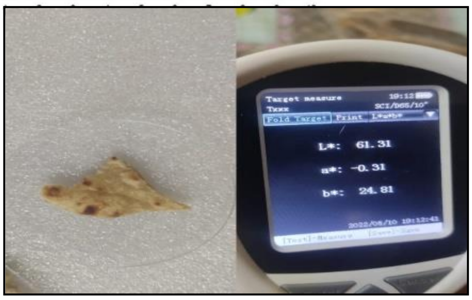




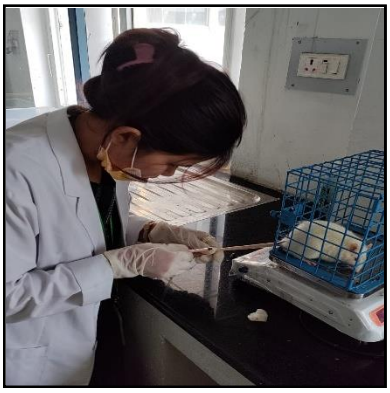
Colour value of formulated bread



Colour value of formulated chapati

Figure 4: Colour value of formulated bread and chapati

Figure 5: Blood collection of wistar albino rats



Measurement of weight of the albino

Venipuncturing technique

Blood sucking from wistar albino rats

Measuring blood glucose with glucometer

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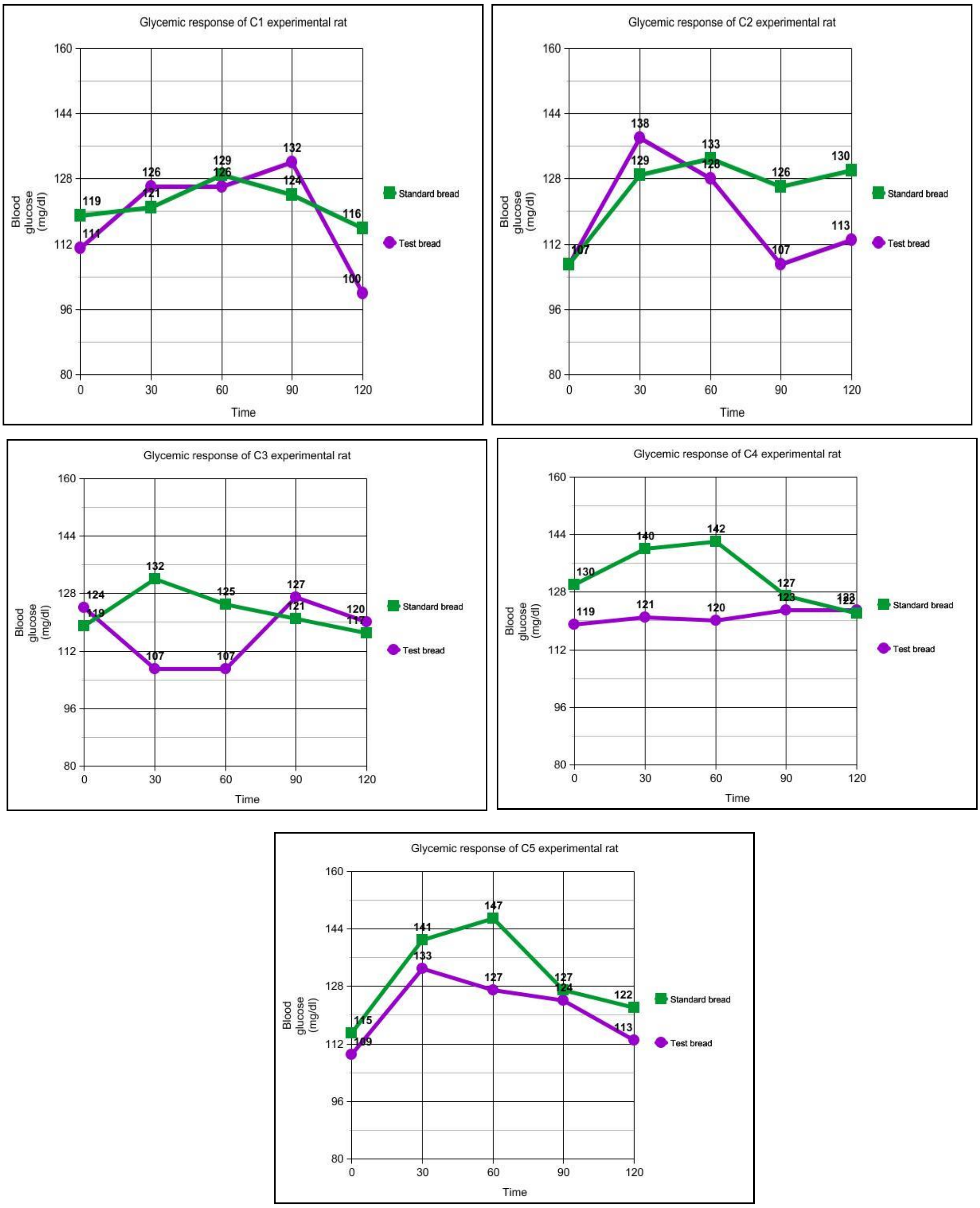

Figure 6: Graphs plotted for glycemic response of experimental group 1 rats

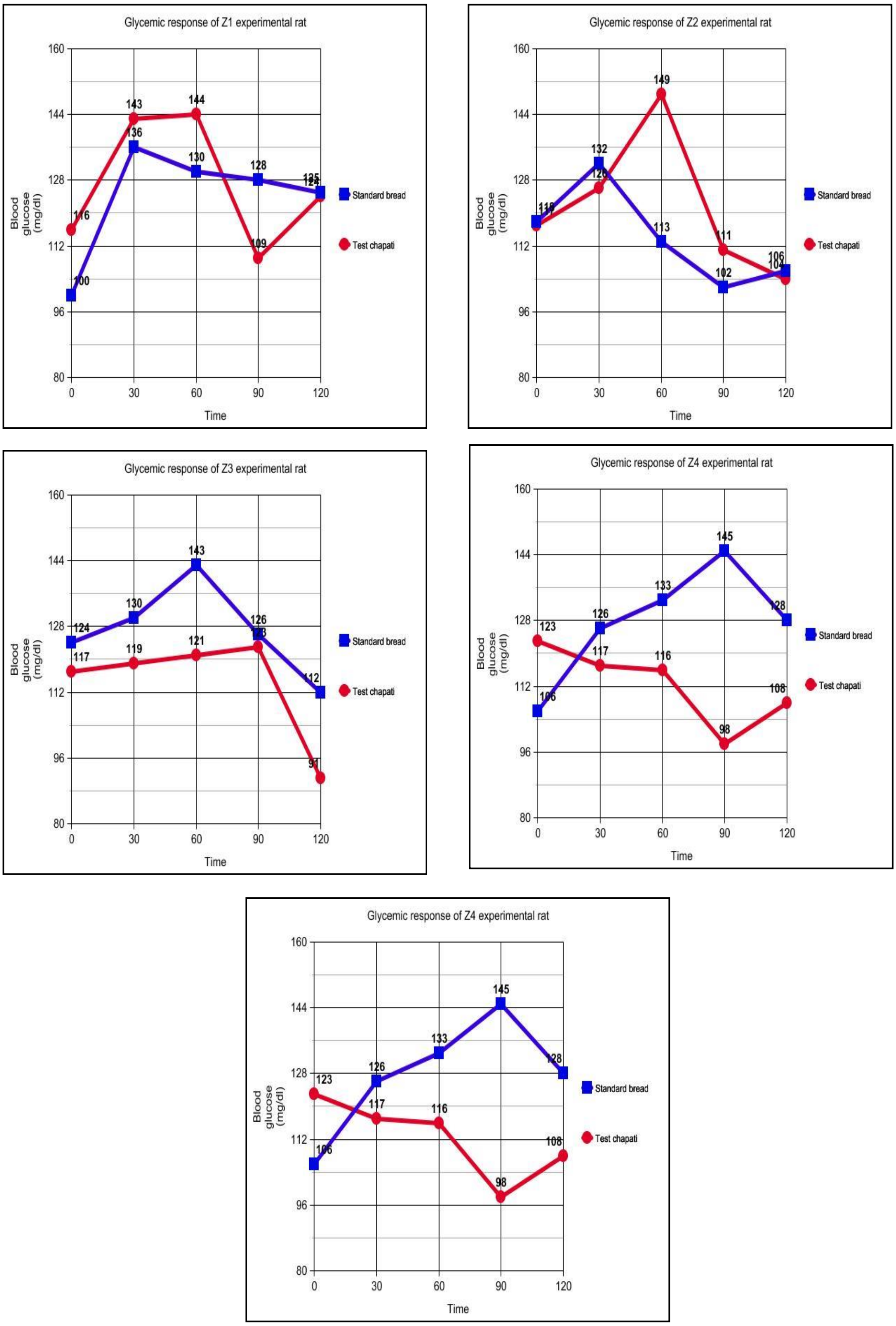

Figure 7: Graphs plotted for glycemic response of experimental group 2 rats