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(RESEARCH ARTICLE)

Quality evaluation of therapeutic noodle from water yam, millet and wheat composite flour and its effect on lipid profile and blood glucose concentration using albino rats

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Abstract

This study investigated the development and sensory qualities of therapeutic noodle from wheat, pearl millet (*Pennisetum glaucum*) and water yam composite flour and the effect of feeding the product on lipid profile and blood glucose concentration using alloxan induced albino rats. The therapeutic noodle was produced using different ratios of flour blends of wheat, millet and water yam. Sensory analysis was carried out based on color, taste, aroma, slipperiness and overall acceptability on the basis of a 9-point hedonic scale. The therapeutic noodle samples competed well with the commercial noodle (control) sample as they were all rated above average (>5.0) with noodle sample (WMF_5) having a very high score of 8.40 in the overall acceptability. Alloxan induced male albino rats were fed the formulated therapeutic noodle for 21 days and assessed for their resultant body weight, blood glucose concentration and lipid profiles. The total cholesterol levels of all diabetic albino rats fed the formulated therapeutic noodle were reduced to within the normal range of below 200mg/dl ideal for adults after the 21days. The therapeutic noodles also helped to significantly ($p < 0.05$) reduce the high blood glucose concentration of the diabetic rats to below 200mg/dl while diabetic rats fed control diet (100:0) had the highest concentration of blood glucose (485mg/dl). Due to the high anti-diabetic properties of the therapeutic noodles, it can be recommended as a functional food source for the treatment of overweight, obesity, and diabetes.

Keywords: Therapeutic noodle; Sensory qualities; Lipid profile; Blood glucose

1. Introduction

Increasing occurrence of health related problems such as diabetes and obesity has led to heightened consumer interest in the nutritional composition of their diets which in turn has led to more pronounced awareness on dietary diversification. This growing interest has greatly limited the variety of foods of special-needs consumers such as the elderly, diabetics and those that are gluten intolerant. A notable shift from consumption of traditionally prepared meals from grains such as sorghum, barley, rye, maize and millet to more refined cereals, like polished rice and wheat has become the norm both among the urban and rural population. These changes could result in a significant decrease in the overall fiber content of the diet of the populations [1] leading to increasing prevalence of chronic degenerative diseases like overweight/obesity, diabetes etc [2]. The global concern for the diversification of the uses of plant foods to improve normal and therapeutic nutrition for diabetes control has shifted scientists' interest to enhancing the potential sources of beneficial constituents in plant foods such as their anti-diabetic potentials.

Diabetes is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces and is characterized by high level of blood glucose also known as hyperglycaemia. The most common is type 2 diabetes, resulting from the body's ineffective use of insulin, and accounting for about 90% of diabetes incidences [3]. The type of food consumed plays a key role in diabetes along with

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exercise, smoking and obesity and according to World Health Organization (WHO) an estimated 1.5 million deaths per year are attributed to diabetes directly [3].

Noodle is a staple food made from unleavened dough which is stretched, extruded, or rolled flat and cut into one of a variety of shapes. It is typically made from wheat flour and is widely consumed throughout the world including Nigeria and has become a fast growing sector of the industry. The demand for noodles in Africa has been predicted to increase with population growth [4] mainly because noodles are convenient, easy to cook, low cost and have a relatively long shelf-life making them suitable for the rural dwellers and low income earners. In response to this expectation, the need to develop noodles with improved nutrients from indigenous crops such as water yam and millets has become imperative. The quality and nutritional value of noodles can be improved by substituting refined flour or low-fiber flour such as wheat flour with an enriched source of dietary fiber and minerals, sugar or fats can be replaced by various substitutes which results in a reduction of glucose level, carbohydrates without any harmful health effects, and millet and water yam flours portend such properties. This among many other benefits will contribute to reducing the overdependence on wheat flour.

One inherent danger in the chemistry of wheat (apart from gluten intolerance) is its high Glycemic Index (GI) of 71 as compared to that of water yam, which is 24 [5] and millet which is 54 [6] and both are very low. Recent studies have shown that the regular consumption of diets containing high GI foods is associated with a heightened risk of type 2 diabetes mellitus and coronary heart disease [7]. However, the inclusion of low GI foods in diet, with no change in the total amount of carbohydrate consumed, may improve blood glucose control, reduce serum triglycerols [8], prolong endurance during physical activities and improve insulin sensitivity [9].

Water yam (*Dioscorea alata*) a staple starchy food crop for many resource-restricted Nigerians is a highly economical yam species, which is desirable for the diabetic due to its low sugar content [10]. It also contains good amount of antioxidant and Vitamin C which plays some important roles in anti-ageing, immune function, wound healing and bone growth and also suppresses the blood sugar because of its high fibre content [11]. Research has shown that water yam is also a rich source of carbohydrate and has a good percentage of ash content which is a reflection of mineral status, and a small percentage of sugar [12] making it an ideal meal for the diabetics. According to Baah *et al.* [13] the total dietary fibre (TDF) content of *D. alata* tubers ranged between 4.1% and 11.0%. Dietary fiber (DF) is an essential component in human and animal nutrition and high intake of DF is positively related to different physiological and metabolic effects. It contributes less to calories, and can bind and flush cholesterol, carcinogens and undesirable chemicals from the body [13]. Reports have also indicated that *D. alata* contains appreciable number of minerals such as phosphorus, calcium, potassium, magnesium, zinc among others [13]. Calcium is vital for the development of healthy bones and teeth, making it an important food for the special needs. It is also needed for muscle contraction and regulation of the heart beat, and is involved in the formation of blood clots. Potassium is a mineral that helps the kidneys to function normally and control blood pressure. With appreciable content of potassium in the varieties of *D. alata* it could be recommended for people with high blood pressure.

Millets are a group of small seeded species of cereal crops, widely grown around the world for food and fodder. Millets, especially pearl millet (*Pennisetum glaucum*), are important sources of essential nutrients such as amino acids, vitamins like thiamine, niacin, and riboflavin as well as minerals such as calcium, iron and phosphorus as well as dietary fibre [14]. Millet is one of the most important grains receiving specific attention because of its excellent nutritive value and potential health benefits such as anti-diabetic, anti-oxidant and anti-arteriosclerotic effects [15]. Pearl millet is rich in fat content [16] such as Omega 3, linolenic acid (C18:3n-3) (LNA) comprises 4% and its mineral contents are B-vitamins, potassium, phosphorous, magnesium, iron, zinc, copper and manganese [16]. Health benefits of millets due to their high contents of fibre, phenolic compounds, anti-oxidants and meta-ion-reducing powers have also been acknowledged [14]. The role of dietary fibre in management of diabetes, lowering blood glucose concentration, improvement of insulin sensitivity, reduction in harmful cholesterol and control of other diseased conditions have been reported [17]. Millets have been shown in numerous trials to improve glycemic management, decrease fasting and postprandial rises in blood glucose concentration, and reduce insulin index and insulin resistance, and lower glycosylated haemoglobin (HbA1c) levels [18]. It has been reported that blood sugar level of diabetic person was decreased due to regular consumption of millets: wheat flour in the ratio of 30:70 respectively [19]. Due to the presence of high fibre content and antioxidants in millet, it reduces insulin spikes gradually and eases digestion for diabetics. It takes a longer time for the body to metabolize and break down millets due to their low glycemic load hence they are absorbed more slowly into the blood stream and requires less insulin and consequently raise the blood sugar slowly and gradually instead of in quick spikes. Many previous studies have shown that blends of indigenous plant-based materials are effective for the control and reduction of the prevalence of certain diseases [20, 21]. Production of noodle with greater percentage of millet and water yam flours will be a good choice for people who are looking for a healthy alternative to other types of noodles. This study therefore, hoped to ascertain the roles of the product in ameliorating and managing the health of the special needs mainly the diabetics when consumed over a period of time, by analyzing its effect on the blood glucose concentration and lipid profiles using alloxan induced albino rats. The increase in utilization of water yam and millet in industrial food processing such as instant noodles promises to further enhance nutrient diversification, their visibility and economic potentials. This would certainly cascade into better productivity and improved socio-economic status for key actors along the value chain of these commodities.

2. Materials and Methods

2.1. Procurement of raw materials

Abakaliki species of water yam (*Dioscorea alata*), pearl millet (*Pennisetum glaucum*), wheat flour (Golden Penny brand) and other materials were bought from Eke market, Afikpo, in Afikpo North Local Government of Ebonyi State with the exception of the albino rats for the bioassay procured from the Department of Veterinary Medicine, University of Nigeria, Nsukka.

2.2. Processing of Water yam Flour

The water yam flour was produced using the method described by Ukpabi [22]. These include the peeling of the water yam tubers, washing and slicing of the tubers, dehydration of the sliced water yam tubers in an oven, milling with a dry milling machine, and sieving to produce a floury material of such fineness that all the aggregates could pass through a Muslim cloth. The produced flour was stored in sealed polyethylene bags prior to use.

2.3. Processing of millet flour

The millet flour was produced using the method as described by Mbaeyi-Nwaoha and Obetta [23]. Pearl Millet (*Pennisetum glaucum*) seeds (2 kg) were manually cleaned/winnowed, weighed and fermented for 48 h. The fermented grains were oven-dried, milled and sieved by passing through a 1mm pore size sieve to yield flour. The flour was packaged in air tight container and stored for further usage.

2.4. Formulation of Composite flour

The composite flour samples were formulated as shown in Table 1. The 100% wheat flour served as the control.

Table 1 Composite flour formulations

Sample	Wheat flour (%)	Millet flour (%)	Water yam flour (%)	Total (%)
WMF_1	100	0	0	100
WMF_2	60	25	15	100
WMF_3	40	40	20	100
WMF_4	20	55	25	100
WMF_5	0	70	30	100

2.5. Therapeutic noodle production

The noodles were produced using the method described by Hou [24]. All the ingredients were weighed out in the right proportions. The flour blends were introduced into a mixer and brine added to the flour. The crumbly dough obtained were rested to mature and then kneaded to uniformly distribute the ingredients and hydrate all the flour particles. The dough was then repeatedly folded and passed through the rollers of the manual extruder to facilitate gluten development which gave the noodle its stringy and chewy texture. The gap between the finishing rolls was adjusted to produce the desired thickness and shape of the noodles belt which was immediately cut into desired length. The noodles were steamed at 100^{o}C within 5 minutes to gelatinize the starch and improve the texture of the noodles, after which the noodles were dried by frying in vegetable oil at 160^{o}C for 2 minutes.

2.6. Sensory evaluation of noodle samples

The basic sensory qualities considered were: color, taste, aroma, slipperiness and overall acceptability using the method described by Iwe [25]. Semi trained panelists of 10 judges consisting of both genders of different age groups having different eating habits evaluated the sensory qualities of the noodle samples. The noodles were rated on a 9- point Hedonic scale ranging from 1 (extremely dislike) to 9 (extremely like).

2.7. Bioassay

49 male albino rats of same age bracket (three months old) weighing about 150-180g were used for the study. They were purchased from the Faculty of Veterinary Medicine Teaching Hospital, University of Nigeria, Nsukka. The effect of the noodle samples on the body weight, blood glucose concentration and lipid profile of the experimental animals were determined.

2.8. Treatment of animals

49 male albino rats were housed in properly designed and well ventilated cages containing wood shavings for beddings in a normal environmental temperature. The rats were divided into six groups corresponding to six treatments and one other group containing the normal rats fed with the normal rat chow which served as the control. Each rat was labeled to avoid ambiguity and to ensure randomization of treatments was done. The rats were allowed to acclimatize for seven days receiving normal rat chow and water. Diabetes was induced by slow intraperitoneal injections of 1% solution of alloxan (120mg/kg body weight) dissolved in normal saline and administered within few minutes of preparation. Diabetic state was confirmed after two days. Only rats with glucose concentration above 200mg/dl were considered diabetic. Each group of rats was fed their respective diets for a period of 21 days. The study was conducted in accordance with the guidelines of Akanu Ibiam Federal Polytechnic, **Unwana** in accordance with the rules governing the use of laboratory animals as accepted internationally (National Institute of Health Guide for Care and Use of Laboratory Animals). The animals were observed throughout the 21 days for clinical signs/behavioral changes and or mortality patterns before and after dosing.

2.9. Grouping of rats

The rats were divided into eight groups as:

- Group 1: Healthy rats fed normal rat chow (control)
- Group 2: Diabetic rats fed rat chow
- Group 3: Diabetic rats fed A (control diet)
- Group 4: Diabetic rats fed B
- Group 5: Diabetic rats fed C
- Group 6: Diabetic rats fed D
- Group 7: Diabetic rats fed E

Daily food and water intake of the rats were monitored and recorded. The animal house was cleaned and disinfected regularly. Soiled wood shavings were replaced daily.

2.10. Evaluation of body weight of rats

The body weight of the rats was monitored weekly and measured in grams using weighing balance.

2.10.1. Determination of biochemical indices

Blood glucose determination

Blood sample was collected from the rats after overnight fasting by ocular method. The blood glucose level was determined at day 0, 7, 14 and 21 respectively using the glucose oxidase principle [26]using one touch digital glucometer. A drop of whole blood was placed on a strip connected to the glucometer and the glucometer automatically displayed concentration of the blood in mg/dl.

Lipid profile determination

Blood sample was collected from the rats by ocular method after overnight fasting. The blood sample was collected in non-EDTA (ethylene diamine tetra acetic acid) tubes. The serum collected was separated by centrifugation at 2500 rpm for 15min and used to determine the total cholesterol by enzymatic analysis, total triglyceride, high density lipoprotein (HDL) and low density lipoprotein (LDL) using the Randox commercial kit as described by Siedel *et al.* [27].

2.11. Statistical analysis

All the data obtained were subjected to Analysis of Variance (ANOVA) by using Statistical Package for Social Sciences (SPSS) version 20. Duncan New Multiple Range Test (DNMRT) was used to determine significant differences and to separate means at p<0.05 using SPSS version 20.

3. Results and discussion

3.1. Sensory evaluation of therapeutic noodle samples

Results from the sensory evaluation studies are shown in Table 2. The results generally show significant variations in the sensory attributes for the various therapeutic noodle samples. Commercial noodles made from wheat flour (used as control), obtained the highest score for some of the attributes assessed such as color, texture and overall acceptability. The sensory scores obtained for the all the attributes in the present study were above average (≥5), an indication that the products were well accepted.

Table 2 Sensory Scores of therapeutic noodle samples

Samples	Color	Taste	Aroma	Slipperiness	Overall acceptability
WMF_1	$8.12^{e}\pm0.01$	$6.70^{c}\pm0.01$	$6.90^{c}\pm0.10$	$6.05^{a}\pm0.01$	$8.53^{c}\pm0.20$
WMF_2	$7.30^{d}\pm0.01$	$6.25^{b}\pm0.02$	$6.40^{b}\pm0.11$	$6.70^{b}\pm0.02$	$8.15^{ab}\pm0.10$
WMF_3	$7.20^{c}\pm0.03$	$6.20^{a}\pm0.01$	$6.30^{a}\pm0.10$	$6.80^{c}\pm0.02$	$7.90^{a}\pm0.20$
WMF_4	$7.00^{b}\pm0.02$	$6.80^{d}\pm0.01$	$7.05^{d}\pm0.15$	$7.80^{d}\pm0.01$	$8.05^{a}\pm0.15$
WMF_5	$6.60^{a}\pm0.02$	$7.05^{e}\pm0.03$	$7.35^{e}\pm0.11$	$8.03^{e}\pm0.02$	$8.40^{c}\pm0.10$

Values are means of 3 replicates ± standard deviation. Means with different superscripts are significantly different (p<0.05); W: wheat flour M: millet flour F: water yam flour;WMF_1:100%W Noodle; WMF_2:60%W + 30%M + 10%F Noodle; WMF_3: 50%W + 35%M+ 15%F Noodle; WMF_4: 40%W + 40%M + 20%F Noodle; WMF_5: 30%W + 45%M + 25%F Noodle

The sensory scores obtained in this study for the formulated noodle samples were comparable to the results reported for root and tuber noodles by Akonor *et al.* [28] and those of noodles produced from wheat flour and modified starch of African breadfruit (*artocarpus altilis*) blends [29]. In terms of color, noodle sample (WMF_1) which was the control sample had the highest score of 8.12 while noodle sample (WMF_5) had the least score of 6.60 with significant variations among the samples. This may be attributed to the off-white color impacted by the millet flour. However, the addition of the millet and water yam flours did not have any negative impact on the color as noodle samples were scored above average. The taste of all the test samples was liked "very much" as they were rated above average (>5.0) with noodle sample (WMF_5) having the highest score of 7.05. Analysis of variance showed that increased proportions of millet and water yam flours did affect ($p < 0.05$) the aroma of noodles, as the panelists were more inclined towards the noodles made with higher proportions of millet and water yam flours thereby rating them higher than the control sample (WMF_1).The evaluation further showed that panelists were more inclined to the texture (slipperiness) of the noodles with higher proportions of millet and water yam flours. Slipperiness may be defined as the extent to which the product slides across the tongue [30]. Slippery surface texture is desirable in flour noodles. Slipperiness increased steadily with increasing addition of millet and water yam flours. The texture of noodles, according to Chang and Wu [31], is a key quality index for assessing cooked noodles, and it is affected by the source of starch used. In this case, the type of starch present in water yam flour may have influenced the slipperiness as the sample (WMF_5) with the highest proportion of water yam flour has the highest score of 8.03. There is no significant ($p < 0.05$) difference in the overall acceptability scores of the control sample (WMF_1) and sample (WMF_5) with the highest proportions of millet and water yam flours. Acceptability of noodles from this study was higher than that of cassava-wheat-soybean noodles [32], noodles made from wheat-sweet potato composite flour [33] as well as noodles from wheat flour and modified starch of African breadfruit (*artocarpus altilis*) blends [29].

3.2. Effect of experimental diet (therapeutic noodle samples) on body weight of albino rats

The effect of the experimental diet on body weight after 21 days of feeding on the therapeutic noodles is shown in Table 3. The healthy rats fed control diet showed a little increase in body weight from 168.26 to 170.03g after 21days, but a drastic significant (p<0.05) decrease in body weight (169.70-141.56g) was observed in the diabetic rats fed control diet.

This might be attributed to decreased food consumption demonstrated by the diabetic rats leading to decreased body weight probably as a result of the polyphagic condition that always characterizes untreated type II diabetes.

Table 3 Effect of Experimental diet on body weight (g) of albino rats

Groups	Exp'tal diets	DAY 0	DAY 7	DAY 14	DAY 21
1	HRCD	$168.26^{b}\pm3.67$	$163.84^{b}\pm4.83$	$167.13^{b}\pm1.37$	$170.03^{d}\pm3.55$
2	DRCD	$169.70^{b}\pm6.16$	$162.20^{b}\pm7.64$	$157.78^{a}\pm2.12$	$141.56^{a}\pm2.71$
3	WMF_1	$158.81^{a}\pm5.43$	$156.12^{a}\pm4.33$	$158.93^{a}\pm3.06$	$157.79^{b}\pm4.79$
4	WMF_2	$170.42^{b}\pm4.52$	$170.40^{d}\pm3.36$	$169.75^{c}\pm4.53$	$172.41^{c}\pm2.35$
5	WMF_3	$167.96^{b}\pm3.67$	$167.46^{bc}\pm4.38$	$166.54^{b}\pm3.16$	$168.33^{c}\pm6.26$
6	WMF_4	$173.76^{c}\pm1.27$	$171.70^{d}\pm7.06$	$172.73^{d}\pm2.91$	$173.53^{e}\pm3.36$
7	WMF_5	$174.36^{bc}\pm6.28$	$174.28^{d}\pm5.08$	$174.66^{d}\pm6.12$	$174.20^{e}\pm4.72$

Values are means of 3 replicates ± standard deviation. Means with different superscripts are significantly different ($p<0.05$); W: wheat flour M: millet flour F: water yam flour; WMF_1:100%W Noodle; WMF_2:60%W + 30%M + 10%F Noodle; WMF_3: 50%W + 35%M+ 15%F Noodle; WMF_4: 40%W + 40%M + 20%F Noodle; WMF_5: 30%W + 45%M + 25%F Noodle; HRCD: Healthy rats fed control diet (rat chow) – Normal control; DRCD: Diabetic rats fed control diet (rat chow) – Diabetic control

All the diabetic rats fed formulated noodles showed some levels of reduction in body weight within the period of the 21days of the study as shown in table 3. This might be as a result of the high fibre content of millet and water yam flours known to help in controlling of body weight. Millet and water yam both have lower glycemic index (GI) than many other grains and tubers [5, 6]. High-fiber and low-GI foods keep blood sugar steady, lower cholesterol, and help in weight loss. All of these qualities are helpful for people with diabetes. Most importantly, millet as a major source of complex carbohydrates provides satiety thus initiating weight loss and reduces blood sugar spikes.

3.3. Effect of experimental diet on mean blood glucose concentration (mg/dl) of albino rats

Mean values for blood glucose concentration is shown in Table 4. The results of this study indicated that the blood plasma glucose level in the diabetic control group was significantly ($p<0.05$) higher than that of the healthy control group after induction of diabetes with alloxan. The diabetic rats fed control diet recorded highest concentration of blood glucose (485mg/dl) on the 21st day. Next to that was group 3 (diabetic rats fed with 100% wheat flour noodle) with a value of 363.05mg/dl while other diabetic rats fed formulated therapeutic noodles recorded some levels of recovery from high blood glucose concentration to below 200mg/dl, with the rats in group 7 fed (WMF_5) having the lowest blood sugar concentration (100mg/dl). The results obtained from the diabetic rats fed formulated therapeutic noodles (102 to 121mg/dl) was slightly lower than the blood glucose concentration of 142.0±36mg/dl reported by Chandalia *et al.,* [34] on American Diabetic Association (ADA) diet. The findings in the present study agrees with the results of Sada *et al.* [35] who reported that the administration of pearl millet (*Pennisetum glaucum*) supplement at different percentages lowered blood glucose level and was even more effective than the standard drug glibenclamide.

Researchers have found out that millets reduce the α-glucosidase and pancreatic amylase thereby reducing the hydrolysis of various carbohydrates by the enzymes and further causing a reduction in postprandial glucose level [36]. Experimental studies have indicated that pearl millets can exert antioxidant effects and reduce oxidative stress and hyperglycemia [37] and this agrees with the findings of this work. Pearl millet and water yam as good sources of dietary fiber can help to impair mixing of intestinal contents thereby impairing digestion due to limited access of the food to enzyme. Hence hypoglycemic action of dietary fibre could be due to delaying of starch hydrolysis and glucose absorption and also improvement in glucose utilization and insulin sensitivity in target tissues. The result of this research supports the claim by Awolu *et al.* [17] on the role of dietary fibre in management of diabetes, lowering blood glucose concentration, improvement of insulin sensitivity, reduction in harmful cholesterol and control of other diseased conditions. The blood glucose lowering effect of water yam and pearl millet and the possible mechanism involved in the hypoglycemic action of millets and water yam may be the stimulation of insulin secretion by the pancreas or/and enhancement of insulin sensitivity in various organs due to the high amount of magnesium. Magnesium helps to improve the ability of cells to respond to insulin, by increasing the levels of adiponectin hormone. Adiponectin prevents the accumulation of glucose in the blood by increasing fat metabolism in tissues [39]. Therefore, control of postprandial blood glucose surge is critical for treatment of diabetes and for reducing chronic vascular complications [40] which can be controlled by intake of high complex carbohydrate and high fibre diet.

Table 4 Effect of Experimental diet on mean blood glucose concentration (mg/dl) in experimental albino rats

Groups	Experimental diets	DAY 0	DAY 2	DAY 7	DAY 14	DAY 21
1	HRCD	65.00^{a}±10.54	65.00^{a}±10.54	75.16^{a}±6.45	63.43^{a}±4.75	60.37^{a}±7.38
2	DRCD	76.00^{b}±7.10	258.20^{d}±12.21	288.13^{e}±7.16	360.72^{f}±7.01	485.75^{f}±6.81
3	WMW_1	66.40^{ab}±6.35	227.15^{b}±11.14	290.10^{e}±4.17	313.25^{e}±6.10	363.05^{e}±8.32
4	WMW_2	58.35^{a}±6.30	234.35^{c}±10.21	199.83^{d}±7.10	145.73^{d}±3.10	121.32^{d}±6.35
5	WMW_3	64.23^{a}±8.30	224.32^{b}±11.22	199.15^{d}±3.31	136.55^{c}±3.25	116.26^{d}±5.36
6	WMW_4	65.50^{a}±6.33	231.60^{b}±15.10	185.75^{c}±1.03	147.66^{d}±4.33	110.50^{c}±0.54
7	WMW_5	70.26^{b}±3.47	223.31^{c}±11.25	172.66^{b}±1.05	131.43^{b}±1.21	102.10^{b}±0.27

Values are means of 3 replicates ± standard deviation. Means with different superscripts are significantly different ($p<0.05$); W: wheat flour M: millet flour F: water yam flour; WMF_1:100%W Noodle; WMF_2:60%W + 30%M + 10%F Noodle; WMF_3: 50%W + 35%M+ 15%F Noodle; WMF_4: 40%W + 40%M + 20%F Noodle; WMF_5: 30%W + 45%M + 25%F Noodle; HRCD: Healthy rats fed control diet (rat chow) – Normal control; DRCD: Diabetic rats fed control diet (rat chow) – Diabetic control

3.4. Effect of experimental diet on serum lipid profiles

Table 5 showed that total cholesterol (TC), total triglycerides (TG), high-density lipoprotein (HDL) and low-density lipoprotein (LDL) of the rats ranged from 144.81 - 210.46 mg/dl, 134.45 - 216.46 mg/dl, 38.65 - 80.47 mg/dl and 40.16 - 105.36 mg/dl, respectively. The results of this study have revealed that the formulated therapeutic noodle had a significant ($p<0.05$) impact on the lipid profiles as it was able to lower cholesterol levels dose significantly when compared to the diabetic untreated group more than the normal rat chow. It also showed that the therapeutic noodle was able to depress the value of the Triglycerides and Low-density lipoprotein (LDL) serum levels ($p<0.05$) and also spiked the High-density lipoprotein (HDL) serum levels significantly ($p<0.05$).

Table 5 Effect of Experimental diet on Lipid profile (mg/dl) in experimental albino rats

Groups	Experimental diets	Total cholesterol (TC)	Total Triglyceride (TTC)	High density Lipoprotein (HDL)	Low density Lipoprotein (LDL)
1	HRCD	166.69^{c}±2.31	142.65^{b}±4.15	45.26^{b}±3.46	96.70^{e}±4.56
2	DRCD	210.46^{f}±3.01	216.46^{e}±8.16	38.65^{a}±6.65	105.36^{g}±6.27
3	WMF_1	183.63^{e}±7.32	195.10^{d}±10.26	41.02^{a}±1.37	94.84^{f}±3.42
4	WMF_2	172.77^{d}±3.15	158.30^{c}±3.37	62.38^{c}±1.16	61.36^{d}±4.34
5	WMF_3	167.66^{c}±1.26	144.76^{b}±1.67	64.18^{d}±1.20	48.74^{c}±2.45
6	WMF_4	152.14^{b}±3.46	140.15^{b}±2.70	68.36^{e}±1.21	43.56^{b}±2.31
7	WMF_5	144.81^{a}±4.12	134.45^{a}±1.96	80.47^{f}±2.36	40.16^{a}±1.56

Values are means of 3 replicates ± standard deviation. Means with different superscripts are significantly different ($p<0.05$); W: wheat flour M: millet flour F: water yam flour; WMF_1:100%W Noodle; WMF_2:60%W + 30%M + 10%F Noodle; WMF_3: 50%W + 35%M+ 15%F Noodle; WMF_4: 40%W + 40%M + 20%F Noodle; WMF_5: 30%W + 45%M + 25%F Noodle; HRCD: Healthy rats fed control diet (rat chow) – Normal control; DRCD: Diabetic rats fed control diet (rat chow) – Diabetic control

The total cholesterol levels of all the groups fed experimental diet (therapeutic noodle) were within the normal range of less than 200mg/dl ideal for adults as reported by 2018 Providence Health and Service [41]. There was a significant ($p<0.05$) difference in TG level of diabetic rats fed control diet and diabetic rats fed experimental diets. The TG levels of all the groups fed therapeutic noodle were within the normal range of less than 150mg/dl reported by Morris [42]. The HDL value of the diabetic control was found to be below 40mg/dl while those of the groups fed therapeutic noodle were above 40mg/dl. The ideal HDL levels should be above 40mg/dl as this type of fat is considered good because it lowers the risk of heart disease. The higher the values the lower the risk and 60mg/dl or above is considered the level to protect one against heart disease [43]. It is notable that reductions in plasma cholesterol levels observed in the groups fed the formulated noodles were accompanied by significantly higher HDL level when compared to that of diabetic group fed the control. High levels of HDL have been reported to be inversely related to the incidence of coronary heart disease [44]. HDL may facilitate the removal of cholesterol from peripheral tissue to the liver for catabolism and excretion. HDL plays a role in lipid metabolism, complement regulation and the immune response, it is also thought to carry excess cholesterol back to liver where it is converted to bile acids and excreted into the small intestine; because of this, HDL is often referred to as 'Good Cholesterol' with high levels associated with a decreased risk of myocardial infarction. HDL removes cholesterol from non-hepatic tissues to liver through the process known as reverse cholesterol transport [44]. The LDL levels of all the experimental diets were less than 100mg/dl which is the goal for people with diabetes or heart disease as opined by Fielding and Fielding [45]. The findings of the present study agrees with the findings of Sada *et al.* [35] who opined that the levels of triglycerides, low density lipoprotein decreased while high density lipoprotein levels increased significantly in diabetic mice fed supplement. Nishizawa *et al* [39] also reported that dietary Japanese millet protein ameliorated plasma levels of lipids in type 2 diabetic mice and also increased the levels of high density lipoprotein. The ability of pearl millet (*Pennisetum glaucum*) supplement and water yam (*Dioscorea alata*) to reduce plasmacholesterol and triglycerides in diabetic animals could be explained by their reported high content of magnesium aids cells torespond to insulin by spiking the levels of adiponectin hormone. Adiponectin is produced in fat tissues, which isa beneficial hormone that helps in energy metabolism and helps cells burn fats for energy and improve cardiovascular health [39]. Insulin is required for the inhibition of hormone-sensitive lipase and hence increases the utilization of glucose and thereby decreasing the mobilization of free fatty acids from the fat depots. Whole grains such as pearl millet and water yam therefore, could be of beneficial effect on the health of the humans by improving sensitivity towards insulin, inhibition of inflammation and humanizing lipid profile [46].

4. Conclusion

This study has demonstrated that plant foods with anti-diabetic potentials such as millet and water yam could be successfully integrated into the diets of the special needs as an ameliorative measure towards hyperglycemia, hypercholesterolemia and hypertriglyceridemia. Incorporation of millet and water yam flours into the production of therapeutic noodle improved the quality in terms of nutrient density without any significant negative impact on the organoleptic and physical properties of the therapeutic noodle. It was observed that pearl millet and water yam have a beneficial effect on human health as they possess inherent potentials that can help to bind and flush out cholesterol and also improve the ability of cells to respond to insulin, by increasing the levels of adiponectin hormone. Consequently, millets and water yam may be utilized to formulate ideal meals for diabetic and pre-diabetic patients as well as for persons without diabetes and even the obese as a preventive measure. Therefore, increase in utilization of water yam and millet flours by substituting greater percentage of wheat flour in the production of noodles will contribute to reducing the overdependence on wheat flour and enhance their visibility and economic potential. This will consequently enhance nutrient diversification, ameliorate food insecurity to a large extent and increase the economic base of the suppliers.

Compliance with ethical standards

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Statement of ethical standard

The study was conducted in accordance with the guidelines of Akanu Ibiam Federal Polytechnic, Unwana in accordance with the rules governing the use of laboratory animals as accepted internationally (National Institute of Health Guide for Care and Use of Laboratory Animals).

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